Ministry of Environment and Physical Planning
The Government of the Republic of Macedonia

THIRD NATIONAL COMUNICATION TO UNFCCC

SECTOR: WASTE

CLIMATE CHANGE MITIGATION POTENTIAL

FINAL DRAFT REPORT

Skopje, August 2013

This document presents time series of national greenhouse gases emissions for the period 1990-2009 for the key emitting sectors, identifies gaps and provides recommendations in the area of climate changes in order to comply with the obligations to report greenhouse gas emissions under UNFCCC. This document provides important guidance for policy-makers in developing strategies to reduce emissions and further strengthens the dialogue, information exchange and cooperation among all the relevant stakeholders including governmental, non-governmental, academic, and private sectors.

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ABBREVIATIONS

AD	Anaerobic digestion
ASP	Aerated Static Pile
BOD	Biological oxygen demand
BAU	Business as usual (scenario)
COD	Chemical oxygen demand
DOC	Degradable organic carbon
GHG	Greenhouse gases
GWP	Global warming potential
IPCC	Intergovernmental Panel on Climate Change
MAC	Marginal Abatement Curve
MCF	Methane Correction Factor
MOEPP	Ministry of Environment and Physical Planning
MSW	Municipal solid waste
NIR(s)	National Inventory Report(s)
NWMP1	National Waste Management Plan 2006-2012
NWMP2	National Waste Management Plan 2009-2015
PCE(s)	Public Communal Enterprise(s)
PPP	Public Private Partnership
SDC	Swiss Agency for Development and Cooperation
WMR(s)	Waste Management Region(s)
WWTP	Waste water treatment plant

CONTENTS

A. INTRODUCTION

A.1. Climate change mitigation and developing countries

Although the waste management sector makes a relatively minor contribution to greenhouse gas (GHG) emissions, it is in a unique position to move from being a minor source of global emissions to becoming a major saver of emissions. While minor levels of emissions are released through waste treatment and disposal, the prevention and recovery of wastes (i.e. as secondary materials or energy) avoids emissions in all other sectors of the economy. The work plan for the focal area on waste and climate change aims to promote a holistic approach to waste management that will have positive consequences for GHG emissions from the energy, forestry, agriculture, mining, transport, and manufacturing sectors. Better waste and wastewater management is an important sustainable development goal because it can lead directly to improved health, productivity of human resources, and better living conditions. It can also have direct economic benefits in terms of higher value of property due to improved living conditions. The challenge is to develop improved waste and wastewater management using low to medium-technology strategies that can provide significant public health benefits and GHG mitigation at affordable cost. The major impediment in developing countries is the lack of capital. Another challenge is the lack of urban planning so that waste treatment and disposal activities are segregated from community life. A third challenge is often the lack of environmental regulations enforced within urban infrastructure. In many developing countries, waste recycling occurs through the scavenging activities of informal recycling networks. Sustainable development includes a higher standard for these recycling activities so that safety and health concerns are reduced via lower technology solutions that are effective, affordable, and sustainable. In some cases, *landfill gas* might be used to provide heating fuel for a factory or commercial venture that can be an alternative source of local employment. Also, *compost* can be used for agriculture or horticulture applications, and closed re-vegetated landfills can become public parks or recreational areas.

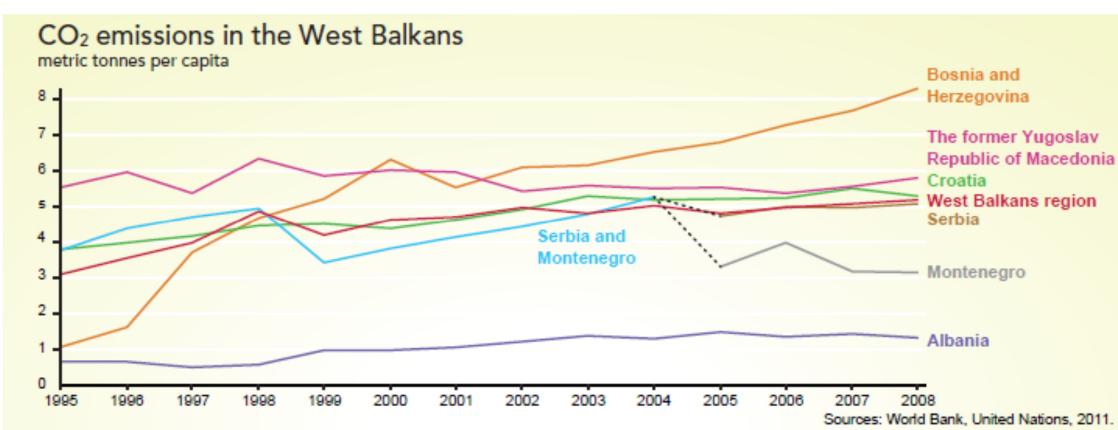


Figure 1 CO_2 emissions in West Balkans

The figure1 above and figure 2 below present the comparison between the west Balkan countries regarding the CO_2 emissions from all sources. Macedonia is near to average generation of GHG gases.

