Guideline on climate change mainstreaming into waste sector policies

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Abbreviations

AD — Anaerobic digestion

AISWM — Alternative (to landfill) Integrated Solid Waste Management

BC — Black Carbon

BOD — Biological Oxygen Demand

CH_4 — Methane Gas

cMRF — Clean Materials Recovery Facility

CO_2 — Carbon dioxide

COD — Chemical Oxygen Demand

VOC — Volatile Organic Compounds

dMRF — Dirty Materials Recovery Facility

MSW — Municipal Solid Waste

DOC — Degradable Organic Carbon

F — Fraction of CH_4 in generated landfill gas

FOD — First Order Decay

GHG — Greenhouse Gases

IVC — In-Vessel Composting

IPCC — Intergovernmental Panel on Climate Change

MBT — Mechanical-Biological Treatment

MCF — Methane Correction Factor

MHT — Mechanical Heat Treatment

MRF — Materials Recycling Facility

N_2O — Nitrous oxide

NDC — Nationally Determined Contributions

OECD — Organization for Economic Cooperation and Development

PCI — Pulverized Coal Injection

SLCP — Short Lived Climate Pollutants

SW — Solid Waste

SWD — Solid Waste Disposal

TOW — Total organically degradable carbon

UNFCCC — United Nations Framework Convention on Climate Change

The context and content of the guideline

The context of the guideline

The objective of the EU4Climate project is to contribute to climate change mitigation and adaptation, and to development towards a low carbon, climate resilient economy, in line with the Paris Agreement, in Armenia, Azerbaijan, Belarus, Georgia, the Republic of Moldova and Ukraine.

The Paris Agreement establishes a new transparency regime, by which the countries will have to report the progresses recorded in terms of greenhouse gas emissions (GHG) reduction and strengthening of climate change resilience. This transparency regime is currently negotiated within the annual meetings of the United Nations Framework Convention on Climate Change (UNFCCC) and its final details are still to be defined. The three regional members of the Energy Community (Georgia, Moldova and Ukraine) are encouraged to align their legislation with the EU Regulation on the monitoring mechanism and to prepare for the development and adoption of integrated energy and climate national plans and might need to align soon their legislation with the new EU Regulation on the Governance of the Energy Union.

The Paris Agreement has generated a new wave of climate change mitigation policies by drafting the so-called Nationally Determined Contributions (NDC). The updated NDC of the Republic of Moldova has been officially presented to the UNFCCC Secretariat on March 4th, 2020. Several NDCs, including the updated one of the Republic of Moldova, comprise mitigation methods in the waste sector. The decision-makers in the ministries, regional authorities and municipalities are currently facing the challenge of incorporating the NDC objectives at a high level in their sectoral waste management policies and in the local waste management plans.

The "Guideline for integrating climate changes in the waste management policy" is the support material for a series of dedicated trainings to facilitate the implementation of the Paris Climate Agreement at sectoral level in the Republic of Moldova.

Therefore, this Guideline is structured into six distinct chapters addressing relevant topics individually. On the one hand, it includes information on how to measure the impact on climate changes resulting from this sector, and how can these impacts be mitigated. On the other hand, it includes an analysis of the interaction between the effects of climate change and the development of waste management infrastructure. Methods for aligning sector policies and climate change policies are presented, together with a series of funding opportunities dedicated to climate changes and their relevance for the waste sector in Moldova. The final chapter contains examples of good practices in waste management that lead to the reduction of greenhouse gases or increase resilience.

Content of the guideline

Chapter 1 refers to compiling the GHG inventories in the waste sector. It also contains a subchapter on collecting the necessary data to put together this inventory. Before we can do something for mitigation, we need to know the GHG sources. Many times, the inventory conducted at national level remains unseen and is not understood by the organizations participating in data collection or data aggregation, and which are responsible for the drafting and implementing of emission reduction in the sector. This chapter helps the interested parties that participate in the data flow and analysis underlying the inventory to write the inventory and understand the role and contribution of each of these, as well as the meaning of this inventory exercise.

Once the magnitude of the GHG issue in the waste sector is understood, Chapter 2 focuses on the best practices for emission reduction in the sector. Chapter 2 also explains the fact that national inventories are based on a small part of what circular economy is, so that, if we focus on a wider approach of raw matter management (from extraction, production, use and, in the end, resulting waste management), we can reach much more significant GHG reductions. The chapter addresses topics such as the GHG emission reduction potential as part of the selection criteria for the investment projects, the assessment of the GHG reduction impacts in projects and various investment scenarios in the sector. Among the solutions, the chapter presents waste management technologies that achieve GHG mitigation, circular economy strategies that also have GHG reduction potential and a subchapter dedicated to the improvement of landfill management in order to reduce GHG impacts. There is a special focus on this last aspect because, with small investments and through proper management methods, good mitigation results can be achieved, very relevant in the context of Moldova.

Chapter 3 is innovative. It focuses on the risks and vulnerabilities of the sector and infrastructure caused by climate change, on the adaptation potential and resilience building in the sector, as well as on enhancing the resilience of the communities by implementing certain targeted measures. These aspects are currently less frequently addressed and known, but they are important and can prevent significant damages, they can protect the critical infrastructure in the sector and can also create mitigation opportunities especially by the treatment and use of organic waste and their use in agriculture.

Chapter 4 summarizes what the prioritizing of climate changes in the sector and the correct inventory of the GHG emissions mean. It also covers the GHG emissions reduction and adaptation to the climate change risks, with specific focus on the sectoral policies in Moldova.

Chapter 5 focuses on the funding opportunities created for the mitigation of and/or adaptation to climate change, which are relevant for the waste management sector. These include those dedicated funds and funding sources such as Green Climate Fund and NAMA Facility. At the same time, the chapter presents opportunities to access revenues from the marketing of the GHG reduction units either by voluntary systems or by systems based on international agreements. Climate change had a profound effect on the manner of approving funding from the International Financing Institutions.

Chapter 6 presents examples of best practices in waste management and climate change based on the information provided in all the previous chapters, relevant for the Republic of Moldova.

The target group

The target group of this guide includes all the parts directly or indirectly involved and interested in:

- development of policies in the waste sector;
- collection and aggregation of data in the waste sector;
- reporting and inventory of greenhouse gases;
- daily operation and/or administration of municipal waste management;
- organizations and institutions that develop and implement projects in the field.

Depending on the chapter and the specific topic, representatives of various organizations and institutions will be interested. We include below a list of organizations that we identified as target group, without mentioning exactly what chapters and topics they might be interested in:

- Ministry of Agriculture, Regional Development and Environment (offices and directorates with attributions in the environmental field) and the subordinated institutions:
  - The Inspectorate for Environmental Protection,
  - The Environmental Agency,
  - The State Hydrometeorology Service etc.
- The Regional Development Agencies
- The Climate Change Office
- Moldova Waters Agency
- POP Sustainable Management Office
- Local administrations and/or regional authorities – representatives with attributions/interested in waste collection, treatment and storage, adaptation to climate changes and urban development
- Non-governmental organizations active in waste management
- The private sector active in waste management and recovery
- The economic operators authorized for the taking over responsibilities related to waste management
- Landfill operators:
  - Private operators
  - Municipal enterprises
  - Communal services departments in the city halls
- Public and/or private institutions and organizations in the field of design, operation and control related to the waste management services, that is the waste collection, sorting, transport and storage
- Institutions/entities with attributions in emergency response in case of floods, fires, and landslides
- Large volume organic waste generators and private operators in the field of:
  - agriculture,
  - waste management,
  - urban development etc.

Drafting the GHG inventory in the waste sector

1

1. Drafting the GHG inventory in the waste sector

The countries report the National Communications in the UNFCCC basis, as well as the Biennial Update Reports that also contain the national greenhouse gases inventories. The national inventories are reported based on the methodology developed by the Intergovernmental Panel on Climate Change (IPCC).

The Commission is composed of governments representatives, employees, scientists and experts working groups. Among others, this commission has developed and then improved the methodology for the national inventory of the greenhouse gases in the Energy, Industry, Agriculture, Forestry and Land Use, as well as in the waste sector. In this guide, we focus on the waste sector.

1.1. The IPCC guideline for inventories

The countries currently report based on the 2006 Guideline, and sometimes even based on the guideline of 1999. The 2006 Guideline was perfected over the last years, so that a series of methodology updates were proposed and approved in May 2019.

1.1.1. The 2006 IPCC Guideline

The volume on waste in the 2006 IPCC Guideline is structured in five subchapters, namely that of the landfills, biological treatment, incineration and burning of wastes, treatment and disposal of wastewater and others. Figure 1 below shows the structure of chapters and subchapters.

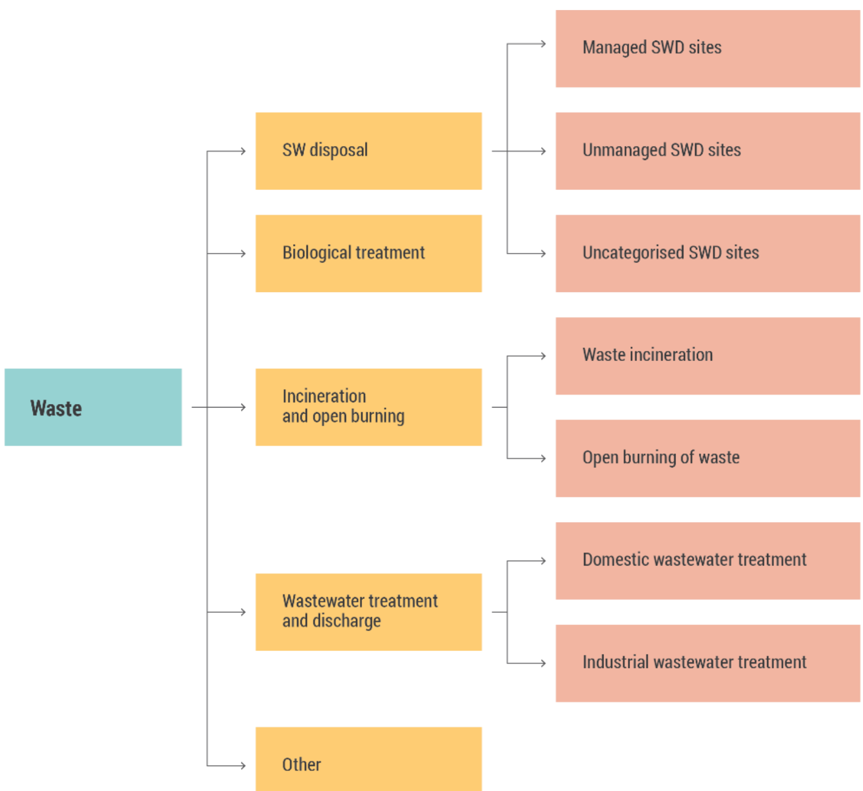


Figure 1 - The structure and contents of the volume on Waste in the 2006 IPCC Guideline

1.1.2. Update of the 2019 IPPC Guideline

The update of the methodology is not a complete revision, but rather an improvement and update of some aspects that have changed since 2006 until today because of the changes in waste compositions and quantities, but also because of the waste treatment technologies that have evolved in the meantime. The updates fields are indicated here briefly, and we refer to them in the relevant subchapters below, when the case:

- *The generation rate, composition and waste management* - Some key parameters are updated in relation to these aspects.
- *The First Order Decay Method* uses waste generation rate and the waste composition by countries and regions defined according to UN. The 2019 update contains default values in terms of carbon and nitrogen content, as well as degradable organic carbon in the sludge resulting from household and industrial wastewater.
- *Assessment of CH_4 emissions at landfills* - Additional help for the necessary correction in the case of landfills with different management conditions. The degradable organic carbon fraction was also changed for the different types of wastes.
- *The incineration and burning of waste* - Additional information for the estimation of emissions in case of some new technologies, such as gasification and pyrolysis. The oxidation factor was also updated in case of waste burning.
- *CH_4 emissions from wastewater treatment* - The update of the methodology for the estimation of methane emission from wastewater treatment, the update of default factors of emissions from septic tanks and centralised wastewater treatment systems, as well as the update of the emission factors in the case of storage or discharge of untreated wastewater.
- *N_2O emissions from the treatment of wastewater* - Update for the categories mentioned above for CH_4.
- *CO_2 emissions from anthropogenic sources (fossil sources) from wastewater treatment and discharge* - The emissions for wastewater, where the fossil carbon is present in the treated or discharged wastewater, are added in the updates.
- *Discharge in surface waters* - A set of alternative emissions factors is provided for the untreated wastewater discharged in surface waters, in the case of the countries that have information referring to the surface waters into which such discharges occur.

1.2. Activity data

Our everyday actions result in the generation of waste. The volume of such waste has steadily increased over the years and its composition has become more varied and complex in line with trends in economic growth and associated production and consumption patterns, particularly in emerging and developing economies. The sources and types of waste are as diverse and distributed as our presence on earth.

Waste, by definition, represents a loss to our economy, as all the resources that went into producing the wasted material are now discarded along with it. Greenhouse gas emissions arise from the treatment and disposal of such liquid and solid waste that present additional impacts to our well-being beyond resource and economic loss. Clearly this is unsustainable for many reasons, but how big an impact is it? What actions are creating the emissions and where do they occur, and what can be done to mitigate the impact?

“Measurement is the first step that leads to control and eventually to improvement. If you can’t measure something, you can’t understand it. If you can’t understand it, you can’t control it. If you can’t control it, you can’t improve it.”[1]

1.2.1. Waste data collection

Waste management services are delivered at sub-national level, either through the various sub-national governmental jurisdiction levels (e.g., regional, provincial, municipal etc.), or also at NGO (interest group), corporate, facility, and project level.

Due to the complexity and number of stakeholders, data generation and collection needs are equally as complex and numerous, as the examples provided in Table 1 show.

Data related to waste is invariably already being collected by various sector stakeholders, for various purposes, by various means, using various methodologies, at various points in the waste management system and reported by different means to different parties.

Knowing What information is already being collected by Who, Where, When and Why is important to prevent duplicating efforts, over burdening limited sector resources and ensuring accuracy, efficiency and effectiveness of data gathering.

Diversity of data generation and collection	
Who (collects the data)	Landfill manager; Collection / fleet manager; Industry operator (waste producers); Private operators; Recyclers; Contracts department; Water / Wastewater department; Consultancies; City manager / City council; Universities; National Statistical Offices; Custom Agencies; International Organizations (i.e. Eurostat, OECD, IFIs, UNSD, UNEP, BSR Secretariat etc.); and other sector prospectors.
What (data is collected)	Waste quantity (mass, density, volumes), population, collection rates; transport costs, exports and imports, operating cost; Waste treatment and disposal facility weigh bridge (in and out); composition; generation rates; revenues; residential type, income groups, kWh.
Where (is it collected)	Treatment / Disposal facility; Industrial waste storage area; facility, city, municipal, national level; on collection truck; ports and borders.
When (is it collected)	Each collection; Monthly; Quarterly; Billing periods; Performance periods; Annually; Random sampling.
Why (is it collected)	Contract management (performance indicators); Benchmarking; Cost / quality control; Aid decision-making by government; inform policy, investment, strategies and planning; monitoring progress towards targets; Aid enforcement and compliance monitoring; statutory reporting; identifying sector trends; research.

Table 1 - Diversity of data on waste generation and collection

[1] Source: Harrington Management Systems

This data diversity results in different data sets, using different measurements, covering different waste streams that are often incompatible, resulting in data gaps for some, data overload for others, and inconsistent sector understanding, strategies and plans.

Understanding this diversity of stakeholders and their different data requirements is important in determining how to obtain the data that is needed, interpret it and validate it correctly. There are commonalities that can be exploited and improving on this should be given priority.

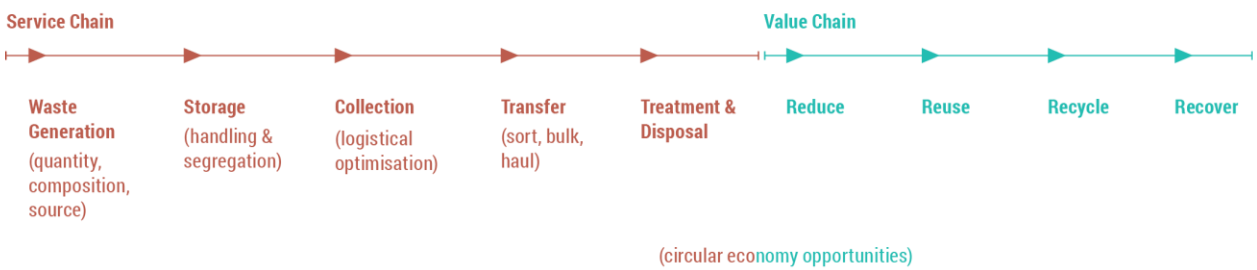


Figure 2 - Typical integrated solid waste management service chain

Figure 2 illustrates a typical integrated solid waste management service chain, being the core local service provision of collecting and transporting waste. The value chain is also a key focus, introducing circular economy approach to retrieve value from the waste resources. At an operational level, these are the factors that waste practitioners, who produce the raw subnational data, are focused on in delivering their services.

Of the nine main links in the waste management service and value chain introduced in Figure 2, only two - Waste Generation (specifically mass, volume and origin of waste being generated) and Treatment & Disposal (specifically the mass, composition of waste delivered to treatment and disposal destinations) - are of particular interest for the GHG Inventory process. Therefore, most of the data considered interesting and relevant for a waste operator (volume, quality, transport, markets, costs, storage, collection, transfer etc.) are not necessarily of interest for the GHG Inventory analysis.

The main category	Subcategory	Specific areas of interest
Solid municipal waste (Household waste, garden (yard) and park waste, commercial / institutional waste)	Food Waste	Specific interest within waste reporting due to high Degradable Organic Carbon (DOC) content
	Garden (yard) and park waste	
	Paper and cardboard	
	Wood	
	Textiles	
	Nappies (disposable diapers)	
	Rubber and leather	Mainly relevant where open burning or incineration is prevalent, or in IPPU sector
	Plastic	
	Metal	Mainly related to IPPU Sector
	Glass (and pottery and china)	
	Other (e.g., ash, dirt, dust, soil, electronic waste)	Limited impact potential
Wastewater & Sludge	Sludge from domestic wastewater treatment plants	Storage, Conveyance and treatment (CH_4 release)
	Sludge from industrial wastewater treatment plants	Storage, Conveyance and treatment (CH_4 release)

The main category	Subcategory	Specific areas of interest
Industrial Waste *(process solid waste only, office and other waste regarded as MSW and industrial sludge reported as such)*	Manufacturing industry process waste (other than sludge)	(report by industry types, i.e.: Food, beverages & tobacco; textile; wood and wood products; pulp & paper; petroleum products, solvents, plastics; rubber; others)
	Construction and Demolition waste	Mainly inert
Other waste types	Clinical Waste	Syringes, needles, animal tissues, bandages, clothes, etc.
	Hazardous Waste	Waste oils, solvents, ash, cinder, & others of hazardous nature (flammability, explosiveness, causticity, toxicity)
	Agricultural Waste	Certain manure, agricultural residues, animal carcasses, plastic film for greenhouses etc.

Table 2 - The main waste categories and composition sub-categories of interest to the waste sector GHG Inventory

The quantity and composition of waste varies between countries, but also between income groups, social groups, industrial processes, geographies, and climatic conditions within a country and even within a city. High income groups usually produce more waste with a higher percentage of plastics, electronic equipment etc., while low-income groups generally produce less waste overall, with a greater percentage being food, and fines (ash, soil, sand, etc.). Knowing the waste generation and composition of different groups alongside population / size of each group is essential to producing reliable waste generation estimations, especially in locations where the formal waste collection system does not capture and report on all wastes.

1.2.2. Key category analysis

The key category analysis is recommended by the methodology so that the efforts made by countries for improving the inventories have maximum impact. Therefore, prioritisation of emission categories is recommended and are defined as key categories by two criteria:

- The category of emissions resulting in the highest emissions as absolute value and/or,
- The categories of emissions that change most significantly according to the trend analysis from one year to another.

Using these criteria, almost always, the landfills and emissions from the landfills fit in the key category of emissions in the waste sector. The rest of the categories are country-specific - for Moldova this could be the emissions from the treatment of wastewater or those from biological treatment, for example.

After the key categories are defined, the potential uncertainty sources are analysed regarding the estimations. The availability and quality of primary data is analysed for these categories, and efforts are being made for their improvement.

1.2.3. Avoiding double counting

The emissions inventories are similar to an accounting system where the budget lines are very well defined. This is necessary to avoid the double counting of some emissions in several sectors and to ensure a standard reporting, so that the countries' reporting is comparable.

The way the emission categories are defined excludes completely the reporting of some categories of emissions that we consider to be part of the management sector of emissions and/or circular economy, such as the recycling industry, while others are reported in other sectors, such as emissions related to achieving the electric energy from biogas, which is reporting in the energy chapter in the National Inventory.

Figure 3 below identifies the most important sources of emissions and deviation of GHG emissions in the waste sector, circular economy, marking with a red circle those processes that are included in the national inventory. The graphic focuses on the most important emissions in a circular economy, as well as on the reduction potential. All the treatment options result in emissions due to the electricity consumption, but usually represent only a low percentage of the total emissions avoided by the use of the treatment technology.

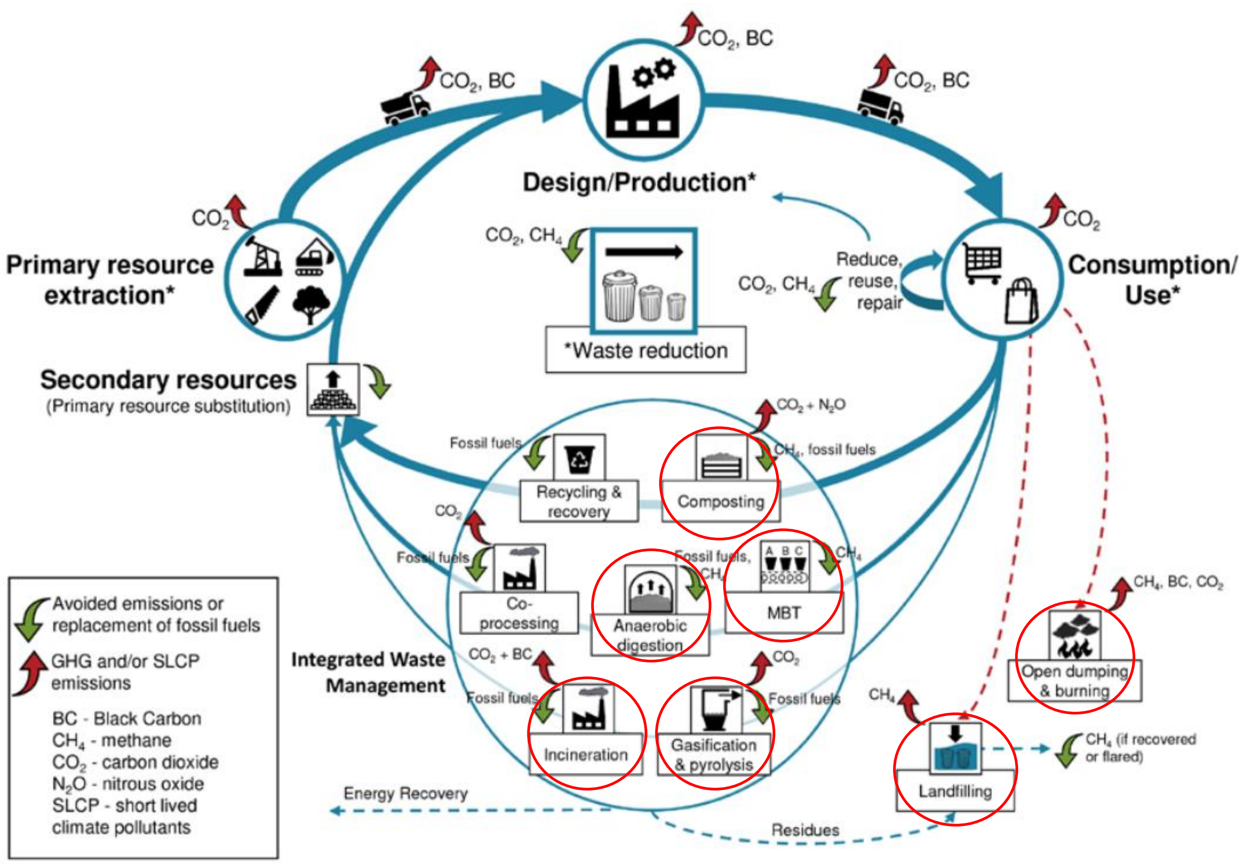


Figure 3 - Activities in the waste sector included in the inventory (marked with a red circle) [2]

1.3. Solid waste disposal sites

The main pathways for GHG emissions from landfills are methane generation through anaerobic digestion of biodegradables. This methane is either oxidized in cover layers, released into atmosphere,

[2] Source: Produced by RWA Group / GIZ, adapted from GIZ, 2017

or extracted for flaring or energy recovery, as illustrated in Figure 4. The methane generated at disposal sites is estimated based on IPCC guidelines for the purposes of the inventory.

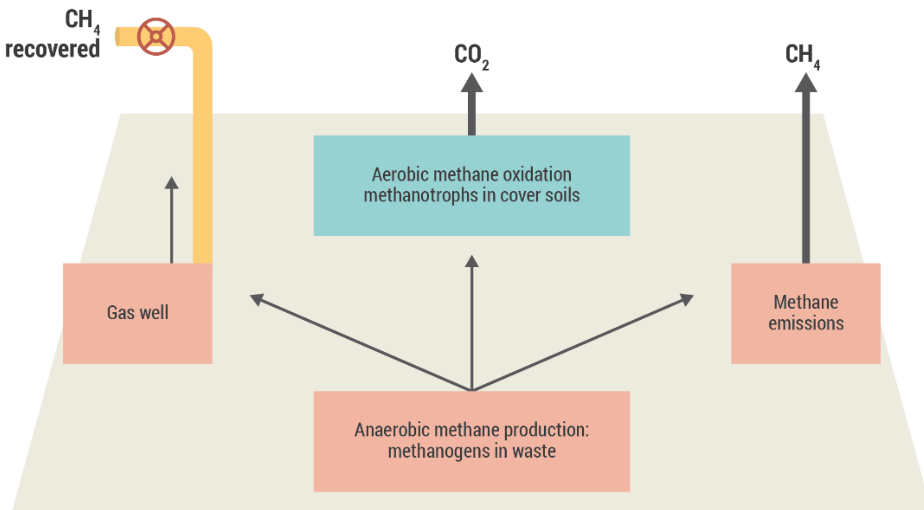


Figure 4 - GHG sources in the landfills

The IPCC methodology implements the First Order Decay method for the estimation of emissions from the solid waste disposal sites. According to this method, the rate of CH_4 generation depends on the quantity of carbon remaining in the waste and the time span needed for the degradable organic fraction of the waste to slowly decay, throughout tens of years. A typical methane generation curve is depicted in Figure 5. It illustrates how methane is generated from biodegradable waste in a typical landfill over time (years since waste deposited).

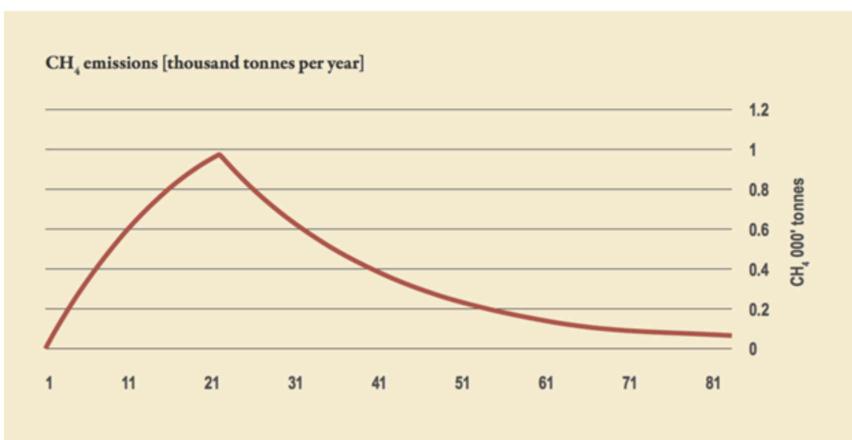


Figure 5 - Typical CH4 generation curve from waste disposal sites over time [3]

In addition to CH_4, anaerobic decomposition also produces CO_2, which is usually not accounted for since the decaying organic matter originates from biomass sources. Other waste streams such as plastics contain fossil derived organic matter, but these are non-biodegradable so associated emissions are not

[3] Source: GIZ - Training concept on GHG emissions in the waste sector, 2018

accounted. CO_2 emissions from disposal sites are considered entirely biogenic in origin and therefore not accounted for in the waste sector GHG inventory, as this would represent a double count with the net carbon losses reported under AFOLU sector (AFOLU – Agriculture, Forestry and Other Land use).

The IPCC calculation model

The IPCC calculation model is an Excel tool designed to estimate GHG emissions from waste disposal sites using the First Order Decay method. The IPCC Waste spreadsheet model is the basis for country inventory compilation and allows calculation of CH_4 emissions from landfills. There are several ways in which the model can be used by countries to compile inventories, all being dependent on the tier used. Tier 1 method uses a set of default data for all the parameters feeding the model. Therefore, there is no need for any country specific activity data. This also creates the possibility for every country to compile the country inventory. Tier 2 consists in using country specific data instead of the default values, thus allowing a more accurate compilation of the inventory. The use of a Tier 3 method would consist in providing specific data for some of the parameters in the model. Nevertheless, in practice, the use of complete Tier 3 is difficult as it requires site specific data; therefore, the most developed countries use in the best case a combination of Tier 2 and Tier 3 (e.g., Germany).

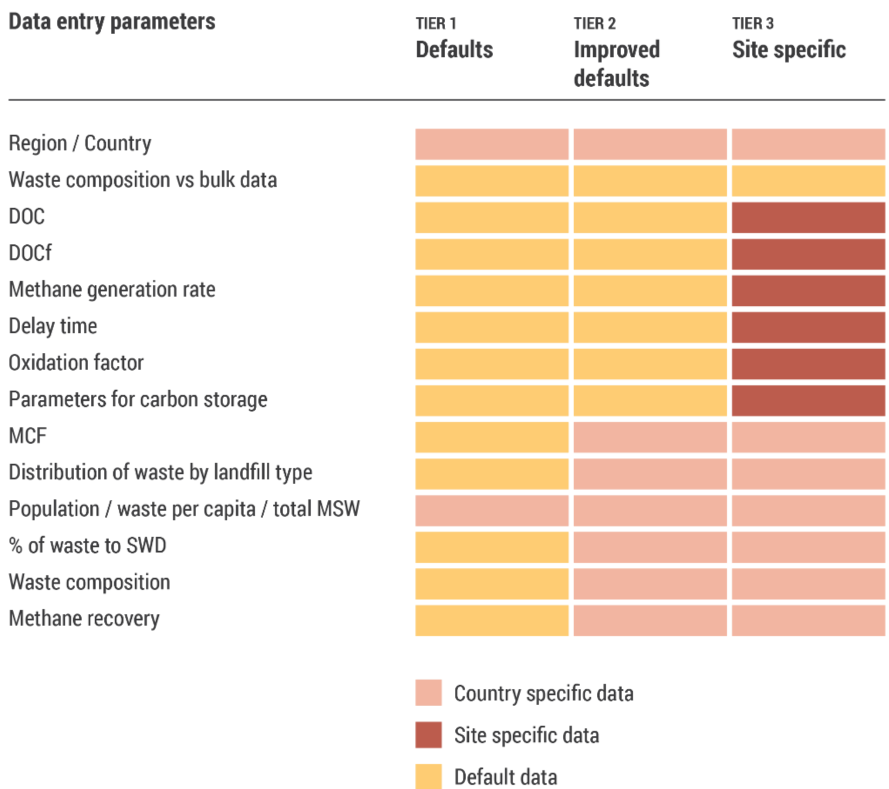


Figure 6 - Country specific data need for the three tiers [4]

The spreadsheet contains several sections in which input parameters are inserted and other parameters are automatically calculated and cannot be changed by the user. For the input data, the user can insert

[4] Source: Idem

specific data or use IPCC default data. Table 4 provides step by step directions on how to use the IPCC waste model.

No.	Step	Input parameters	Details
1	**Country and region**	Input country name and select region using the drop-down menu	The selection of a region will adjust the default values along the model
2	**Key parameters**	Fill in the values for DOC, DOCf, methane generation rate constant, fraction to methane and oxidation rate	Where no national data are available, use IPCC default values shown in the model
Note	The drop-down menu in the DOC area allows for selection of DOC and methane generation rate by waste composition or bulk waste.		
Note	The drop-down menu in the methane generation rate area allows for selection of appropriate IPCC default value based on the selected climate zone.		
3	**Time delay**	Enter time delay before decay to methane starts	
4	**Distribution of waste between different type of sites**	The distribution of waste disposed by site management type needs to be entered in the MCF sheet	Variations in site management practices over time should be inserted
5	**Activity data**	Population data, waste generation rate per capita, waste composition	Variations in waste generation rates, population and waste composition over time should be inserted

Table 3 – Instructions on how to use the IPCC calculation model

Once all the steps related to data input have been completed, the results section will show the methane generation per year for each of the waste streams in the IPCC model. In this section, information about potential methane recovery is also requested and deducted from total methane emissions.

Year	Food	Garden	Paper	Wood	Textile	Nappies	Sludge	MSW	Industrial	Total	Methane recovery	Methane emission
	A	B	C	D	E	F	G	H	J	K	L	M = (K-L)*(1-OX)
	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg	Gg

Figure 7 - Methane generation per year per waste stream [5]

Calculation methods

The CH_4 emissions from solid waste disposal are calculated using the equation described below. The landfill gas generation occurs with the partial degradation of organic material (DOC) under anaerobic conditions which depend on the waste management practices at the disposal sites. Approximately 50% of the landfill gas consists of CH_4.