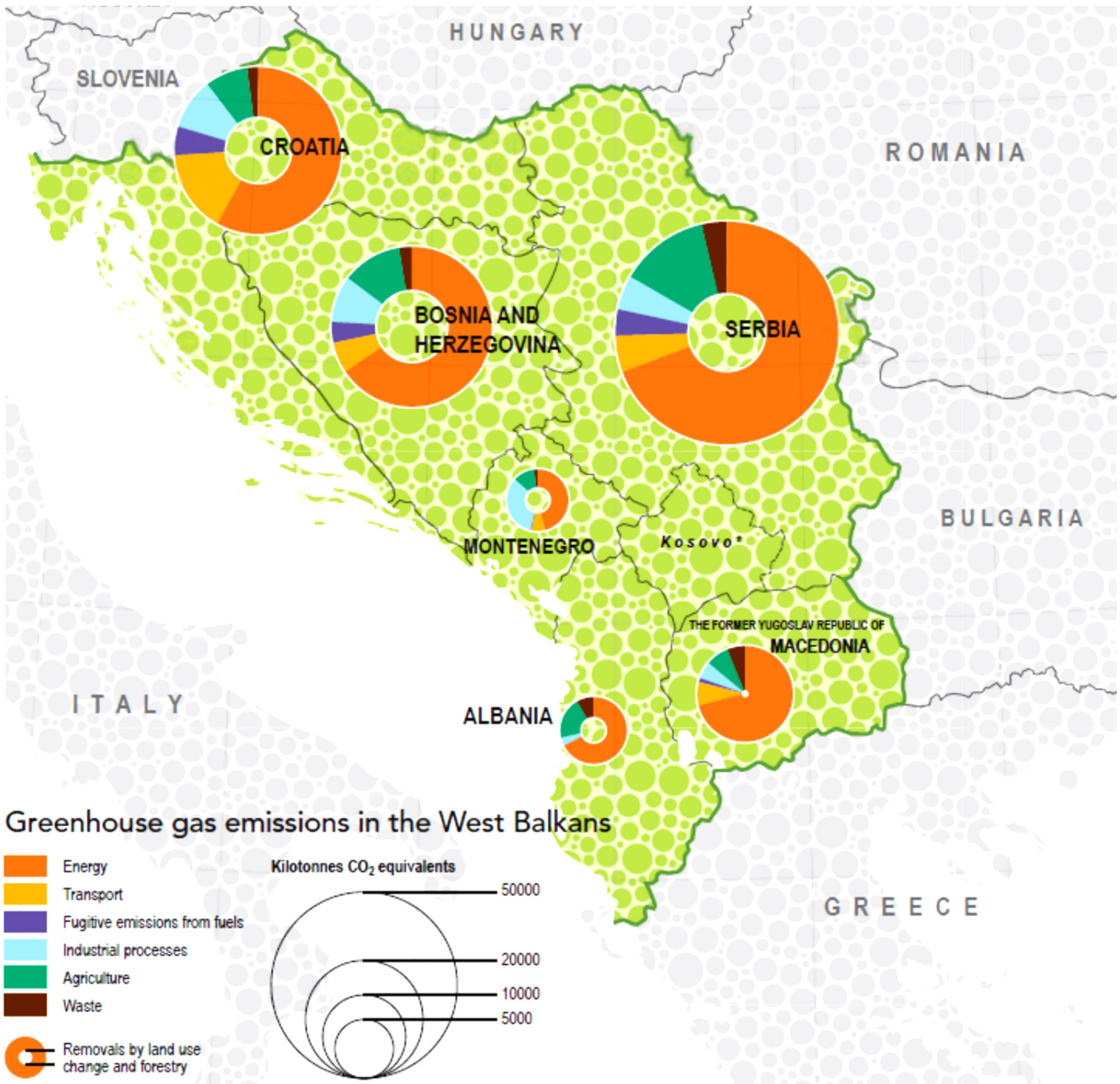


Figure 2. Greenhouse emissions in West Balkans

A.2. Sector Waste in developing countries

According to IPCC Guidelines, in the national inventories the following sources are used for GHG emissions for the waste sector: CH_4 emissions from solid waste disposal sites, CH_4 emissions from residential/commercial wastewater and sludge, CO_2 emissions from waste incineration, and N_2O emission from human sewage and domestic/industrial wastewaters. Taking into account that the main GHG emissions are result of poorly organized landfills, which is the only present practice for organized waste disposal, the greatest potential for reduction of emissions are noted in this area. The realization of the potentials for the mitigation of GHG emissions may be accomplished by establishing regional landfills, along with utilization of the landfill gases, as well as by increasing the degree of recycling and the introduction of co–combustion of selected waste in power and/or heat production facilities. A large portion of these activities, related primarily to recycling and co–combustion, depend on foreign financial and technical support.

Rehabilitation of existing municipal solid waste disposal sites, closure and rehabilitation of illegal landfills, opening of modern regional landfills in accordance with EU environmental legislation, investment in *new technologies to utilize waste for heat and electricity production* and *minimize waste disposal on landfills* are common mitigation measures from the waste sector in all developing countries. Figure 3 represents GHG emissions from waste sector in Balkan countries taken from National Inventory Reports (NIRs).

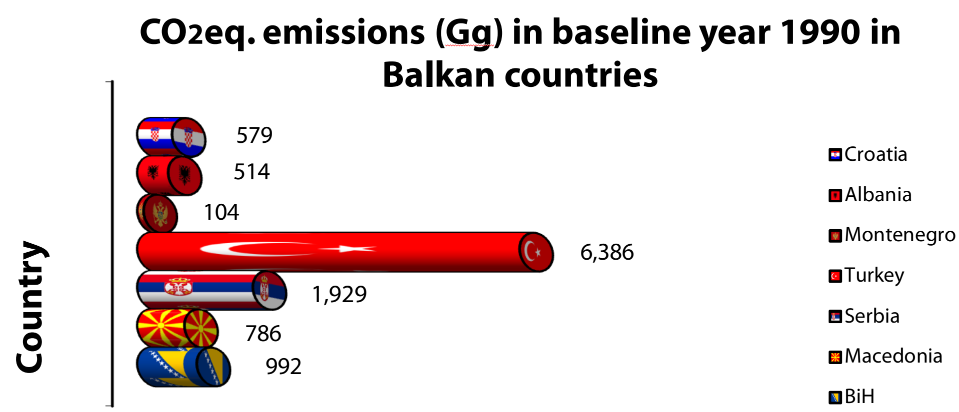


Figure 3. CO_2 emissions for baseline 1990 for Balkan countries

On table 1 there are summary of all adaptation, mitigation and sustainable development issues for the waste sector:

Table 1: Summary of adaptation, mitigation and sustainable development issues for the waste sector

Technologies and practices	**Vulnerability to climate change**	**Adaptation implications & strategies to minimize emissions**	**Sustainable development dimensions**			**Comments**
			Social	**Economic**	**Environmental**	
Recycling, reuse & waste minimization	Indirect low vulnerability or no vulnerability	Minimal implications	Usually positive Negative for waste scavenging without public health or safety controls	Positive Job creation	Positive Negative for waste scavenging from open dumpsites with air and water pollution	Indirect benefits for reducing GHG emissions from waste Reduces use of energy and raw materials. Requires implementation of health and safety provisions for workers
Controlled landfilling with landfill gas recovery and utilization	Indirect low vulnerability or positive effects: Higher temperatures increase rates of microbial methane oxidation rates in cover materials	Minimal implications May be regulatory mandates or economic incentives Replaces fossil fuels for process heat or electrical generation	Positive Odour reduction(non-CH_4 gases)	Positive Job creation Energy recovery potential	Positive Negative for improperly managed sites with air and water pollution	Primary control on landfill CH_4 emissions. Important local source of renewable energy: replaces fossil fuels Landfill gas projects comprise 12% of annual registered CERs under CDM Oxidation of CH_4 and NMVOCs in cover soils is a smaller secondary control on emissions
Controlled landfilling without landfill gas recovery	Indirect low vulnerability or positive effects: Higher temperatures increase rates of microbial methane oxidation rates in cover materials	Minimal implications Gas monitoring and control still required	Positive Odour reduction (non-CH_4 gases)	Positive Job creation	Positive Negative for improperly managed sites with air and water pollution	Use of cover soils and oxidation in cover soils reduce rate of CH_4 and NMVOC emissions
Optimizing microbial methane oxidation in landfill cover soils ('biocovers')	Indirect low vulnerability or positive effects: Increased rates at higher temperatures	Minimal implications or positive effects	Positive Odour reduction (non-CH_4 gases)	Positive Job creation	Positive Negative for improperly designed or managed biocovers with GHG emissions and NMVOC emissions	Important secondary control on landfill CH_4 emissions and emissions of NMVOCs Utilizes other secondary materials (compost, composted sludges) Low-cost low-technology strategy for developing countries
Uncontrolled disposal (open dumping & burning)	Highly vulnerable Detrimental effects: warmer temp. promote pathogen growth and disease vectors	Exacerbates adaptation problems Recommend implementation of more controlled disposal and recycling practices	Negative	Negative	Negative	Consider alternative lower-cost medium technology solutions (e.g., landfill with controlled waste placement, compaction, and daily cover materials)

Thermal processes including incineration, industrial co-combustion, and more advanced processes for waste-to-energy (e.g., fluidized bed technology with advanced flue gas cleaning)	Low vulnerability	Minimal implications Requires source control and emission controls to prevent emissions of heavy metals, acid gases, dioxins and other air toxics	Positive Odour reduction (non-CH_4 gases)	Positive Job creation Energy recovery potential	Positive Negative for improperly designed or managed facilities without air pollution controls	Reduces GHG emissions relative to landfilling Costly, but can provide significant mitigation potential for the waste sector, especially in the short term Replaces fossil fuels
Aerobic biological treatment (composting) component of mechanical biological treatment (MBT)	Indirect low vulnerability or positive effects: Higher temperatures increase rates of biological processes (Q_{10})	Minimal implications or positive effects Produces CO_2 (biomass) and compost Reduces volume, stabilizes organic C, and destroys pathogens	Positive Odour reduction (non-CH_4 gases)	Positive Job creation Use of compost products	Positive Negative for improperly designed or managed facilities with odours, air and water pollution	Reduces GHG emissions. Can produce useful secondary materials (compost) provided there is quality control on material inputs and operations. Can emit N_2O and CH_4 under reduced aeration or anaerobic conditions
Anaerobic biological treatment (anaerobic digestion) component of mechanical-biological treatment (MBT)	Indirect low vulnerability or positive effects: Higher temperatures increase rates of biological processes	Minimal implications Produces CH_4, CO_2, and biosolids under highly controlled conditions Biosolids require management	Positive Odour reduction (non-CH_4 gases)	Positive Job creation Energy recovery potential Use of residual biosolids	Positive Negative for improperly designed or managed facilities with, odours, air and water pollution	Reduces GHG emissions. CH_4 in biogas can replace fossil fuels for process heat or electrical generation. Can emit minor quantities of CH_4 during start-ups, shutdowns and malfunctions
Wastewater control and treatment (aerobic or anaerobic)	Highly vulnerable Detrimental effects in absence of wastewater control and treatment:Warmer temperatures promote pathogen growth and poor public health	Large adaptation implications High potential for reducing uncontrolled GHG emissions Residuals (biosolids) from aerobic treatment may be anaerobically digested	Positive Odour reduction (non-CH_4 gases)	Positive Job creation Energy recovery potential from anaerobic processes Use of sludges and other residual biosolids	Positive Negative for improperly designed or managed facilities with odours, air and water pollution and GHG emissions	Wide range of available technologies to collect, treat, recycle and re-use wastewater Wide range of costs CH_4 from anaerobic processes replaces fossil fuels for process heat or electrical generation Need to design and operate to minimize N_2O and CH_4 emissions during transport and treatment

(Source: IPCC Fourth Assessment Report: Climate Change, 2007)

B. AN OVERVIEW ON THE NATIONAL WASTE MANAGEMENT SECTOR

On the state level, Ministry of environment and physical planning (MOEPP) is responsible body for waste management. MOEPP has already adopted national waste management planning documents and gives support for preparation and implementation of regional and municipal waste management plans. Also, the Law on waste management is adopted and there are lots of amendments in order to improve the situation. The related sub laws are adopted and put in force. Municipal waste management is responsibility of the municipalities. The general policy in municipal waste management is regional approach which means construction of regional landfills with appropriate treatment of waste in accordance with EU standards. There are three cases of Public Private Partnership (PPP) in this sector (Skopje, Polog and Southeast regions). Two of these tender procedures were supported by the MOEPP. Introduction of the principle “producer responsibility” is under implementation for packaging waste.

Total annual quantities of waste generated in the country are 26,218,257 tonnes/y (data from National Waste Management Plan 2009-2015 - NWMP2) of which the biggest parts (95%) are related with extraction and processing in the mining industry (17,246,000 t/y or 66%), agriculture waste (5,610,000 t/y or 21%) and waste from thermal processing industry (2,015,379 t/y or 8%).

The other parts are related to industrial waste, construction waste and municipal waste, medical waste and waste water treatment waste. On the table 2 there is a presentation on different types of waste and the share of the main types.

Table 2. National waste generation by the waste types

Type of waste	***Quantities (t/year)***	***(%)***
Mining industry – extraction and processing	17,246,000	66%
Agriculture	5,610,000	21%
Thermal processing waste (non-hazardous)	2,015,379	8%
Industrial waste (non-hazardous)	103,302	
Industrial waste (hazardous)	76,942	
Oils, polyhydrobiphenols (PHB)	8,898	
Construction and demolition waste	500,000	1.9%
End of life vehicles, used tires, car batteries etc.	27,050	
Municipal waste	570,000	2.1%
Medical waste (non-hazardous)	5,670	
Medical waste (hazardous)	1,000	
Wastewater plants (non-hazardous waste) including waste from purification of drinking water	54,000	
Wastewater plants (hazardous waste)	16	
Total	**26,218,257**	**100%**

Source: NWMP2

For the purpose of this study only municipal solid waste (MSW) and wastewater treatment waste are subjects of analysis, since they are the only ones considered in the emissions calculation from sector waste under IPCC methodologies (Revised 1996 IPCC Guidelines). The big portions of the industrial waste are not consisted of biodegradable waste.

Waste sector has become a significant source of emissions at 7% of total GHG emissions in the country and needs to be addressed more thoroughly in the future. Some 89% of these emissions are CH_4 emissions from SWDS, incineration and wastewaters, 5% are N_2O from human sewage, incineration and wastewaters, and 6% are CO_2 emissions from waste incineration. In the Key category analysis, the Solid Waste Disposal Sites is the only identified key source category as it emits 82% of total emissions from the waste sector. Waste incineration is responsible for 8%, followed by wastewaters from treatment of domestic households (5%) and from sewages-3.42%, while industrial wastewater treatment is responsible for1.58% of total emissions from the sector.

B.1. SOLID WASTE DISPOSAL SITES

Collection, transport and landfilling are the main, regular methods for the final disposal of almost each of the waste fractions. Available facilities and capacities for treatment and disposal of wastes are inadequate, legislation and standards are not effectively enforced, and current waste management practices contribute to the pollution of air, water resources and land. The main waste disposal option is landfilling. There are 55 legal municipal landfills which are not in accordance with EU standards with one exception (Drisla landfill) although there is a lack of basic infrastructure on this landfill.

Our country has 2,069,219 citizens (World Bank predictions) which produce 332.63 kg per capita per year or 688,284 t/year. This level of waste generation is in the expected values for the developing country. On the whole territory, 70% of population are covered with collection schemes of Public communal enterprises (PCE), but only 10% in the rural areas mainly due to lack of technical equipment (vehicles) and staff in the PCEs. This percentage of 30% not served population is reason for existence of around 1.000 wild dumps. The percentage of the biodegradable waste is significant (75.1%) which includes organic waste, paper and cardboard, wood and textile. These figures are based on the findings by the investigations done in the separate study, which is a part of the first NWMP1 (2006), through the special municipal waste analyses. On the table 3 and figure 4 there is presentation of the results.

Table 3.Composition of municipal waste in the country

Average,% in area of investigation	**Single dwellings***	**Multi storey buildings***	**Household waste#**	**Commercial waste***	**total waste ##**
Organic	29.5	22.2	27.59	22.4	26.2
Wood	4.1	2.4	3.20	1.4	2.7
Paper and Cardboard	5.9	13.0	7.78	21.8	11.6
Plastics	7.1	11.8	8.55	12.5	9.6
Glass	2.0	3.9	2.62	6.0	3.5
Textiles	3.2	4.1	3.54	1.3	2.9
Metals	2.2	2.2	2.30	3.5	2.6
Hazardous Household Waste	0.1	0.0	0.04	0.5	0.2
Composites	2.1	2.5	2.14	2.2	2.2
Complex Products	0.0	0.0	0.02	1.1	0.3
Inert	4.8	1.9	4.39	1.6	3.6
Other Categories	3.9	4.8	4.17	2.1	3.6
Fines	35.2	31.1	33.63	23.7	30.9
TOTAL	100.0	100.0	100.0	100.0	100.0

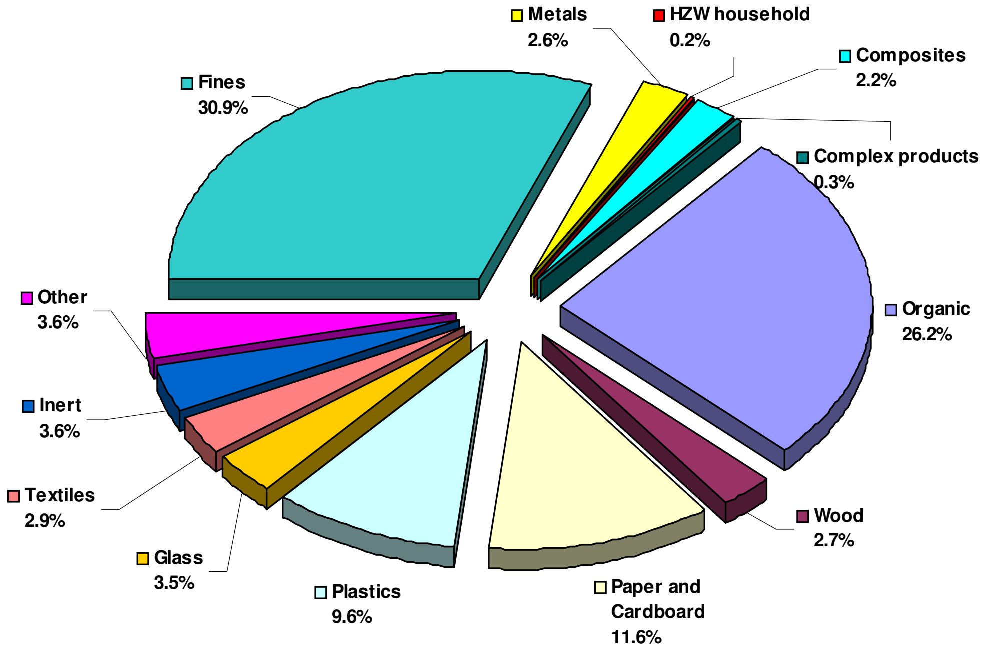


Figure 4 Percentage of each fraction in MSW

Following percentages (Table 4) of waste fractions (considered by the IPCC FOD methodology from 1996 Revised IPCC Guidelines) are taken into account in the calculation of GHG emissions:

Table 4. Percentages of waste fractions (considered by the IPCC FOD methodology):

A. paper and textiles	26.5%
B. garden waste, park waste or other non-food organic	10.99%
C. food waste	30.1%
D. wood or straw	7.5%

Different landfill types in the country, population served, quantities of disposed waste and appropriate methane correction factors (MCF) for each type of landfill according to IPCC Guidelines are shown on Table 5 below.