[5] Source: The IPCC calculation model

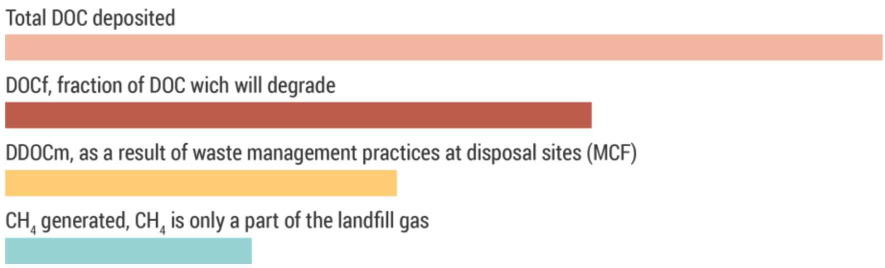


Figure 8 - CH_4 production in SWDS

The CH_4 generation potential can be estimated based on the quantity of waste, composition and waste management practices at the disposal sites:

$$Emissions\ CH_4 = \left[\sum_x CH_4\ generated_{x,T} - R_T\right] * (1 - OX_T)$$

CH_4 emissions = CH_4 emissions emitted in the year T, Gg
T = inventory year
x = waste category or type/material
R_T = recovered CH_4 in year T, Gg
OX_T = oxidation factor in year T, (fraction)

The DDOCm is the fraction of the organic carbon deposited which will degrade under anaerobic conditions:

$$DDOCm = W * DOC * DOC_f * MCF$$

DDOCm = mass of decomposable DOC deposited, Gg
W = mass of waste deposited, Gg
DOC = degradable organic content in the year of deposition, fraction Gg C/ Gg waste
DOC_f= fraction of DOC that can decompose (fraction)
MCF = CH_4 correction factor for anaerobic decomposition in the year of deposition (fraction)

Methane generation potential:

$$L_0 = DDOCm * F * 16/12$$

L0 = CH_4 generation potential, Gg CH_4
DDOCm = mass of decomposable DOC deposited, Gg
F = fraction of CH_4 in generated landfill gas (volume fraction)
16/12 = molecular weight ration CH_4/C (ratio)

1.4. Biological treatment of solid waste

Biological treatment of solid waste through composting and anaerobic digestion of organic waste fractions (putrescible materials in the waste) is one of the possible interventions in the waste management systems both in developed and developing countries. At present, this type of treatment is common in developed countries.

Composting is an aerobic method of decomposing solid waste where a large quantity of DOC (Degradable organic carbon) in the waste material is converted into CO_2. However, CH_4 can also be produced in case anaerobic sections develop during the composting process, but it is oxidized to a large extend in interaction with the surrounding aerobic processes. It is estimated that the methane released into the atmosphere varies from less than 1% to a few percent of the initial carbon content in the material. Another gas emitted in this process is N_2O, with very low shares ranging from 0.5% to 5% of the initial nitrogen of the material.

Anaerobic digestion of organic waste is an anaerobic process that breaks down organic matter in a controlled environment where temperature, moisture content and pH parameters are monitored. The methane emissions generated from this process vary from 0 to 10%, while N_2O emissions are considered to be negligible.

The product resulting from biological treatment, depending on the technology used and the quality of the processed material, can be used as organic fertilizer for soils or stored in the municipal waste deposit site. The anaerobic treatment is usually followed by recovery and use of biogas for energy. In most cases, biogas is used as fuel for combustion engines which power an electric generator to produce electricity. The process of biogas generation consists in several stages from the preparation of the input material to the fermentation or the digestion stages in which the feedstock undergoes different biological phases such as hydrolysis and methanogenesis, the conversion of the biogas to energy and the post-treatment of the digestate.

Within these processes, the decomposition of organic waste is much faster than landfilling, so the emissions are estimated annually. In both cases, emissions are due to the processing of waste.

The emissions from both composting and anaerobic digestion are higher in poorly managed treatment sites as compared to well-managed ones. In the case of composting emissions, this can occur due to anaerobic conditions that may occur in certain parts of the aerobic compost piles if aeration is not optimal. In the case of anaerobic digestion, during the anaerobic phases of the process some methane release may occur. Figures 8 and 9 provide a graphic depiction of these sources of emissions.

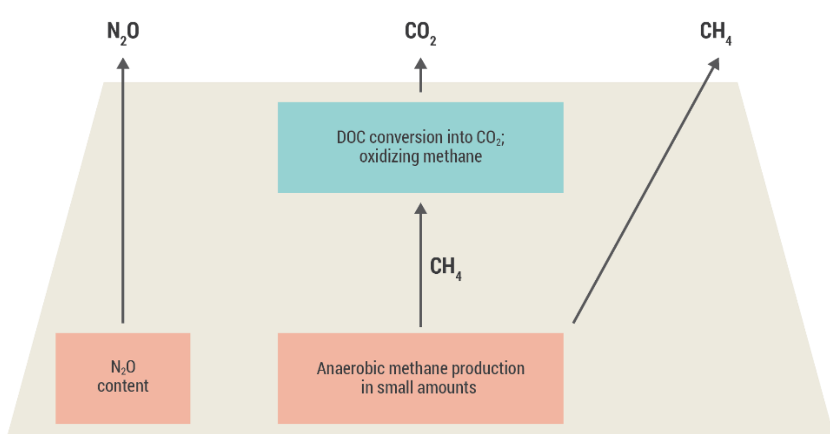


Figure 9 - Sources of emissions from composting [6]

[6] Source: Developed by RWA Group, adapted from IPCC 2006

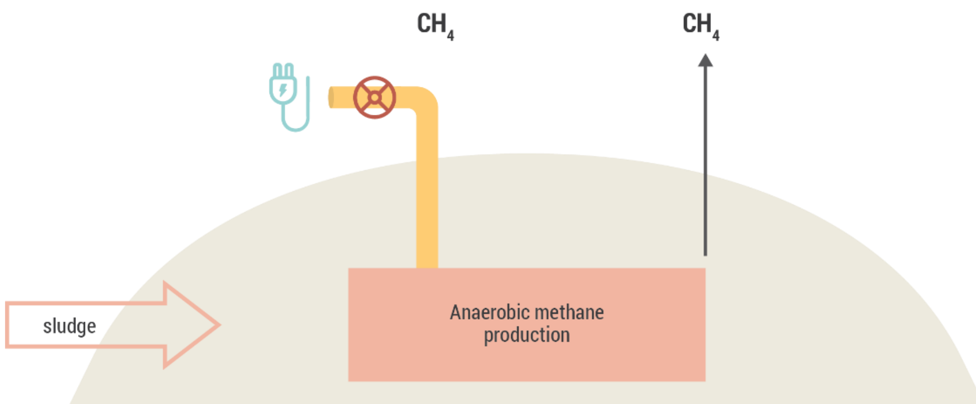


Figure 10 - Sources of emissions from anaerobic digestion [7]

Calculation methods

The emission factors from composting and anaerobic digestion depend on factors such as type of waste, composition, quantity, temperature, moisture, aeration, etc. The amount of recovered gas should be subtracted from the amount generated.

The CH_4 and N_2O emissions resulting from the composting and anaerobic digestion processes can be estimated by using the formula below.

$$emissions\ CH_4 = \sum_i (M_i * EF_i) * 10^{-3} - R$$

CH_4 emissions = total CH_4 emissions in inventory year, Gg CH_4
M_i = mass of organic waste treated by biological treatment type i, Gg
EF = emission factor for biological treatment i, g CH_4/kg waste treated
i = composting or anaerobic digestion
R = total quantity of CH_4 recovered in inventory year, Gg CH_4

$$emissions\ N_2O = \sum_i (M_i * EF_i) * 10^{-3}$$

N_2O emissions = total N_2O emissions in inventory year, Gg N_2O
M_i = mass of organic waste treated by biological treatment type i, Gg
EF = emission factor for biological treatment i, g N_2O/kg waste treated
i = composting or anaerobic digestion

Amount of organic waste treated

Default values in the guidelines related to the amount of organic waste managed through biological treatment are scarce, therefore national activity data should be used (see examples in Table). Even if there is limited data reported by limited number of sites, countries are encouraged to use the available data as a starting point and use various methods to fill in the gaps.

[7] Source: idem

Emission factor for treatment

Default values for emissions from various biological treatment processes are available although countries are encouraged to develop national emission factors (Tier 2) or measure emissions at sites (Tier 3). Country examples show that usually Tier 1 is used for emission estimations and uncertainty is high.

1.5. Incineration and open burning (combustion)

Waste incineration is a waste to energy (WtE) technology in which combustion of solid and liquid waste is conducted within a controlled environment to produce energy while diverting waste from landfills. The types of waste to which incineration can be applied extensively are municipal solid waste (MSW), industrial waste, hazardous waste, clinical waste and sewage sludge. Waste-incineration technology, in general, and emission control, in particular, have improved substantially over the past years. Incineration takes place in a relatively low number of controlled installations. This is a common treatment for clinical waste in developing countries. Modern facilities have incorporated combustion chambers, which provide high temperatures, high resistance times and air inflows to ensure complete combustion.

Data sets of interest for emission estimates from incineration include the following:

- Waste burned per type of waste including municipal, industrial, hazardous, clinical, sewage sludge and share of fossil carbon per waste type;
- Amount of fossil liquid waste;
- Site specific data is often collected for the controlled installations. Methodologies are available for gap filling, for example estimating the clinical waste amount per number of beds in hospitals.

Open Burning of waste is defined as uncontrolled combustion of the dry fractions of the MSW in open air or dumpsites where emissions are released directly into atmosphere without prior treatment. In developing countries, open burning has been practiced for many years by individuals or at dumpsites, occurring more frequently in rural areas than in urban areas. Therefore, it is recommended to take this category into consideration.

Data sets of interest for emission estimates from open burning include the following:

- Population burning waste and waste generation among this population;
- Fraction of waste burned;
- open burning is an incomplete process, the default value is that 60% of waste is actually oxidized and 40% remains together with ashes on site;
- The population not connected to a collection service and the quantity of waste going to open pits are possible entry points for estimating quantity of waste openly burned.

The relevant gases covered by existing inventory systems for IOB include CO_2, CH_4, N_2O while other gases such as NMVOCs (Non-methane volatile organic compounds), CO, NOx, SOx are not covered by IPCC and other existing methods published under international agreements are recommended. Figures 10 and 11 below depict the process emissions that are counted as part of the GHG Inventory. Emissions from burning of fossil fuel are accounted for in the GHG Inventory, while those from biomass origin are not. The CO_2 emissions from combustion of biomass materials contained in the waste are biogenic emissions and should not be included in national total emission estimates. It is assumed that the emissions related to biomass equals the quantity of CO_2 absorbed in biomass, thus assuming no GHG impact.

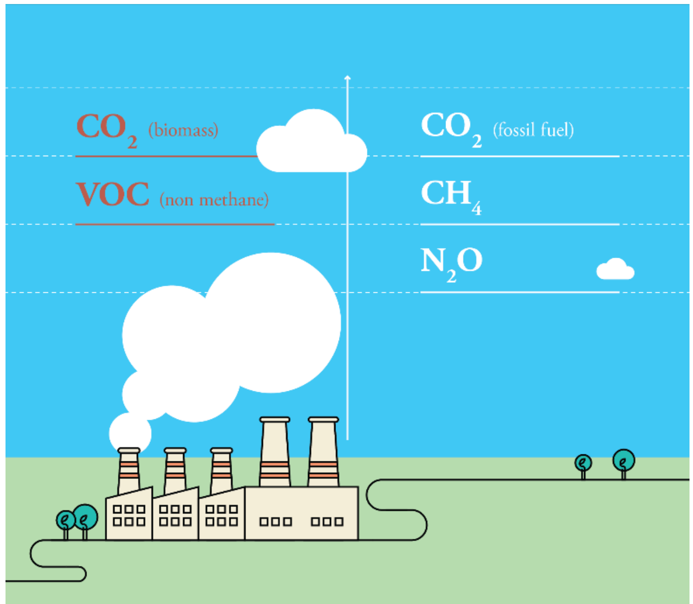


Figure 11 - Emission sources from incineration [8]

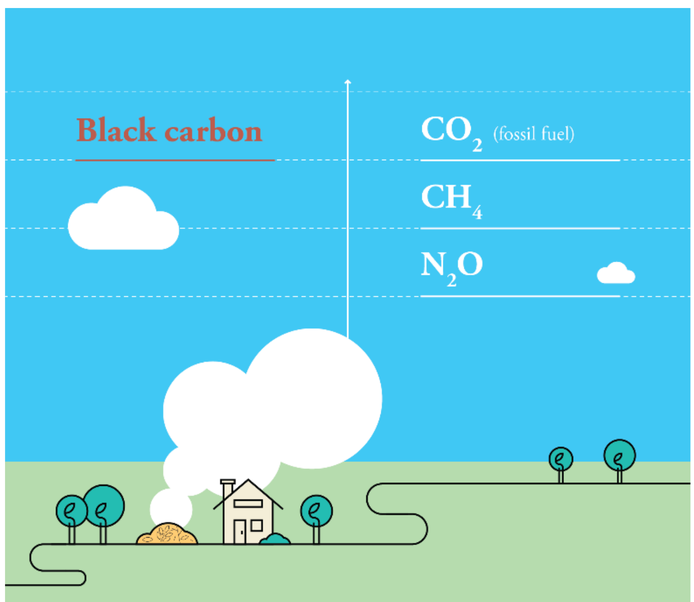


Figure 12 - Emission sources from open burning [9]

Emission factors depend on the fossil carbon content of the waste for CO_2, while for CH_4 and N_2O they depend on the combustion technology.

Calculation method

For estimating the CO_2 emissions from incineration and open-burning using Tier 1 method, data on the quantity of waste incinerated and open-burned are necessary. There are two methods that can be

[8] Source: Developed by RWA Group / GIZ
[9] Source: Developed by RWA Group / GIZ

followed, one based on the total quantity of waste combusted (the first equation) and another one based on the composition of the MSW (second equation). Where CO_2 emissions from incineration and open burning are considered a key category, it is a good practice to apply a higher tier.

CO_2 emissions estimate based on the total amount of waste combusted:

$$emissions\ CO_2 = \sum_i (SW_i * dm_i * CF_i * CF_i * FCF_i * OF_i) * 44/12$$

SW_i = total amount of solid waste type i, incinerated or open-burned, Gg/year
dm_i = dry matter content in the waste, incinerated or open-burned, (fraction)
CF_i = fraction of carbon in the dry matter (total carbon content), (fraction)
FCF_i = fraction of fossil carbon in the total carbon, (fraction)
OF_i = oxidation factor (fraction)
44/12 = conversion factor from C to CO_2
i = type of waste incineration / open-burned

CO_2 emissions estimate based on waste composition:

$$emissions\ CO_2 = MSW * \sum_j (WF_j * dm_j * CF_j * FCF_j * OF_j) * 44/12$$

MSW = total amount of municipal solid waste as wet weight incinerated or open-burned, Gg/year
WFj = fraction of waste type/material of component j, incinerated or open burned, Gg/year
dm_i = dry matter content in the component j in the waste, incinerated or open-burned, (fraction)
CF_i = fraction of carbon in the dry matter of component j
FCF_i = fraction of fossil carbon in the total carbon of component j
OF_i = oxidation factor
44/12 = conversion factor from C to CO_2

The calculation of CH_4 emissions is based on the quantity of openly incinerated / burned waste and the related emission factor, as highlighted in the equation below:

$$emissions\ CH_4 = \sum_i (IW_i * EF_i) * 10^{-6}$$

Emisii CH_4 = CH_4 emissions in inventory year, Gg/year
IW_i = quantity of solid waste of type i incinerated or openly burned, Gg/year
EF_i = aggregated emission factor of CH_4, kg CH_4/Gg of waste
10^{-6} = conversion factor from kilograms to gigagrams
i = category or type of incinerated / burned waste, specified as follows: municipal solid waste (MSW), industrial solid waste, hazardous waste, clinical waste, sewage sludge, other (that need to be specified)

The calculation of N_2O emissions is based on the amount of openly incinerated / burned waste and the related emission factor. This relationship is summarized in the following equation:

$$emissions\ N_2O = \sum_i (IW_i * EF_i) * 10^{-6}$$

Emisii N_2O = N_2O emissions in inventory year, Gg/year
IW_i = quantity of solid waste of type i incinerated or openly burned, Gg/year
EF_i = aggregated emission factor of N_2O, kg N_2O/Gg of waste

10^{-6} = conversion factor from kilograms to gigagrams
i = category or type of incinerated / burned waste, specified as follows: municipal solid waste (MSW), industrial solid waste, hazardous waste, clinical waste, sewage sludge, other (that need to be specified)

The amount and composition of waste should be in compliance with activity data used for the calculation of CO_2 and CH_4 emissions.

1.6. Wastewater treatment and discharge

The assessment of GHG is of interest for wastewater treatment and discharge processes as these facilities can contribute to the production of methane, carbon dioxide and nitrous oxide. The sources of wastewater can be domestic, industrial, commercial and further treatment may refer to onsite treatment, collected wastewater transferred to a centralised plant or disposed without any treatment in unauthorized places.

In developing countries, the collection systems consist mostly of open systems (canal, road drainage systems, gutters, ditches) which are subject to heating from the sun, and in case of stagnant sewer, the development of anaerobic conditions is likely and results in CH_4 generation and emissions.

The wastewater treatment systems vary in most developing countries. In some cases, industrial wastewater is discharged directly into water or treated onsite. Domestic wastewater is treated in centralised plants, pit latrines, septic systems or disposed of in unmanaged lagoons or waterways via open or closed sewers. In coastal areas, domestic wastewater is discharged directly into the ocean without any prior treatment. Centralised wastewater treatment systems can be classified as primary, secondary and tertiary treatment systems put in place to remove large solids and allow particles to settle and be subjected biodegradation by microorganisms and further purify the wastewater.

Methane emissions from wastewater occur due to the biological degradation of the organic carbon content of the wastewater under anaerobic conditions in deep and slowly moving waters and these can be found in both treatment and discharge pathways. CH_4 emissions generation also depends on the temperature and the type of the treatment system. In warm climate zones, increases in temperature levels allow higher CH_4.production rates.

Direct emissions of N_2O during processing occur only in countries with predominantly advanced centralised wastewater treatment plants with nitrification and denitrification steps. N_2O is associated with the degradation of nitrogen components in the wastewater. Direct emissions of N_2O may be generated during both nitrification and denitrification of the nitrogen, both occurring either in plant or after the effluent is discharged to a water body. Nitrification is an aerobic process converting ammonia and other nitrogen compounds into nitrate, while denitrification occurs under anoxic conditions (without oxygen).

In order to estimate the CH_4 emissions, and also N_2O in this category, the Total Organic Biodegradable (TOW) content of the wastewater needs to be known. Biological Oxygen Demand is the most common measurement of the TOW content of the wastewater.

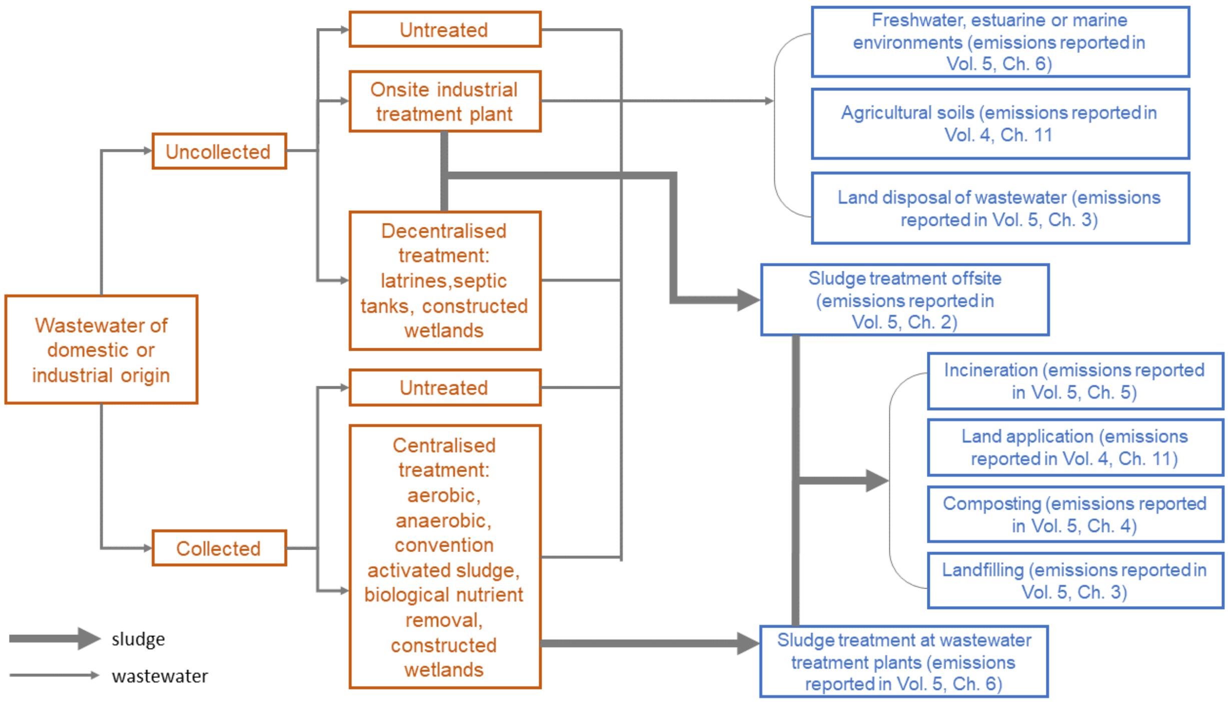


Figure 13 - Wastewater treatment and discharge pathways [10]

Emissions from boxes with blue frames in Figure 12 are accounted for, according to the IPCC guidelines for wastewater treatment and discharge. It is a good practice for countries to draw a similar diagram to consider all pathways, including all anaerobic treatment and discharge systems as well as collected, uncollected, treated and untreated wastewater.

Data sets of interest for emission estimates from wastewater treatment include the following:

Domestic wastewater

- Determine Total Organic Biodegradable Content (TOW) of wastewater;
- Determine or choose default value for emission factors for each pathway of the system (see Figure 13). For domestic wastewater, default values are available based on the quantity of carbon in the wastewater determined through the BOD and COD concentration (biochemical / chemical oxygen consumption);
- Determine the relative share of each pathway in the system. Systems may be distributed based on rural, urban high income, urban low-income populations.

Industrial wastewater

- The main industries to consider are pulp and paper, food and beverage and organic chemical industry for emissions from industrial wastewater, due to the high volumes of wastewater containing high level of biodegradable organics or organic carbon levels;
- Activity data is based on production output from the relevant industries and a Chemical Oxygen Demand per unit of output for each industry;

[10] Source: Developed by RWA Group / GIZ, adapted from the 2006 IPCC Guideline

- An important parameter to estimate N_2O emissions, is the protein intake per person. Protein intake may be available from nutritional statistics or international organizations.

Calculation methods

The CH_4 emissions from domestic wastewater are calculated depending on the organic content of wastewater, for each treatment / evacuation system used, using the equations:

$$emissions\ CH_4 = \left[\sum_j emissions\ CH_{4j}\right] * 10^{-6}$$

emissions CH_4 = CH_4 emissions in inventory year, kg CH_4/year
emissions CH_{4j} = CH_4 emissions from treatment / drainage system j in inventory year, kg CH_4/year
j = treatment / drainage system
10^{-6} = conversion factor from kg to Gg

$$emissions\ CH_{4j} = \left[\left(TOW_j - S_j\right) * EF_j - R_j\right]$$

emissions CH_{4j} = CH_4 emissions from treatment / disposal system j in inventory year, kg CH_4/year
TOW_j = total organic biodegradable waste content in wastewater in treatment / drainage system j in the inventory year, kg BOD (biological oxygen demand) / year.
Sj = organic component extracted from wastewater as sludge, from the treatment / drainage system j, in the inventory year, kg BOD / year; for wastewater discharged in aquatic environments, there is no sludge removal (Sj = 0) and no recovery of CH4 (Rj = 0).
j = treatment / drainage system
EFj = emission factor for treatment / drainage system j, kg CH4/kg BOD.
Rj = quantity of CH_4 recovered or burned in the treatment / drainage system j, in inventory year, kg CH_4/yr. The default value is zero.

$$EF_j = B_0 * MCF_j$$

EF_j = emission factor, kg CH_4/kg BOD
j = treatment / drainage system
B_o = maximum CH_4 emission capacity, kg CH_4/kg BOD
MCF_j = methane correction factor

$$TOW_j = \left[\sum_j TOW * U_i * T_{ij} * I_j\right]$$

TOW_j = total organic biodegradable waste content in wastewater in treatment / drainage system j in the inventory year, kg BOD (biological oxygen demand) / year.
TOW = total organic biodegradable waste content in total wastewater in inventory year, kg BOD/year
U_i = percentage of population from income group i in inventory year
T_{ij} = treatment / discharge system degree of utilization, j, for each fraction of the income group
I_j = correction factor for additional industrial BOD offloaded in the treatment / discharge system j (implicit values are 1,25 if collected, 1,00 if uncollected)

Also, according to the IPCC methodology update in 2019, the organic component discharged as sludge in the treatment plants or in the septic systems, S, is calculated according to the formula below.

The default value of S for all the other systems is zero. It is important to mention that the organic component discharged as sludge is not equivalent with the mass (tons) of sludge produced in wastewater treatment. By contrast, the organic component removed as sludge is a function of the sludge produced from wastewater (S_{mass}) and a sludge factor (K_{rem}) which indicated the quantity of organic matter discharged in the sludge treatment process per kilogram of produced sludge.

The organic component removed as sludge in the aerobic treatment plants:

$$S_{aerobic} = S_{mass} * K_{rem} * 1000$$

$S_{aerobic}$ = organic component removed from wastewater as sludge, in aerobic treatment stations, kg CBO / an
S_{mass} = quantity of sludge eliminated through the epuration of wastewater as dry mass, tone / year
K_{rem} = sludge factor, kg CBO / kg

The organic component removed as sludge from the septic systems:

$$S_{septic} = TOW_{septic} * F * 0.5$$

S_{septic} = organic component removed from wastewater as sludge in septic systems, kg CBO / year
TOW_{septic} = total organic biodegradable waste content in wastewater from septic systems in inventory year, kg BOD / year.
F = percentage of population that manages their private septic systems according to sludge removal instructions
0.5 = fraction of organic substances in wastewater removed as sludge when septic systems are managed according to sludge removal instructions

1.7. Inventory practiced in the waste sector of the Republic of Moldova

In Sector 5 “Wastes” the direct greenhouse gases emissions (CO_2, CH_4 and N_2O) originating from the management of solid household waste, industrial waste, from incineration and open burning of waste, and from wastewater treatment and discharge are included, counted by the application of assessment methodologies available in the 2006 IPCC Guideline. The categories of sources estimated in this sector are: 5A “Solid waste disposal”, 5B “Biological treatment of waste”, 5C “Incineration and open burning” and 5D “Wastewater treatment and discharge”.

1.7.1. The dynamics of greenhouse gas emissions at sectoral level

According to the Biennial Report updated by the United Nations Framework Convention on Climate Change, in 2019, sector 5 “Wastes” had an approximate 11.0% weight of the total national emissions of the direct greenhouse gases in the Republic of Moldova (without the contribution of sector 4 “Land use, land use change and forestry”), being the third major source of GHG emissions after the energy and agriculture sector. It should be noted that sector 5 “Wastes” has represented a major source of CH_4 emissions, with an approximate 50.6% weight of the total methane emissions recorded at national level. During the 1990-2019 period, the dynamics of the total GHG emissions coming from sector 5 “Wastes” has experienced a slight increase, from approx. 1514.2 kt CO_2 equivalent in the year 1990 to approx. 1550.6 kt CO_2 equivalent in the year 2019 (Table 1). The economic growth over the last 20 years has led to a higher level of industrial production and population welfare, and the increase of consumption results also in a higher waste generation rate.

Year	CO_2 kt	CH_4, kt CO_2 equivalent	N_2O, kt CO_2 equivalent	Total, kt CO_2 equivalent	CO_2, % of total	CH_4, % of total	N_2O, % of total
1990	14.9667	1408.7400	90.5302	1514.2369	1.0	93.0	6.0
1991	14.9994	1449.2809	83.7658	1548.0461	1.0	93.6	5.4
1992	15.0476	1458.7057	77.0182	1550.7715	1.0	94.1	5.0
1993	15.0447	1523.1283	71.8949	1610.0679	0.9	94.6	4.5
1994	15.0947	1507.5656	69.8180	1592.4783	0.9	94.7	4.4

Year	CO_2 kt	CH_4, kt CO_2 equivalent	N_2O, kt CO_2 equivalent	Total, kt CO_2 equivalent	CO_2, % of total	CH_4, % of total	N_2O, % of total
1995	15.0979	1504.6903	70.6313	1590.4195	0.9	94.6	4.4
1996	15.0960	1508.4213	69.6101	1593.1275	0.9	94.7	4.4
1997	15.0456	1501.7762	70.8125	1587.6344	0.9	94.6	4.5
1998	15.0794	1476.9649	71.8643	1563.9087	1.0	94.4	4.6
1999	15.0071	1474.0693	70.3233	1559.3997	1.0	94.5	4.5
2000	14.9965	1449.4802	71.9066	1536.3833	1.0	94.3	4.7
2001	14.9689	1423.3404	72.9912	1511.3005	1.0	94.2	4.8
2002	14.9402	1411.2146	74.8848	1501.0396	1.0	94.0	5.0
2003	14.9100	1381.0338	72.4388	1468.3826	1.0	94.1	4.9
2004	14.8621	1367.6534	69.1043	1451.6198	1.0	94.2	4.8
2005	14.4670	1372.2194	63.5382	1450.2245	1.0	94.6	4.4
2006	14.1260	1358.5767	65.4365	1438.1392	1.0	94.5	4.6
2007	13.7672	1352.5491	61.1190	1427.4352	1.0	94.8	4.3
2008	13.4533	1373.5215	56.4784	1443.4532	0.9	95.2	3.9
2009	13.1613	1385.8912	57.6921	1456.7446	0.9	95.1	4.0
2010	12.8663	1411.7694	55.8425	1480.4782	0.9	95.4	3.8
2011	12.5793	1423.0137	56.8734	1492.4663	0.8	95.3	3.8
2012	12.2708	1408.2919	57.3241	1477.8869	0.8	95.3	3.9
2013	11.9033	1350.8284	57.7380	1420.4697	0.8	95.1	4.1
2014	11.5371	1341.1070	57.2478	1409.8919	0.8	95.1	4.1
2015	13.3135	1338.6144	58.3437	1410.2717	0.9	94.9	4.1
2016	13.0346	1365.4065	58.9584	1437.3995	0.9	95.0	4.1
2017	14.6448	1453.0492	61.2178	1528.9118	1.0	95.0	4.0
2018	14.2880	1468.1098	62.5879	1544.9857	0.9	95.0	4.1
2019	13.9120	1473.9781	62.7228	1550.6129	0.9	95.1	4.0
1990-2019. %	**-7.0**	**4.6**	**-30.7**	**2.4**	**-9.2**	**2.2**	**- 32.3**

Table 4 - The dynamics of the total greenhouse gas emissions from sector 5 "Wastes" in RM during the 1990-2019 period

In 1990, the CO_2, CH_4 and N_2O emissions had a distribution of approx. 1.0%, 93.0 % and 6.0 % of the total GHG emissions coming from sector 5 "Wastes". Towards 2019, this distribution has not changed significantly, representing approx. 0.9%, 95.1% and 4.0% of the total GHG emissions recorded at sectoral level. At the same time, during the 1990-2019 period, the total GHG emissions in this sector increased by 2.4 %, while the CH_4 emissions increased by 4.6 %, the CO_2 and N_2O emissions decreased by 7% and 30.7%, respectively.

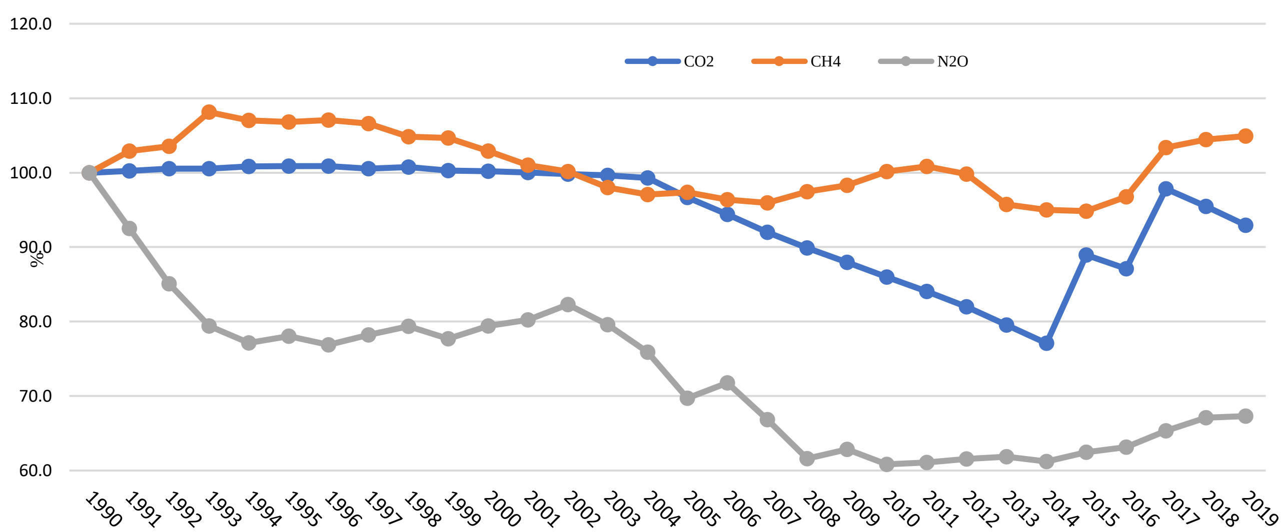


Figure 14: Direct greenhouse gas emission trends in the Waste sector during the 1990-2019 period, where year 1990 represents 100%

During the reference period, the direct GHG emissions from the 5A category of sources "Solid waste disposal" increased by approx. 17.7 %, those in the 5B source category "Biological treatment of waste" increased by 2.7 %, those in the category of sources 5C "Incineration and open burning" decreased by approx. 7 %, and those in the 5D category of sources "Wastewater treatment and discharge" decreased by another approx. 32.8 %.

1.7.2. Applied methodologies

For the estimation of the GHG emissions originating from the 5A category of sources "Solid waste disposal", 5B "Biological treatment of waste", 5C "Incineration and open burning" and 5D "Wastewater treatment and discharge", Tier 1 and Tier 3 assessment methodologies, emission factors used implicitly in the 2006 IPCC Guideline, as well as country specific emission factors (Table 2) were applied. A more detailed description of the used assessment methodologies and emission factors is available in Annex 1 of this guideline.

The IPCC category	The category of sources	CO_2		CH_4		N_2O	
		Method	FE	Method	FE	Method	FE
5 A	Solid waste disposal	NA	NA	T3	D, CS	NA	NA
5B	Biological treatment of waste	NA	NA	T1	D	T1	D
5C	Incineration and open burning	T1	D, CS	T1	D, CS	T1	D
5D	Wastewater treatment and discharge	NA	NA	T1	D, CS	T1	D

Abbreviations: T1 – Tier 1 method; T2 – Tier 2 method; CS – country-specific; D – default; NA – Not Applicable; NO – Not Occurring.