Table 5. Division on the landfill types for the country and appropriate waste quantities by Revised IPCC Guidelines (1996).

	Type of the landfill site (by IPCC)	**Criteria for landfill type**	**Population served and un served (2006)**	**Cumulative quantities (m^3 – 2006)**	**Quantities in weight (tones - 2006)**	**Percentage of total MSW (by weight)**	**Methane correction factor**
1	2	3	4	5	6	7	8
Served population	**Un-managed, shallow**	Less than 300,000 m^3	279,555	1,921,938	960,969 (0.5 t/m^3)	12 %	0.4
	Un-managed, deep	More than 300,000 m^3	390,487	5,432,000	3,802,400 (0.7 t/m^3)	46 %	0.8
	Managed Anaerobic	By the IPCC	590,455 (Skopje region)	1,625,000 (Drisla landfill)	1,300,000 (0.8 t/m^3)	16 %	1
	Managed, semi-aerobic	/	/	/	/	/	0.5
Total for above categories (total served population and quantities)			**1,138,831**	**8,978,938**			
Un-served population	**Wild dumps**		**790,171**	**4,791,256**	2,156,065 (0.45 t/m^3)	26%	0.6
	Total		**2,050,688**	**13,770,194**	**8,219,434**	100	

Details on calculation on landfill types and other parameters can be found in Annex 1.

The above data only serve for determination (done by desk study) of illegal landfill waste quantities.

B.1.1 Illegal landfills

The problem of illegal landfills is caused by the absence of waste collection services in the rural areas. Therefore approximately 30 to 40% or 660,000 to 880,000 citizens are dumping waste on illegal landfills (790,000 by the desk study – see Table 5 above). Figure 5 below shows locations of potential illegal landfills in the country, identified by the MOEPP (Report: Building capacities for implementation on EU Landfill directive, closure of non-compliant landfills and inspection, MOEPP, 2011, p.15)

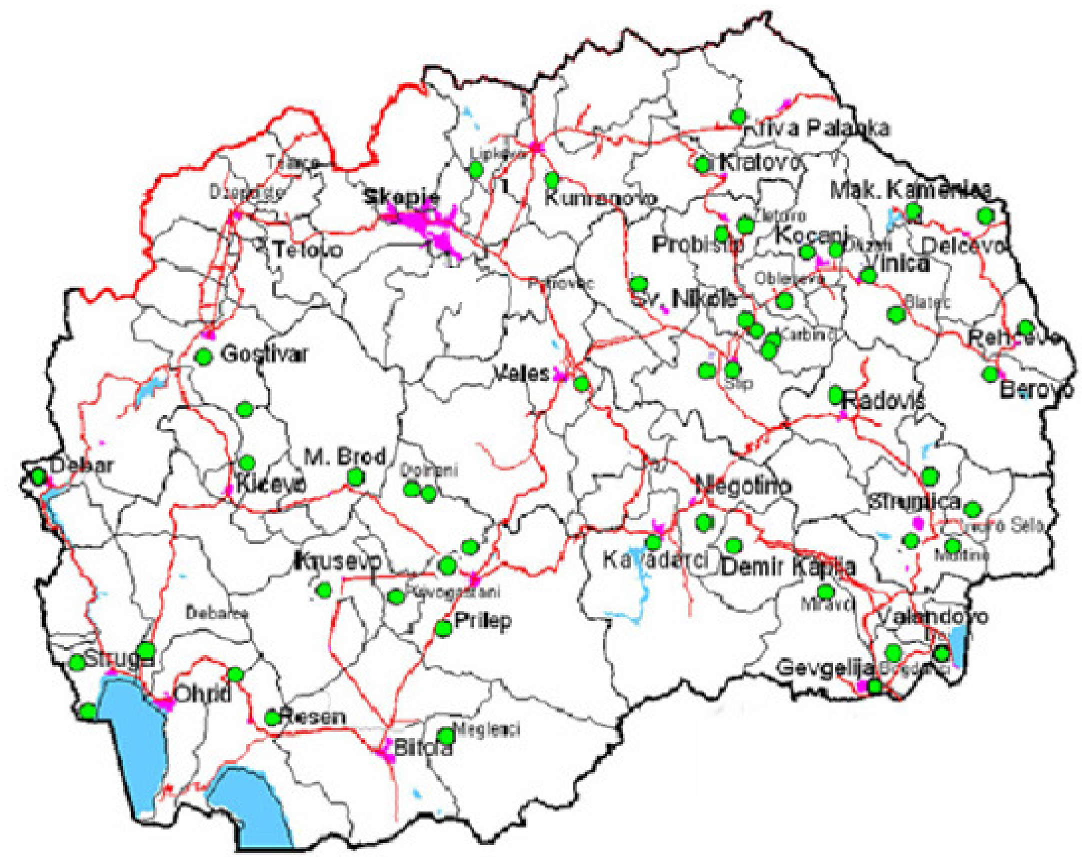


Figure 5 Illegal landfills in Republic of Macedonia (MOEPP, 2011)

B.2 WASTE FROM INCINERATION SITES

There is only one incineration plant in the country which burn medical waste. It is located on Drisla landfill and serves the health institutions (public and private) in the region of Skopje and municipalities of Kumanovo and Veles. On the Table 6 below there is a quantity of treated medical (clinical) waste.

Table 6. Technical characteristics of current Drisla incineration plant (Source: Strategies other than Municipal Solid Waste Part B: Medical Waste (Special study in the frame of NWMP1 2006 – 2012)

Capacity (hour)	**200 kg/hour**, approx. **1 tonne/shift**
Actual waste input (year)	2000: **155 tonne,** 2010: 4**44 tonne**
Incineration temperature	**Chamber 1: 800°C,** **Chamber 2: 1000 °C**
No. and Type of staff	5 workers, 1 driver, 1 engineer, 1 administrator
Flue gas cleaning system	Non additional cleaning system beside secondary chamber
Emission Data	Inspection by Inspectorate of the Ministry of Environment
Ash disposal	Land filling

The current incineration plant is old fashioned and designed in the 80's. It was granted from the British Government during the Kosovo refugee crisis in 1999. The plant is not in accordance with EU directive 2000/76/EC on waste incineration (the Waste Incineration Directive).

The peak of burned medical waste (499 tonnes) was in 2009.

The outputs of the medical incineration are flue gases and ash. It is assumed that quantities of generated ash are 10% of the input material which means around 40 t/y. There is no investigation done on waste characteristics of the ash. The ash is disposed on the nearby landfill Drisla. It should be stressed that new medical waste incineration plant is under construction on the landfill Drisla. It will be in accordance with all the relevant EU directives for the planned activities. It will serve for the whole country.

B.3 WASTE FROM THE WASTEWATER TREATMENT PLANTS

B.3.1 Wastewater from households

Only *59.9% of households are connected to the public sewage system,* while 28% use septic tanks and 12.1% discharge their wastewater directly. Connection to the public sewage system is relatively low, especially considering the higher connection to the water supply system (close to 90%). *Six water treatment plants* were in place up to year 2008: M. Brod, Kumanovo, Ohrid-Struga, Resen, Dojran and Sv.Nikole. Overall they can serve about 280,000 person equivalent (p.e.), but not all of them are entirely compliant with the requirements of the UWWT Directive (Environment situation in the Former Yugoslav Republic of Macedonia, DG Internal Policies 2008, p.9**)**. No data are available on the urban wastewater quality, due to lack of systematic monitoring and of legal enforcement.
Several investment plans in wastewater treatment management are currently managed by Ministry of Environment and Physical Planning and Swiss Agency for Development and Cooperation (SDC) and a newly planned Waste Water Treatment Plants (WWTP) in Prilep, Berovo and Gevgelija (on the Vardar river).