Table 5 - Methodologies for the assessment of the GHG emissions regarding sector 5 "Waste"

Solutions for the mitigation of GHG emissions in the waste management sector

2

2. Solutions for the mitigation of GHG emissions in the waste management sector

2.1. The emission reduction potential in the sector

The waste and resource management sector is often called the orphan of the sectors with emission reduction potential. The limited attention paid to the potential of this sector can be due to the fact that the sector is a relatively small contributor to the global GHG emissions, as compared to other sectors. However, if we look at the potential of this sector, it warrants our entire attention. Thus, the sector contributes with an average of 3% of the global emissions, but has the potential to reach reduction rates of 15-20% by the implementation of some measures of recycling and recovery of the material and energy value from wastes.

There are numerous studies and publications that estimate the GHG reduction potential of this sector. For example, a study conducted by the German Environmental Agency addresses this potential in the OECD countries, estimating the benefits of two scenarios comparatively with a modest baseline scenario, where no improvements are brought to waste management standards. The estimations take into consideration both emissions and emission reduction in each scenario, showing the net benefits of each scenario.

In 1,000 t CO2-eq	America	Europe, Turkey and Israel	Japan, South Korea and the Pacific area	OECD total
Collection, sorting and transport*	6.041	5.094	2.271	**13.407**
Storage	122.336	81.904	13.122	**217.362**
Incineration (no energy)	77	3.226	1.183	**4.486**
Incineration (with energy)	-574	-3.234	-2.241	**-6.049**
Recycling	-67.764	-74.107	-21.642	**-163.514**
Composting	174	291	50	**466**
Total**	**60.323**	**13.339**	**-7.305**	**66.358**

**Collection, sorting and transport were calculated identically for all OECD countries*
***Results for residual-waste composting are included in the net result but are not listed separately, due to small quantities*

Table 6 - Emissions in the waste sector in the baseline scenario [11]

[11] Source: The GHG Emission Mitigation Potential of the Waste Sector; page 20, Table 2, Federal Environment Agency (Germany)

The implementation of medium- and high-ambition interventions estimated for the OECD countries show significantly diminished emissions as compared to the baseline scenario presented in the table above. The results for the two scenarios are presented in the table below.

	Description of scenario	**in 1,000 t CO2-eq**
Baseline scenario	The real situation as it was at the time of report drafting, year 2017	66.385 (100%)
Medium scenario	The quantity of stored wastes will be halved and all landfills will be equipped with biogas extraction systems. This measure would increase the biogas collection efficiency in the OECD countries from 37.9% to 50%. Wastes that do not reach landfill are recycled, and the non-recyclable residues are incinerated at the rate of 80% with energy recovery. The 20% of the non-recyclable wastes remaining are directed towards anaerobic digestion in mechanical-biological treatment plants.	-154.646 (-233%)
Ideal scenario	The countries stop practicing landfilling. Wastes are directed towards recycling, and the residual fractions are treated similarly to those mentioned in the medium scenario. The 20% of non-recyclable waste that are not incinerated are mechanically and biologically treated to achieve their stabilization and to produce RDF, subsequently used for energy recovery.	-286.906 (-432%)

Table 7 - Net GHG emissions estimated for the two scenarios as compared to the baseline scenario, globally

The table above reveals that in the two scenarios not only that all emissions in the sector are reduced, but also a reduction performance is achieved, 3-5 times higher as compared to the emission quantity in the baseline scenario.

If we expand the horizon and think about solutions from circular economy, that is reduction of dependence on primary matters, streamlining the production lines, replacement of some conventional materials with new ones that need less energy to produce and do not generate emissions throughout the life cycle, remodelling of distribution networks for their efficiency, specific design for waste reduction, to favor the dismantling of products, etc., this reduction potential is even higher.

Circular economy is a concept of major impact in economy, which, similarly to that of climate changes, is gradually integrated in all the economic sectors and thoroughly transforms the economy. Europe's Green New Deal from this year brings to the fore the circular economy solutions, together with those aimed at addressing climate change. The main strategies of circular economy are presented in the figure below.

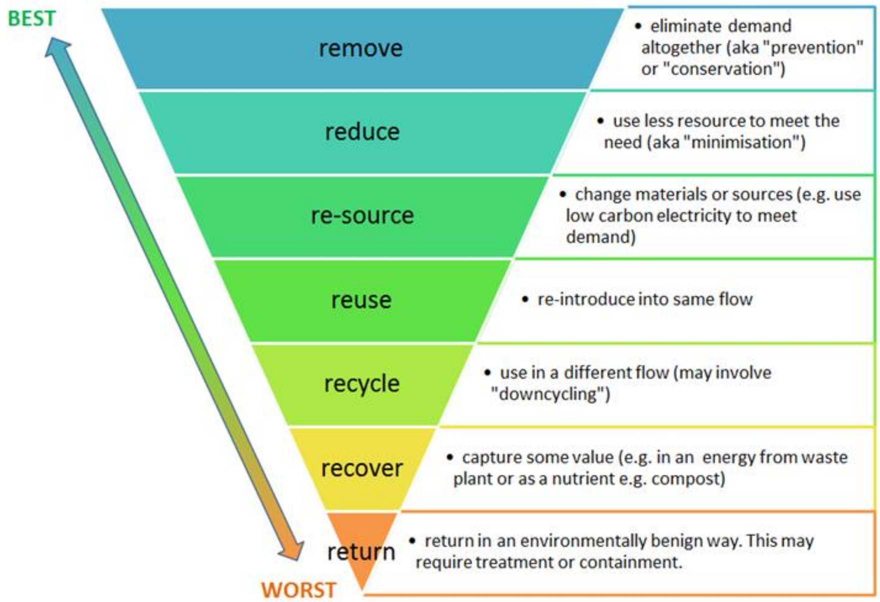


Figure 15 - Resource efficiency hierarchy [12]

There are increasingly more and more studies that estimate the mitigation potential of GHG emissions by circular economy solutions. Among the most important it is the study of the Institute for European Environmental Policy, which estimated that these measures could reduce by 33% the carbon emissions associated with production. That would be half of the necessary reduction to achieve the targets of the Paris Agreement.

A 2016 report on Circular Economy drafted by Ecofys indicates significant mitigations in streamlining the use of material and energy resources with impact on the entire process of added value creation of the products. Of all the emissions generated at global level, half are related to production, and these can be reduced by 30% through circular economy measures.

2.2. Technologies and solutions for the mitigation of GHG emissions in the waste sector

Once the GHG emissions mitigation potential has been established in this sector, it is important to know the technologies and solutions that can contribute to these mitigations.

Table 5 presents generically the adequate waste streams and treatment options of waste management. The incorrect waste management such as their burning, illegal dumping, lack of treatment and recycling of wastes, as well as inadequate disposal, they all contribute to the increase of GHG. All the technologies presented below have the potential to mitigate GHG to a smaller or a higher extent.

The technological options presented in Table 8 provide a good overview of the GHG mitigation options, but are not a comprehensive list. The most important mitigation source is avoiding the biodegradable

[12] Source: Niall Enright, Sustain success, available at www.sustainsucces.co.uk

organic materials that reach the disposal sites and generate methane. To these are added different other GHG mitigation sources.

Using a cover material on the landfill can oxidize a significant amount of the methane generated in the landfill body and recovering and flaring landfill gas will also reduce methane.

For the other technologies, using the output of the treatment as secondary material or energy will replace more energy intensive primary materials or traditional fuels, which will result in avoided emissions. Compost and compost-like materials improve soil and increase carbon sequestration in soils.

The best waste is the waste never generated. As such, waste prevention, reduction, repair, reuse and home-composting are the most climate-friendly approaches, but also the most difficult to measure. Optimizing or avoiding transport is another source of GHG mitigation.

The adequate management of the landfills itself can lead to significant GHG mitigations, see subchapter 3.3.

Waste stream	Suitable technologies	Description	Technology restrictions	Correlation with the current situation in Moldova
Residual / raw waste	Dirty Materials Recycling Facility (dMRF)	A facility employing a number of separation techniques to recover recyclable materials from mixed waste, usually of a relatively low grade. The remaining residual will be processed into a fuel (refuse derived fuel, RDF) for use in energy recovery facilities.	Not suitable for hazardous materials. Will only recover a small amount (<25%) of relatively low-grade recyclables.	The "ABS" waste sorting facility in Chișinău separates the recyclable fractions and the RDF (at the moment there are no capacities to use the selected RDF).
	Mechanical-biological treatment	A facility that combines mechanical separation techniques with biological treatment to either stabilize or dry the organic fraction of the waste. Mechanical separation is used to recover relatively low-grade recyclable materials in much the same way as dirty as a dirty MRF. The organic fraction can be used as an RDF, a feedstock for anaerobic digestion (to recover biogas) or stabilized compost like output with reduced volume.	Not suitable for hazardous materials. Not suitable for bulky or large waste streams. Will only recover a small quantity of relatively low-grade recyclable.	One of the specific objectives of the Strategy is to develop the household waste disposal capacities (2 facilities for the mechanical-biological treatment in Chișinău and Bălți).
	Mechanical Heat Treatment (MHT)	MHT facilities combine mechanical and thermal treatment techniques, often with the prime aim of extracting either relatively high quality recyclables and/or fuel fractions (refuse derived fuel) from waste. In addition, dependent on the technology employed, they may: reduce the volume of the waste; derive an organic fiber for use as a raw material /	Not suitable for hazardous waste. Not suitable for bulky or large waste streams. Due to the nature of accepted waste, streams will only recover mid-grade and low quantities	No remarks.

Waste stream	Suitable technologies	Description	Technology restrictions	Correlation with the current situation in Moldova
		substitute fuel.	of recyclables.	
	Incineration treatment	The mass burning of waste to reduce volume. Modern facilities should be designed to recover energy from waste (often referred to as energy-from-waste (EfW) or waste-to-energy (WtE)) in the form of heat, electricity or heat and electricity. Metals can be extracted from the processed waste (bottom ash) ready for remelting and preparation for new uses.	Not suitable for for bulky or large items. Will destroy all non-metal recyclable materials. Energy recovery efficiencies are usually lower than conventional power plants and 'RDF only' thermal treatment facilities.	Waste incineration is regulated by art. 17 of Law on wastes no. 209/2016.
	Landfill	The mass disposal of waste to land under controlled circumstances. Energy can be recovered from waste through collection of gases resulting from natural decomposition of the waste.	Capture of gas from decomposition requires significant infrastructure to cover entire site. There will always be landfill gas that escapes to atmosphere and smaller quantities that are uneconomic capture. Land intensive option with no material recovery.	At the moment, the most frequently used household waste treatment methods is landfilling, not always in controlled conditions.
Comming led Dry Recycling	Clean Materials Recycling Facility (cMRF)	Mixed dry recycling is separate into fractions by a complex collection of mechanical and manual segregation techniques and conveyors. Fractions can be targeted dependent on value, with different levels of purity achievable if the end-market dictates.	Co-mingling of glass and paper will reduce the output quality of both materials. Mechanical technologies required for separation of materials by grade are capital intensive. Hand sorting can be used to varying degrees within the process.	One of the specific objectives of the Strategy is "to promote and implement the selective collection systems in all localities, both in the household sector, and in the production sector, as well as the sorting, composting and recycling facilities".
	Clean	Clean MRFs using advanced	Mechanical	One of the specific

Waste stream	Suitable technologies	Description	Technology restrictions	Correlation with the current situation in Moldova
Segregated / Partially Segregated Recyclables	recyclable MRF	mechanical separation techniques can refine the quality in single waste fractions to meet specific end-user requirements and increase the economic value of the material. Partially segregated recycling can be separated in the same way as a commingled stream.	technologies required for separation of materials by grade are capital intensive. Hand sorting can be used to varying degrees within the process.	objectives of the Strategy is "to promote and implement the selective collection systems in all localities, both in the household sector, and in the production sector, as well as the sorting, composting and recycling facilities".
	Recycling reprocessor	Recycling that has been segregated by material type can be sent directly to the reprocessor if it meets their quality demands.	Requires diligent separation of materials at source and low contamination.	Currently, there are 4 companies authorized to recycle plastics, 2 for cardboard and 2 for glass. the recycling rate has been slowly increasing over the last 3 years.
Refuse Derived Fuel (RDF) / Solid Recovered Fuel (SRF)	Incineration treatment	When accepting a pre-treated residual waste (like RDF) incineration is used to burn the feedstock to reduce the volume and to recover energy (electricity and/or heat) through generation of steam for use in a steam circuit. Metals can be extracted from the processed waste (bottom ash) ready for re-melting and preparation for new uses.	Incineration facilities with high energy recovery efficiencies are very capital intensive. These require feedstock to be pre-treated (to an RDF) or a local producer of RDF. Will destroy all non-metal recyclable materials. Requires a specialist grate to handle higher temperature generated by RDF.	No remarks.
	Co-combustion / industrial processes	RDF is used as an alternative feedstock for conventional power plants (when mixed with fossil fuels / conventional feedstock) or a subtle fuel for industrial facilities, e.g., cement kilns.	RDF needs processing to a high enough standard to suit the configurations of existing plant.	LaFarge cement factory has the capacities to use some fuel fractions. In the absence of the legal frame, this

Waste stream	Suitable technologies	Description	Technology restrictions	Correlation with the current situation in Moldova
			Requires local or accessible facilities which are suitable for the waste derived fuel.	activity is ceased until the approval of the Regulation regarding waste incineration.
	Gasification treatment	Pre-treated waste feedstock (RDF) is treated in a reduced oxygen environment, therefore limiting the process to partial combustion and partial oxidation. The process produces a synthesis gas (syngas) which can be cleaned up as a replacement for natural gas or combusted and used to feed a steam circuit producing electricity and/or heat. Metals can be extracted from the processed waste (ash / slag) ready for re-melting and preparation of new uses.	RDF is required to meet specifications determined by the technology chosen. Gasification systems can be capital intensive. Operational performance in Europe has been questioned (with regards to energy efficiency and emissions abatement). Will destroy all non-metal recyclable materials.	No remarks.
	Plasma gasification	Plasma gasifiers combine the gasification technology described above with plasma torches generating very high temperatures (> 1000°C). In theory, this generates a cleaner syngas, enables use of gas in more efficient gas engines (after further clean up to remove sulphurs etc.), increasing the energy generation from the same quantity of feedstock.	As with gasification, however with extra expenditure required for the purchase and operation of plasma torches/arc. Plasma technology is energy intensive and will therefore drastically reduce the gross energy output of the facility; however more efficient theoretical energy recovery could improve net energy output.	No remarks.
	Pyrolysis treatment	Refuse Derived Fuel (RDF) is thermally treated in an oxygen starved	The technology has a limited track	No remarks.

Waste stream	Suitable technologies	Description	Technology restrictions	Correlation with the current situation in Moldova
		environment in order to facilitate the separation of waste into a char (non-combustibles, residues etc.) and syngas. Syngas from pyrolysis typically has a higher calorific value than syngas from gasification-based processes, and will be fed through a steam circuit in the same way as an incineration or some gasification facilities.	record on mixed waste streams. Metals and inerts require separation before thermal treatment if they are intended for removal. Pyrolysis technology is capital intensive. Pyrolysis is energy intensive which reduces the gross energy output of plant significantly.	
Mixed organic waste	In-vessel composting (IVC)	Mixed organics contain food (and other potentially hazardous or nuisance materials) so they require treating in-vessel. In-vessel composting decomposes the feedstock in an enclosed aerobic environment to produce compost suitable for application to agricultural or horticultural land.	It requires several weeks to fully decompose and stabilize materials. It requires mechanical agitation techniques, some of which may have reliability issues.	One of the specific objectives of the Strategy is to "encourage the recovery by aerobic and anaerobic procedures and the strengthening of waste composting and fermentation capacities, at least one per district".
	Dry anaerobic digestion	Mixed organics contain food (and other potentially hazardous or harmful materials), so they require treatment in-vessel (IVC or AD). Anaerobic digestion utilizes natural microbes to digestate and decompose materials in an anaerobic environment to produce biogas (suitable for use in CHP engines or for use as a replacement for natural gas) and nutrient rich digestate. The digestate can be spread to land either in its output state or after dewatering (more suitable if no immediate end user is available).	Requires low levels of contamination. Requires a high degree of monitoring and control over conditions to maintain digestion process. Can be sensitive to imbalances in feedstock (e.g., high quantities of food versus garden waste or vice versa).	One of the specific objectives of the Strategy is to "encourage the recovery by aerobic and anaerobic procedures and the strengthening of waste composting and fermentation capacities, at least one per district".
Garden wastes	Open composting	Garden waste generally has a lower moisture content and less potentially hazardous elements than mixed organic waste and is therefore best suited to aerobic composting	Long process time (c. 12 weeks) Requires low levels of contamination, or some	One of the specific objectives of the Strategy is to "encourage the recovery by aerobic

Waste stream	Suitable technologies	Description	Technology restrictions	Correlation with the current situation in Moldova
		processes, usually taking place in the open. Open composting follows the same biological processes as in-vessel composting; however, it is not practiced in such controlled conditions and therefore requires a longer decomposition time.	mechanical treatment to remove contaminants. Compost turned by mechanical means. Should not be practiced in close proximity to sensitive receptors (e.g., human population) in case of odour / bioaerosol issues.	and anaerobic procedures and the strengthening of waste composting and fermentation capacities". In the SFF development phase, the distribution of bio-composters was proposed for households.
Food Wastes	Wet anaerobic digestion (AD)	Anaerobic digestion utilizes natural microbes to digest and decompose food wastes (including animal products) in an anaerobic environment to produce biogas (suitable for use in CHP engines or clean-up for use as a replacement for natural gas) and nutrient rich digestate. The digestate can be spread to land either in its output state or after dewatering (more suitable if no immediate end user is available). Food waste has a higher moisture content than mixed organics and is therefore most suitable for "wet" AD systems.	Requires low levels of contamination. Requires a high degree of monitoring and control over conditions to maintain digestion process.	One of the specific objectives of the Strategy is to "encourage the recovery by aerobic and anaerobic procedures and the strengthening of waste composting and fermentation capacities," There are plants obtaining biogas from wastes coming from livestock farming or processing of agricultural products operating in 4 economic operators.
	In-vessel composting (IVC)	Food waste is suitable for in-vessel composting if either the moisture content of the food waste stream is suitable, or the food waste is blended with a co-substrate to ensure the natural digestion process occurs in optimal conditions. In-vessel composting decomposes the feedstock in an enclosed aerobic environment to produce compost suitable for application to agricultural or horticultural land.	Requires low levels of contamination, or some mechanical treatment to remove contaminants. Suitable providing moisture content is controlled through blending of co-substrates or use of dry feedstocks.	One of the specific objectives of the Strategy is to "encourage the recovery by aerobic and anaerobic procedures and the strengthening of waste composting and fermentation capacities, at least one per district".

Table 8 - Adequate waste streams and treatment options of waste management

The energy potential of biodegradable wastes generated annually in the agriculture and industrial sector could significantly contribute to the solving of the energy problem, and the use of these wastes as fuels contribute to GHG emission mitigation. Thus, during the year 2019, there were 48 economic operators that were producing pellets and briquettes, who used in the production process cereal straws, wood sawdust, sunflower seed shells, nut shells and other plant debris.

Animal manure waste are dangerous sources of environmental pollution. At the same time, the sources that generate biodegradable wastes from the livestock sector represents the highest production potential for organic fertilizers and biogas by the anaerobic fermentation technology, which is not used enough in local practice. There are plants obtaining biogas from wastes coming from livestock farming operating in Fîrlădeni village, Hâncești district (SRL „Farma Grup"), Târnova village, Dondușeni district (SRL „Rom-Cris") and in the Zăbriceni Monastery, Zăbriceni village, Edineț district.

The sugar factory in the city of Drochia Municipal Enterprise "Sudzucher Moldova" SA uses the wastes resulting from the beet sugar extraction process in order to obtain biogas, generating electricity for the needs of the company.

According to the low emission development strategy of the Republic of Moldova, approved by Government Decision no. 1470 of 30.12.2016, the reduction in greenhouse gases coming from waste sector by the year 2030 is envisaged up to 47% as compared to the year 1990.

The activities supported by donors in the waste sector are to be removed, especially in the support of investments for the implementation of the biogas recovery technologies from the municipal solid waste; waste composting; mechanical-biological treatment, with subsequent disposal of residues by landfilling.

Thus, the following actions are planned for the development of the regional waste disposal infrastructure by building seven municipal solid waste sites, 22 transfer stations, 23 sorting stations for the recyclable wastes and 25 composting stations, two mechanical-biological treatment plants in the municipalities of Chişinău and Bălţi; equipping the technological block for the treatment of wastewater coming from the water-sewage plants in the municipality of Chişinău, with sludge treatment technologies under anaerobic conditions.

Also, the implementation of the mitigation actions that can be credited in the waste sector is planned. This is possible by projects focused on the recovery of the biogas from the managed municipal solid landfills and on the recovery of the biogas from the wastewater treatment plants (through the sludge treatment technology under anaerobic conditions.

2.3. The efficient management of landfills

The efficient management of landfills is important for the Republic of Moldova and may be a first step towards becoming aware of the impact of uncontrolled waste dumping. The potential impact referring to dumping refers mainly to the greenhouse gas emissions or short-term pollutants, including the methane obtained from the anaerobic decomposition of the organic matter, as well as the particles generated from fires. The exposed wastes are prone to fire during the dry months and to water seepage in the water table during the wet season. Also, the increase of leachate production contributes to the decomposition process, thus resulting methane and other gases. The high biochemical oxygen consumption and high toxicity leachate can determine the surface waters to become depleted in oxygen, anaerobic, resulting in the generation of large quantities of methane.

In order to improve the waste storage conditions, the limitation of methane production and oxygen biochemical consumption it is necessary to periodically use the machinery intended for the compacting and cover of wastes. This practice allows a better access to the waste dump, a more efficient use of space and prevents the burning of the exposed wastes.

Figure 16 - Section of an open pit loaded with waste and leachate, brought downstream by river water

Key-approaches in controlling the landfills.

A major benefit achieved from minimizing the problems associated with exposure of wastes on the surface of the soil is the reduction of the polluted leachate quantity. The main methods for the limitation of the seepage water volume in wastes are:

- Prevent access of surface water on the landfill.
- Limit the access and speed of water reaching the site by the spreading and compacting of wastes in thin layers,
- Minimizing the surface of wastes exposed to rainfall by compacting them on a small area.
- The cover of wastes with soil to reduce the amount of water that can seep.
- Checking the slopes from the inside and around the site. These direct the rainwater flow outside the waste area.

- The access of all equipment for the site management and delivery of wastes on the yard and the internal roads are adequate for the transportation of wastes to the landfill and their mass compacting in case of unfavourable meteorological conditions.

Why is water the enemy of controlled waste storage?

The increase of greenhouse gas level and unpleasant smells are caused by the water infiltrating the landfill. The water seeping through the wastes becomes acid and dissolves the toxic elements from wastes (e.g., heavy metals from batteries, electrical and electronic wastes, fireproof chemical substances from furniture etc.) and transports them into the underground and surface waters that could be used for drinking or for agriculture. Water can prevent access of collection trucks to the dumping area, which may lead to an uncontrolled dumping of wastes. Pools, water and wet wastes represent the perfect habitat for insects and other disease vectors.

The necessary equipment.

For the transition from the uncontrolled dumping to waste storage management, it is necessary to have and use a well-maintained machine, with resources to push and consolidate the wastes in place. If a piece of machinery is unavailable, wastes are dumped by the collection trucks on a wide area. By compressing the wastes, a smaller area is ensured, and the impact associated to the dumping is low. For a small capacity landfill (less than 20 tons / day) and with no protection, a wheeled loader is necessary for daily transportation or every 2 days. For a high-capacity landfill, a larger bulldozer needs to operate on a daily basis. Some of the necessary equipment may be found in the following table:

Waste compactor (steel wheels) 	***Bulldozer*** 
Backhoe 	***Wheeled loader*** 

Wheeled leveler	***Agrimotor***
	

Table 9 - Necessary equipment for landfill operation

Landfill organization.

Regardless of the location of the landfill, a plan must be developed. The plan will include:

- Defining measures for waste location;
- Ensuring the adequate distances (minimum 100 m) between waste and water courses, buildings, public roads etc.;
- The general rule for the stability of the structure: all lateral slopes of the site must not exceed a 3:1 inclination, that is 1 m vertical height for each horizontal 3 m.

The calculation of the volume and the land surface necessary

The collection quantity of waste and the volume need of the landfill will provide an idea about the amount of waste and the storage volume needed per one year. Also, depending on the available equipment and the quantity of wastes, one can obtain data regarding the necessary surface for waste storage over a given period.

Drafting a plan for the filling of the landfill.

Based on the topography, the available surface, the volume and the area necessary for the disposal of wastes over a given period (for example, annually) and based on the access pathways on the landfill, a model of waste placement is developed. If it is a flat site, without natural lateral slopes, an earth wall can be created to delineate the area. If it is a natural depression or a similar topography, the filling of wastes begins in the respective area (either in the upper corner or in the lowest one). The filling plan will depend on the accessibility of the site and on the availability of the processing machinery, which will determine the depth where the waste will be picked up. Generally, it is recommended to fill the landfill by means of 2.5 m high elevators, with subsequent additions until the desired height is reached.

Diverting of the surface water.

It is important to check the surface water leaks from the areas surrounding the landfill. Install and maintain the drainage ditches around the site on any slanting land towards the storage area in order to ensure the drainage of the rainwater and any flows near the planned waste filling area.

Development of an access plan for all meteorological conditions.

The storage place is not usable if the waste collection vehicles cannot access the dumping area. A permanent access road, not influenced by the weather forecast, must be installed from the nearest asphalt road to the waste storage place. Temporary roads connecting the permanent access road (that reaches the waste dumping area) are also suitable for all vehicles, regardless of the weather conditions. These tracks can be built over older waste layers, as they are better developed. Their building can be made of residual materials coming from constructions and demolitions.

Defining and controlling the daily work cell and the waste storage area.

This stage involves the overthrow of wastes in a pre-set place, then pushing them on the working surface, arranged in a thin layer to be pressed by means of a compactor or a tip lorry, followed, in the end, by compacting. At the end of the day, the wastes delivered that day will be compacted into several layers.

The dumping area.

The dumping area (or dumping buffer) is connected to the working area, where collection vehicles load the wastes to later push them over the working area. Generally, a 6 m width per vehicle is necessary. Therefore 3 vehicles can unload at the same time on a working area / dumping area of 20 m in width. However, a 3 m of space per load is necessary, so that 6 loads of average size of the vehicle can be placed on the dumping area along the working surface. This process occurs before the vehicle pushes the load in the working area and before the arrival of the following load. The dumping surface must have a 10 m depth and an area compact and covered enough to allow waste collection trucks to enter, unload and go out of the area safely.

The site vehicle should be equipped in order to help the collection vehicles reach the working area and back on the landfill roads. The dumping area can be located above the working surface, so that wastes can be pushed downwards or below the working surface. The downward push has the advantage to reduce to a minimum the chance that collection vehicles go into the humid ground that could form at the base of the landfill due to rainfall waters. The upward push is advantageous because it improves the capacity of the vehicles to batter and crush the bulky wastes at the base of the working surface and so, a higher compacting rate is achieved.

It is recommended to set some visual markers for the dumping area at the beginning of each day, so that the vehicle operators know where to unload the wastes. The landfill workers should guide the vehicles into/out of the area. The fire extinguishers shall be located in the dumping area on a trolley, to enable the workers to put out any fire that can occur on the working surface.

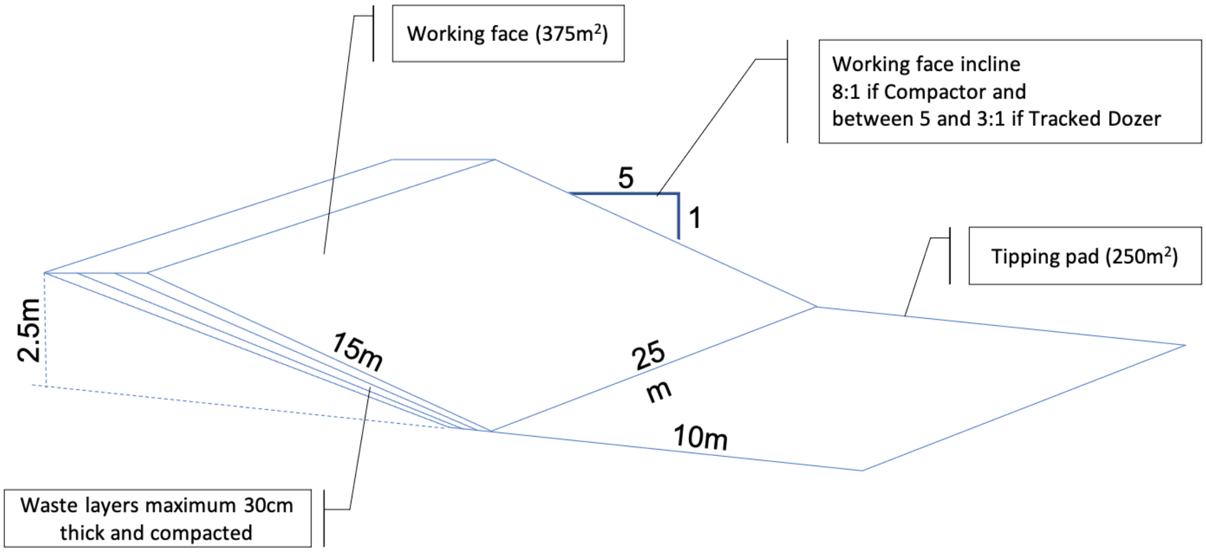


Figure 17 – Typical sizes of a daily cell – the working surface and the dumping area

The working surface.

The working surface of a landfill must be kept as small as possible. The advantages of maintaining a small surface include a lower generation of leachate, streamlining the compacting and waste coverage, and the cover quantity of soil is reduced, the amount of waste thus being smaller. Also, the fire chances are reduced and the control of animals that consume the residues is improved. A large landfill should not have the dumping surface area larger than 30 m per 50 m, while smaller landfills should take into consideration an area of approximately 15 m per 20 m.

During the rainy season, efforts should be made to minimize the size of the dumping area as much as possible, as this will help reducing the surface water quantity that penetrates the wastes to produce leachate. It is recommended to mark the working surface daily with visual markers to help operators maintain it.

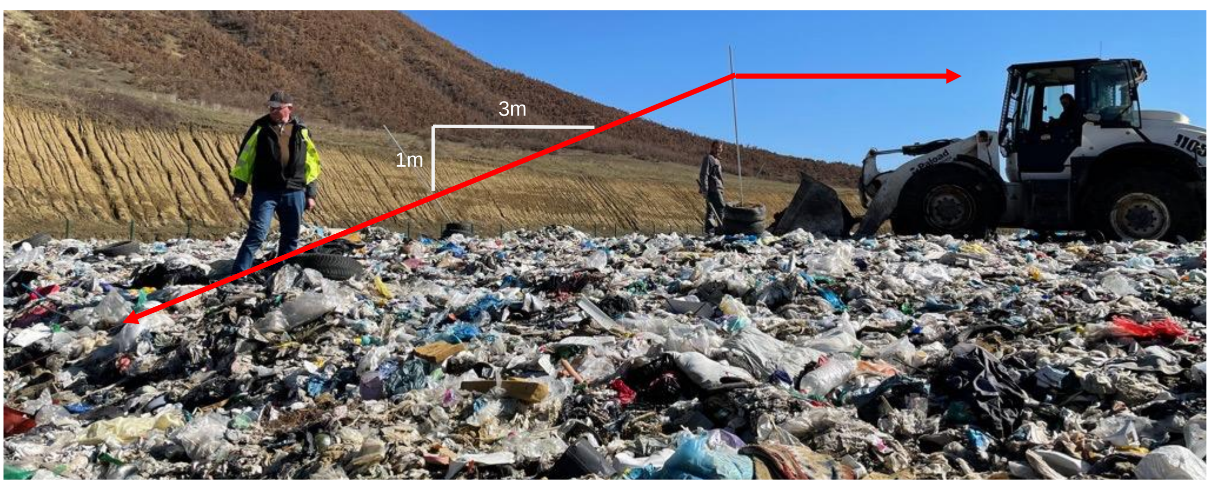


Figure 18 - Example of installing the visual markers on the landfill

The working face gradient and the elevation height.

It is recommended to fill the wastes in "elevators" approximately 2.5 m high and to maintain the working surface on a slope, advancing the elevator by vehicles, the wastes being compacted in 30-50 cm thin layers. This can be applied by the wheeled loader or bulldozer and may be pushed upwards or downwards. It is recommended that the angle of the working surface is 8:1 (that is 1 m vertically for each 8 meters horizontally) when a compactor with steel wheels is used and approximately 5:1 when a bulldozer or a wheeled loader is used. Bringing the slope to 3:1 at the end of the working day may reduce the size of the working area that needs cover and, therefore, reduce the seepage of the surface water.

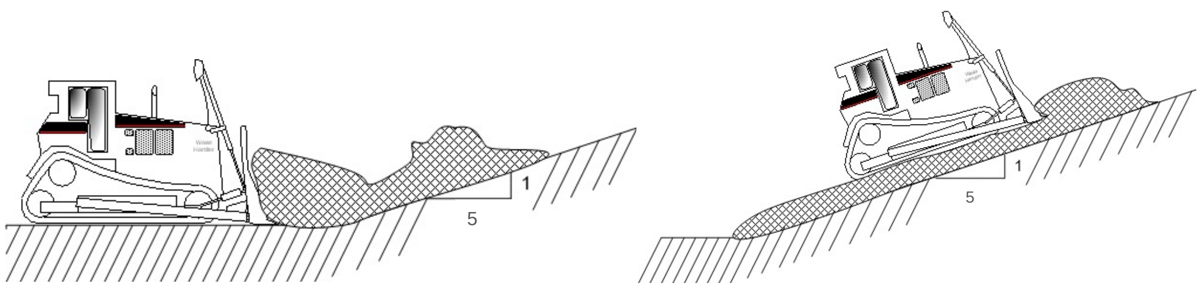


Figure 19 - Pushing and applying the residual loads on the working face in thin layers throughout the entire day.

Applying the cover materials.

The waste area from the working face that will receive more waste the next day (or next month) is then covered with a 15 cm thin layer of soil or similar material, while the areas that will not receive waste for 30 days or longer, will be covered by 30 cm of soil or similar material (intermediate cover).

Layering, compacting and application of the cover material serve several purposes, including:

- Reduction of the water quantity leaked in waste.
- Can provide an oxidation layer that can reduce methane release.
- Prevent the fire risk by reducing the oxygen content in wastes, as well as by reducing the exposure to fire sources.
- Minimize the smell by sealing the wastes on-site, as well as by oxidation.
- Prevent birds, animals and unauthorized persons to look for materials and food.
- Prevent infestation from mosquitoes, flies, parasites and other disease vectors by covering the reproduction habitats of wet waste.
- Prevent wind blowing of light plastic materials and other materials on the site that might cause more garbage.
- Improve the visual aspect of the landfill.

Many materials can be used as cover material. Generally, the soil excavated from the area to be filled can be used, from the stocks gathered when building the site or from construction projects nearby. Clay soils that do not flow are suitable for the intermediate cover, but not for the daily cover, which should be a lighter and drained soil layer.

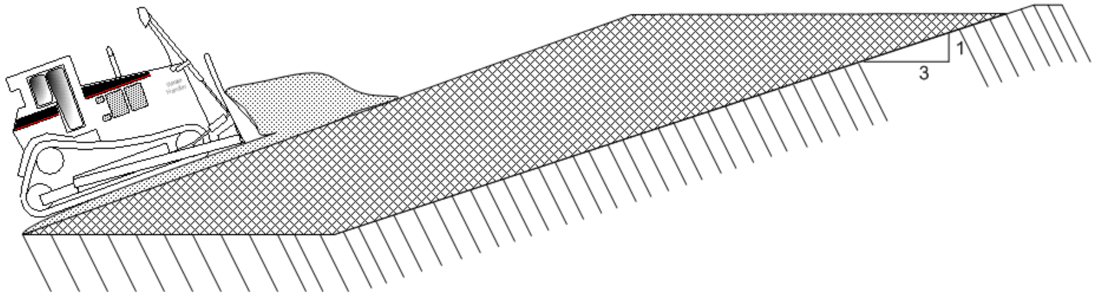


Figure 20 - Application of daily cover material on the working face

Drainage of leachate and installation of gas venting pipes.

Installing several perforated pipelines, surrounded by gravel or a similar channel enables the leaking of the gas and extraction of the leachate. The connection of these pipelines enables the oxygen to leak through the waste mass and thus, to create aerobic conditions that accelerate waste decomposition and reduce methane generation, biochemical oxygen consumption and leachate toxicity. Installing such pipelines can contribute to transforming the landfill from a managed anaerobic one to a semi-aerobic managed landfill that can contribute to the reduction of methane production by 50%.

Figure 21 - Installing the leachate line at the base of the site (SPREP, 2010).

2.4. Business strategies and models for circular economy

In the context of circular economy, business models are continuously evolving. They incorporate technical innovations to adapt to ambitious policies in the field and to generate changes. For example, the waste management operators such as Suez (example in chapter 5), who are usually paid by waste tonnage they manage, are more often contracted based on some performance indicators on the efficiency of resource and waste management. These companies are no longer interested to manage higher and higher quantities of waste, but to contribute to creating solutions for their reduction, which can lead to business models similar to those of the energy suppliers, but focusing on the increase of process efficiency and material use and not on energy efficiency.

The products are more frequently replaced by services, people are increasingly interested in buying services instead of being caught and tied up by assets for long periods. An example in the context of this trend is Philips, a lighting luminaries producer providing lighting services for several years now. Instead of lamps and lighting luminaries, clients purchase electricity for a giver period. Such a practice gives an impulse to producers to make sure that their products are as sustainable as possible. In this way, products need less repairing, causing the increase of producers' profits. From the consumers' perspective, possessing many products becomes incompatible with the increasingly flexible ways these act and produce value. For example, data storage practices were changed by the availability of cloud data storage, thus causing a transition from hardware towards a service.[13]

Possession is replaced by division, which increases the productivity of materials and products, it reduces the costs and increases the profits of the asset owners. Policies support the "car sharing" type of initiatives, and the mutual facilities become more popular in the case of industrial parks and commercial centers and in the urban development plans.[14]

Besides the innovative business models, the European Union contributes to the development in the field, by encouraging public procurement in the context of circular economy by specific publications. The Guide of Good Practice on Public Procurement for Circular Economy developed by the European Commission, presents the benefits of circular procurement, procurement methods and examples of good practices in Europe, that can be adapted also to the situation of the Republic of Moldova.[15]

The CALC (Circular and Low Carbon Cities) project implemented by ISWA (International Solid Waste Association) has targeted for the first time to define and then calculate the benefits of mitigation solutions of waste reduction by circular economy strategies. The aim of the project is to support cities in making choices for increasing circularity and reducing the emissions. The explanations related to each process or action can be seen in the table below.

Definition of the process and of the action	Who is involved in the process?	Examples
The user is not the owner purchasing a service; renting, leasing an equipment;	renting companies, platforms, neighbours, new equipment suppliers, insurers	The vehicles and bikes sharing services (car share, bike share), library, equipment renting, common use equipment for a community / quarter
Maintenance of the product by the user Avoid or prevent damage, buy or replace parts;	Small retailers, flea markets, parts suppliers;	Reuse or maintenance, including sewing, purchasing new parts or hardware / lubricants at home or at the office

[13] Source: UNFCCC Report, author: Reka Soos, https://unfccc.int/sites/default/files/resource/tpMitigation.pdf
[14] Source: Idem
[15] Source: https://ec.europa.eu/environment/gpp/pdf/Public_procurement_circular_economy_brochure.pdf

periodical cleaning, resetting and checking;	repairs by the owner	
Second-hand trading Buying, exchange and selling of used objects (usually without paying additional taxes)	consumers, private sellers, charitable organizations, NGOs, churches, private retailers	The second-hand shops and flea markets, Internet platform (E-bay), scrapping companies, original and vintage equipment retailers
Professional processes that keep the product or material in the initial state, without changing the owner and the parts	professionals, enthusiasts, charitable repairs coffee shop	The repair sheds for watchers, shoes, phones, computers, etc. specialized services providers
Industrial craft industry of "as good as new" products like goods which compete with the original equipment; replacing the components	re-manufacturers specialized in renovations	Furniture and jewellery reconditioning shops, etc.

Table 10 - Definitions of the CALC project and update of the data points in the process

2.5. Steps for selecting the GHG emission reduction intervention

The consumption behaviours and the subsequent management of wastes / resources are a complex system within local and global social and political economy. There is a high number of factors and obstacles to the implementation of waste management systems and technologies which conduct GHG mitigation, and it is seldom (or should be) that the GHG mitigation is the main factor that determines the selection of a waste management option. Therefore, a series of criteria influence the selection of technological / waste management intervention. As a simplified summary of these obstacles and determinants, the following process flow identifies an approach of selecting a suitable waste management technological intervention that takes into consideration the potential of GHG mitigation as part of the intervention selection criteria.

Step 1: Driver identification	Step 2: Waste Streams Focus	Step 3: Baseline Evaluation	Step 4: Intervention Options Assessment
Driver of change Intervention, Objectives, Determination	Municipal waste (Household, commercial, institutional) Parks and Gardens Clinical Waste Industrial Waste Construction and Demolition wastes Agricultural Waste Mines and Quarries	Enabling environment review Stakeholder Capacity review (Functional & Technical) Waste Audits (Quantity and Composition)	Technical Options Identification Consolidated Evaluation Capacity Needs Assessment.

Table 11 – Simplified technology / intervention scheme in waste management

Step 1: Driver identification

The driver that triggers a movement away from the status quo waste management system and motivates investment in new waste management systems includes a range of possibilities. These can include environmental drivers such as mitigating GHG emissions, technical, socio-economic, financial, institutional, legal, and / or political drivers (or indeed barriers) to pursuing a specific waste management system. Identifying and knowing which of these is the main driving force behind pursuing a change in the system or specific objective enables the ultimate goal to be determined, pursued and met easier, with minimal objection or target misalignment.

Figure 22 - Common drivers of change in a waste management system [16]

Step 2: Waste Streams Focus

Different waste different impact potential (negative impact when mismanaged or positive mitigation impact when managed well). Different locations generate different types and quantities of waste. Identifying which waste streams are the most problematic in the target community, and which align with the intervention driver identified in Step 1 facilitates a more streamlined technology selection. As previously discussed, target waste streams include:

- Municipal waste (Household, commercial, institutional)
- Parks and Gardens
- Clinical waste
- Industrial (Manufacturing)
- Construction & Demolition
- Agricultural
- Mines and Quarries

Step 3: Baseline Evaluation

At the core of waste management decision-making is the functional capacity required in conventional wastes and resources management. This is the capacity required that enables decisions to be made, implemented and systems to function. In the centre of this framework are the dimensions in which the functional capacity must exist to varying levels of competence and understanding, within individual stakeholders, organizations, and target communities, in the local, national and global resource and waste management sector.

Figure 23 - The favourable framework and the functional capacity in a waste management system [16]

Another way of presenting the technologies and systems available for managing waste in a more sustainable manner is described in the diagram below. The diagram presents the range of common technical options in conventional wastes and resources management chain that enhance the system and can mitigate climate impact. This diagram provides a quick reference to assess what practices are in place for the baseline study, as well as to identify the technologies available in Integrated Solid Waste Management that can be considered within a mitigation strategy with narrowed selection subsequently evaluated according to established GHG mitigation potential methodologies.

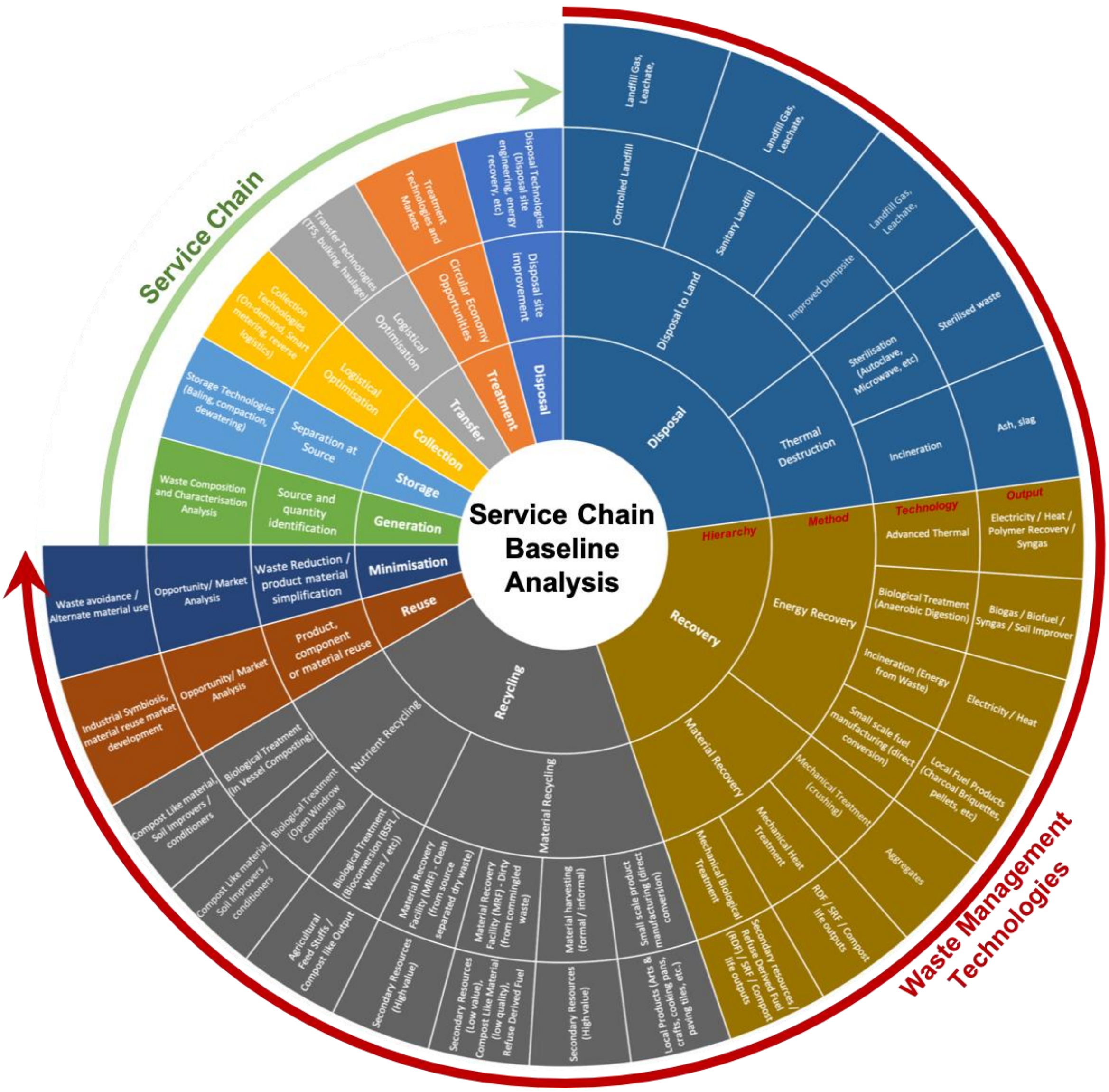


Figure 24 - Integrated Solid Waste Management Service Chain and Treatment Options Wheel [16]

[16] Source: Developed by RWA / GIZ

Step 4: Intervention options selection and evaluation

Once the potential desired technology interventions are identified, it is important to evaluate them in a multi-criteria assessment method. The "Pent A" Consolidated Evaluation Method, is used to assist waste management strategy development rapidly and methodologically to assess and identify the "preferred" project or technical intervention to take forward to action planning and implementation based on five key criteria, namely: (1) how institutionally **appropriate** it is, (2) whether it is technically **applicable**, (3) whether it is legally **achievable**, (4) if it is **affordable**, and (5) whether is it environmentally **acceptable**.

Evaluation Criterion	Questions Answered	Rationale
Technically applicable	Is the intervention technically (stage and scale, technical complexity, utilities and land usage, etc.) applicable for the local context and conditions?	Applicability relies on the professional judgment, and empirical assessments of the specialists, by utilizing all the information pertinent to the individual intervention, system interventions and scenarios.
Institutionally appropriate	Is the intervention supportive of internal planning and policy frameworks, and compatible with the municipality's organizational structure and protocols?	It is appropriate to conduct an institutional assessment of the local governments organizational strength that is required to plan, implement, operate and maintain AISWM.
Legally achievable	Is the intervention legitimate and compatible with the current local and national policy and regulatory frameworks, or can these frameworks be readily adjusted to improve legitimacy and compatibility?	Achievability assessment considers the legal capacity to implement the scenario (in particular the bylaws), and the complexity of the legal implementation requirements, considering the legal decision making, procurement and contracting framework.
Environmentally acceptable	Is the intervention environmentally and socially acceptable to the international community, national government, local government and local citizens, including those already engaged formally or informally in waste management?	Acceptance relies on the professional judgment of the individual performing the analysis utilizing information pertinent to the specific site location and evidence from any social and environmental impact assessment criteria and GHG mitigation commitments.
Financially affordable	Are the full intervention savings (benefits) greater than the full intervention costs?	Affordability assesses the savings less costs to government, on an intervention-wide net present value (NPV) basis. The financial assessments have been structured to determine, inter alia, the subsidy required for the private sector to deliver the selected AISWM interventions.

Table 12 - The "Pent A" criteria for the assessment of strategies

2.6. GHG accounting for mitigation policies and projects

In order to decide whether a project is more favourable than another from the GHG mitigation point of view, one must analyse the impact of the various technical scenarios. For this, a mindset change is necessary in terms of national inventories. Whereas in the case of inventories it was important to keep the budget lines separate, our intention is to promote a project in order to get funding from approved sources for the mitigation of climate change or for achievement of emission reduction certificates. Hence, the accounting of all positive effects is necessary.

2.6.1. What GHG emission reductions can we estimate and calculate

Thus, in case of accounting the impacts of projects, we take into consideration all emission mitigation benefits that are direct or indirect, occurring as secondary impact of our interventions.

For example, if we take into account composting as mitigation technology, we calculate reduced emissions in the landfill by avoiding the storage of some biodegradable waste generating methane, a strong GHG, but also the emissions resulting from replacing a chemical fertilizer that needs more resources and energy during production, with compost, a material produced by preponderantly biological processes. Also, the application of high-quality compost helps improving soil quality and results in carbon sequestration in soil, thus having an additional mitigation impact. The figure below is a summary of the technologies and major sources of GHG emission mitigation associated to each technology.

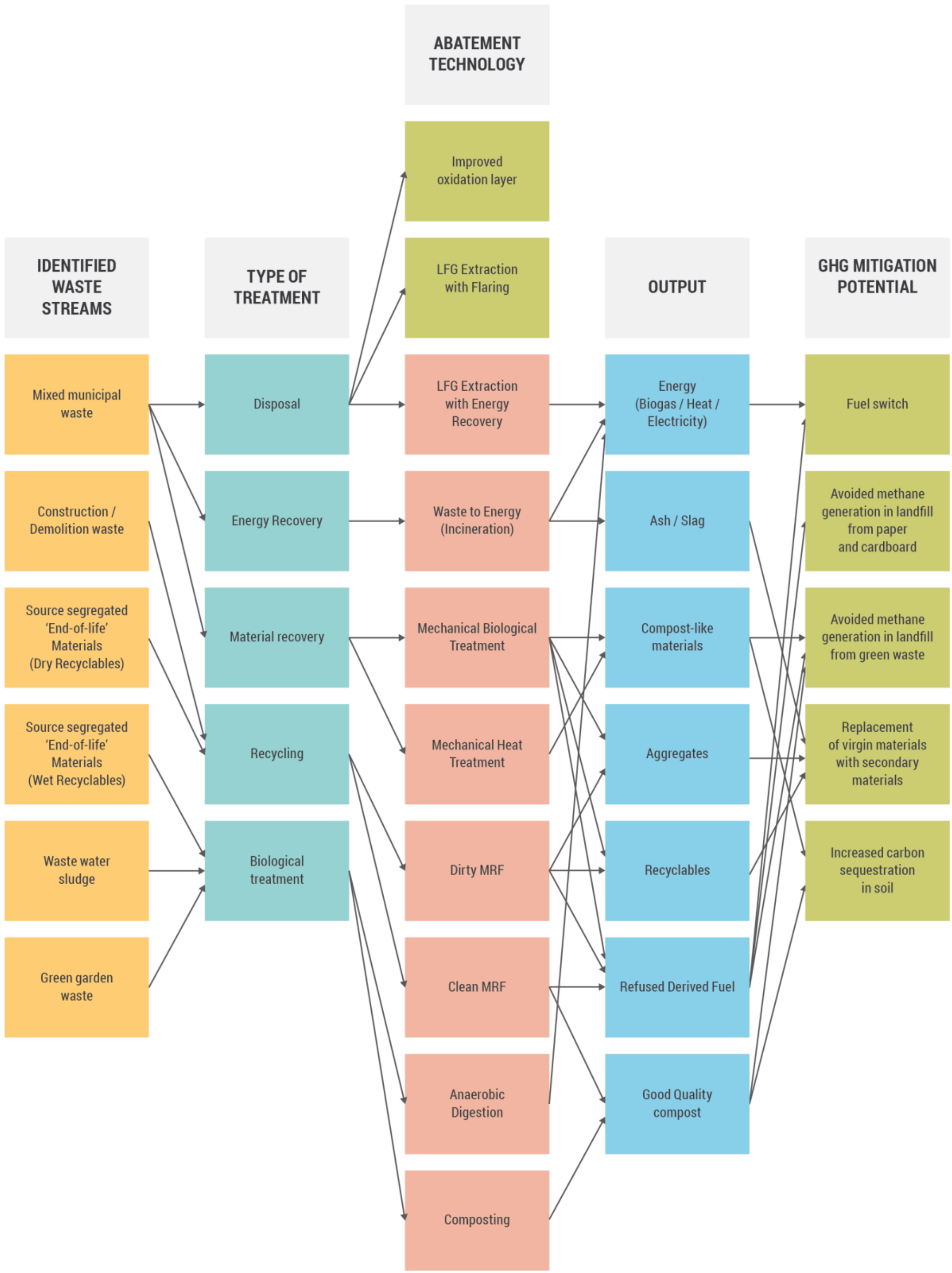


Figure 25 - Technological options for the mitigation of GHG emissions and their impact [17]

[17] Source: Developed by RWA / GIZ

2.6.2. Tools and methodologies for GHG impact assessment

To estimate the impact of emissions at project level and compare the emissions associated to the mitigation scenarios, a series of tools and methodologies were developed. Sometimes, these are used in combination with elements from the IPCC guidelines.

The table below presents the most familiar and used instruments to quantify GHG emissions used in the waste sector. These tools help the users compare scenarios based on input data, having already all equations integrated, together with the emission factors and statistical data in case data are missing on various aspects of projects.

#	Methodology or Tool	Scope and application
1	SWM-GHG Calculator, Tool for calculating Greenhouse Gases (GHG) in solid waste management (SWM) GIZ/IFEU	The SWM-GHG Calculator allows accounting and comparison of GHG emissions for different waste management strategies at an early stage in the decision-making process. Default values allow approximations to be made even if basic data are not (yet) available. https://www.ifeu.de/en/project/tool-for-calculating-greenhouse-gases-ghg-in-solid-waste-management-swm/
2	CCAC waste sector tool, SWEET 3.1	Excel tool quantifying the methane, black carbon and other pollutants emissions from sources in the municipal solid waste sector. The tool provides estimations of emissions and reductions of emissions at project, source and municipality level. Cities may use this information for several purposes, including for setting up a basic scenario with up to four alternative scenarios, the analysis of specific projects for the potential reduction of emissions, the estimation of contribution of activities in the waste sector to the general objectives of emission reduction in cities and the pursue of progress in time. https://www.waste.ccacoalition.org/document/solid-waste-emissions-estimation-tool-sweet-version-31
3	Tool package for the accounting of short-lived climate pollutants and GHG in the waste sector (emission quantifying tool) Version 2 (CCAC, IGES, 2018)	This emission accounting tool will be useful for political decision-making in selecting the most suitable set of technologies for a city. By using this tool, cities will be able to perform a rapid emission assessment (GHG and SLCP) associated with their current waste management practices (as usual) and they will be able to identify suitable alternative solutions. In addition, cities will be able to compare the emissions in the business as usual (BAU) scenario with alternative solutions to identify the most suitable set of waste management practices. The decision-makers can then keep track and monitor the mitigation efforts from the selected waste management systems in time, using the monitoring and reporting module. https://www.waste.ccacoalition.org/document/tool-package-quantification-short-lived-climate-pollutants-slcp-and-other-greenhouse-gas
4	The GHG Protocol tool	Used by waste management operators to measure and monitor the impact of their activities. Process emissions are considered. https://ghgprotocol.org/sites/default/files/Waste%20Sector%20GHG%20Protocol_Version%205_October%202013_1_0.pdf

#	Methodology or Tool	Scope and application
5	ICLEI Recycling and Composting Emissions Protocol	This tool is looking at emissions tracking at community level and is inclusive of upstream and downstream emissions. https://icleiusa.org/publications/recycling-composting-emissions-protocol/
6	The CDM (Clean Development Mechanism) Methodology	Used for projects emission accounting for projects developed with the aim to reduce emissions. These are rigorous methodologies that are used to issue and certify emission reduction that is traded on the market governed by the UNFCCC. Several methodologies are relevant. The CDM methodologies are available on the UNFCCC website and can be easily screened using the online booklet. https://cdm.unfccc.int/methodologies/documentation/index.html
7	GHG Calculator for the solid waste sector (IGES, 2013)	The tool facilitates calculation of emissions along the waste stream and decision-making covering disposal, composting, digestion, MBT, recycling, incineration, open burning and transportation. Very useful for estimating emissions from other sub-categories (open burning, incineration, composting etc.). https://www.iges.or.jp/en/pub/ghg-calculator-solid-waste-ver-ii-2013/en
8	Biogas model (US EPA, 2007)	The model allows calculation of mitigation potential for methane recovery in landfills. The model is useful to estimate mitigation potential from CH_4 recovery, default data for Latin American countries can be used in the IPCC model. https://www.globalmethane.org/documents/models/pdfs/UsersManualCentralAmerica_LFG_model_final_English_REV1.pdf
9	Waste reduction model WARM	Useful to estimate emissions reductions from several different waste management practices. WARM is intended as planning tool and not as a GHG accounting tool. https://www.epa.gov/warm
10	2.0 ECAM	Water and wastewater sector tool with potential relevance for mitigation options in sludge and wastewater management. https://wacclim.org/ecam/help_pdf/ECAM_2.0_Manual_170822.pdf
11	Greenhouse Gas Protocol, Policy and Action Standards	This is an accounting and reporting standard for estimating the greenhouse gas effects of policies and actions across all sectors. https://www.wri.org/sites/default/files/Policy_and_Action_Standard.pdf
12	Greenhouse Gas Protocol, Policy and Action Standard, Waste Sector Guidance	This document provides sector-specific guidance to help users implement the GHG Protocol Policy and Action Standard in the waste sector. The example is using a hypothetical food waste landfill diversion policy. http://www.ghgprotocol.org/sites/default/files/ghgp/standards_supporting/Waste%20-%20Additional%20Guidance.pdf

Table 13 - Tools and methodologies for GHG impact assessment

2.7. Significance of the GHG emission mitigation impact for projects in the sector

An increasingly large number of stakeholders in the sector and economy, manufacturers, consumers, decision-makers at political level, but also the sponsors take into account the GHG emission mitigation impacts in this sector. The ambitious policies at international level and Europe's leader role in reducing the GHG emissions and adaptation to climate changes take its toll on the vision and ambitions of the stakeholders in the sector.

- The selection of the investment scenario is strongly influenced
- Waste operators report their impact
- The cities report
- The organizations in the sector report and renegotiate contracts based on the achieved GHG reductions
- The NGOs report and do fund-raising by help of the GHG emission mitigation results
- The producers report
- The consumers choose products with low impact on climate changes
- The sponsors develop monitoring and verification methods, they choose projects with positive impact

Identification and implementation of actions for the adaptation to climate changes in the

3

3. Identification and implementation of actions for the adaptation to climate changes in the waste sector

3.1. The scenarios regarding climate change relevant for the waste sector in Moldova

The Strategy of the Republic of Moldova for the adaption to climate change until the year 2020 [18] mentions the fact that, according to the provisions of the climate scenarios for the Republic of Moldova, what is considered at the moment extreme, low-frequency phenomena, with absolute maximum temperatures of 34-35°C for the 1961-1990 reference period, in the future will probably become summer average temperatures. In addition, the general prognoses for Europe show that the flood risk increases in North, Central and Eastern Europe, including in the Republic of Moldova, and that the frequency of droughts currently recorded for each approximately 100 years will increase.

These trends are confirmed also by other studies on the specific influence of climate change on certain sectors, such as energy, transport and especially agriculture. A study on the influences of climate change in the Nistru[19] river basin envisions the increase of maximum temperatures and especially the increase of the minimum air temperatures, the reduction of the number of frosty days and extremely low night temperatures, the increase of the number of hot days, of the amount of extreme precipitation and their increasingly more non-homogeneous distribution, with more frequent manifestations. The study also mentions that the biggest changes are possible during the warm period, especially during the summer months in the lower course of the Nistru river. A significant increase in the precipitation amount in case of strong rainfalls (more than 10–20 mm/day) is possible during the autumn months.

The Figure below, presented in the report mentioned and shown below indicates high probability and consequence occurrences in relation to the volume and variability of discharge, the state of agricultural land and level and quality of underground and surface water. These effects are assessed also in terms of their adaptation potential, with a low to medium potential.

[18] Source: http://lex.justice.md/index.php?action=view&view=doc&lang=1&id=355945
[19] Source: ENVSEC; UNECE; OSCE; (2015) Strategic trends for the adaptation to climate change in the Nistru river basin, https://www.uncclearn.org/wp-content/uploads/library/dniester_rom_2016_small.pdf

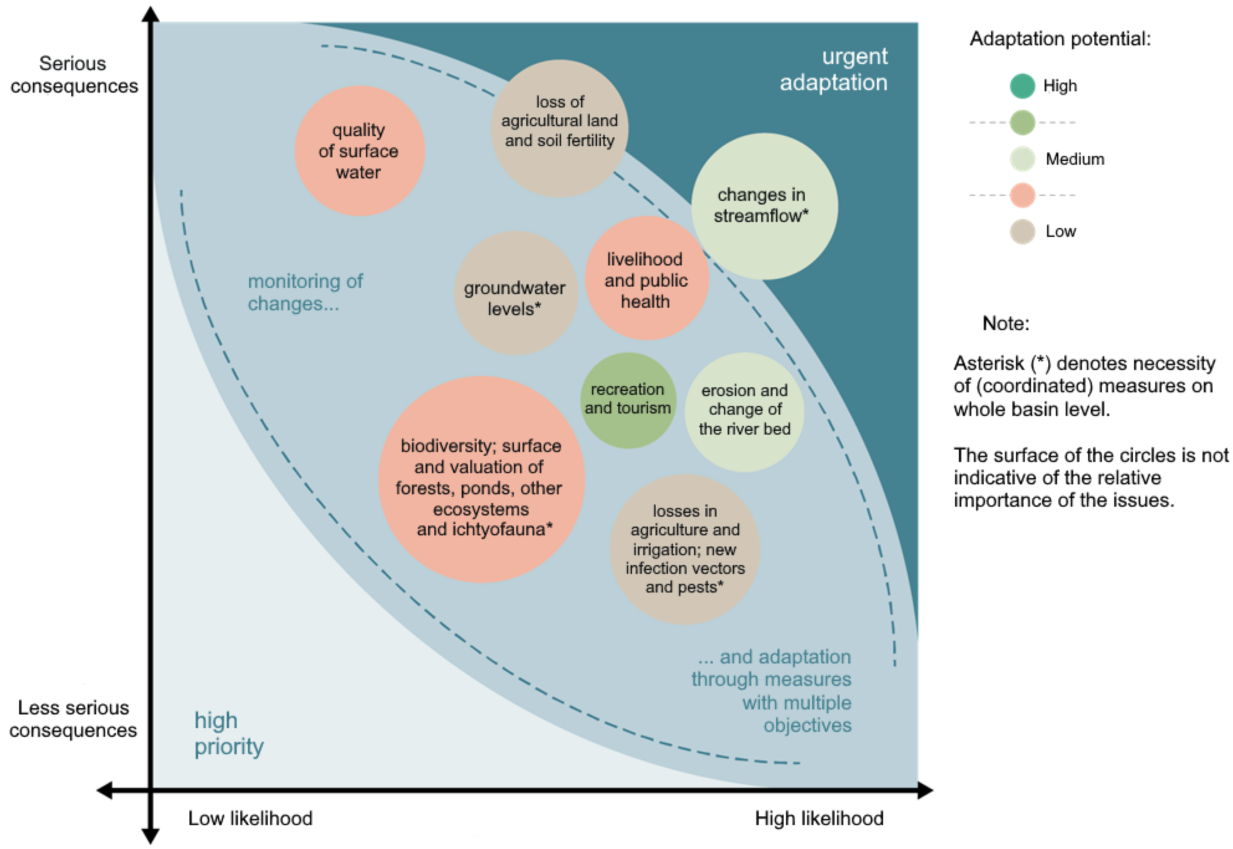


Figure 26 - The impact of climate change on the sectors and resources of the economy in the Nistru river basin [20]

These expected impacts are stated also in the 2020 Report in the Updated Nationally Determined Contribution of the Republic of Moldova [21]. According to the National Communications in 2009, 2013 and 2018, most probably Moldova will be affected by three types of climate impacts: temperature increase, changes of the precipitation regimes and increase of climate dryness, which are associated with frequency increase and extreme weather event intensity, such as heat waves, frosts, floods, heavy rainfall and hail storms, serious droughts.

The waste management sector is not a first priority sector in terms of climate change adaptation, like agriculture, water resources, health, forestry, energy or transport, according to the dedicated website developed by the Climate Change Office [22]. For the above-mentioned sectors, specific actions are taken to increase resilience and adaptation to climate change. However, the waste management sector has the potential of being significantly affected by these changes, as such, it needs an increase in adaptation capacity. At the same time, the effects of climate change manifested in the waste management sector can negatively affect other sectors considered to be priorities, especially agriculture, water resources

[20] Source: The ''Zoi'' ecological network, Co-report of the climate change problems in the Nistru River Basin, 2015
[21] Source: The Ministry of Agriculture, Regional Development and Environment, the National Updated Determined Contribution of the Republic of Moldova, March 2020, http://clima.md/download.php?file=cHVibGljL3B1YmxpY2F0aW9ucy80MzkyOTNfZW5fbWRfdXBkYXRlZF9uZGNfLnBkZg%3D%3D
[22] Source: http://www.adapt.clima.md/index.php?l=ro, accessed on 20 Dec 2020.

and health and, in a less direct way, energy, transport and forestry. The improvement of waste management performances in a sustainable way and resilient to climate change can bring a series of positive action opportunities in the other sectors, especially in agriculture.

3.2. Identification and analysis of the potential climate impacts and of the resilience of the waste management sector

Identification of potential impacts of the climate changes on the waste sector, such as resilience of this sector to the expected changes is a process that is recommended to be implemented both at the sector level, and at the level of each element in the waste sector. It is thus necessary to conduct an analysis of risk and vulnerability to climate change of the entire waste sector, as well as of the individual elements in this sector. The analysis can be conducted at a national, regional or local level, using different established methodologies in the literature, depending on the specificity, availability of time and resources, the need for details in order to make decisions, etc.

Regardless of the methodology used for the analysis and assessment of risk and vulnerability used, it is recommended that this is conducted in a cooperative manner with all the relevant stakeholders involved.

In this section, we present a simple methodology for the qualitative and semi-quantitative analysis of risk and vulnerability, which can be considered the minimum necessary or starting point for more complex analyses in the sector.

The minimum elements of risk and vulnerability analysis should include:

1. Identified climate hazards, environmental hazards or others, relevant particularly for the considered local /regional/national area or at system/element level.
2. The vulnerabilities at local/regional/national level or system/element level.
3. The expected impacts (consequences) at local/regional/national level or system/element level.
4. Persons, goods, functionalities/systems subjected to risk in the case of occurrence of these impacts.
5. The list of prioritized risks for the implementation of remediation measures.