B.3.2 Wastewater from industries

The wastewater from industry and mining appears after being used in the technological production processes, in cooling systems, from sanitary facilities or from other sources. This indicator shows the structure of the wastewater from industry and mining by the purpose. The largest quantities of wastewater in 2010 were generated during the production processes (89.0%), from cooling 2.8%, and approximately 5.7% from sanitation water. It is important to point out that the cooling waters, after the use, are usually discharged without previous cooling by which they cause thermal pollution of the recipient.

- *Treated Wastewaters*

In the country only around 3-4% of the total wastewater quantities are treated. Out of a total of 20,131 thousand m^3 of treated wastewater in 2010, approximately 2.0% originated from power generation, 58.2% from processing industry and 39.7% from mining. In 2010, approximately 51.0% of the total wastewater quantities were discharged in the soil, 39.7% in water reservoirs, 0.9% in sewers and 8.4% in watercourses (Environmental Report, MOEPP 2011, p.76).
It is important to point out that the treatment of wastewater greatly depends on the technical functionality of the treatment facilities, and the construction of new facilities shows no significant upward tendency, which, of course, indicates that it is necessary to make further efforts for improving the situation in this sphere.

- *Untreated Wastewaters*

In 2010, of the total discharged untreated wastewater from industry and mining, 7.2% were discharged in public sewers, 92.3% in watercourses, and the rest in reservoirs and the soil.
In 2010, there was no discharge of untreated wastewater from industry and mining in the lakes (Environmental Report, MOEPP 2011, p.75).

C. MACEDONIAN BUSINESS-AS-USUAL (BAU) WASTE SECTOR

C.1 SOLID WASTE DISPOSAL SITES

In our country, data for the exact current annual amount of the waste, as well as historical waste quantities could not be obtained. Those data are available only for Drisla landfill where municipal solid waste (MSW) from Skopje region is disposed. In the previous National Communications on Climate Change (GHG inventory for period 1990-2002) the default mass balance method (Tier 1) was applied. Activity data were taken mainly from the *Statistical Yearbooks of the Republic of Macedonia*, published by the State Statistical Office of the Republic of Macedonia. By the expert proposal, the eight statistical planning regions in the country were grouped into five (5) waste management regions (WMRs) (figure 6):

-WMR1: Skopje region,

-WMR2: East, Northeast and Vardar regions,

-WMR3: Southeast region,

-WMR4: Pelagonia and Southwest regions,

-WMR5: Polog region.

Figure 6. Waste management regions in the country

In the Third National Communication (data for period 2003-2009), in addition to the Tier1 method calculations, a more detailed - *Tier 2 FOD methodology* that produces more accurate estimates of annual emissions was implemented for the first time. The FOD methods require data on solid waste disposal (amounts and composition) that are collected for 50 years. Historical data was taken from Censuses 1950, 1962, 1971, 1981, 1991, 2002 and current population estimations from

State Statistical Office and from Environmental Reports of MOEPP (data on waste generation per capita). Data for the missing years were obtained with extrapolation. On the figure 7 there is comparison of the results obtained by Tier 1 and Tier 2 methodology.

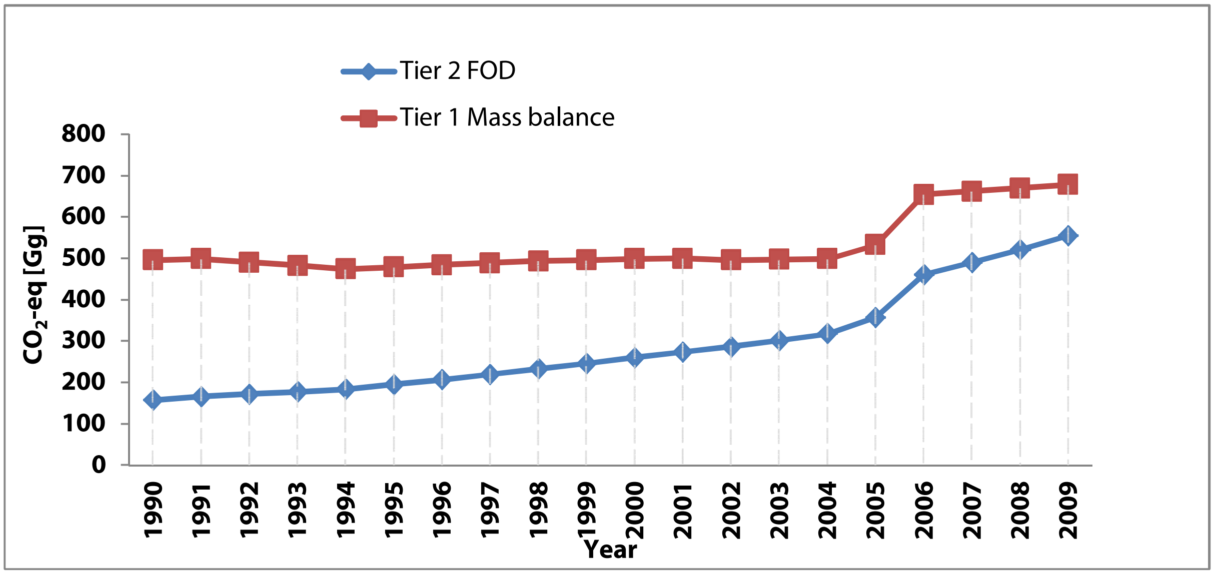


Figure 7. GHG emissions (CO_2-eq in Gg) from SWDS obtained with two different IPCC methodologies (Tier 1 and Tier 2).

Under the BAU scenario, there are no changes in current waste management practices, no measures implemented to reduce quantities of waste going to landfill sites. As population is also expected to increase up to year 2020 (World Bank predictions) the consumer habits (waste generation per capita) and percentage of municipal waste going to a landfill is expected to increase (88.4% in the year 2020 and 100% in 2030), quantities of municipal solid waste are also expected to increase. On the next tables (Table 7 – Table 12) there are information regarding the country and for each Waste Management Region (WMR).

Table 7. Population, waste generation and disposal on landfills for period 1950-2030 in different Waste Management regions (WMRs)

Year	Population	WMR1 28.80%	WMR2 25.30%	WMR3 8.40%	WMR4 22.40%	WMR5 15.10%
1950	1,225,000	352,800	309,925	102,900	274,400	184,975
1960	1,366,000	393,408	345,598	114,744	305,984	206,266
1970	1,623,178	467,475	410,664	136,347	363,592	245,100
1980	1,882,953	542,290	476,387	158,168	421,781	284,326
1990	2,021,481	582,187	511,435	169,804	452,812	305,244
2000	2,034,000	585,792	514,602	170,856	455,616	307,134
2010	2,060,563	593,442	521,322	173,087	461,566	311,145
2020	2,072,880	596,989	524,439	174,122	464,325	313,005
2030	2,043,382	588,494	516,976	171,644	457,718	308,551

Table 8. WMR1- Population, waste generated and disposed waste for period 2010 - 2030

Year	Population	MSW per capita kg/cap/y	Waste generated (t/y)	Percentage of MSW going to landfill (%)	Waste disposed (t/y)
2010	593,442	322.85	191,591	76.93	147,398
2020	596,989	356.62	212,901	88.47	188,346
2030	588,494	393.94	231,828	100	231,828

Table 9. WMR2 – Population, waste generated and disposed waste for period 2010 - 2030

Year	Population	MSW per capita (kg/y)	Waste generated (t/y)	Percentage of MSW going to landfill (%)	Waste disposed (t/y)
2010	521,322	322.85	168,308	76.93	129,485
2020	524,439	356.62	187,028	88.47	165,457
2030	516,976	393.94	203,655	100	203,655

Table10. WMR3 – Population, waste generated and disposed waste for period 2010 - 2030

Year	Population	MSW per capita (kg/yr)	Waste generated (t/yr)	Percentage of MSW going to landfill (%)	Waste disposed (t/yr)
2010	173,087	322.85	55,881	76.93	42,991
2020	174,122	356.62	62,096	88.47	54,934
2030	171,644	393.94	67,617	100	67,617

Table11. WMR4- Population, waste generated and disposed waste for period 2010 - 2030

Year	Population	MSW per capita (kg/y)	Waste generated (t/y)	Percentage of MSW going to landfill (%)	Waste disposed (t/y)
2010	461,566	322.85	149,015	76.93	114,643
2020	464,325	356.62	165,590	88.47	146,492
2030	457,718	393.94	180,311	100	180,311

Table12. WMR5- Population, waste generated and disposed waste for period 2010 - 2030

Year	Population	MSW per capita (kg/y)	Waste generated (t/y)	Percentage of MSW going to landfill (%)	Waste disposed (t/y)
2010	311,145	322.85	100452	76.93	77281
2020	313,005	356.62	111625	88.47	98751
2030	308,551	393.94	121549	100	121549

The Table 14 shows emissions by WMRs for the next period.