The resilience of the waste management sector can not be improved without knowing and understanding the risks this sector is exposed to. Assessment Report No. 5 (AR 5) of the IPCC Working Group (2014)[23] defines risk as a product of interaction between three components: hazard, exposure and vulnerability, as shown in the figure below. Each of these three components must be analysed as part of the assessment.u

[23] Source: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf

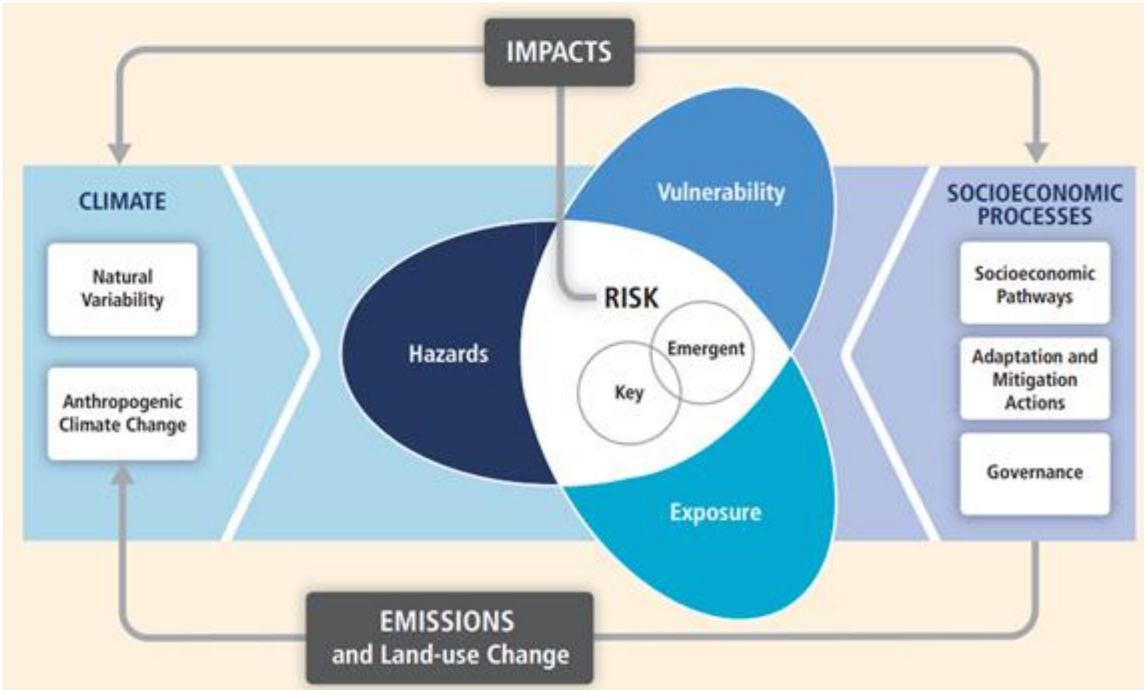


Figure 27 - Definition of risk - adaptation according to IPCC AR5

Risk and vulnerability assessment must contain information on the risks and vulnerabilities to impacts due to climate changes, but also other relevant impacts on the waste management sector. This assessment needs to take into consideration the vulnerable population and environmental media.

The risk and vulnerability qualitative assessment needs fewer resources and it is much faster to implement, as compared to a quantitative assessment, which is very specific from the spatial point of view and needs detailed information. For the identified higher risk elements, it is recommended that they are analysed to a higher level of detail. The in-depth analysis of some selected areas may show differences in terms of vulnerability or degree of exposure for certain groups of persons/elements of the system and it is necessary for drafting of the risk maps and identification of actions with a very specific character for risk reduction.

Step 1: Identification of possible hazards

The analysis team will identify the hazards that are likely to occur starting from the climate predictions in the analysed area. This will be conducted by using the reports of the IPCC working group, reviewing the historic climate events as well as by analysing the existing studies and discussions with the Universities, research institutes and NGOs at national/regional or local level.

Once identified, it is necessary to assess each of these hazards, taking into consideration the following elements:

- The nature of the hazard: its description and the nature of the expected impact (acute or chronic)
- The magnitude of the expected changes, in relation to the current baseline level for the considered time interval within the project

- The geographical area that is likely to be affected
- The certainty level regarding the occurrence of the hazard and explanation of the rationale
- The source of information (for subsequent reference)

Step 2: Identification of impact on the system/elements of the waste management system

Once likely-to-occur hazards are identified, it is necessary to identify the potential impact on the waste management system and its elements, as well as the impact on the relationship between them.

It is also important to identify the possible domino/cascading impacts on other sectors/elements.

This process is also important to be conducted in a way that involves the cooperation of all stakeholders to identify the possible impacts as comprehensively as possible.

Step 3: Vulnerability analysis

Vulnerability refers to the characteristics of the elements exposed to hazard (system, elements, goods, persons etc.) that can either increase or decrease the impact of that hazard. Vulnerability is a function of **the damage degree** (magnitude of the expected impact) and **the adaptation capacity** (capacity to react to and recover from the impact).

For every one of the elements that are likely to experience an impact, assess the ability of that element to adapt to the expected changes, at minimum costs and with minimum disturbances, using **ratings from very low to very high.** Some criteria that can be taken into account are availability or access to private or public economic resources, access to technology, social capital etc.

In case some persons/communities are likely to be exposed to the identified hazards, it is necessary to analyse their vulnerability based on the expected damage degree and their capacity to adapt to the changes that occurred. In this case, too, there will be given ratings from very low to very high, both for the damage degree and the adaptation capacity. For this, a series of criteria can be considered:

- Access to economic or technical resources
- Access to social capital
- Availability of existing information and skills
- Availability of institutional or community support systems
- Social/political inequalities
- Pre-existing exposure to hazards or pre-existing disadvantages.

Adaptation capacity and the damage degree can be represented as a matrix similar to that presented in the following table, to identify the degree of vulnerability to impact.

		Damage degree				
		1 – very low	2- low	3 - medium	4 - high	5 – very high
Adaptation capacity	5 – very low	V2	V2	V4	V5	V5
	4- low	V2	V2	V3	V4	V5
	3 - medium	V2	V2	V3	V4	V4
	2 - high	V1	V2	V2	V3	V3
	1 – very high	V1	V1	V2	V3	V3

Table 14 - Combining the adaptation capacity and the damage degree to determine vulnerability

As it can be noticed in the figure above, the impacts affecting to a high or very high extent elements of a low or very low adaptation capacity will lead to a very high vulnerability score (V4 and V5).

Step 4: Analysis and prioritisation of risk and vulnerabilities

The results achieved above will be used to develop a risk matrix, indicating priority risks.

A simple risk prioritisation method is to assign scores on a scale from 1 to 5 for the occurrence probability (very low =1, very high =5) and for the consequences (insignificant = 1, catastrophic = 5). The consequence assessment of the identified hazard occurrence will take into account the vulnerability determined in the previous step. By multiplying these two scores, the risk score will be achieved, depending on the values corresponding to the priority risks. A guideline for determining the score for consequences is presented in the table below.

Type of consequences	The expected impact on the system/its elements	The impact on the vulnerable population	Score
Catastrophic	The system is destroyed and cannot supply critical services; it can generate significant effects in associated systems	Severe impacts, including on the vulnerable groups, leading to extreme damage degrees	5
Major	Serious impact on the ability of the system to supply the basic services, without it being destroyed	Serious impact on the targeted population, which affects its life and wellbeing	4
Moderate	Significant problems, but the service can be supplied to a certain extent	Moderate impact on the life and wellbeing of the target population	3
Minor	Certain problems are manifested, the degree of service supply can be reduced	Minor impact on the life and wellbeing of the target population	2
Insignificant	Minimum impact, certain revisions are necessary, but operation is not affected	Minimum impact on the life and wellbeing of the target population	1

Table 15 – Guideline for determining the score for consequences

Similar to the table above, scores will be assigned for the occurrence probability of each identified hazard, assigning scores from 1 to 5, as follows:

- 1 – Rare

- 2 – Improbable
- 3 – Possible
- 4 – Probable
- 5 – Almost certain

Once the score is determined for the occurrence probability (P) and the consequence magnitude (C), the risk score (R) is determined according to the formula: R= PxC.

For risk assessment, similarly to determining vulnerability, the matrix represented in Table 16 - Risk score determination and risk assessment matrix 3 below can be used:

	Risk score	Consequence magnitude				
		1 -Insignificant	2 - Minor	3 - Moderate	4 - Major	5 – Catastrophic
Occurrence probability	5 – Almost certain	Medium (R=5)	Medium (R=10)	High (R=15)	Extreme (R=20)	Extreme (R=25)
	4- Probable	Low (R=4)	Medium (R=8)	High (R=12)	High (R=16)	Extreme (R=20)
	3- Possible	Low (R=3)	Medium (R=6)	Medium (R=9)	High (R=12)	High (R=15)
	2- Improbable	Low (R=2)	Low (R=4)	Medium (R=6)	Medium (R=8)	Medium (R=10)
	1 – Rare	Low (R=1)	Low (R=2)	Low (R=3)	Low (R=4)	Medium (R=5)

Table 16 - Risk score determination and risk assessment matrix

For each of the identified hazards, a risk description table will be drafted, as exemplified in the table below.

No.	Identified hazard	Impact description	Occurrence probability score (P)	Consequence score (C)	Risk score (R) R=PxC	Risk assessment
1	Increase of maximum temperatures during summer	High temperatures will determine an accelerated decomposition of the organic waste fraction, generating unpleasant smells and discomfort to inhabitants near the waste collection point	3	2	6	Medium
2						
3						
..						
..						

Table 17 - Risk analysis and assessment in terms of climate change adaptation

After filling in the table according to the example above, the identified hazards will be listed in risk descending order. For the hazards with an extreme and high risk level, it is necessary to establish priority intervention measures. The established measures will target the possible magnitude reduction, reduction of the occurrence frequency of the respective hazard impact and/or increase of the system capacity and its elements to resist the impact and to rapidly recover, with minimum disturbances after hazard occurrence. Intervention in case of hazards with a moderate or low risk level can also be decided if, following a cost-benefit analysis conducted with stakeholders' involvement, it is concluded that these interventions are appropriate.

It is recommended that the risk and vulnerability analysis process described in the steps above is performed periodically, but mandatory resumed after each intervention or event with serious consequences on the waste management system or its elements.

3.3. The potential impacts of climate changes on the waste management sector

From the waste management sector perspective, the expected climate changes and their effects, two types of effects are outlined:

- Acute effects or shocks, which include extreme weather phenomena - storms, heat waves, frosts.
- Chronic effects, that exert long-term pressures on the waste management system. These include the increase of mean temperatures and the increase of drought frequency.

The potential impacts of climate changes on waste generation, collection, transport, treatment and storage are mentioned below. It is important to mention the fact that these impacts may occur or not, or they can occur with variable intensity depending on the local conditions, waste type and waste management practices.

Generation

- In the context of temperature increase, the increase of organic waste quantities in markets and fairs, or from the population. Increased frequency and intensity of the extreme weather phenomena can generate increased quantities of wastes resulting from the material damages caused by this type of natural disasters.

Collection

- In the context of increased temperatures and humidity, the need to increase the frequency of waste collection and avoid complaints from the population in terms of smells

Transport

- More frequent collection will have an impact on the waste transportation; besides, due to climate extremes, more frequent floods are likely to occur, but also landslides (including of roads), which might make waste transportation more difficult, especially in rural areas.

Treatment

- Extreme weather events can lead to the temporary increase of some waste flows, interruption of waste sorting and contamination of sorted fractions, which can hinder waste treatment processes. In addition, high temperatures can determine the need of more frequent treatment of organic/green wastes.
- In the case of organic waste treatment by composting, drought can affect negatively this process which needs maintaining an optimum level of humidity

Storage

- Landfills may be affected by extreme weather phenomena; high temperatures may lead to an increase of fire frequency at landfills, which leads to an intense pollution. Extreme weather events may hinder operations at landfills, and in the case of unsanitarylandfills/inappropriately operated landfills, may lead to the increase of the leachate quantities in case of abundant rainfall/more frequent in the context of climate changes.

Figure 28 - Potential impacts of climate changes on waste management

3.4. Potential impacts of the waste management sector on the environment and society in the context of climate changes

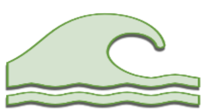
3.4.1. Negative impacts

The inadequate management of wastes has a negative impact on the environment and population health in any conditions. However, in the context of climate change, these negative impacts can manifest themselves with an increased frequency and in very specific ways. Some of the negative environmental impacts of the waste management sector that can occur as a result of climate change are described below in the figure.

More frequent fires at landfills that are improperly operated, in the context of ambient temperature increase and accentuated decomposition of the organic fraction in an anaerobic environment – air pollution

Increased amounts of precipitations can lead to the increase of the leachate amount that is formed. In the absence of sufficient capacity to treat this leachate or in case of non-sanitary landfills, this phenomenon can lead to pollution of the water table or ground water.

An increased amount of precipitations over a short time can generate a loss of stability in landfills that are improperly operated, leading to landslides, to washing off of non-compacted wastes from the landfill or the occurrence of overflows in the leachate retention basins.



In the case of unsound waste management, especially of inappropriate collection, illegal waste dumping in riverbeds, on the public domain or in the rain gullies, the effects of these rainfalls may significantly amplify and may lead to floods/flash floods. In the context of climate change, a higher frequency of short-term, but quantitatively significant rainfalls is expected. These often draw wastes in the drainage gullies or in riverbeds, causing blockages that later generate overflows with potentially devastating effects, especially in urban areas.

The temperature and humidity increasing during summer can lead to a more accentuated decomposition of the organic fraction from the municipal wastes, causing unpleasant smells and increased discomfort to the citizens

Figure 29 - Negative potential impacts of the waste sector on the environment and society, in the context of climate changes

3.4.2. Opportunities to generate positive impacts

The source separation and widespread regular collection both in urban areas and in the rural ones have positive effects on the increased resilience to climate change in priority sectors, such as that of water resources management by:

- Mitigation of riverbed pollution by wastes;
- Mitigation of flood frequency in urban areas, once the risk of blocking the sewage system and stormwater drains with wastes is removed.

In the case of separate collection of the green and organic fraction from municipal wastes, this fraction can represent a resource, not a waste. The appropriate management of organic wastes by composting and then the use of compost in agriculture may lead to positive impacts in this sector. Applying compost to soil can increase the resilience of treated soil to cope with climate changes, by the actions presented below in the figure.

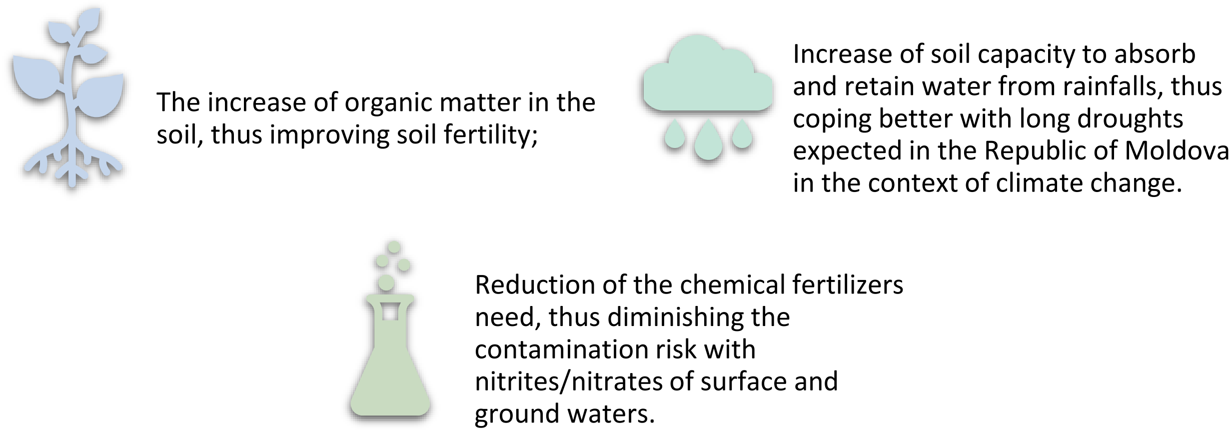


Figure 30 - Mechanisms to increase the resilience of the agricultural sector by using compost produced from organic and green wastes

Integration of climate change aspects in the waste management sector policies

4

4. Integration of climate change aspects in the waste management sector policies

4.1. Mitigation of GHG emissions

In the UNDP EU4Climate [24] project in the Republic of Moldova, an analysis of the policies and legislation in the waste management sector was conducted. This was done to identify the necessary interventions to integrate the aspects regarding the climate change in the sector. The analysis included a review of the sectoral policies, where discrepancies were revealed between the existing legislation and the international policies and suggestions were recommended for legislative changes/amendments.

The scope of the revision was twofold:

(1) identification of climate risks for the existing waste management infrastructure and for the future investments and the way these can be reduced;

(2) identification of opportunities to improve the impact of the sector on climate change mitigation at national and global level.

The study presents legislation adaptation recommendations, which should result in GHG mitigation by:

- Application of landfill construction and closure standards
- Regulation of the waste disposal regime
- Treatment of biodegradable wastes
- Recycling
- Circular economy
- Wastewater treatment

4.2. Climate change adaptation

4.2.1. Integration of climate change adaptation actions in the national level policies in the waste management sector

The analysis of the policy framework regarding waste management in the Republic of Moldova developed by the project EU4Climate [25] highlighted the improvement potential of the existing legislation in the waste management field, thus formulating a series of recommendations, such as:

- Implementation of a study meant to identify the risk and vulnerability of the existing and planned infrastructure for waste management to the impacts of climate change:
  - The areas that are frequently flooded imply additional measures to protect the infrastructure against floods and the formation of anaerobic conditions in landfills;

[24] Source: Integration of climate change aspects in the waste management sector policies; Progress Report no. 2, April 2020; Project EU4CLIMATE
[25] Source: idem

    - The desertification or fire-prone areas imply additional measures for the prevention of fires at landfills, treatment plants and a frequent system for the collection of wastes coming from gardens and parks, and their treatment;
    - The dry areas where the waste treatment processes need water, which are subjected to damage in the absence of water;
    - Identification of areas with high risk of sanitation services interruption caused by natural events.

- The framework content for the risk and vulnerability identification study:
    - Description of the waste sector, policies, existing and planned infrastructure, identification of the structures that belong to critical infrastructure for a subsequent prioritisation of the proposed measures
    - Identification of climate vulnerability and risk areas, of climate change impacts
    - Analysis of climate change impacts on the waste management infrastructure

For each potential impact selected as priority, with major consequences, the prevalence of that risk and the associated impact will be analyzed by regions, together with the waste management infrastructure to identify those structures and communities that are exposed to a high risk and significant impacts.

The study will recommend options for adaptation and resilience building towards the identified risks, both in terms of necessary changes in policies and a plan of actions.

- It is necessary that the Regulation for disposal and other relevant policies establish building and operation standards to take into consideration the results of the vulnerability study. The recommendation is to insert in Chap. II, point 38 of the Regulation for disposal new requirements within the environmental permit issue procedure for landfills. Therefore, the projects for landfills should contain:
    - Identification of risks related to climate change and measures that increase the capacity of the project to adapt to climate change;
    - Measures for the reduction of risk of the project to be affected by climate change (such as access to insurance tools);
    - Measures that prevent the occurrence of certain risks (such as, for example, choosing the location of the project so that its exposure to certain risks induced by climate changes is minimum);
    - Measures that enable the operation within the project and in case some constraints induced by climate changes occur (such as, for example, facilities with efficient use of water or energy, from their own resources).

- The options for adaptation and resilience-building may include:
    - Technological changes
    - Development of risk management plans as part of the infrastructure operation manual
    - Increase of sensitivity in terms of good practices
    - Rethinking the zonal planning and the strategical location of the new infrastructures
    - Risk management and risk communication.
    - Introduction of the waste sector in the critical infrastructure of the country and in the National Adaptation Strategy.

4.2.2. Synergies related to climate change adaptation in the waste management sector with other economic sectors

The waste management sector provides a series of opportunities to establish synergies with other sectors of the economy, facilitating the implementation of the circular economy concepts.

Depending on each waste flow, opportunities for networking can be established with various sectors. The best known and convenient model is represented by the industry. Thus, certain secondary products may represent wastes in the technological process for an industrial unit, but the same products may successfully be the raw material for another industrial unit. There is the opportunity to establish an "industrial symbiosis". From the climate change perspective, this process leads both to resource savings and to "emissions savings", both associated with the processes necessary for the achievement of primary raw materials and the processes alternatively associated with the resulting waste management.

In terms of climate change adaptation, the most obvious synergy may be noticed in the organic/green waste streams and in the agriculture sector. From these waste streams collected separately, compost can be obtained successfully, to be used for soil treatment. The treatment of soil with compost improves both soil fertility and its capacity to retain water and its resistance to erosion. Thus, sound organic waste management contributes to climate change adaptation of soil and agriculture sector in general.

The connection between waste management and the water resources management sector is not that obvious, but there can be many influences and dependencies between these sectors. As mentioned in previous chapters referring to potential impacts, inappropriate management of wastes can hinder the integrity and safety of water resources by physical pollution - blockages on water courses due to illegally dumped wastes or waste carried by stormwater, or chemical – leachate pollution from unsanitary landfills or direct pollution of soil, surface and underground waters with hazardous wastes that are illegally dumped. A potential synergy between the waste sector, the agriculture sector and water management is represented by the use of compost produced from green wastes and organic fraction of municipal waste. This offers opportunities for the reduction of surface and underground water pollution by nitrites/nitrates coming from the use of chemical fertilizers in agriculture.

Finance of fighting climate changes

5

5. Architecture of climate finance

5.1. Key actors in climate finance

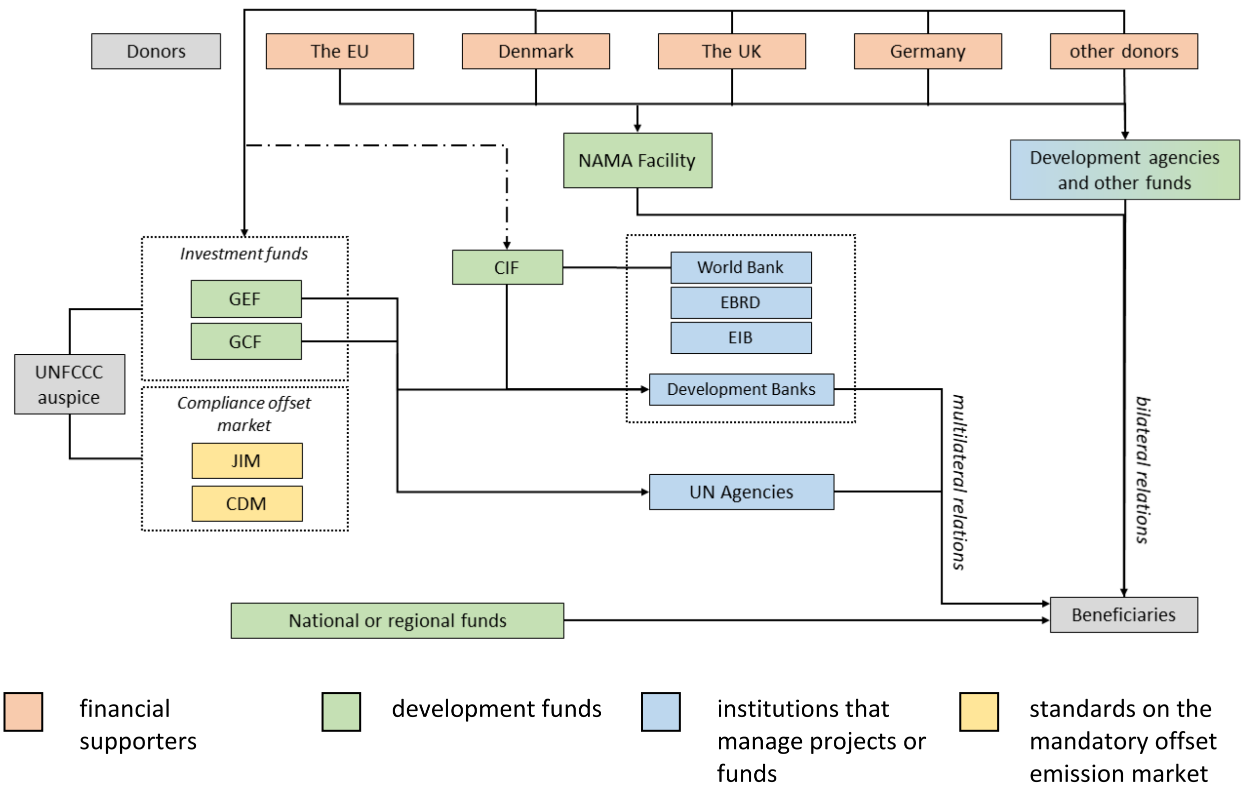


Figure 31 - International architecture of the climate change finance sector [26]

The climate change finance sector is diverse, including numerous mechanisms by which the funds made available by financial supporters may reach the climate projects that need support. Besides the mechanisms implemented under the auspices of the UNFCCC, as a result of international treaties signed between the member states, there are various initiatives with similar structures, which are guided by the same principles. For example, the mandatory offset emission market where carbon credits can be traded through the Clean Development Mechanism (CDM) and through the Joint Implementation Mechanism (JIM), has an equivalent on the voluntary offset market. In this, the standards issuing credits operate similarly, being guided in some cases by the methodologies approved on the mandatory offset market, but the credits can be traded by anyone, not only by the UNFCCC member countries.

Along the same line, Green Climate Fund – GCF ("the successor" of Global Environmental Facility – GEF) is the main mechanism by which the Convention transfers funds subscribed by the developed countries (financial supporters like United Kingdom, Germany etc.) towards the climate projects in the developing countries. GCF operates partnerships with Accredited Entities, which are usually international financial institutions, such as regional development banks (e.g.: The European Investment Bank, the European

[26] Source: adapted from Climate Funds Update – *The Global Climate Finance Architecture* (2020)

Bank for Reconstruction and Development) and, by a competitive process for the selection of projects that will be funded.

On the other hand, CIF (Climate Investment Funds) is an umbrella development fund created at the initiative of several developed states, which is managed by the World Bank. This fund is guided by the UNFCCC principles, but it works differently than GCF. The funds are offered to several regional development banks, which implement investment programs in developing countries. Therefore, the selection process of the funded processes is not competitive.

Besides the two funds described above, there is a very large variety of international funds that are guided by similar principles and that can have general or very precise interest areas. The way the funds are wired from the financial supporters to the beneficiary projects represents a "multilateral relationship". Funds are subscribed from several sources (from several financial supporters) and are aggregated in a single fund, managed separately by another entity. The access of governmental institutions to funding may be direct or restricted by the collaboration with an accredited institution (like in the case of GCF and CIF).

The "bilateral relationships" are established between the projects that benefit from support and the financing governments, directly by the agencies or development banks of the financial supporters. Such examples are the German Development Bank (KfW) and the German Agency for International Cooperation (GIZ). Another example that can be included in this context is the NAMA Facility, where funds are subscribed by four financial supporters and are transferred to the selected projects by a competitive process, by means of GIZ, without the need for accreditation to submit proposals in project calls.

5.1.1. NAMA Facility

The **NAMA** concept (*Nationally Appropriate Mitigation Actions*) was introduced by the United Nations Framework Convention on Climate Change (UNFCCC) in COP 13, since 2007, by adoption of the Bali Plan of Actions, and subsequently, key elements of this framework will be defined and materialized in the following years.

The NAMAs are a framework of concrete voluntary actions taken by developing countries, for the reduction of GHG as compared to the status-quo, adapted to the national context and capacities, initiated by public authorities, supported by the developed countries (by information and technology transfer and by financial support), with a biannual report of the conducted actions towards the UNFCCC. [27] For appropriate actions, a "top-down" approach may be adopted, so that development policies like NAMAs are developed and lead towards concrete actions in fighting climate changes or a "grassroot" approach, by which the NAMAs like projects contribute to the creation of a favourable framework for the subsequent development of policies.

[27] Source: UNDP, UNFCCC, UNEP Risø – *Guidance for NAMA design: building on country experiences* (2013)

There is a register that contains all the actions declared by the convention member countries. [28] The purpose of the register is twofold, both to provide visibility to actions and to offer implementation examples, and to facilitate the support of actions that need backing.

Although this framework of climate change actions was introduced 14 years ago, it remains topical for two reasons:

- it is a way by which the UNFCCC member states may reach their Nationally Determined Contributions (NDC) to which they have committed themselves by the Paris Agreement;
- international funds continue to be made available for the funding of NAMAs.

NAMA Facility is an organization established in 2012 by the contribution of the Department for Business, Energy and Industrial Strategy of the United Kingdom and of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of the German Government, which has the purpose of providing financial help to NAMAs in developing countries that stand out by initiatives in fighting climate changes, regardless of the concerned economic sector. The two institutions are accompanied as financial supporters by the European Commission, Denmark (by the Danish Ministries of Climate, Energy and Utilities, and of Foreign Affairs). Until 2021, the organization has offered more than 202 mil. USD and 26 mil. EUR [29] in terms of funds for the implementation of successful NAMAs in seven project calls. Taking into account that the calls are regular, it is useful to know the project submission process.

In December 2020, the second project call (*the Ambition Initiative*) was launched, with accent on the ambition of the states towards the NDCs undertaken until the end of the selection period – May 2021 [30]. Therefore, the proposed projects must be framed in the context of national contributions and of the development and environmental strategies. Strictly in the context of this call for projects, the proposals need to contribute to the integration of climate change mitigation measures in the national recovery plans after the Covid-19 pandemic. **The entities that can initiate the submission of projects** (*Applicants*) **within the calls are**:

- legal, public or private persons that need to receive the support of relevant national ministries;
- national ministries, but these need a legal person partner.

These need to fulfil certain eligibility criteria to initiate the process. However, more important and more restrictive are those that help assessing the Support Organisations, which need to draft detailed plans and implement projects after they received funding. Support Organisations do not necessarily have to be those initiating the project submission within the call for projects, but they need to be identified and involved along the way to be able to sign the grant awarding contract with the NAMA Facility guarantor (*Grant Agent*), GIZ. A Support Organisation:

- can be a national or international organization, but not a state authority, because the NAMA Facility mechanism does not allow the fund transfer to governmental institutions;

[28] https://www4.unfccc.int/sites/PublicNAMA/SitePages/Home.aspx
[29] Source: UNEP DTU Partnership – *NAMA Pipeline Overview*: http://namapipeline.org/
[30] Source: NAMA Facility – *General Information Document: Ambition Initiative Call for NAMA Support Projects*

- has to have the express approval and support of governmental authorities.

The first phase of the selection process is the drafting of a project outline (*NSP Outline*), in English, by filling in the forms that need to be sent to the NAMA Facility Secretariat (*Technical Support Unit*), observing the eligibility criteria for projects.

1. The NDCs undertaken by the implementing country until the closure of the call for projects must contain increased objectives, with additional engagements;
2. The country where the project will be implemented must be in the eligibility register for development assistance (*ODA eligibility DAC-list*) of the Organisation for Economic Cooperation and Development, throughout the entire project implementation duration;
3. The project must not generate GHG emission reduction certificates that can later be traded on the emission offset markets;
4. The implementation period is 3 – 5.5 years;
5. The grant requested must be between 5 – 25 mil. EUR (without the editing costs of the detailed project).

Once the eligibility of the submitted proposal is checked, the Project Outline is assessed based on a 50 points grid, with various aspects addressed. A rating of minimum 25 points is necessary to go to **the second selection stage, the preparation of the Detailed Proposal,** which is financed by the NAMA Facility (the amounts are not part of the project proposal budget). Therefore, consultants and experts can be contracted in this phase. The deadline for the drafting of the plan is 10 or 15 months. During this stage, a Support Organisation shall be identified in less than three months, to submit the detailed plan.

The submitted plan is also assessed on the 50 points scale, but this time, the criteria related to the project feasibility have a higher weight in the total and the assessment is much stricter. **The assessment criteria followed by NAMA Facility for granting the funding** in both stages of the selection process are listed in the following table:

Potential for transformational change	Measured by the engagement level of the public authorities, by the inclusion in national policies and NDCs, by the sustainability of the project and the replicability potential etc.
Financial ambition	Represents the ability of the project to attract funding from the public or private stakeholders
Mitigation potential	The project must contribute to the reaching of the national decarbonisation targets
Project rationale	Represents the correct identification of the obstacles in the targeted sector and the proposal of feasible solutions for their removal
Project design	The actions proposed within the project must be feasible
Detailed Preparation Phase concept	By this criterion it is demonstrated the ability of the project proposer to develop the detailed plan of the project and the implementation ability

Pursuant to the promising projects selection, the Governing Board of the NAMA Facility decides upon the funding assigned, depending on the availabilities. In case the available funds are exhausted, the projects that do not receive funding will be considered as soon as new contributions are subscribed by the donors. In the meantime, these projects can be submitted for other funding lines, too, but there cannot be overlapping between the funded items and those funded by the NAMA Facility. Once the grant award contract is signed between the Support Organisation and the NAMA Facility guarantor (*Grant Agent*), the implementation of the project can begin.

In conclusion, **the funding opportunities offered by NAMA Facility are the following**:

- Support for the detailed development of the project plans, during the second phase of the selection process, when experts can be contracted for the development of the necessary analyses. The amounts are contracted by entities that have initiated the submission of the Project Outlines. There are no limits for the amounts required in this stage, but these are on an average around the value of 250,000 EUR.
- The funds made available are in the form of grants, within the 5 – 25 mil. EUR range (deviations from this range are rare and should be very well justified). There are no conditions related to the co-funding degree, but it is important that the project succeeds to attract funds from other sources, too (among which the national authorities that have expressed their support) to prove the sustainability and the transformative nature. It is not a condition, but analysing the projects funded until 2021, it was revealed that the ratio is, on an average, 1:7 between the contribution of NAMA Facility and the funds attracted from other sources.
- The expansion of the project is possible after the end of the implementation period and only in case of the projects that succeed to prove the replicability of the proposed concept. The decision to give additional funds belongs to the financial donors of the NAMA Facility.

There are no restrictions on the economic sector targeted by the projects plans, as long as the projects can bring tangible benefits in terms of GHG emission reduction and climate change mitigation, and as long as the sector targeted within the project is framed within the NDC of the respective country. Therefore, **interventions in the waste management sector can also be proposed.** Also, the NAMA Facility values the exchange of information and good practices. Therefore, the Support Organization must be sure that it has the sufficient funds in the project budget to be able to communicate with the interested parties and disseminate information related to the project and the resulting impacts. For these two reasons, there are already examples of projects funded in the field of waste management that can be consulted and serve as models for initiatives that can be implemented in the Republic of Moldova.

5.1.2. Green Climate Fund

Green Climate Fund (GCF) is at the moment the largest investment fundfor climate change projects. The fund was established in 2010 and in 2015 it provided the first funding for a project. Currently, the fund serves as main mechanism in the post Paris Agreement period by which the UNFCCC member states can reach their Nationally Determined Contributions.

The GCF priority is to finance both projects with climate change mitigation benefits (by reduction of GHG emissions and increase of the contained carbon volume), and with adaptation impacts (by increasing resilience of the communities to the effects felt due to climate changes). There are numerous projects that manage to bring benefits both in terms of mitigation and in terms of adaptation (e.g.: a project for the prevention of deforestation brings obvious benefits related to the GHG absorption, but it also improves the standard of living of the neighbouring communities in various ways). These are called cross cutting actions.