Table14. GHG emissions by WMR in CH_4 and CO_2-eq [Gg] calculated by default (Tier 1) mass balance IPCC method

Year	**WMR 1**	**WMR 2**	**WMR 3**	**WMR 4**	**WMR 5**	**Total CH_4 (Gg)**	**Total CO_2-eq (Gg)**
2009*	11.31	7.45	2.47	6.60	4.45	32.28	677.8
2010	11.64	7.67	2.55	6.79	4.58	33.22	697.7
2020	18.59	9.80	3.25	8.68	5.85	46.17	969.6
2030	22.88	12.06	4.00	10.68	7.20	56.83	1,193.4

* Last Inventory year

C.1.2 ILLEGAL LANDFILLS

According to the MOEPP, there are around 1,000 illegal landfills in rural Macedonia. Cities and towns have their own garbage disposal problem: out of approximately 50 urban landfills, only one follows regulations (Drisla). It is extremely important to identify the locations and waste composition on these sites, since they are potential sources of hazardous direct and indirect greenhouse gas emissions (CH_4, N_2O, HFC/PFCs, VOCs, SO_2). Illegal dumping of garbage, discarded appliances, old barrels, used tires, furniture, garden waste, oil, antifreeze and pesticides can threaten human health, wildlife and the environment. Illegal landfills can pollute local waterways and groundwater by leaching, or cause injury to children playing in or around the dumps. Tires retaining water become breeding grounds for mosquitoes and other noxious insects. Some illegal landfills become home to rodents. Also, illegal landfills depress the value of surrounding land and neighborhoods.

Under BAU scenario, illegal landfilling should only increase, especially in rural areas where no organized collection of MSW is done by the Public Enterprises in municipalities. People in rural areas tend to dispose larger amounts of waste on sites than in urban (including non-municipal solid waste). This can result in opening new illegal sites and spreading of existing ones and by the year of 2030 can reach number 1,200 sites. Rural population in the country is 688,000 inhabitants disposing average amounts of 0.5kg waste/day which goes 100% to illegal sites. According to Waste Management Strategy 2008-2020, p.3, 70% of population is involved in the public municipal waste collection system, which is performed by the public enterprises. 481,600 inhabitants don't have another way to dispose of 240,800 tonnes generated waste per year, resulting in additional emissions of 330 CO_2 eq. per year. However, these *emissions are excluded* from total national GHG emissions due to strict EU legislation (Landfill Directive 99/31/EC) for closure of these dumps. This is the main reason why they are also excluded in the IPCC calculation methodologies.

C.2 WASTE INCINERATION

Incineration and open burning of waste are sources of greenhouse gas emissions, like other types of combustion. Relevant gases emitted include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Normally, emissions of CO_2 from waste incineration are more significant than CH_4 and N_2O emissions. In the Third National Communication they have been reported for the first time. Since the Drisla landfill is not practicing any selection or treatment of wastes, the calculations are based only as emissions from open burning of wastes.

Clinical and hazardous waste amounts are relatively constant over the period, giving constant emissions over time. Municipal waste and amount of disposed waste per capita are increasing with population, so as the incineration and emissions from MSW burning. Emissions are correlated with the amounts of municipal solid waste disposed on landfills by population, under the BAU scenario with incineration only at Drisla. Landfill amounts of MSW disposed and associated greenhouse gas emissions (in CO_2eq.) are presented in the table 15:

Table15. Emissions from open burning of waste in the country

Year	Population estimates	MSW generated [tonnes]	MSW disposed [tonnes]	MSW open burned [tonnes]	GHG emissions [CO_2 kt]	GHG emissions [CH_4 kt]	GHG emissions [N_2O kt]	CO_2-eq in [kt]
2009*	2,052,722	720,505	545,999	382,035	65.99	15.76	0.77	***82.52***
2030	2,043,382	775,382	587,585	411,133	71.01	16.96	0.82	***84.91***

*Last Inventory year

C.3 EMISSIONS FROM WASTE WATER

C.3.1 DOMESTIC/COMMERCIAL ORGANIC WASTEWATER AND SLUDGE

In the country most of the wastewater produced in rural areas is managed without formal handling and/or treatment systems. This means that the suggestion given in the *Revised 1996 IPPC Guidelines for National Greenhouse Gas Inventories: Workbook* and *Revised 1996 IPPC Guidelines for National Greenhouse Gas Inventories: Reference Manual,* that the waste waters from the rural area should be excluded from the further calculations holds for country conditions too. National average of population in urban areas ***(59.9%)*** has been taken into consideration when calculating methane emissions, since only they are connected to sewage networks and some kind of treatment prior to disposal in the recipients (source: State of environment in 2011, p.65, MOEPP). Organic wastewater load from domestic and commercial sectors is showing constant values around 22,000 (tonnes Biological oxygen demand - BOD/year) although urban population is slowly increasing, mainly because the wastewater treatment is unchanged over the period. Thus, GHG emissions during the whole inventory period were in the range of 33–40 Gg. On the next table 16 there is a presentation of emissions in the period 1990 – 2009.

Table16. Emissions from domestic and commercial waste water sector in the country 1990 - 2009

Year	***CO_2-equivalent emission (kt)***
1990	***33.81***
2000	***29.19***
2002	***28.98***
2009	***40.96***

Rural areas can also be sources of greenhouse gas emissions since the wastewater is no treated (pits, ponds, etc.) and can cause health problems as well as environmental pollution.

Under BAU scenario, population connected to sewage network remains 59.9% and Maximum methane producing capacity (kg CH_4/kg BOD) is 0.25 and the wastewaters are treated aerobically 75% and anaerobically 25%. Overall greenhouse gas emissions are expected to increase to 31.5 kt of CO_2 eq. by the 2050 (table 17).

Table17. Emissions from domestic and commercial waste water sector in the country 2009 - 2030

Year	***Total population***	***Urban population***	***Domestic wastewater (kgBOD/year)***	***CH_4 emissions [Gg]***	***CO_2 eq. emissions [Gg]***
2009	2,052,722	1,229,579	22,439,822	1.4	***29.4***
2030	2,043,382	1,313,953	23,979,646	1.5	***31.5***

C.3.2 INDUSTRIAL WASTEWATER AND SLUDGE

In order to estimate emissions from industrial wastewaters, the amount of wastewater produced by each industry (in m^3/tonnes product) was used:

Iron and steel, non-ferrous metals, fertilizer, food and beverage, paper and pulp, petroleum refining/petrochemicals, rubber (together with plastics) and other industries, including textiles, soaps and cleaning agents, pharmaceuticals and organic chemicals, degradable organic component (in kg Chemical oxygen demand - COD/m^3 wastewater) was taken as default value from IPCC Guidelines, Module 6, Reference manual, p.6.24 and 6.25. To estimate the emission factor for industrial wastewater, the value of the fraction of wastewater treated by the handling system was considered. The value for the fraction of wastewater was taken as 0.9 for aerobic and 0.1 for anaerobic treatment.

Emissions from industrial wastewater show that the wastewater produced (m^3/tone product) from non-ferrous and steel industries have the highest values, followed by the pulp and paper industries, canneries and wine production. Since total industrial production decreased during the inventory period, organic industrial wastewater and total methane emissions from industries also decreased significantly, falling by 50% from 1990 to 2009 (figure 9). These emissions are 1.5% of total CO_2-eq emissions from sector Waste.

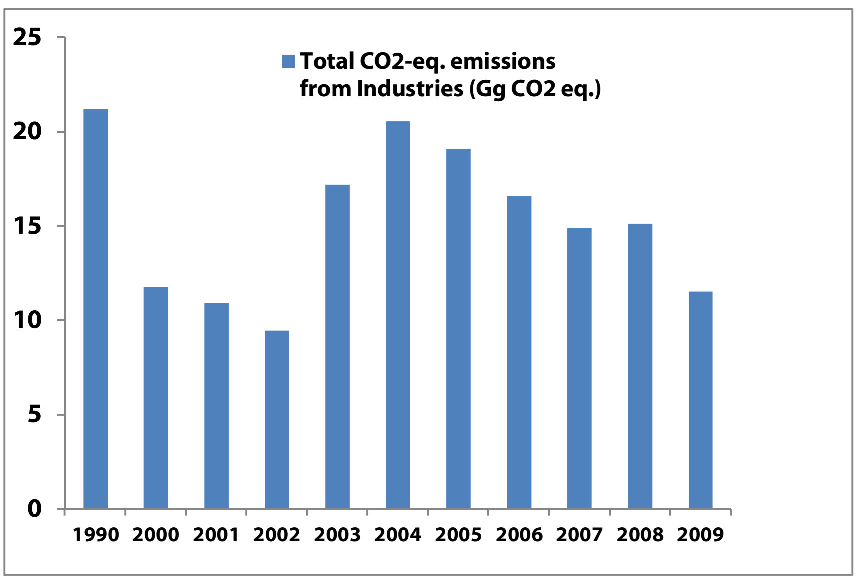


Figure 9. Total CO_2eq emissions from industrial wastewater sector 1990 - 2009

C.3.3 NITROGEN EMISSIONS (N_2O) FROM HUMAN SEWAGE

Values on protein consumption per capita (gr/person/day) were obtained from FAOSTAT[1]. Data for N_2O emission and CO_2-equivalent emissions [Gg] are given in the next table 18.

Table 18 CO_2-equivalent emissions from human sewage 1990 - 2030

Year	CO2-equivalent emission (Gg)
1990	**52.70**
2000	**52.70**
2009	**44.67**
2030	**46**

In the First and Second National Communications, a default value of 33.9 was used for the protein uptake by person, resulting in high values, but in the Third National Communication a country-specific value of 27.9 was set, giving more accurate calculation of emissions. This value was used for prediction of emissions until the year 2050 under BAU scenario. Emissions from human sewage depend on population values and the same linear trend line was used as in SWDS to obtain these values.

[1] (source: http://faostat.fao.org/site/609/DesktopDefault.aspx?PageID=609#ancor)

D. MITIGATION POTENTIAL IN SECTOR WASTE

D.1. METHODOLOGY

Based on the population growth rate obtained from the World Bank, the population growth for the country is determinate (period from 2010 to 2050), but for the purpose of this project, it is used only to 2030. Based on the average amount of waste in Europe, it is assumed that after 2007 the amount of waste per capita will increase by 1% each year in order to bring the country closer to an average in Europe. The quantities of waste received in each year in the period considered, were calculated using the number of inhabitants and the amount of waste per capita. It is also assumed that the amount of waste disposed to landfill will increase over time and in 2030 all the waste quantities will be landfilled. There has been division to the population and the amount of waste by regions. The amount of waste is used to calculate the amount of emissions in the period considered. For this purpose, two methods are used Tier 1 and Tier 2. The difference is that Tier 1 methodology is obtained the waste emissions in certain year, and Tier 2 receive cumulative emissions using half-life of methane (k=14 years) from years prior to observed year.

If the Tier 2 methodology is used and the values below the exponential curve are compiled it shows how much emissions of waste will be emitted from that year. This is equal with the results of Tier 1 methodology. It is useful to see the example of 2013 (set as a base year for emissions prediction calculation). It shows how much emissions of waste will remain from previous years or in this case of 1981. Here it should be emphasized that only 75.1% of municipal solid waste in the country is used for calculation of degradable organic carbon (DOC) value, with following percentage of various fractions in the waste:

DOC = (0.4*A) + (0.17*B) + (0.15*C) + (0.3*D)

A = Fraction of paper in MSW (value 21.8%) and textile (4.7%)
B = Fraction of garden waste in MSW (value 10.99%)
C = Fraction of food waste in MSW (value 30.1%)
D = Fraction of wood waste in MSW (value 7.5%)

D.2 MEASURES TO REDUCE GHG EMISSIONS

D.2.1 SOLID WASTE DISPOSAL SITES

Following measures for reduction of methane emissions from landfill sites have been recommended:

D.2.1.1 EXISTING MUNICIPAL NON-COMPLIANT LANDFILLS

Current practice of the municipal landfills is only to unload the waste without compaction and covering activities. Based on the special study of NWMP1 (2006 - 2012) there are 55 landfills which are not in accordance with EU standards. The whole surface which is necessary to be covered and rehabilitated is 86 ha (p.65 of Macedonian version of NWMP1). There are four municipal landfills which need urgent closure and rehabilitation:

- Kicevo
- Ohrid
- Kriva Palanka
- Gevgelija

They occupy 11 ha of land.

For the existing landfills the most feasible option suggested by waste experts worldwide and prescribed in NWMP1 is to cover the whole disposal area and introduce gas extraction and flaring, converting methane emissions to CO_2 which has significantly lower Global warming potential (GWP).

D.2.1.2 GAS EXTRACTION WITH FLARING

Landfill gas is generated through the degradation of municipal solid waste by microorganisms. The quality (higher percent methane gases signify higher qualities) of the gas is highly dependent on the composition of the waste, presence of oxygen, temperature, physical geometry and time elapsed since waste disposal. Aerobic conditions, presence of oxygen, leads to predominately CO_2 emissions. In anaerobic conditions, as is typical of landfills, GH_4 and CO_2 are produced in equal amounts. Landfill gas is gathered from landfills through extraction wells placed depending on the size of the landfill (Figure 10).

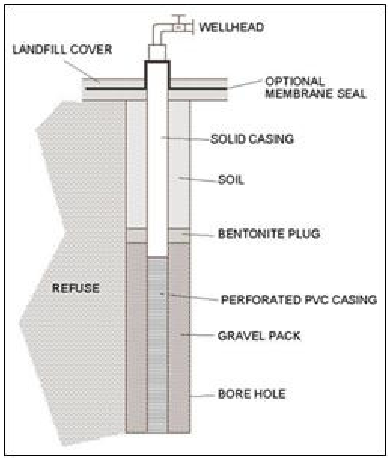


Figure10. Landfill gas extraction well

Figure 11. Open and enclosed flare

If gas extraction rates do not warrant direct use or electricity generation, the gas can be flared off with open or closed flare (Figure 11). A 100 m^3/h is a practical threshold for flaring. Flares are useful in all landfill gas systems as they can help control excess gas extraction spikes and maintenance down periods. Burning one tone of CH_4 results in 7.6 times less emissions of $CO_{2,}$ which is a significant GHG reduction. Production of electricity as an option is not chosen in this project because there is uncertainty in landfill gas quantities.

D.2.2 NEW REGIONAL WASTE MANAGEMENT LANDFILLS

Establishment of the new regional municipal waste management systems in accordance with EU requirements on landfilling and implementation of the integral approach are prescribed in the National Waste Management Strategy (2008- 2020), where new regional landfills should be opened in all WMRs. It means collection, transportation and disposal of waste, waste treatment (Mechanical-biological treatment – MBT - followed by composting or anaerobic digestion of biodegradable waste) and eventual use of Refuse Derived Fuel (RDF) as a fuel in cement facilities as a final stage of the waste management cycle. The aim is as much as possible less waste on the landfills. These two groups of measures are connected because the closure and remediation measures for the existing non – compliant landfills cannot be implemented if there is no construction of the new regional landfills. Regarding the treatment of biodegradable waste there are four basic measures applicable for developing countries:

- Mechanical treatment (MT) followed by a biological aerobic treatment (composting);
- MBT with an anaerobic treatment (Anaerobic digesters with energy production);
- MBT with an anaerobic treatment (Anaerobic digesters with energy production + production of RDF);
- MBT with an aerobic treatment (composting + production of RDF);

D.2.2.1 MECHANICAL AND BIOLOGICAL TREATMENT

A mechanical - biological treatment system is a type of waste processing facility that combines a sorting facility with a form of biological treatment such as composting or anaerobic digestion. MBT plants are designed to process mixed household waste as well as commercial and industrial wastes.