The connection between GCF and the beneficiaries of the funding is facilitated by:

- means of NDAs (*National Designated Authorities*), which are public authorities and which coordinate and monitor the activities funded by GCF at national level;
- and by means of the AEs (*Accredited Entities*), which are public or private, national / subnational or international / regional non-governmental entities involved in the project proposal development and implementation and monitoring of the funded projects.

Besides funding in the public sector, the stakeholders in the private sector can be engaged in the projects and programs funded by GCF. These can sign agreements with Accredited Entities in order to implement adaptation or mitigation projects.

GCF does not implement environmental projects and programs directly, but it finances them by means of partnerships with Accredited Entities which submit project proposals (in cooperation with the NDAs) and supervise the implementation of the approved projects. Therefore, the AEs are not always the ones implementing the projects. **The selection process of the projects is composed of two stages and includes the following steps**:

1. In the first phase, a concept note is submitted by the Accredited Entity, by which prior information on the project are provided. The concept note is assessed by the GCF Secretariat.

2. The second phase implies the submission of a funding proposal, also by the AE, in compliance with the templates provided by GCF. The NDAs of the countries involved in the project must issue letters of recommendation for the submitted proposal.

3. The GCF Secretariat conducts a detailed analysis of the proposal to make sure the GCF policies are observed.

4. A commission composed of six experts conducts a technical analysis of the proposal, taking into account the investment criteria of GCF.

5. The proposals are forwarded to the Governing Board of the GCF. This can decide the award of funding for a project, the refusal of granting the funding or the conditioning of funding on certain changes made to the plans.

6. If the project proposal is approved for funding, the Accredited Entity and the GCF Secretariat sign a funding contract. After that, the AE is responsible for ensuring the favourable framework for project implementation.

There are two more special procedures by which funding proposals can be submitted:

- GCF can launch calls for projects in specific domains when gaps are identified in some sectors in the field of climate finance. Legal persons that are not accredited can submit project proposals as the accreditation is awarded pursuant to this project selection process.

- The simplified approval procedure is intended for small size projects (up to 10 mil. USD), which present minimum investment risks and are ready to be extended and replicated. The assessment and approval process is similar to the standard one, but the necessary documentation is not equally extended.

The criteria taken into consideration by the GCF for the award of the funding are similar to those within NAMA Facility, i.e.:

Impact potential	Impacts concerning the climate change mitigation and adaptation are measured.
Paradigm shift potential	Project sustainability and replicability are assessed so that this does not remain a unique and isolated action, but instead it leads to long-term changes.
Sustainable development potential	The project must bring also secondary benefits (social, equal opportunities, economic, etc.). In other words, the project must observe the GCF policies in these fields.
Needs of the recipient	The obstacles that hinder funding in field affected by climate changes need to be revealed, together with the solutions provided by the proposed project or program.
Country ownership	The project needs to contribute to the NDCs' targets in the countries concerned and observe the national policies and strategies. Also, the interested parties at national level need to be involved.
Efficiency and effectiveness	The cost / benefit ratio of the project and the public and private co-financing degree are assessed.

The financial instruments made available by GCF are the following:

- Grants and loans. In order to establish the finance level granted by each tool, the concession level is analysed. By this the funding percentage is proved, that can be awarded as loan, so that the project remains feasible from financial point of view and the funding percentage that needs to be awarded as grant.
- Regardless of the chosen tools, funds are offered only for capital investments, but not to cover the project operation expenses. The co-finances are not mandatory, but these are, in practice, mandatory to cover the operation expenses.
- GCF offers financial support, too (within the limit of 1.5 mil. USD) to the Accredited Entities, as well as technical assistance for the development of project proposals.

GCF has identified eight spheres of interest, considering that investments in these bring the most potent effects in terms of fighting climate changes. **The waste management sector is classified in the second sphere of interest** ("buildings, cities, industry, equipment"), according to the GCF Guideline on Urban Environment:

Strong climate change mitigation impacts	***Strong climate change adaptation impacts***
forests and land use	*ecosystems and ecosystem services*
buildings, cities, industry, and appliances	*health, food, and water security*
energy generation and access	*Infrastructure and build environment*
transports	*livelihoods of people and communities*

5.1.3. Climate Investment Funds

Climate Investment Funds (CIF) represent one of the first tools in the climate change finance field (launched in 2008), by which climate change mitigation and adaptation projects are funded. CIF is structured into four sub-funds:

- *Clean Technology Fund* (focused on GHG emission reduction technologies)
- *Pilot Program on Climate Resilience* (for the integration of changes in the development policies and adaptation projects)
- *Forest Investment Program* (designed to the deforestation combat projects)
- *Scaling-Up Renewable Energy Program* (focused on renewable energy sources)

Funds are managed by the World Bank, while regional development banks, among which EBRD, propose investment programs in developing countries, in partnership with governmental institutions in these countries and with amendments to the national strategies and objectives in the climate field. Therefore, the amounts made available for each program are fixed and negotiated in advance, after the submission of the plans. Each development bank has its own policies for the preparation and implementation of the projects, but there are basic indicators in each sub-fund that need to be monitored. The presence of CIF in Europe is felt in Turkey, by projects for the use of renewable energy sources, with the support of EBRD.

The financial instruments made available by CIF are in the form of loans and grants. The concession level is analysed in the context of each submitted proposal. The integration of a loan component is not mandatory to benefit from grants. However, the financial instruments available differ in terms of the origin sub-fund and of the development level of the country where projects will be implemented (some sub-funds offer exclusively funding under the form of loans, while others tend towards a balanced distribution). Also, amounts of 1 - 1.5 mil. USD are made available (depending on the specific of the proposals and the targeted sub-fund), as a grant, for the development of the investment plans.

5.2. GHG emission offset options

5.2.1. Mandatory emission offset market

The GHG emission reduction systems can take different forms, but one of these is the compliance emission offset market. By this, the limits on the GHG emissions (imposed by regional, national or international regulations to reach the climate change combat objectives) can be reached also by compensating the emissions that exceed the determined threshold, by acquiring credits granted to other projects that brought benefits in terms of emission reductions. To this end, the Clean Development Mechanism and the Joint Implementation Mechanism were developed, under the auspices of UNFCCC, setting the basis for the development of other similar regional or national programs and the standards of the voluntary offset market.

Once assuming the Nationally Determined Contributions through the Paris Agreement by all participating parties, the emission compensation mechanisms have become more complicated, because the states need to establish a balance between the emission reductions they will be claiming for reaching the national targets and the reductions they will "export" (avoiding double counting). By contrast, Article 6 of the Agreement stipulates the fact that the states can make use of international agreements and cooperations to generate transferable benefits for climate change mitigation. In this regard, numerous bilateral or multilateral pilot mechanisms were developed between the participating countries, most of them in the planning stage. The concrete transactions by such mechanisms will be possible once the templates for the reporting of inventories will be established. Also, another important point of discussion is the way in which the credits already issued or which will be issued over the following years by the Clean Development Mechanism can be used or not for the achievement of the objectives established by the Agreement, once Article 6 will be completed. The future role of standards on the voluntary offset market remains an open topic for debate.

Some of the pilot mechanisms are focused on the waste management sector. For example, Canada and Chile have signed in 1997, an agreement regarding cooperation for climate change combat. Under this agreement, after the Paris Agreement was signed, Canada offered technical support and funding to its partner, for the development of a project investment program for the methane emission reduction from the landfills in several cities in Chile. The procedures for the emission reduction transfer between the inventories of the two countries will be completed only after the materialization of the international regulations regarding Article 6, but negotiations in this regard and for other cooperations of this kind are currently under way. [31]

Similar initiatives in the Republic of Moldova can serve as a starting point for negotiations with other states, in view of establishing some cooperations for the emission reductions transfer. Thus, new funding and investment sources can be attracted in the country, to facilitate the achievement of Nationally Determined Contributions and can enable the "export" of additional reductions.

5.2.2. Voluntary offset emission market

On the voluntary offset market of the GHG emissions, both legal and natural persons can purchase carbon credits in order to compensate the produced emissions (e.g.: by the production processes – in the case of companies conducting social responsibility campaigns; by everyday living or by using the air transport for private use – in the case of individuals), with no obligation to do that. In some cases, these credits can be accepted on the mandatory offset markets (e.g.: in the United States of America, credits issued by the Climate Action Reserve can be claimed also in the California Compliance Offset Program), by agreements. Of course, in such cases, the credits issued must observe the requirements of the compulsory market.

[31] Source: Climate Focus; Perspectives Climate Group - *Article 6 piloting: state of play and stakeholder experiences* (2020)

Therefore, the credit demand on this market is created by interested buyers, by the demand and supply mechanisms specific to an economic market and not by legal regulations. There are numerous intermediate stakeholders on this market, who can also provide adjacent services, such as marketing and public relations services (relevant especially in the case of companies with social responsibility programs) or services that provide the shortest and cleanest air transport routes (for individuals). The credits can be bought and resold by these stakeholders, but the final buyer is the one claiming the GHG reductions and thus disables the respective credits (this is recorded in the registries of the standards issuing the credits).

Initially, the credits are made available to project managers who resell them to intermediaries or final buyers to achieve additional funds (one part of these credits are claimed by the issuing standards to cover the administrative expenses). The credits are usually issued after the emission reductions were completed and validated, so this is an ex-post or intermediate source of funding for the project, but there are also mechanisms by which the credits are issued ex-ante to the reductions completion, such as the new Climate Forward program of Climate Action Reserve (of course, subjected to some stricter verification criteria and incorporating the risk related to this procedure).

On this market there is no homogeneity regarding the requirements and working procedures. Each institution which issues carbon credits has its own objectives, procedures and protocols, emission accounting mechanisms etc. However, these are usually built based on previous regulations (such as those of the Clean Development Mechanism). Therefore, each issuing standard is focused on various types of projects with emission reduction benefits (can have a wider or less spectrum), places accent in a different way on the adjacent benefits of the projects (such as the socio-economic benefits) and covers a different geographic area (either they accept international projects, or they are limited at national level), and the verification and validation process for the reduction of emissions resulting from the submitted projects is similar in most of the standards. New methodologies for the project types which are not targeted by the issuing standards can be, in some cases, proposed by interested buyers or project managers, in which case the reliability of this proposal is analysed. The development of new programs and methodologies can come also from organizations, as a result of the opportunity analyses. For example, Verra (standard active since 2005) is on the verge of launching a new program (*the Plastic Waste Reduction Program*) by which certificates prove the collection and/or recycling of a ton of plastic by the endorsed project.

A common denominator on this market is the “additionality” concept. By this principle, it should be proven that the benefits brought to the project proposed for certification would not have existed in the absence of the project (in other words, the fact that there are no other economic, social, technological, political, etc. factors to lead in the end to the development of such project). Practically, the GHG emissions (and other socio-economic indicators, if the case) are estimated in two scenarios and are compared: the basic scenario or the status-quo (*business as usual*) vs. the scenario where the project is implemented. The emission difference between the two scenarios represents the benefits in terms of emission reductions brought by the project. This principle is present in the approach of all standards on the emission offset market.

According to the Ecosystem Marketplace study, an organization studying the market state, there is an evolution of the voluntary offset market, which gained a considerable scale over the last years, especially due to the increased interest of the population and companies in emission offset and the increase of national engagements number for a sustainable recovery after the current pandemic. Most of the credits issued on this market come from projects in the renewable energy and forestry sectors, because the emission reduction benefits are accessible at a low investment cost. According to available data, in the year 2019, the main types of projects benefiting of carbon credits, as well as their average price and the emission volume covered by credits were the following:

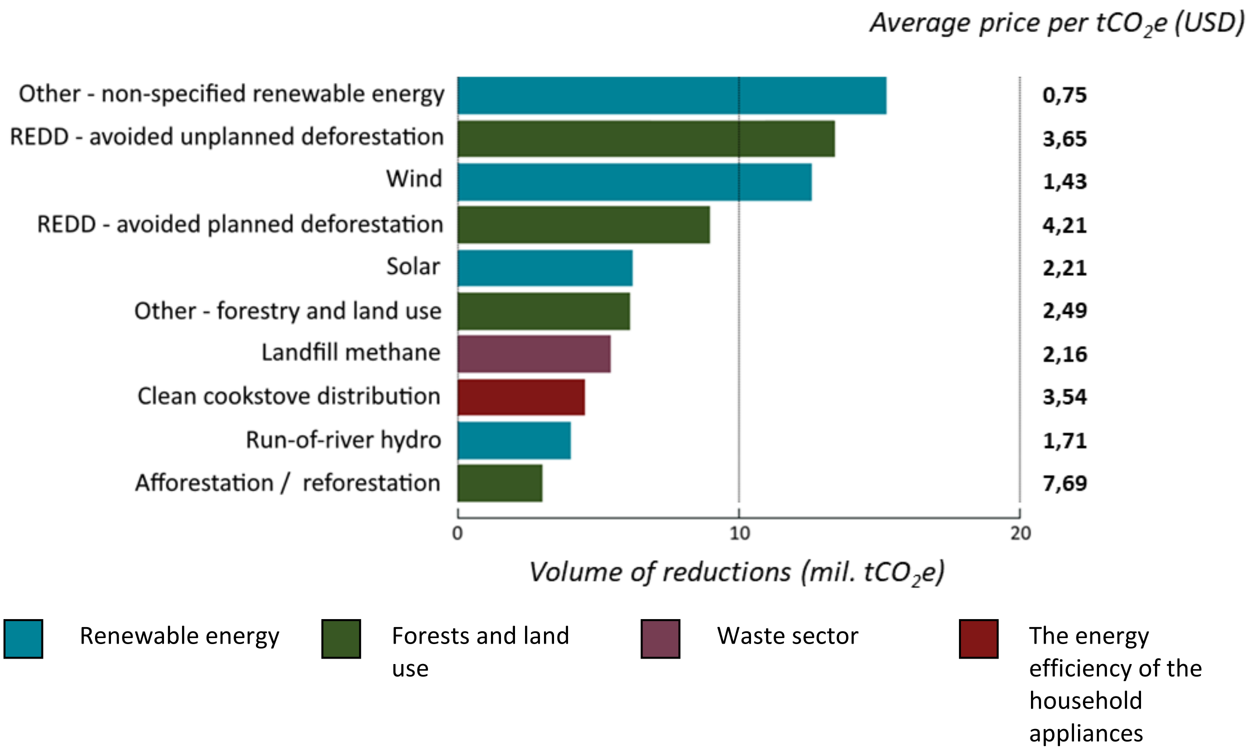


Figure 32 - Top 10 types of projects with impacts on the GHG emissions and average prices per credits, from the voluntary emission offset market [32]

One of the biggest carbon credits issuing standards is Gold Standard, which operates on this market since 2003. Initially, the credits issued by this were used within the Clean Development Mechanism, but three years later, credits on the voluntary market started to be issued, too. Gold Standard has an international opening and accepts projects in the field of waste management, which imply: waste recovery by composting, energy generation by capturing the gases from landfills or recyclable materials recovery. Beside the methodologies specific for each type of project for the recording of GHG emissions, there are also methodologies that record the socio-economic benefits of the projects. These benefits are included in the "project value", due to the Gold Standard vision, which implies an increased focus on the Sustainable Development Objectives.

The certification process of a project includes the following steps:

1. Project planning, impact estimation, alignment to Gold Standard requirements and the development of a concept note with key information.

[32] Source: adapted from Ecosystem Marketplace – *State of the Voluntary Carbon Markets 2020: second installment*

2. The preliminary verification of the project, targeting especially the following aspects: the consultation report of the interested parties and the detailed project plan (including with estimation of the impacts and monitoring and reporting methodologies).

3. Once the project plan is approved, this becomes listed by Gold Standard, receiving the go-ahead for initiation.

4. The validation of the project follows next (with a review of the documentation and a field visit), by an external auditor accredited by the Clean Development Mechanism (under the auspices of UNFCCC). The results of this verification are a validation report and a project plan which observes all the methodological and administrative requirements of Gold Standard and has the potential to bring real benefits in terms of reductions. Once these steps are finalized, the project becomes listed as having "approved design" and can be implemented.

5. The project needs to be constantly monitored, annual reports are submitted by the developer.

6. The verification of the project by another external auditor comes next. Its scope is to certify whether the GHG reductions were actually reached or not, based on the data and reports drafted throughout the project monitoring process. In case of a favourable conclusion, the project becomes "certified".

7. The carbon credits (and / or other similar products, made available by Gold Standard) are issued and recorded in the register.

Climate good practice examples in the waste management sector

6

6. Climate good practice examples in the waste management sector

A2UFood – Avoidable and unavoidable food wastes: a holistic management approach of urban environments – Greece

The large quantity of food wastes, both avoidable and unavoidable, especially in the urban environment, induces multiple challenges to the modern society. A2UFood proposes a holistic management outline where there are included all the aspects of the reduction, reuse and recycling of food wastes. Specifically, a series of project complementary actions target the reduction of avoidable food waste, the use of unavoidable food wastes as raw matters and the adequate management of the unavoidable food waste.

To develop the proposed solution, a series of innovative instruments will be projected and implemented:

- software to support the families in avoidable food waste reduction
- software and hardware for the avoidable food waste reduction in the hospitality sector
- a second restaurant with food products
- a bioplastic production system for the production of compostable bags
- a series of state-of-the-art autonomous composting units (ACU), where treatment will be conducted in situ.

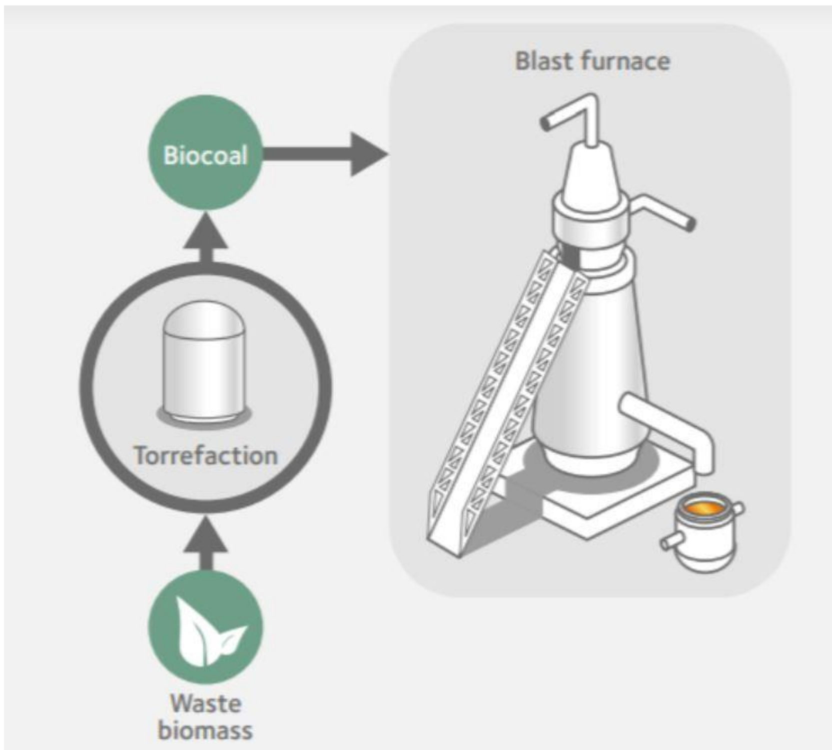

A2UFood expects to reduce the quantity of avoidable food wastes, to cause the use of unavoidable food wastes as raw materials and facilitate the processing of food wastes in an ecological and beneficial manner form financial point of view in the city of Heraklion. A2Ufood aims to reduce food waste **by 1% in households** and **by 2-3% in the hospitality sector.** In addition, **1,000 tons or 2.5% of the food wastes** unavoidable for the Heraklion municipality will be redirected to composting on a yearly basis.

Source: https://www.uia-initiative.eu/en/uia-cities/heraklion

ArcelorMittal – Production of steel by using the waste fuels – Belgium

Production of steel is an important industrial greenhouse gas emission emitter. Integration of renewable energies, especially the use of biomass resources and wastes in the steel sector could substantially reduce the greenhouse gases.

Torrefaction is a thermal process to convert biomass, including wood and solid wastes, into a material with better properties for the use as fuel for combustion and gasification applications. The process involves a light pyrolysis, at 200-350 °C temperatures, to produce a fuel of a higher energy density.



Results expected by Life Smart:

- a decrease of 161 000 tons of CO_2 / year in the fossil coal, using a basic level of the Pulverized Cole Injection (PCI) emissions of 3 223 M ton / year and a replacement of 5% PCI with solid wastes at demonstrative scale;

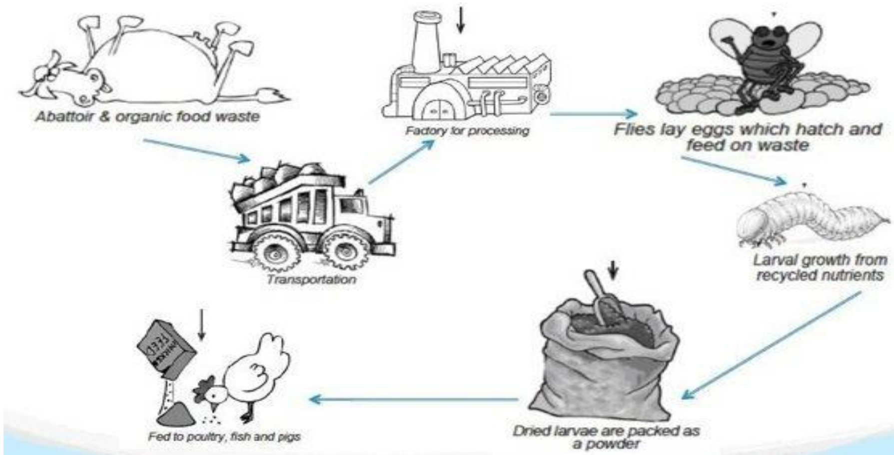
- a 4% cost saving by implementing a new technology which uses wastes, resulting in economies of approximately 6.3 million EUR / year;

- it will significantly contribute to the extension and promotion of new approaches of the renewable energy in the EU industry. This will contribute to climate change mitigation, will reduce landfills, will limit the processing and coke / coal import, and will produce biofuel as a secondary product.

Source: www.automotive.arcelormittal.com

AgriProtein – Recycling of nutrients from wastes – International

An innovative answer to the protein needs, AgriProtein refers to a new industry, the recycling of nutrients. Using fly larvae and feeding them with existing organic wastes, AgriProtein has developed a sustainable source of natural proteins. AgriProtein has started in Cape Town, South Africa, in 2018 it has extended in Belgium and now it has the global headquarters in the United Kingdom.



The technological process covers three main operations:

- The wastes supply chain, where mixed organic waste streams and the wastes from restaurants, factories and farms and from other sources are collected and processed in a filling material with nutrients, called LarvaeLunch;
- The fly eggs and juvenile larvae production, where eggs are collected from flies kept under ideal conditions, digitally controlled, bio-secured;
- Product manufacturing, resulting in three final products: MagMeal - an insect-based complete protein, MagOil - an extracted fat and MagSoil - a soil improver;

In 2016, the first industrial scale insect-based recycling plant was put into function in Cape Town, with a 100 ton organic waste capacity diverted per day and a 2,000 tons MagMeal production per year.

Environmental impact:

- The impact of the landfill: the factories have a biological conversion capacity of 250 tons of wastes per day, resulting in a total diversion of 90,000 tons of organic wastes annually;
- Impact on the ocean: if MagMeal is used as a replacement of the fish flour, each ton enables the existence of three tons of fish;
- Impact on the carbon: 2056 kg CO_2 / ton magMeal as compared to 10875 Kg CO_2 / ton of fish flour - as compared to the fish flour alternative, MagMeal has an environmental footprint 5 times smaller and environmental costs savings of 2,000 USD per ton; MagMeal can be produced where necessary, saving the transport costs and the emissions associated to GHG.

Source: www.agriprotein.com

Circular residential area – the Super Circular Estate project in Kerkrade – Holland

The project contributes to a low carbon emissions, sustainable economy, using the resources in an efficient manner. Its scope is to create a qualitative urban environment and accessible housing opportunities, offered based on some innovative circular solutions regarding the materials involved and the social aspects. The first circular residential area of Europe will be created in the Stadsregio Parkstad Limburg region in the south of Holland, an area with decreasing population. Three tall blocks of flats in the area offer valuable materials, qualities, and social structures. The objective of the project is to reuse these values while stimulating local economy and creating an attractive and high-quality urban environment. The previous social structures will be recovered by urging former residents to come back to the area.


More exactly, four housing units will be built by different reuse and recycling techniques, from materials resulted from the circular demolishing of one of the tall blocks of social houses.

The target results:

1. The circular demolishing of a tall block of 100 apartments, achieving 24 types of materials.
2. Building of four housing units by different reuse and recycling techniques, from materials recovered from the demolishing of the block.
3. Approximately 125 former residents returned to the area.
4. Closed water cycle supplying 35 households with drinking water.
5. A social center with six functions, which will consolidate social cohesion and stimulate the formation of a community interested in reducing the waste quantity.

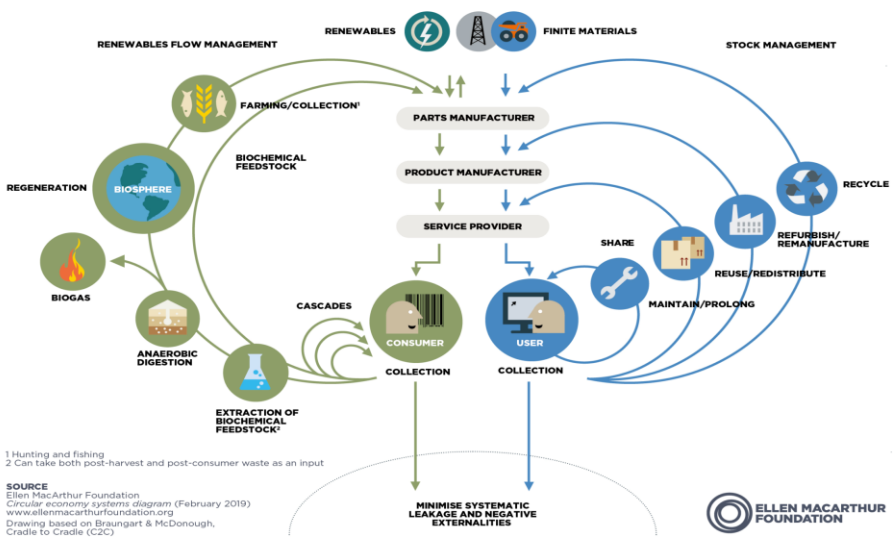
The project is funded by the European Union by UIA (Urban Innovative Actions), with a budget of 4,712,765 EUR.

Source: https://www.uia-initiative.eu/en/uia-cities/kerkrade

The initiative of the regional program for the circular economy (almost zero wastes) – International

The objective of the project is to catalyze the expansion of the circular economy initiatives by overcoming the barriers to investments in technologies and circular economy processes, together with adoption of circular economy strategies and commercial practices. The project adopts a complete approach of the cycle, from source reduction to waste recovery, reduction, and disposal. The regional project pursues, also, the expansion of the market for the waste reduction investments, by addressing the existing barriers on the market, as well as by raising funds for high replicability potential investments and minimum penetration of the market, in case the markets will be defined in each project.

GHG emission reduction target: CO_2e (direct) = 6,250,000 tons; CO_2e (indirect) = 15,625,000 tons.



The project is regional, it will be implemented in 5 countries: Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Serbia, Turkey. The project has 3 components:

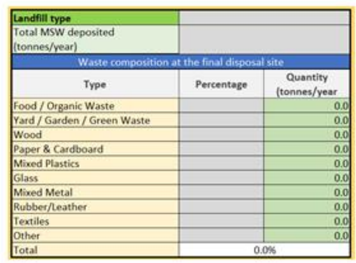
- Component 1: Implementation of performance-based funding of the circular economy;
- Component 2: Technical assistance for adopting technologies and strategies in circular economy;
- Component 3: Monitoring and assessment.

It is expected that the project has a demonstrative effect in the target countries where circular economy investments are currently undeveloped. The project will catalyze a transformation at market level towards a circular economy in the private sector, promoting companies to reconsider their production processes, technologies, products, and business model. The expansion will be further supported by targeted awareness campaigns, as well as by connecting the beneficiaries and the conclusions of the project with the existing platforms, such as the material market. The project is funded by GEF and BERD, with a total budget of 155 million USD.

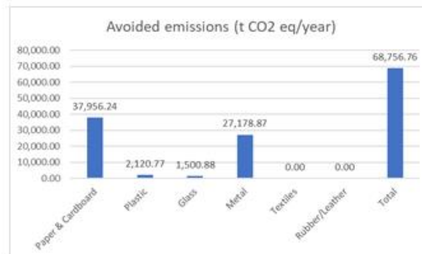
Source: https://www.thegef.org/project/circular-economy-regional-programme-initiative-near-zero-waste

WIEGO – Greenhouse gas emissions reduction by inclusive recycling – Accra & Dakar & Buenos Aires

A large part of the worlds' wastes is recycled and reused by the informal waste gatherers. The few studies that have tried to document their impact on climate have proven the contribution to greenhouse gas emissions reduction by their collection, recycling, and reuse practices. The calculator developed as part of the project aims at developing even more the knowledge on the impact of waste gatherers on greenhouse gases mitigation, offering them, at the same time, an accessible instrument, easy to use, to conduct their own calculations related to processing, recycling, and informal collection.



Landfill type		
Total MSW deposited (tonnes/year)		
Waste composition at the final disposal site		
Type	Percentage	Quantity (tonnes/year
Food / Organic Waste		0.0
Yard / Garden / Green Waste		0.0
Wood		0.0
Paper & Cardboard		0.0
Mixed Plastics		0.0
Glass		0.0
Mixed Metal		0.0
Rubber/Leather		0.0
Textiles		0.0
Other		0.0
Total	0.0%	



The calculation instrument and the methodology focus on the main mitigation sources resulting from inclusive recycling. These are:

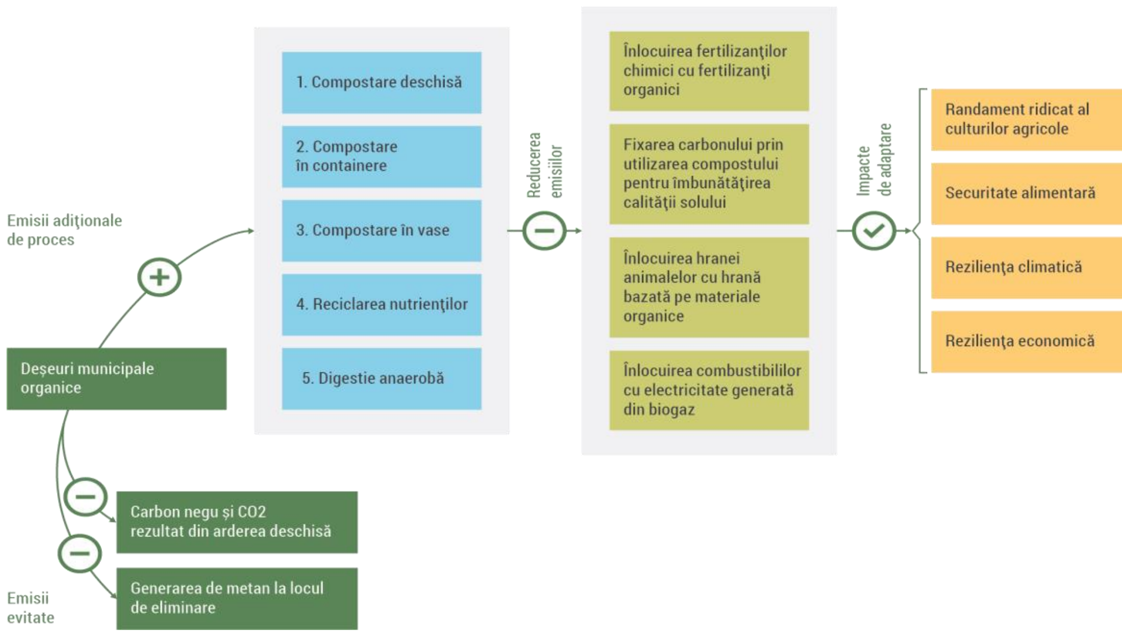
- Avoiding emissions at the disposal sites, coming from the biodegradation of the organic content from wastes;
- Avoiding emissions coming from transport;
- Avoiding emissions due to replacing the virgin raw materials by recycling;
- Avoiding emissions due to the energy consumption in the sorting and processing facilities;
- Avoiding emissions coming from the open burning of municipal wastes at disposal sites.

When calculating the impact of one of the wastes gatherers organizations involved in the project, it was determined that the collection and processing activities of the Cooperativa Amanecer de los Cartoneros din Buenos Aires, Argentina, contribute to **223,970,50 t CO_2** eq / year mitigated every year, mainly due to the fact that these prevent approximately **50,000 tons of recyclable wastes** from entering the landfill, where they contribute to methane generation and insert these materials in the local recycling chains, where they are further used as raw materials. Although the organizations of the gatherers contribute to emission reduction and due to some waste transport means that do not consume fossil fuel, the impact due to transport is almost insignificant as compared to the one coming from collection and recycling.

Source: RWA Group

Waste Management Flagship Programme – South Africa

The Development Bank of South Africa and the Ministry of Environment, Forests and Fisheries in South Africa implement together the Waste Management Flagship Programme, included as one of the eight short-term programs in the Response Policy on Climate from South Africa. The program will redirect organic waste streams from disposal to one of the five solutions: open air or container composting, decentralised container composting, anaerobic composting, and biomass treatment for the recovery of nutrient qualities. The program receive funding for project preparation and six municipalities in South Africa are in the first phase, that of preparing the preliminary designs of the solutions, to be presented to local councils for approval and opinion. The feasibility report for another 24 similar such projects is in preparation, with completion date set in February 2021. The program is structured in preparation, implementation, evaluation, and supplementation phases, in batches of six projects each.

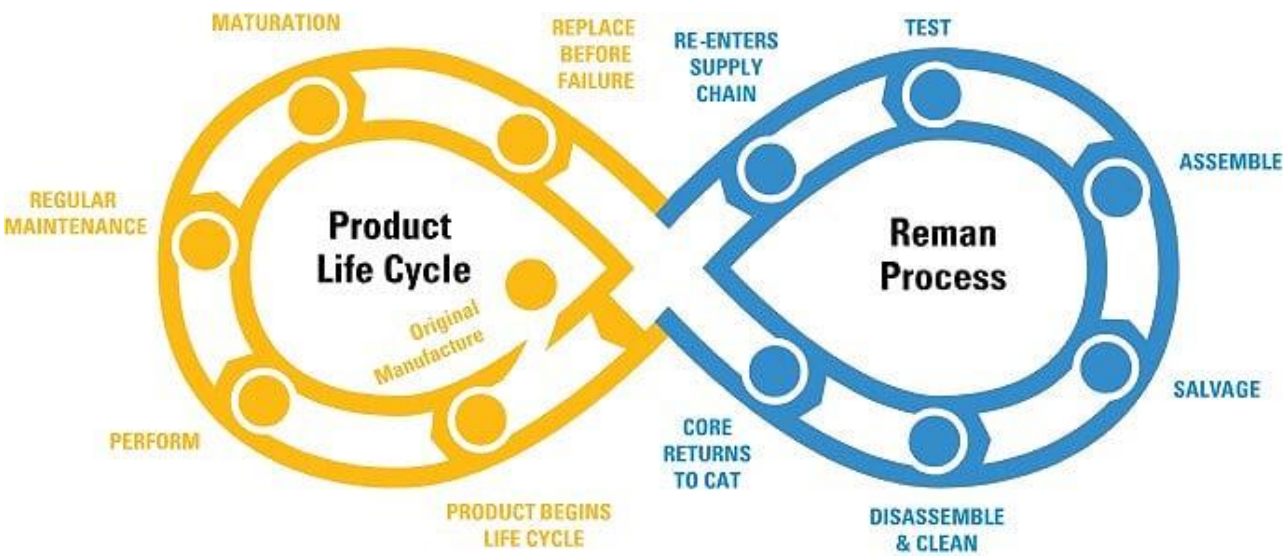


Impacts in terms of climate change mitigation are reached by the prevention of methane generation in landfills, by substituting the chemical fertilizer and animal food with products derived from organic materials, by changing the fuel used and by CO_2 sequestration in soil due to the use of compost. The targets addressed by the implementation of the program are the GHG emissions reduction by 9 million CO_2e and the optimization of the quality of 64,000 ha of agricultural land, while 150,000 citizens will benefit directly from the impacts of the program.

Source: RWA Group

The restructuring of the production processes and the redesign of the industrial components – International

The Caterpillar Company has restructured its production processes to create a resilient and adaptable global distribution network. The company coordinates the activity of thousands international suppliers, each with its own operation and distribution chain. Caterpillar administers the information and material flows between all these nodes of the network, thus managing one of the most complex distribution networks in the world, to ensure its optimum operation.



The WesTrac and Caterpillar Companies have reintroduced the reuse practice, checking the reuse potential and safety of the components in the construction of the produced machinery. Therefore, the practice was introduced to reduce equipment waste and additional wastes generation. The process is managed by the WesTrac Components Reconstruction Center, in which the clients can require this service. The reuse processes are constantly updated based on experiences and results.

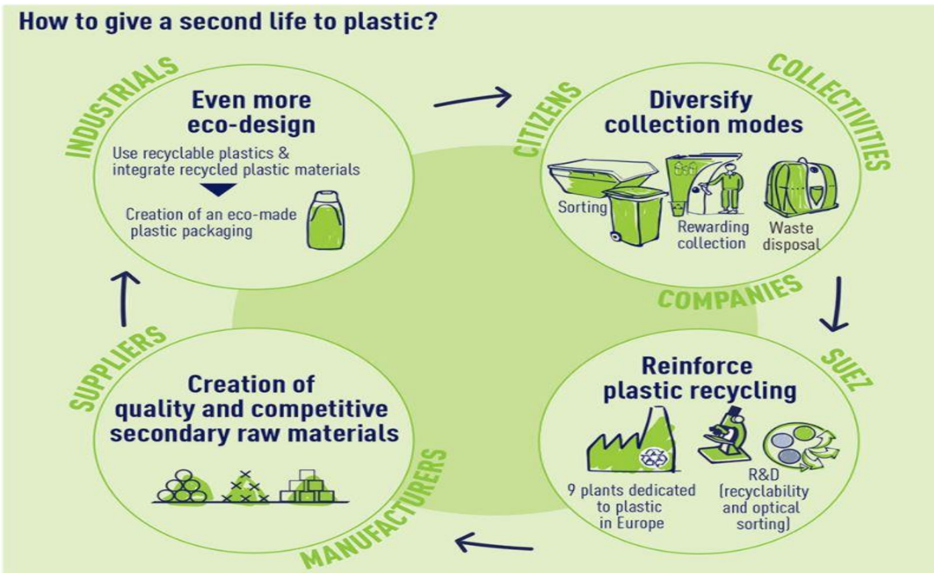
The Cat Reman® programs offer the clients products at lower costs, shorter non-operating periods and faster and more reliable service options. Leader in the re-manufacturing technologies and processes, Cat Reman brings again the products at the end of their service live cycle under similar conditions to the new ones. This helps in reducing the exploitation and holding costs, offering an equally new quality, from a fraction of the cost of a new part. By the re-manufacturing process, Caterpillar reduces wastes, decreases the greenhouse gas production and reduces the need for raw materials

Source: https://www.caterpillar.com/en/company/sustainability/remanufacturing.html

SUEZ offers a new life to plastic, encouraging people to collect it with RECO® solutions – Europa

Due to the resources and climate changes reduction, giving plastic a second life is a moral example of circular economy. The production of a ton of recycled plastic saves five barrels of oil, the equivalent of 1.6 tons of CO_2 and up to 90% of the energy as compared to the production of a ton of virgin plastic.

SUEZ, a key player in plastic recycling with nine dedicated factories in Europe, processes over 400,000 tons of plastic each year over the entire continent and already produces 150,000 tons of recycled polymers. The group innovates today by increasing its contribution. This established the objective of increasing its processing capacity by 50%, to over 600,000 tons, until 2020.



In France, the 100 RECO® kiosks - founded in partnership with the large retailers, supported by the Citeo eco-organization and the Nestlé Waters industry - encourages people to practice sorting. Each bottle handed in (water, milk, detergent, shampoo etc.) gives the consumers the right to a shopping voucher of 1 up to 2 euro cents. These can be purchased back at the partner company or with a local retailers group. The collected bottles are then sent to a processing and recovery center to be transformed into secondary polymers which are used to produce new similar products (bottles, food packages, textile etc.).

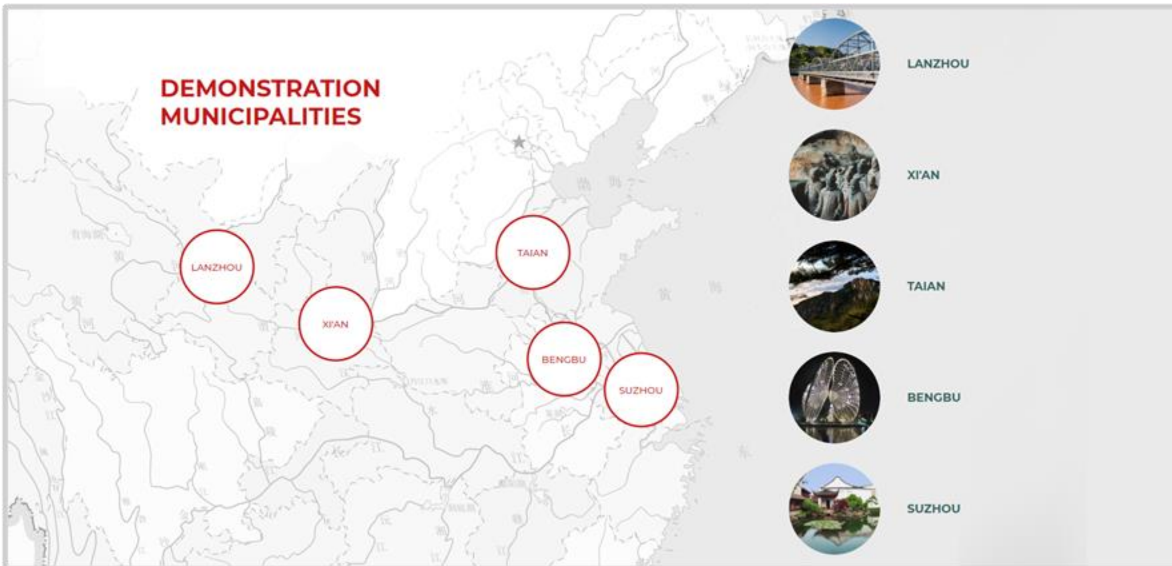
More than 125 million plastic bottles were completely recovered this way starting with 2014. Seven thousand eco-responsible citizens citizen visit these kiosks every day. Encouraged by this success, SUEZ goes further with a complete range of solutions designed to be more easy to use. These include RecyclingBox for small spaces and the RecyclingVan mobile solution, which is ideal for large events (festivals, sport events etc.), recreation areas or events organized by municipalities and companies.

Source: https://www.suez.com/en/news/press-releases/suez-gives-plastic-a-new-life-by-encouraging-people-to-collect-with-reco-solutions

The NAMA Integrated Waste Management Project – China

Designed to accelerate the low emissions development of waste sectors in China, by five demonstrative examples in five municipalities, the objective of the China IWM NAMA project is to induce profound changes to the waste management practices in China, replacing the simple collection and disposal models with an integrated approach, associated to the necessary physical infrastructure and governance aspects.

GHG emission reduction target: 433,100 to 736,270 t CO_2e/year (total in all cities).



The project is structured in five components:

- Component 1: Technical assistance for the selected municipalities;
- Component 2: Policy advice;
- Component 3: The analysis of GHG effects reduction;
- Component 4: Capacity development;
- Component 5: Mobilization of the private sector.

The technical assistance will be focused on the treatment of organic wastes treatment (YES/anaerobic digestion and composting), that is food wastes from households and restaurants; improved management and maintenance of landfills after closure, including the capturing of gases and leachate generated by landfills, long-term conception and planning of MID; data collection and monitoring; waste collection logistics.

The project is funded by NAMA Facility, with a total budget of 8 million EUR. The project implies only technical cooperation; the implementation of technical solutions will be funded by the partners in China.

Source: https://www.iwm-nama.org/

Sălacea project – EcoBihor company, Oradea, Romania

Within this pilot project, the SC Eco Bihor SRL company, in cooperation with the city hall of the Sălacea commune, Zero Waste Romania, and the local sanitation company SC Ave Bihor SRL, has introduced in Sălacea in April 2018, 5 fractions (paper and cardboard, plastic and metal, glass, biowastes, residual waste) of municipal wastes.

Initial stages:

- Awareness campaigns in each village of the commune.
- The equipment of each generator, economic agent, institution, natural person with recipients for the separate collection in 5 fractions.

Subsequent stages:

- Building waste yards for the separation of wastes coming from constructions (large volume and hazardous wastes)
- Withdraw of the separate collection systems from the public domain.
- The continuous verification during the project period (April-October) of the implementation and operation of the system by the employees of the TAUs (territorial administrative units) and of the sanitation company.

Results:

- Increase of the separate collection rate to 60%.
- Increase of the percentage from 3% to 64% of the usable wastes from municipal wastes.
- The Sălacea commune has joined the Zero Waste system.

Source: https://ecobihor.ro/proiect-salacea/

The mechanical-biological treatment plant – the EcoBihor company, Oradea, Romania

From the analyses and yearly reporting of Romania towards the EU, it was recorded the continuation of using new lands for waste disposal on the soil, without using the incineration or recyclable waste recovery alternatives. The Eco Bihor Company has invested in the construction of a mechanical-biological treatment plant of the municipal wastes.

The mechanical-biological treatment plant was inaugurated on 20 April 2016 and meets the strictest Romanian requirements, as well as those of the European Community. The establishment of the treatment plant had the purpose of ensuring the appropriate treatment and assimilation of municipal wastes coming from the Oradea metropolitan area, thus reducing the quantities of wastes eliminated by disposal.

The technological stages are the following:

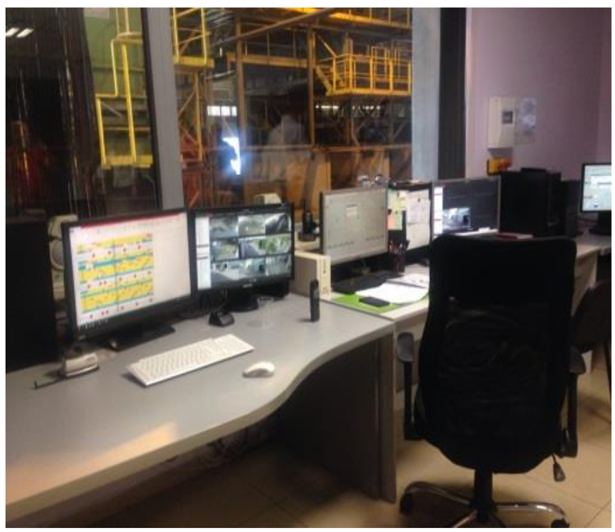
1. Reception of wastes. Wastes are unloaded on the surface of a concrete platform with a 1270 m^2 area, surrounded by metallic fence. Wastes are loaded in a rotary sieve for their pre-selection by size.
2. Mechanical sorting. Wastes larger than the holes of the sieve move forward through a belt in the sorting hall. The wastes smaller in size than the holes of the sieve are transported with a special vehicle on the biological treatment platform of the storage cell.
3. Treatment of biodegradable wastes (dimensions: 0-80 mm).
4. Manual sorting of large wastes (sizes: >80 mm).
5. Recyclable wastes baling.
6. Energy recovery wastes baling.
7. Temporary storage and delivery of the baled wastes.
8. Leachate capture and treatment.

Source: https://ecobihor.ro/statia-de-tratare-mecano-biologica/

The mechanical-biological treatment plant – Varna, Bulgaria

The mechanical-biological treatment plant in Varna is one of the most advanced facilities of this type in Europe. Its capacity is 150,000 tons of mixed wastes per year and serves approximately 500,000 residents.

The station includes three main units focused on waste preparation and separation of recyclable materials, production of high-quality Refuse Derived Fuel (RDF) and the biological treatment of the small size fractions that contain predominantly biodegradable wastes. The factory is a private investment and it was founded due to a public-private partnership with the municipality of Varna. Later, other municipalities in the Varna region have started the delivery of wastes to the plant. The investment costs for construction are approximately 30 million euros. The plant receives 35 EUR/t of input wastes. The processes in the facility are completely automatized and monitored. The fuels produced are delivered to the cement plant in Devnia located approximately 22 km away.



The main objectives:

1. Reduction of the waste volume that are to be disposed and the maintenance of the necessary waste volume.
2. Reduction of the biological activity of the organic fraction so that the storage gas escapes in an uncontrolled way in the smallest possible volume.
3. Reduction of the harmful substances entering the water table together with the leachate.

Source: RWA Group

GreenTech Buzău – CO_2 emission reduction by PET recycling - Romania

GreenTech Buzău is one of the largest recyclers of plastic materials in Central and Eastern Europe, with a **yearly processing capacity** of **150,000 tons of PET**. The products made of the basic materials are flakes, granules and PET band and polyester synthetic fibers (as the only producer in Romania).

The project developed by Greentech Buzău and accredited by **Gold Standard** contributes to the achievement of GHG emission reductions by facilitating the substitution of the raw materials with recycled materials and by diverting the recyclable waste streams from landfills. The project counts the reduced emissions over a period of **10 years (2016-2025)**, the total estimated volume to be reached during this period is **453,800 tCO_2e**. Therefore, equal quantity of carbon credits can be issued based on the project.

Besides the direct benefits bought in terms of emission reduction, the project also brings socio-economic benefits according to the Sustainable Development Objectives:

- GreenTech is among the biggest employers in Buzău county, contributing to the increase of economic wellbeing of the citizens; at the same time, the taxes paid by the company are an important source of funds for the local budget;

- The expertise of the company contributes to the development of the Buzău city towards a circular economy; also, the company as an autochthon technological innovation pole;

- The gender equality is one of the principles guiding the company, women being also promoted in leadership positions in the company;

- The company conducts education and empowerment campaigns related to climate changes and recycling projects in schools and neighboring communities;

The company intends to use the funds attracted by the selling of the credits to increase the recycling capacity and diversify the types of recycled materials.

Source: https://www.green-group-europe.com/ro/companii/green-tech-1

https://marketplace.goldstandard.org/products/plastic-recycling-romania-europe

https://opiniabuzau.ro/buzoienii-pot-proteja-mediul-prin-achizitia-de-certificate-de-carbon-emise-de-greentech-romania/

Appendixes

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Appendix 1 - The assessment methodology and emission factors used at national level

1. Solid waste disposal (5A category of sources)

1.1. Description of the category of sources

In the Republic of Moldova, the situation in the field of Municipal solid waste (MSW) is similar to the one in other developing countries, in a first stage of development and includes two basic elements: the sources of MSW generation and the MSW landfills. The most frequently used method for municipal waste treatment is storage on the soil, which frequently represents an important pollution source of soil and underground waters. The environmental impact of wastes has alarmingly increased over the last years, while their improper management generates soil and water table contamination, as well as CH_4, CO_2 and toxic gases emissions, with direct effects on the health of the population and environment.

1.2. Applied methodologies, emission factors and activity data

When assessing the methane emissions from the storage of solid wastes, the IPCC 2006 Guideline proposes the First Order Decay (FOD) Method conducted by three alternative methodological approaches – Tier 1, 2 and 3; Tier 1 methodological approach implies the use of activity data and emission factors used by default; Tier 2 methodological approach implies the partial application of some emission factors used by default, with the involvement of national activity data on solid waste disposal in landfills for historical period longer than 10 years; Tier 1 methodological approach implies the use of national statistical data on solid waste disposal in landfills for more relevant series of time (for example, longer than 25 years), while involving emission factors and country-specific relevant parameters that result from measurements and researches conducted periodically at national level.

The assessment methodology

Assessment of methane emissions from the category of sources 5A “Solid waste disposal” was conducted by means of the First Order Decay Method (IPCC FOD), Tier 3 methodological approach. The methane emissions were calculated according to equation 3.1 in the IPCC 2006 Guideline (Vol. 5, Chap. 3, page 3.8):

$$emissions\ CH_4 = [\textstyle\sum_x CH_4\ generated_{x,T} - R_T] \bullet (1 - OX_T)$$ where:

emissions CH_4 = methane emissions in year T, kt;
T = inventory year;
x = type of waste;
R_T = recovered methane in year T, kt;
OX_T = oxidation factor in year T (fraction).

A key element in the IPCC FOD model is the quantity of Degradable Organic Matter (DOCm) in SWDS – Solid Waste Disposal Sites. This parameter is estimated based on the information on the disposal of various waste categories MSW – Municipal Solid Waste, sludge, industrial wastes, and other kind of wastes) and various different types of wastes (food products, paper, wood, textile etc.) included in this category or, alternatively, as a DOC average in the stored bulk wastes. The basis for the assessment exercise of the methane emissions is the quantity of DDOCm – Decomposable Degradable Organic

Carbon. In other words, DDOCm represents that part of the organic carbon that will degrade under anaerobic conditions in solid waste disposal sites.

The DDOCm value (where m is the mass) is calculated by means of equation 3.2 in the IPCC 2006 Guideline (Vol. 5, Chap. 3, page 3.9):

$$DDOCm = W \bullet DOC \bullet DOCf \bullet MCF$$ where:

DDOCm = mass or quantity of Decomposable Degradable Organic Carbon stored in the solid waste disposal sites, kt;
W = mass or quantity of solid wastes stored, kt;
DOC = fraction of the Degradable Organic Carbon in the year of disposal, kt C / kt wastes;
DOCf = fraction of the Decomposable Degradable Organic Carbon or Dissimilated;
MCF = the correction factor of the methane for anaerobic decomposition in the year of deposition, fraction.

The DDOCm value is subsequently used to calculate the methane generation potential (L_o). This exercise is conducted by the equation 3.3 in the 2006 IPCC Guideline (Vol. 5, Chap. 3, page 3.9):

$$L_o = DDOCm \bullet F \bullet 12/16$$ where:

L_o = methane generation potential, kt CH_4;
DDOCm = mass or quantity of Decomposable Degradable Organic Carbon stored in the solid waste disposal sites, kt;
F = fraction of CH_4 in the volume of gas generated at the SW landfills;
16/12 = fraction of molecular masses CH_4/C, utilized in the conversion of C into CH_4.

DDOCm accumulated in the municipal solid waste disposal sites at the end of the inventory year (T) is calculated by equation 3.4 from the 2006 IPCC Guideline (Vol. 5, Chap. 3, page 3.9), and DDOCm decomposed at the end of the inventory year (T), respectively by equation 3.5 from the 2006 IPCC Guideline (Vol. 5, Chap. 3, page 3.9).

$$DDOCma_T = DDOCmd_T + (DDOCma_{T-1} \bullet e^{-k})$$

$$DDOCm\ decomp_T = DDOCma_{T-1} \bullet (1 - e^{-k})$$ where:

T = inventory year;
$DDOCma_T$ = DDOCm accumulated in solid waste disposal sites at the end of year T, kt;
$DDOCma_{T-1}$ = DDOCm accumulated in solid waste disposal sites at the end of year (T-1), kt;
$DDOCmd_T$ = DDOCm deposited in solid waste disposal sites at the end of year T, kt;
DDOCm decomp $_T$ = DDOCm dissimilated or decomposed in solid waste disposal sites at the end of year T, kt;
k = constant, where $k = \ln(2)/t_{1/2}$ (y^{-1});
$t_{1/2}$ = half of the dissimilation or decomposition period (y).

The methane emissions generated by dissimilation or decay of DDOCm are calculated by means of the equation 3.6 from the 2006 IPCC Guideline (Vol. 5, Chap. 3, page 3.10):

$$emissions\ of\ CH_4\ in\ year_T = DDOCm\ decomp_T \bullet F \bullet 16/12$$ where:

$emissions\ of\ CH_4\ in\ year_T$ = quantity of methane generated from the biodegradable materials;

DDOCm decomp $_T$ = fraction of DDOCm dissimilated or decomposed in year T, kt;
F = fraction of methane in the total volume of biogas generated in the solid waste deposits;
16/12 = fraction of molecular masses CH_4/C, utilized in the conversion of C into CH_4.

Emission factors

The Degradable Organic Carbon (DOC) is the organic carbon dissimilated or available for biochemical decay. The DOC value is calculated according to equation 3.7 from the 2006 IPCC Guideline (Vol. 5, Chap. 3, page 3.13):

$$DOC = \sum_i (DOC_i \bullet W_i)$$ where:

DOC = fraction of biodegradable organic carbon in the quantity of waste deposited at the landfill, kt C/kt solid waste;
DOC_i = fraction of biodegradable organic carbon in the quantity of waste type i (e.g., the implicit value for paper (wet mass) is 0.4);
W_i = fraction of waste type I in the flux of solid waste of a certain category (e.g., the implicit value for paper (wet mass) in the flux of solid household waste in Eastern Europe is 0.218).

The Methane Correction Factor (MCF)

The Methane Correction Factor *(MCF)* considers the effect of the municipal solid waste management practices on the CH_4.emissions generation process The undeveloped Municipal Solid Waste (MSW) disposal sites have a lower potential of methane generation, as in these sites the largest MSW fraction is decayed under anaerobic conditions in the upper layer of the landfill. Table 3 presents the values of the methane correction factor for various types of landfills used by default.

Classification of the MSW sites	The Methane Correction Factor	The Methane Correction Factor used in the Republic of Moldova
Managed – anaerobic[1]	1.0	Chișinău Municipality, for the 1991-2015 period.
Managed – semi-aerobic[2]	0.5	NA
Unmanaged – deep (> 5 m)[3]	0.8	Chișinău Municipality, until the year 1990. Bălți and district centers.
Unmanaged – shallow (< 5 m)[4]	0.4	Rural localities in the Republic of Moldova
Disposal sites not classified in categories [5]	0.6	NA

Table 1 - The Methane Correction Factor based on the MSW disposal sites classification

Degradable Organic Carbon (DOC)

DOC represents the organic carbon subjected to biochemical decay. The DOC value is calculated based on the cardboard, textile, garden and park wastes, as well as other non-food degradable wastes, flood and wood wastes.

DOC dissimilated fraction (DOC_f)

DOCf represents the degradable organic carbon fraction, which subsequently is converted in biogas and reflects the fact that a part of the carbon does not degrade or it degrades very slowly when eliminated at MSW disposal sites. It is admitted that the DOC_f fraction depends on the temperature in the anaerobic area of the landfill, characterized by the relationship: 0.014T + 0.28 (Tabasaran, 1981). The value used by default according to the 2006 IPCC Guideline (Vol. 5, Chap. 3, page 3.13) is 0.5. In RM, the country-specific values of the DOC and DOC_f (Table 4) were calculated by the use of “MSW Learning Tool” developed by the University of Florida (1996) based on the results of the lab experiments conducted by Dr. Morton Barlaz (1987, 1997) and investigation of Chandler, Van Soest (1980).

	1986	1993	1996	1999	2001	2003	2005	2012	2016
DOCf	0.5178	0.5258	0.5667	0.6353	0.6207	0.6277	0.5935	0.4985	0.4204
DOC	0.2069	0.1891	0.1522	0.1091	0.1009	0.1201	0.1410	0.1405	0.1475

Table 2 - Country-specific fractions of the Degradable Organic Carbon (DOC) and Degradable Organic Carbon Dissimilated (DOC_f) used in assessing the CH_4 emissions coming from the MSW disposal sites during the 1986-2016 period

The CH_4 fraction in biogas

The 2006 IPCC Guideline (Vol. 5, Chap. 3, page 3.15) recommends the use of the 0.5 value for the CH_4 fraction in the generated biogas (*F*) at municipal solid wastes disposal sites. However, it is known that the value of fraction *F* can vary between 0.4 and 0.6, depending on several factors that can influence the degradation process of municipal solid wastes, including the morphological composition of MSW (Bingemer, Crutzen, 1987).

The biogas composition was calculated also based on the extended Buswell equation (Table 5), by using activity data on the morphological composition of the MSW eliminated by disposal, based on which the *DOC* and DOC_f coefficients were estimated.

	1986	1993	1996	1999	2001	2003	2005	2012	2016
C --> CH_4	53.1	54.0	54.5	55.4	55.1	54.5	55.6	54.2	55.2
C --> CO_2	46.9	46.0	45.5	44.6	44.9	45.5	44.4	45.8	44.8

Table 3 - Country-specific values of the biogas composition in the Republic of Moldova for the 1986-2016 period, calculated based on the extended Buswell equation, in %

Recovered methane (R)

CH_4 generated at the MSW disposal sites can be recovered and incinerated (with or without energy recovery). The methane quantity recovered in the equation 3.1 from the IPCC 2006 Guideline (Vol. 5, Chap. 3, page 3.8) is noted by *R*. The value used by default is zero. The methane quantities recovered are reported in the inventory only in the case when there are confirmatory documents.

The oxidation factor (OX)

The oxidation factor reflects that part of the methane emitted from the MSW disposal sites which oxidize to CO_2 in soil or in other insulation material of the stored wastes. If OX is equal to zero, methane oxidation does not occur, and when OX equals 1, then the methane oxidizes 100%. The managed MSW disposal sites tend towards a higher oxidation factor, and the unmanaged disposal sites towards a lower oxidation factor. The value used by default according to the 2006 IPCC Guideline (Vol. 5, Chap. 3, page 3.15) equals zero.

The type of municipal solid waste disposal sites	The oxidation factor (OX)
Managed[1], unmanaged and unclassified.	0.0
Managed, covered with material that stimulates methane oxidation[2].	0.1

Note: [1] - Managed, but not covered by aerable material; [2] - for example, soil or compost.

Table 4 - The oxidation factor

The k constant and the decay period $t_{1/2}$

The decay period represents the time in which the DOCm value in wastes is decomposed in half as compared to the initial mass. The relationship between the constant (k) and the decay period ($t_{1/2}$), is the following: $k = \ln(2)/t_{1/2}$. The decay period is affected by several factors, including the morphological composition of the stored wastes, the meteorological conditions specific for the location of the MSW disposal site, the storage practiced etc. The shortest decay period is for k = 0.2 or $t_{1/2}$ = 3 years – in case of food residues and humid climate conditions, while the slowest decay period is for k = 0.02 or $t_{1/2}$ = 35 years for wood and paper wastes and dry climate conditions. Two approaches apply for the appreciation of the decay period: calculation of the average value for the entire mixed waste stream; the division of the MSW stream by categories, according to the decay speed of each type.

NMVOC emissions

The calculation of the non-methane volatile organic compounds (NMVOCs) coming from the disposal of solid wastes was achieved according to the methodological approach available in the EMEP/EEA air pollutant emission inventory guidebook (2019):

$$NMVOC\ emissions = W \bullet EF \bullet 10^{-6}$$ where,

NMVOC emissions = NMVOC emissions in inventory year, kt / year;
W = mass of solid waste deposited, kt / year;
EF = emission factor, kg NMVOC / kt wastes (value used by default, 1.56 kg NMVOC /ton of solid wastes, is available in the EMEP/EEA air pollutant emission inventory guidebook (2019), 5.A category of sources “Biological treatment of waste – solid waste disposal on land”, Table 3-1, page 5);
10^{-6} = conversion factor, from kilograms to kt.

Activity data

In the current counting cycle, the same approach has been employed in accumulating the activity data for municipal and industrial wastes. The information was used regarding the evacuation of municipal solid wastes reported by means of the statistic form no. 2 – “Sanitation of urban localities”.

2. Biological treatment of wastes (5B category of sources)

2.1. Description of the category of sources

Composting and anaerobic digestion of organic wastes, such as food wastes, garden and park wastes and the sludge from the waste water treatment plants are frequent practices both in developed and developing countries. Among the advantages of biological treatment we mention: the reduced volume of wastes, destruction of pathogen agents in the residual material and the biogas production for energy consumption. The final products of biological treatment, depending on its quality, can be used as fertilizer and to improve soil quality or they can be disposed of at the MSW disposal sites.

Composting is an aerobic process and a large part of the Degradable Organic Carbon (DOC) from the residual material is transformed in CO_2. Methane is formed in the anaerobic sections of the compost, but it oxidizes to a large extent in the aerobic sections of the compost. Therefore, less than 1% of the initial carbon content of the material subjected to composting is eliminated in the atmosphere.

Anaerobic digestion of organic wastes accelerates natural decomposition of the organic material without oxygen, by maintaining the temperature, humidity content and pH close to its optimum values. CH_4 generated can be used for heat production and / or electricity production. That is why reporting of emissions in the process is usually done in the energy sector. The CO_2 emissions are of biogenic origin and are reported only for information in sector 1 “Energy”. The CH_4 emissions in such facilities will range between 0 and 10 % of the generated CH_4 quantity, being accounted for by accidental releases during process disturbances or other unexpected events. In the absence of additional information, it is recommended to used the 5% rate as default value for the CH_4 emissions. In case the technical standards for biogas ensure the avoidance of CH_4 emissions, these are considered to be close to zero. It is assumed that N_2O emissions in the process are negligible, but the data on these emissions are very rare.

The mechanical-biological treatment (MB) of wastes becomes more often practiced in Europe, being expected also in Moldova. In MB treatment, wastes go through a series of mechanical and biological operations, which aim to reduce the waste volume, as well as their stabilization to reduce emissions from final removal. The mechanical operations separate the residual material into fractions that will be subjected to an additional treatment (composting, anaerobic digestion, burning, recycling). These may include separation, shredding and crushing of the material. The biological operations include composting and anaerobic digestion. Composting may occur in heaps or in composting facilities with optimization of process conditions, as well as filtering of the produced gas, which enables the quantitative reduction of the organic fraction (representing 40 – 60%.) that needs to be removed at landfills. Due to the small quantity of material subjected to biological treatment, including its organic content and biological activity, wastes subjected to mechanical-biological treatment will produce up to 95% less CH_4 than untreated wastes when they are removed at the MSW disposal sites. The CH_4 and N_2O emissions in various phases of the MB treatment depend on the specific operations and process duration.

2.2. Applied methodologies, emission factors and activity data

First of all, the assessment of CH_4 and N_2O emissions from the 5B category of sources “Biological treatment of solid wastes” can be achieved by the First Decay Order Method (IPCC FOD). The methane emissions were calculated according to equation 4.1 in the IPCC 2006 Guideline (Vol. 5, Chap. 4, page 4.5):

$$emissions\ CH_4 = \sum (M_i \bullet EF_i) \bullet 10^{-3} - R$$ where:

CH_4 emissions = total emissions of CH_4 in the inventory year, Gg CH_4;
M_i = mass of organic waste treated through biologic treatments of type i, Gg;
EF = emission factor of treatment type i, g CH_4 / kg total waste;
i = composting or anaerobic digestion;
R = total quantity of CH_4 recovered in inventory year, Gg CH_4.

When the CH_4 emissions resulting from anaerobic digestion are reported, the quantity of gas recovered is deducted from the generated CH_4 quantity. The recovered gas can be burned in flame or for energy production. The CH_4 quantity recovered is expressed as R in equation 4.1 above. If the recovered gas is used for energy purposes, then greenhouse gas emissions resulted from the burning of the gas should be reported in the energy sector. Nevertheless, the emissions resulting from the recovered gas are insignificant, as the CO_2 emissions are of biogenic origin, and the CH_4 and N_2O emissions are very low, so that the best practices in waste sector does not recommend their estimation. The N_2O emissions coming from the 5B category of sources "Biological treatment of solid waste" are estimated by means of the First Order Decay method (IPCC FOD), according to equation 4.2 from the 2006 IPCC Guideline (Vol. 5, Chap. 4, page 4.5):

$$emissions\ N_2O = \sum(M_i \bullet EF_i) \bullet 10^{-3}$$ where:

emissions N_2O = total emissions of N_2O in inventory year, Gg N_2O;
M_i = mass of organic waste treated through biologic treatments of type i, Gg;
EF = emission factor of treatment type i, g N_2O / kg total waste;
i = composting or anaerobic digestion.

Emission factors

The emissions coming from composting and anaerobic digestion in the biogas facilities will depend on factors such as the type of waste composting, the quantity and type of support material (such as wood chips and peat), temperature, humidity content and aeration during the process.

The type of biological treatment	The CH4 emission factors (g CH4/kg treated wastes)		The N2O emission factors (g N2O / kg treated wastes)		Comments
	dry fraction	wet fraction	dry fraction	wet fraction	
Composting	10 (0.08 - 20)	4 (0.03 - 8)	0.6 (0.2 - 1.6)	0.24 (0.06 - 0.6)	Hypotheses regarding treated wastes: 25-50% of DOC in dry matter, 2% of N in dry matter, humidity content 60%. The emission factors for dry wastes are estimated based on those for wet waste, assuming a humidity content of 60% in wet waste.
Anaerobic digestion in biogas facilities	2 (0 - 20)	0.8 (0 - 8)	It is assumed to be negligible		

Table 5 - The CH_4 and N_2O emission factors from the biological treatment of wastes

CO emissions

The calculation of the CO emissions coming from the biological treatment of wastes was achieved according to the methodological approach available in the EMEP/EEA air pollutant emission inventory guidebook (2019):

$$emissions\ CO = W \bullet EF \bullet 10^{-6}$$ where:

emissions CO = CO emissions in inventory year, kt / an;
W = quantity of composted solid waste, kt / an;
EF = emission factor, kg CO / kt waste (implicit value is, 0.56 kg CO / t of solid waste, and is available in the EMEP/EEA Guide on inventory of emissions in the atmosphere (2019), Source category 5.B1 „Biological treatment of waste – composting", table 3-2, pg. 6);
10^{-6} = conversion factor, from kilograms to kt.

Activity data

In the absence of activity data to test the calculation model, an assumption will be made that the quantity of wastes subjected to composting has gradually increased from 1 to 3% over the years 1990-2019 depending on the total amount of stored municipal wastes.

3. Incineration and open burning of wastes (5C category of sources)

3.1. Description of the category of sources

Incineration of wastes is defined as the burning of solid and liquid wastes in controlled incineration facilities. The following types of wastes are removed by incineration: municipal solid waste, industrial waste, hazardous waste, clinical waste and sludge from wastewater treatment plants. The municipal waste incineration practice is common to developed countries, while the developing countries incinerate especially wastes coming from medical activities.

Incineration and open burning of wastes are GHG emission sources directly (CO_2, CH_4 and N_2O) and indirectly (NO_x, CO, NMVOC and SO_2). The intentional burning of wastes on the territory of solid waste disposal site is a solid waste management practice in some developing countries. The emissions coming from this practice and those from accidental fires on the solid waste disposal sites are to be estimated and reported in compliance with the calculation methodology of the emissions coming from the open burning of solid wastes.

3.2. Applied methodologies, emission factors and activity data

In the 5C category of sources "Incineration and open burning of wastes", the CO_2, CH_4 and N_2O emissions coming from the open burning of the municipal and clinical waste were assessed. The quantity of annual openly burned wastes was estimated by equation 5.7 of the 2006 IPCC Guideline (Vol. 5, Chap. 5.3.2, page 5.16):

$$MSW_B = P \bullet P_{frac} \bullet MSW_P \bullet B_{frac} \bullet 365 \bullet 10^{-6}$$ where:

MSW_B = total quantity of municipal solid waste openly burned, kt/an;
P = population, citizens;
P_{frac} = fraction of the population that openly burns waste;
MSW_P = per capita waste generation, kg waste per capita per day;
B_{frac} = fraction of openly burned waste out of total treated waste quantity;
365 = days in a year;
10^{-6} = conversion factor, from kilograms to kt.

The waste burning practice is characteristic mainly to rural areas of the country, being frequently used both in individual households and on the territory of garbage workers to reduce the volume of solid wastes stored. More often, organic wastes are burned such as paper, cardboard, plastics and vegetable wastes. In the case of the Republic of Moldova, the percentage of population that burns wastes in open air *(P_{frac})* is made of rural population *($P_{rural\ frac}$)* plus the urban population *($P_{urban\ frac}$)* that does not benefit of sanitation services ($P_{frac} = P_{rural\ frac} + P_{urban\ frac}$).

It was admitted that approx. 20% of the urban population that does not benefit from the waste collection system practices open burning of solid organogenic wastes, and the fraction of the burnt solid wastes (B_{frac}) from the total quantity of treated wastes in the urban areas of the country is equivalent to 0.15 (15% of the total). One needs to mention that population of the Chișinău city was excluded from the urban population because it is considered that the former does not practice the open burning of wastes, as the city has platforms for waste disposal. In rural localities, it was admitted that 40% of the population eliminates by open burning the organogenic solid wastes generated, while B_{frac} represents 0.2 (20% of the total).

The total quantity of municipal wastes openly burned by the population was calculated by the use of the following equation:

$$MSW_B = MSW_{B\ rural} + MSW_{B\ urban} \text{ where,}$$

$$MSW_{B\ rural}\ RM\ (kt) = P_{rural}\ (inhabitants) \bullet MSWP_{rural}\ (kg/capita/day) \bullet 0.20 \bullet 365 \bullet 10^{-6}$$
$$MSW_{B\ urban}\ RM\ (kt) = P_{urban}\ (inhabitants) \bullet MSWP_{urban}\ (kg/capita/day) \bullet 0.15 \bullet 365 \bullet 10^{-6}$$

Although there are no authorized incinerators for medical wastes in the Republic of Moldova, a certain category of medical wastes made of plastic generated by several medical facilities in the country are delivered to the economic agents authorized for their treatment by the pyrolysis or autoclaving method (the "UISPAC" SRL[33], "Trisumg" SRL[34] and "Ecostat" SRL companies[35]). The medical institutions in the RM practice the burning of clinical waste by three methods: 1) open burning; 2) closed burning in heating boilers or metal barrels; and 3) transportation for pyrolysis treatment.

The estimation of CO_2 emissions coming from incineration and open burning of wastes was conducted in compliance with equation 5.1 from the 2006 IPCC Guideline (Vol. 5, Chap. 5, page 5.7):

$$emissions\ CO_2 = \Sigma_i\ (SW_i \bullet dm_i \bullet CF_i \bullet FCF_i \bullet OF_i) \bullet 44/12 \text{ where:}$$

emissions CO_2 = CO_2 emissions in inventory year, kt / year;
SW_i = quantity of solid waste of type i (wet mass) that is openly burned or incinerated, kt / year;
dm_i = percentage of dry mass in solid waste mass (wet mass) that is incinerated or openly burned (implicit values are 76% for MSW and 90% for medical waste, and are available in Table 2.4, IPCC 2006 Guide, vol. 5, ch. 2, pg. 2.14)
CF_i = percentage of carbon in dry mass (total carbon content) (implicit values are 47% for MSW and 60% for medical waste, and are available in Table 2.4, IPCC 2006 Guide, vol. 5, ch. 2, pg. 2.14 and in Table 5.2, IPCC 2006 Guide, vol. 5, ch. 5, pg. 5.18)
FCF_i = percentage of fossil carbon in total carbon content (implicit values are 90% for industrial waste, 42% for MSW, 40% for medical waste, and are available in Table 2.4, IPCC 2006 Guide, vol. 5, ch. 2, pg. 2.14 and in Table 5.2, IPCC 2006 Guide, vol. 5, ch. 5, pg. 5.18);
OF_i = oxidation factor (implicit value is 58%, available in Table 5.2, IPCC 2006 Guide, vol. 5, ch. 5, pg. 5.18;
44/12 = ration of CO_2/C molecular weight, used in the C to CO_2.conversion
i = type of wastes incinerated / burned in open air, specified as follows: MSW – municipal solid wastes (if it is not estimated according to equation 5.2 from the 2006 IPCC Guideline, Vol. 5, Chap. 5, page 5.7); ISW: industrial solid waste; SS: sewage sludge; HW: hazardous waste; CW: clinical waste, others (to be specified).

[33] The permit issued by the Environmental Agency, Series 005, AM 20091601 of 02.10.2020 for the collection, transport and (pyrolysis) treatment of plastic wastes and wastes coming from medical health care or veterinary activities and/or related research.
[34] The permit issued by the Environmental Agency, Series 005, AM 20090802 of 30.09.2020 for the transport and treatment of wastes resulting from the medical activity by autoclaving.
[35] Permit no. 071/2016 of 27.05.2016 issued by the Ministry of Environment.

The methane emissions from incineration and open burning are a result of incomplete burning. The important factors affecting the volume of these emissions are temperature, burning time and the access of air (the air volume relative to the quantity of incinerated or openly burned waste amount). The CH_4 emissions from waste incineration in large industrial incinerators are usually very low. Methane is generated also in the bunker of the incinerator under low oxygenation conditions (anaerobic process), especially when wastes that are kept in it are wet, are stored for a long time and are not periodically shaken.

However, if gases that come from it are introduced with the air flow into the incineration room, once incinerated, emissions will be substantially reduced.

The calculation of CO2 emissions coming from incineration and open burning of wastes is conducted according to equation 5.4 from the 2006 IPCC Guideline (Vol. 5, Chap. 5, page 5.12):

$$CH_4\ emissions = \Sigma_i\ (IW_i \bullet EF_i) \bullet 10^{-6}$$ where:

CH_4 emissions = CH_4 emissions in the inventory year, kt / year;
IW_i = quantity of solid wastes of the type *i* incinerated or openly burned, kt / year;
EF_i = emission factor, kg CH_4 / kt wastes of the type *i* (value used by default, 6.5 kg CH_4/ton DMS, is available in the 2006 IPCC Guideline, Vol. 5, Chap. 5, page 5.20);
10^{-6} = conversion factor, from kilograms to kt;
i = type of incinerated wastes / openly-burned, specified as follows: MSW – municipal solid waste; ISW: industrial solid waste; HW: hazardous waste; CW: clinical waste, SS: sewage sludge; others (to be specified).

Nitrogen protoxide emissions are produced when incineration or open burning is produced at relatively low temperatures, between 500 and 950°C. Other important factors affecting the volume of N_2O emissions are the air pollution prevention technologies, the type of waste and their nitrogen content, as well as the air fraction in excess.

The calculation of nitrogen protoxide emissions coming from incineration and open burning of wastes is conducted according to equation 5.5 from the 2006 IPCC Guideline (Vol. 5, Chap. 5, page 5.14):

$$N_2O\ emissions = \Sigma_i\ (IW_i \bullet EF_i) \bullet 10^{-6}$$ where,

N_2O emissions = N_2O emissions in the inventory year, kt / year;
IW_i = quantity of solid wastes of the type *i* incinerated or openly-burned, kt / year;
EF_i = emission factor, kg N_2O / kt waste (the value used by default, 0.15 kg N_2O/ton MSW, is available in the 2006 IPCC Guideline, Vol. 5, Chap. 5, Table 5.6, page 5.22);
10^{-6} = conversion factor, from kilograms to kt;
i = type of incinerated wastes / openly-burned, specified as follows: MSW – municipal solid waste; ISW: industrial solid waste; HW: hazardous waste; CW: clinical waste, SS: sewage sludge; others (to be specified).

The calculation of indirect greenhouse gas emissions, ozone and aerosols precursors (NO_x, CO, NMVOC and SO_2) coming from incineration or open burning of waste is conducted according to the available methodology in the EMEP/EEA air pollutant emission inventory guidebook (2019):

$$Indirect\ GHG\ emissions = \Sigma_i\ (IW_i \bullet EF_i) \bullet 10^{-6}$$ where:

Indirect GHG emissions = indirect greenhouse gas emissions, ozone and aerosols precursors (NO_x, CO, NMVOC and SO_2) in inventory year, kt / year;

IW_i = quantity of solid wastes of the type *i* incinerated or openly burned, kt / year;
EF_i = emission factor, kg indirect GHG/ kt waste (values used by default are presented below in Table 7-24);
10^{-6} = conversion factor, from kilograms to kt;
i = type of incinerated wastes / openly-burned, specified as follows: MSW – municipal solid waste; ISW: industrial solid waste; HW: hazardous waste; CW: clinical waste, SS: sewage sludge; others (to be specified).

	NOx, kg/ton of waste	CO, kg/ton of waste	NMVOC, kg/ton of waste	SO_2, kg/ton of waste
Solid waste [1]	3.8	55.83	1.23	0.11
Clinical Waste [2]	2.3	0.19	0.7	0.54

Source: [1] The EMEP/EEA air pollutant emission inventory guidebook (2019), 5.C.2 category of sources "Open burning of waste", Table 3-1, page 6; [2] The EMEP/EEA air pollutant emission inventory guidebook (2019), 5.C.1.b.iii category of sources "Incineration of clinical waste", Table 3-1, page 8.

Table 6 - Emission factors used by default for the assessment of indirect greenhouse gas emissions from 5C category of sources "Incineration and open burning of waste" by Tier 1 calculation methodology

4. Wastewater treatment and discharge (5D category of sources)

The public sewage system represents the ensemble of technological facilities, functional equipment and specific features which serve together the public sewage system. The system includes the following components: public sewage networks, pumping stations, treatment stations, discharge collectors to the emissary. The current sewage system in the Republic of Moldova, is underdeveloped and has a low capacity to ensure the complete access of population to high quality sewage services.

The sewage systems that ensure the evacuation and treatment of waste waters have a high-wear degree, are physically degraded and morally outdated, as they are used for more than 25-30 years without reconstruction and need a technological modernization of the treatment stages.

Currently, the management of sludge produced in the waste waters treatment facilities is improper and does not correspond to the requirements of the acts in law.

4.1. Description of the category of sources

Within the 5D category of sources "Treatment and discharge of waste waters" the CH_4 and N2O emissions coming from the 5D1 source "Treatment and discharge of domestic waste waters", such as CH_4 emissions coming from the 5D2 source "Treatment and discharge of industrial waste waters".

5D1 "Domestic wastewater treatment and discharge"

Domestic wastewater is the product of usage by the population of the water for domestic purposes. In the domestic wastewater treatment process and the sludge treatment process in the wastewater treatment plants, methane is generated and, to a smaller extent, non-methane volatile organic compounds (NMVOC). The wastewater treatment scheme is a classical one and has a different level of treatment in the urban and rural areas, depending on the technical equipment level of the facilities. The main wastewater treatment methods are: mechanical, biological (based on the degradation of organic substances), chemical (with the use of reagents), as well as combined methods. In some cases, wastewaters are discharged directly in the surface basins for a special treatment and in other cases, they are subjected to treatment and discharged with a different load of organic substances.

The wastewater from individual households in the cities and villages which are not connected to the sewage network are subjected to collection in septic tanks or latrines.

5D2 "Industrial wastewater treatment and discharge"

In the Republic of Moldova, the industrial wastewater treatment process is conducted by means of the domestic wastewater treatment facilities. After generation, industrial wastewaters are discharged in the domestic wastewater sewage systems, being thus treated together. Industrial wastewaters are redirected in the sewage networks based on the technical conditions issued by the "Water-Sewage" operators. At the same time, based on the results of the existing wastewater treatment facilities inventory, it was found that the "Water-Sewage" companies enabled the connection and discharge into the municipal sewage networks of several economic agents in the industrial sector due to lack of generation of the wastewater volumes necessary for the proper operation of the domestic treatment facilities. This resulted in reduction of industrial wastewater volumes treated at the local stations. In the industrial sector, the processing branches contribute the most to the generation of wastewaters with increased content of biodegradable organic substances.

4.2. Applied methodologies, emission factors and activity data

The assessment of methane emissions coming from the 5D category of sources "Treatment and discharge of wastewater" was conducted in compliance with Tier 1 methodologies available in the 2006 IPCC Guideline, the assessment process being conducted in several stages.

5D1 "Domestic wastewater treatment and discharge"

Stage I: Estimation of the total degradable organic carbon in wastewater (TOW)

Determination of the total amount of organic substances in wastewater (TOW). The methodology available in the 2006 IPCC Guideline implies the determination of the quantity of organic substances in wastewater generated by all domestic households, regardless of the fact they are connected or not to the sewage system. The value of this index is influenced, especially, by the number of the population (urban and rural population), and by the degradable organic component (DOC) in wastewater.

In assessing the total quantities of organic substances in wastewater, equation 6.3 was used, from the 2006 IPCC Guideline (Vol. 5, Chap. 6, page 6.13):

$$TOW = P \bullet BOD \bullet 0.001 \bullet I \bullet D \text{ where:}$$

TOW = total quantity of organic substances in inventory year, kg CBO/year;
P = number of population in inventory year;
CBO = degradable organic component in wastewater, the value used by default in European countries is 60 g DOC_5/inhabitant/day (2006 IPCC Guideline, Vol. 5, Chap. 6, Table 6.4, page 6.14); in RM the same value of 60 DOC/capita/day is used (NCM G.03.02-2015 table 7.1);
0.001 = the conversion factor, from grams DOC in kg DOC;
I = the correction factor for industrial DOC discharged in the joint sewage system (the value used by default for the joint sewage system is 1.25, in the case of not-collected wastewater the value used by default is 1.00);
D = number of days over a calendar year (365 days in usual years and 366 days in leap years: 1992, 1996, 2000, 2004, 2008, 2012, 2016).

Stage II: Selection of wastewater treatment systems and discharge pathways

The second stage of the calculation exercise in the selection of the treatment systems and wastewater discharge pathways specific to national circumstances by considering the country-specific activity data. According to which, by the use of equation 6.2 of the 2006 IPCC Guideline (Volume 5, Chapter 6, page 6.12) the emission factors are achieved for each wastewater treatment system and for each wastewater discharge pathway. The value of the emission factor specific to a wastewater treatment and discharge system depends on the methane generation potential (B_0), and on the methane correction factor (MCF) characteristic to the respective wastewater treatment and discharge system. B_0 represents the maximum methane amount that can be produced in a certain amount of organic content (expressed in DOC) in wastewater. MCF indicates the extent to which methane generation capacity (B_0) is conducted within each type if wastewater treatment and discharge. This is also an index of the degree that demonstrates to which extent is the wastewater treatment system an anaerobic one.

$$EF_j = B_0 \bullet MCF_j$$ where:

EF_j = the emission factor, kg CH_4/kg DOC_5;
j = each wastewater treatment and discharge system;
B_0 = the maximum methane generation capacity, kg CH_4/kg DOC_5 (according to the 2006 IPCC Guideline, Vol. 5, Chap. 6, Table 6.2, page 6.12, the value used by default is 0.6);
MCF_j = methane conversion factor (fraction).

Type of systems	Wastewater treatment and discharge systems, j	B_0, kg CH_4/ kg CBO_5	MCF	EF, kg CH_4 /kg DOC_5
Systems without wastewater treatment	The discharge of wastewater in rivers and lakes without preventive treatment	0.6	0.1	0.06
	Open still waters	0.6	0.5	0.30
	Rapid flow discharge sewage (closed or open)	0.6	0.0	0.0
Systems with wastewater treatment	Centralised treatment system with aerobic wastewater treatment managed efficiently (normative treatment)	0.6	0.1	0.6
	Centralised treatment system with aerobic wastewater treatment managed inefficiently (insufficient treatment)	0.6	0.2	0.12
	Anaerobic reactors for sludge coming from wastewater treatment	0.6	0.8	0.48
	Shallow anaerobic lagoons (<2 m)	0.6	0.2	0.12
	Deep anaerobic lagoons (>2 m)	0.6	0.8	0.48
	Septic systems (half of the DOC sediments in anaerobic tanks)	0.6	0.3	0.18
	Latrines, in dry climate areas, located above the underground waters for small families (3-5 persons)	0.6	0.1	0.06
	Latrines, in dry climate areas, located above the underground waters for common use (multiple users)	0.6	0.5	0.30
	Latrines, in high-humidity climate areas, flooded by underground waters	0.6	0.7	0.42
	Latrines with periodical discharge of the sediment to be used as fertilizer	0.6	0.1	0.06

Table 7 - Emission factors used in assessing methane emissions coming from the 5D1 category of sources "Domestic wastewater treatment and discharge"

Stage III: Assessment of total methane emissions from domestic wastewater treatment and discharge

The third stage of the calculation exercise consists in calculating the total methane emissions from the 5D1 category of sources "Domestic wastewater treatment and discharge" as a sum of emissions coming from each wastewater treatment and discharge system specific to the respective country. Emission assessment is conducted according to equation 6.1 of the 2006 IPCC Guideline (Volume 5, Chapter 6, page 6.11):

$$CH_4\ emissions = \left[\sum_{ij}(Ui \bullet Tij \bullet EFj)\right] \bullet (TOW - S) - R\ where:$$

emissions CH_4 = methane emissions from the epuration and evacuation of wastewater in inventory year, kg CH_4/an;
TOW = total quantity of organic biodegradable substances in wastewater, kg DOC/an;
S = organic component removed with the sludge in inventory year, kg DOC/year;
U_i = percentage of type i urban population in inventory year;
$T_{i,j}$ = wastewater treatment / discharge system degree of utilization j, for each group of population i, in inventory year (fraction);
i = population categories by level of economic development: rural population (low income), urban population of low income and urban population of high income;
j = wastewater treatment and discharge systems;
EF_j = emission factor, kg CH_4 / kg DOC;
R = methane emissions recovered in inventory year, kg CH_4/an.

According to recommendations exposed in the 2006 IPCC Guideline (Vol. 5, Chap. 6, page 6.14-6.15), population who generates wastewater is divided into groups by the level of economic development and, implicitly, by the urbanization degree of the localities (Table 11), the access to the wastewater collection and treatment systems depend on, as well as the efficiency of these systems.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
U_{rural}	0526	0525	0529	0531	0532	0532	0538	0538	0537	0539
$U_{urban, low level of development}$	0186	0185	0183	0184	0183	0184	0180	0180	0182	0181
$U_{urban, high level of development}$	0289	0290	0287	0286	0285	0284	0282	0282	0280	0280
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
U_{rural}	0539	0545	0546	0545	0546	0572	0570	0565	0565	0565
$U_{urban, low level of development}$	0182	0177	0177	0178	0184	0142	0143	0152	0150	0150
$U_{urban, high level of development}$	0279	0277	0277	0277	0270	0286	0287	0283	0285	0286
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
U_{rural}	0564	0562	0562	0560	0558	0556	0555	0553	0551	0550
$U_{urban, low level of development}$	0151	0151	0151	0152	0154	0155	0153	0152	0151	0149
$U_{urban, high level of development}$	0286	0286	0287	0288	0289	0289	0292	0295	0298	0301

Table 8 - The weight (U_i, fraction when 100% = 1.0) of various groups in the total number of the population in RM during the 1990-2019 period

5D1 "Industrial wastewater treatment and discharge"

Stage I: Estimation of the total degradable organic carbon in industrial wastewaters (TOW)

The methodology available in the 2006 IPCC Guideline implies the industrial annual output P (tons/year), generation of wastewater W (m^3 / ton of product) and the concentration of degradable organic substances in wastewater COD (kg COD / m^3).

When assessing the total quantities of organic substances in industrial wastewater, equation 6.6 was used, from the 2006 IPCC Guideline (Vol. 5, Chap. 6, page 6.22):

$$TOW_{ind} = P_i \bullet W_i \bullet D_{ind}$$ where:

TOW_{ind} = total quantity of organic substances in industrial wastewater, kg BOD/an[36];
P_i = annual industrial output, t/an;
W_i = quantity of wastewater generated per unit of industrial output, m^3/t;
D_{ind} = biodegradable organic component, kg CCO/m^3 industrial wastewater. For this purpose, the activity data regarding the generation of industrial wastewater (by industry branches) and their discharge in the sewage networks.

For each branch of industry, the value of the degradable organic component was established, expressed in kg COD/m^3 industrial wastewater, the quantity of wastewater formed per production unit in m^3/tons (Table 12), as well as the amount of the annual production for each branch of industry.

Industrial production	D_{ind} – degradable organic component, kg COD/m^3	W_{ind} – amount of wastewater formed per industrial production unit, m^3/t
Meat canning industry	4.1	13.0
Vegetable and fruits canning industry	5.0	20.0
Beer industry	2.9	6.3
Wine and champaign industry	1.5	23.0
Cognac and brandy industry	11.0	24.0
Meat and cold meat industry	4.1	13.0
Diary industry	2.7	7.0
Sugar industry	3.2	11.0
Fish industry	2.5	13.0
Edible oil and fats industry	0.8	3.1
Beverages production	1.0	3.8
Corrugated fibreboard production	9.0	162.0
Plastic and rubber industry	3.7	0.6
Paints and varnishes	3.0	67.0
Detergent and soap production	0.6	2.5
Leather production	7.0	4.2
Textile production	1.0	42.6

Source: The 2006 IPCC Guideline, Volume 5, Chapter 6, Table 6.9, page 6.22; Mircea Gh. Negulescu et al. (1968), *Epurarea apelor uzate industriale*. Editura Tehnică, București 1968; СЭВ. ВНИИ ВОДГЕО ГОССТРОЙ ССР (1982), *Укрупненные нормы по водоснабжению и водоотведению для разных отраслей промышленности*, Москва, 1982; *Канализация населенных мест и промпредприятий.* Справочник проектировщика. Стройиздат. Москва, 1981.

Table 9 - Emission factors used when calculating methane emissions coming from the 5D2 category of sources "Industrial wastewater treatment and discharge"

Stage II: Selection of wastewater treatment systems and industrial wastewater discharge pathways

The second stage of the calculation exercise in the selection of the treatment systems and wastewater discharge pathways specific to national circumstances by considering the country-specific activity data.

[36] BOD– Biological Oxygen Demand.

According to which, by the use of equation 6.2 of the 2006 IPCC Guideline (Volume 5, Chapter 6, page 6.12) the emission factors are achieved for each wastewater treatment system and for each wastewater discharge pathway. The value of the emission factor specific to a wastewater treatment and discharge system depends on the methane generation potential (B_0), and on the methane correction factor (MCF) characteristic to the respective wastewater treatment and discharge system. B_0 represents the maximum methane quantity that can be produced in a certain amount of organic content (expressed in COD) in industrial wastewater. MCF indicates the extent to which methane generation capacity (B_0) is conducted within each type if wastewater treatment and discharge. This is also an index of the degree that demonstrates to what extent is the wastewater treatment system an anaerobic one.

$$EF_j = B_0 \bullet MCF_j \text{ where:}$$

EF_j = emission factor, kg CH_4/kg COD;
j = each system of wastewater treatment and discharge;
B_0 = the maximum methane generation capacity, kg CH_4/kg COD_5 (according to the 2006 IPCC Guideline, Vol. 5, Chap. 6, Table 6.2, page 6.12, the value used by default for industrial wastewater is 0.25);
MCF_j = methane conversion factor (fraction).

Type of systems	Wastewater treatment and discharge systems, j	B_0, kg CH_4/ kg DOC_5	MCF	EF, kg CH_4 /kg DOC_5
Systems without wastewater treatment	The discharge of wastewater in rivers and lakes without preventive treatment	0.25	0.1	0025
Systems with wastewater treatment	Centralised treatment system with aerobic wastewater treatment managed efficiently (normative treatment)	0.25	0.1	0050
	Centralised treatment system with aerobic wastewater treatment managed inefficiently (insufficient treatment)	0.25	0.2	0025

Table 10 - Emission factors used when evaluation of methane emissions coming from the 5D2 category of sources "Industrial wastewater treatment and discharge"

Stage III: Assessment of total methane emissions from industrial wastewater treatment and discharge

The third stage of the calculation exercise consists in calculating the total methane emissions from the 5D2 category of sources "Industrial wastewater treatment and discharge" as a sum of emissions coming from each wastewater treatment and discharge system specific to the respective country. Similar to domestic wastewater, the emission assessment is conducted according to equation 6.1 of the 2006 IPCC Guideline (Volume 5, Chapter 6, page 6.11):

$$CH_4 \text{ } emissions = \left[\sum_{ij}(Ui \bullet Tij \bullet EFj)\right] \bullet (TOW - S) - R \text{ } where:$$

CH_4 emissions = methane emissions coming from wastewater treatment and discharge in inventory year, kg CH_4/year;
TOW = total quantity of degradable organic substances in wastewater, kg COD/year;
S = organic component removed with the sludge in inventory year, kg DOC/year;
U_i = weight of population by the urbanization degree i, in inventory year (fraction);
$T_{i,j}$ = wastewater treatment and discharge system degree of utilization j, for each group of population i, in inventory year (fraction);

i = groups of population by the economic development level: rural population – low income, urban population with low income;
j = wastewater treatment and discharge systems;
EF_j = emission factor, kg CH_4 / kg COD;
R = methane emissions recovered in the inventory year, kg CH_4/year.

It should be noted that, as industrial wastewater are discharged together with domestic wastewater, and most of the economic agents connected to the sewage systems operate in urban areas, the distribution between different wastewater management practices was done by allocation to urban population, subsequently divided in two sub-categories: population with high degree of urbanization and population with low degree of urbanization, being considered only the centralised wastewater collection systems and the direct discharge of waters in rivers and lakes (situation found in some cities of the country).

Therefore, similar to domestic wastewater, by considering the level of economic development of the localities in the Republic of Moldova, the urbanization degree and degree of connection to wastewater collection and treatment systems, based on expert opinion, there were established the values of country-specific factors used when assessing the CH_4 emissions coming from the industrial wastewater during the (1990-2019) reference period (Table 7-36). These values were set based on the statistical information associated to the number of economic agents by economic activities on the territory.

N_2O emissions from the 5D1 category of sources "Domestic wastewater treatment and discharge"

Wastewater discharges in natural aquatic receptors represents a relevant source of nitrogen protoxide emissions. These can be direct emissions from the wastewater treatment plants or indirect emissions from wastewater discharged in aquatic elements (rivers, lakes or seas).

Assessment of N_2O emissions coming from the 5D1 category of sources "Domestic wastewater treatment and discharge" was conducted in compliance with the calculation methodology available in the 2006 IPCC Guideline, following a Tier 1 methodological approach.

The calculation was conducted by the equation 6.7 in the 2006 IPCC Guideline (Vol. 5, Chap. 6, page 6.25):

$$emissions\ N_2O = N_{EFFLUENT} \bullet EF_{EFFLUENT} \bullet 44/28$$ where:

emissions N_2O = emissions of N_2O in inventory year, kg N_2O/an;
$N_{EFFLUENT}$ = total nitrogen quantity in waste effluent discharged in natural aquatic receptors, kg N/year;
$EF_{EFFLUENT}$ = emission factor for N_2O for discharge of wastewater, kg N_2O-N/kg N; implicit value is 0.005 kg N_2O-N/kg N (IPCC 2006 Guidelines, Vol. 5, Ch. 6, Table 6.11, pg. 6.27);
[44/28] = stoichiometric conversion factor of N_2O-N in N_2O.

Activity data necessary for the assessment of N_2O emissions are the nitrogen content in wastewater discharges, the population in the Republic of Moldova and the annual average protein consumption per capita.

When assessing the average protein consumption per capita, it was additionally considered the quantity of non-consumable protein, as well as the quantities of industrial and commercial origin proteins discharged in the wastewater sewage and discharge systems.

Food, as well as food waste that are not consumed and are washed in the wastewater sewage and treatment system, as well as bathroom waters and those coming from clothes washing, as well as industrial origin production wastes and food wastes in commercial sector, for example from food stores and butcher store, contribute similarly with a certain quantity of nitrogen and are considered in the calculation exercise of nitrogen protoxide emissions.

The total quantity of nitrogen in the waste effluent discharged in natural aquatic receptors ($N_{EFFLUENT}$) is calculated by means of equation 6.8 in the 2006 IPCC Guideline (Vol. 5, Chap. 6, page 6.25):

$$N_{EFFLUENT} = (P \bullet Proteins \bullet F_{NPR} \bullet F_{NON-CON} \bullet F_{IND-COM}) - N_{SLUDGE}$$ where:

$N_{EFFLUENT}$ = total nitrogen quantity in waste effluent discharged in natural aquatic receptors, kg N/year;
P = number of inhabitants;
Proteins = annual protein consumption per capita, kg/capita/year;
F_{NPR} = percentage of nitrogen in proteins; implicit value is 0.16 kg N/kg proteins (IPCC 2006 Guidelines, Vol. 5, Ch. 6, Table 6.11, pg. 6.27);
$F_{NON-CON}$ = correction factor for non-consumable proteins discharged in wastewater (acc. IPCC 2006 Guidelines, Vol. 5, Chap. 6, Table 6.11, page 6.27, values used by default are 1.1 for the countries that do not practice garbage disposal, and 1.4 for countries that practice garbage disposal);
$F_{IND-COM}$ = correction factor for the proteins discharged in the wastewater sewage and discharge system by the industrial and commercial sector (according to the 2006 IPPC Guideline, Vol. 5, Chap. 6, Table 6.11, page 6.27, the value used by default equals 1.25);
N_{SLUDGE} = nitrogen discharged with the sludge (IPCC 2006 Guidelines, Vol. 5, Ch. 6, pg. 6.25, the value used as default is zero), kg N/year.

N_2O emissions from the advanced centralised wastewater treatment plants are usually much lower than those coming from the discharge of wastewater in aquatic basins. The methodological approach considered when assessing the respective emissions is valid especially for the countries where there are advanced wastewater treatment plants with control technologies of nitrification and denitrification steps.

N_2O emissions from the advanced centralised wastewater treatment plants with control technologies of nitrification and denitrification steps are calculated according to equation 6.9 from the 2006 IPCC Guideline (Vol. 5, Chap. 6, page 6.26):

$$N_2O_{PLANT} = P \bullet T_{PLANT} \bullet F_{IND-COM} \bullet EF_{PLANT}$$ where:

N_2O_{PLANT} = N_2O emissions from the advanced centralised wastewater treatment plants in inventory year, kg N_2O/year;
P = number of inhabitants served by the advanced centralised wastewater treatment plants;
T_{PLANT} = percentage of performant wastewater centralized treatment plants out of total wastewater generated (in the case of the Republic of Moldova, it corresponds with $U_{urban\ high\ development}$);
$F_{IND-COM}$ = correction factor for the proteins discharged in the wastewater sewage and discharge system by the industrial and commercial sector (according to the 2006 IPPC Guideline, Vol. 5, Chap. 6, Table 6.11, page 6.27, the value used by default equals 1.25);
E_{FPLANT} = emission factor, 3.2 g N_2O/capita/year (The 2006 IPCC Guideline, Vol. 5, Chap. 6, page 6.26).

In the case there will be considered the nitrogen protoxide emissions coming from the advanced centralised wastewater treatment plants (N_2O_{PLANT}), the nitrogen quantity associated to these emissions (N_{WWT}) is to be extracted from the total nitrogen quantity in the wastes discharged in natural aquatic receptors ($N_{EFFLUENT}$). The N_{WWT} values will be calculated by multiplying the values achieved for N_2O_{PLANTS} with the stoichiometric ratio 28/44 (the conversion factor from N_2O to N_2O-N).

The activity data on the average protein consumption per capita in the Republic of Moldova come from the data base of the UN Food and Agriculture Organisation (FAO) (Table 7-37). In the case of the Republic of Moldova, the activity data are available on FAO webpage only starting with the year 1992, so that for the years 1990 and 1991, the activity data were extrapolated by taking into account the evolution of the respective indicator for URSS.

NMVOC emissions from the 5D1 category of sources "Domestic wastewater treatment and discharge"

The calculation of the NMVOC emissions coming from the 5D1 category of sources "Domestic wastewater treatment and discharge" was achieved according to the methodological approach available in the EMEP/EEA air pollutant emission inventory guidebook (2019):

$$NMVOC\ emissions = AR \bullet EF \bullet 10^{-6}$$ where:

NMVOC emissions = non-methane volatile organic compounds emissions in inventory year, kt/year;
AR = total volume of wastewater discharged in inventory year, millions m^3/year (see Table 7-28);
EF = emission factor, mg NMVOC/m^3 discharged wastewater (according to the EMEP/EEA air pollutant emission inventory guidebook (2019), the 5.D category of sources "Wastewater treatment and discharge", Table 3-1, page 7, the value used by default equals 15 kg NMVOC / millions m^3 discharged wastewater);
10^{-6} = conversion factor, from kilograms to kt.