The terms mechanical biological treatment or mechanical biological pre-treatment relates to a group of solid waste treatment systems. These systems enable the recovery of materials contained within the mixed waste and facilitate the stabilization of the biodegradable component of the material.

The sorting component of the plants typically resembles a materials recovery facility. This component is either configured to recover the individual elements of the waste or produce a Refuse-derived fuel that can be used for the generation of power.

The components of the mixed waste stream that can be recovered include:

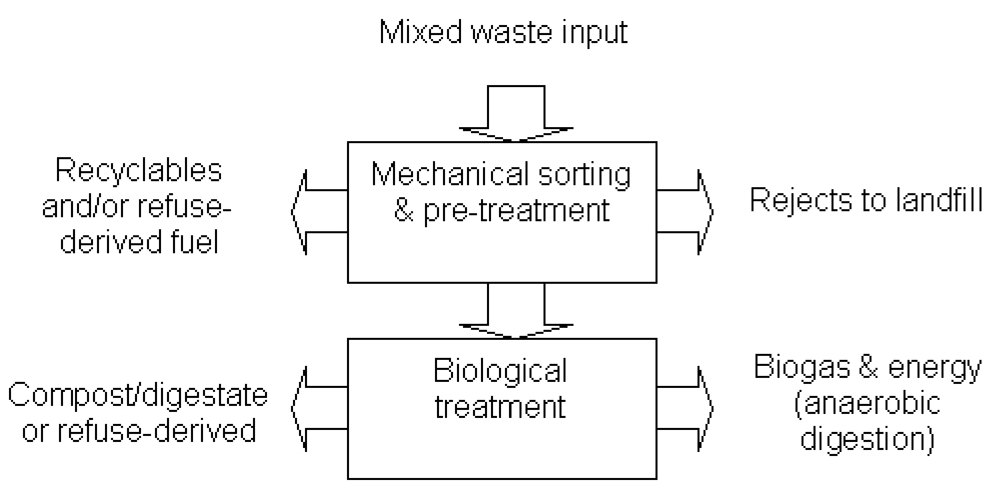
Ferrous Metal

Non-ferrous metal

Plastic

Glass

On figure 12 there is a schematic flow of MBT plant



Schematic flow in typical MBT plant

Figure12. Schematic flow on MBT plant

D.2.2.2 AEROBIC TREATMENT (COMPOSTING)

Compost is organic matter that has been decomposed and recycled as a fertilizer and soil amendment. Compost is a key ingredient in organic farming. At the simplest level, the process of composting simply requires making a heap of wetted organic matter (leaves, "green" food waste) and waiting for the materials to break down into humus after a period of weeks or months. Modern, methodical composting is a multi-step, closely monitored process with measured inputs of water, air, and carbon- and nitrogen-rich materials. The decomposition process is aided by shredding the plant matter, adding water and ensuring proper aeration by regularly turning the mixture. Worms and fungi further break up the material. Aerobic bacteria manage the chemical process by converting the inputs into heat, carbon dioxide and ammonium. The ammonium is further converted by bacteria into plant-nourishing nitrites and nitrates through the process of nitrification.

Aerated Static Pile (ASP) composting, refers to any of a number of systems used to biodegrade organic material without physical manipulation during primary composting. The blended admixture is usually placed on perforated piping, providing air circulation for controlled aeration. It may be in windrows, open or covered, or in closed containers. With regard to complexity and cost, aerated systems are most commonly used by larger, professionally managed composting facilities, although the technique may range from very small, simple systems to very large, capital intensive, industrial installations.

Aerated static piles offer process control for rapid biodegradation, and work well for facilities processing wet materials and large volumes of feedstock. ASP facilities can be under roof or outdoor windrow composting operations, or totally enclosed in-vessel composting, sometimes referred to tunnel composting (Figures 13 and 14).

Figure13. Channeled concrete floor of a composting pad for perforated piping that delivers oxygen to the composting mass

Figure 14.Aeration system for a closed chamber composting facility

D.2.2.3 ANAEROBIC TREATMENT

Anaerobic digestion (AD) is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen. As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gas into the atmosphere. Anaerobic digesters can also be fed with purpose-grown energy crops, such as maize.

There are several stages of anaerobic digestion shown on the next Figure 15:

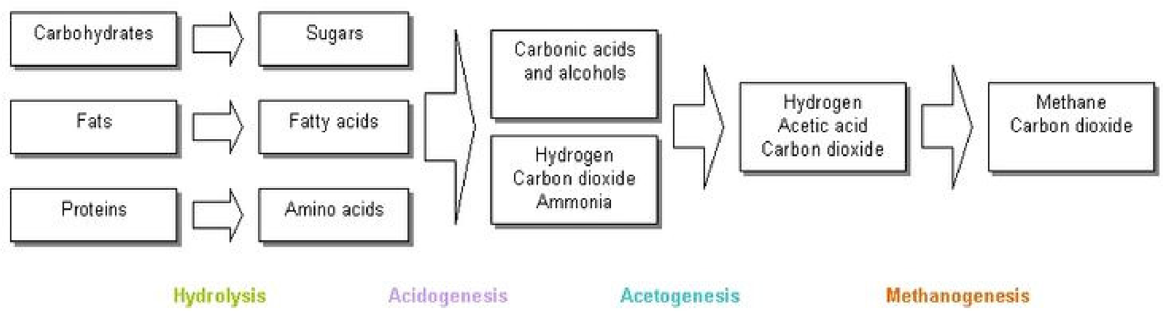


Figure15. Stages of biodegradable waste decomposition in anaerobic conditions

Biogas is the ultimate waste product of the bacteria feeding off the input biodegradable feedstock. Biogas does not contribute to increasing atmospheric carbon dioxide concentrations because the gas is not released directly into the atmosphere and the carbon dioxide comes from an organic source with a short carbon cycle.

The biogas is consisted mainly of methane and carbon dioxide. The typical composition of biogas is shown on the next Table 19:

Table19. Composition of landfill gas

Matter	**%**
Methane, CH_4	50–75
Carbon dioxide, CO_2	25–50
Nitrogen, N_2	0–10
Hydrogen, H_2	0–1
Hydrogen sulfide, H_2S	0–3
Oxygen, O_2	0–2

The methane in biogas can be burned to produce both heat and electricity, usually with a reciprocating engine or micro turbine often in a cogeneration arrangement where the electricity and waste heat generated are used to warm the digesters or to heat buildings. Methane and power produced in anaerobic digestion facilities can be used to replace energy derived from fossil fuels, and hence reduce emissions of greenhouse gases, because the carbon in biodegradable material is part of a carbon cycle.

On the next Figure 16 there is a typical anaerobic digestion plant as a part of MBT plant

Figure16. Two-stage, low solids, digestion component of a mechanical biological treatment system

D.2.2.4 RDF PRODUCTION

The combustible waste materials are converted to an engineered fuel referred to as Refuse Derived Fuel (RDF). RDF is combusted in an engineered RDF combustion grate system with steam generation for power production on site. Residue materials consisting of some inert and non-recyclables and bottom ash and, fly ash are disposed at a sanitary landfill and a hazardous landfill site, respectively (Source: Refuse Derived Fuel – Case Study of Waste as Renewable Resource).

Within these facilities are the unit processes of:

- MSW bag splitting,
- Leachate colletion system,
- Magnetic separation,
- Screening process – trommel and vibrating screens of various sizes,
- Plastic separation – by airlift system,
- Cloth separation – manual process,
- Hazardous and recyclables separation – manual process,
- Two-stages drying and shredding – for drying a bio-inerts and sterilisation of combustible portion into air classifiers as a differential density separator,
- Bunker storage of RDF and feeding to power plant ,
- Power plant,
- Effluent treatment – ammonia treatment, chemical treatment, anaerobic and aerobic treatment and final polishing

On the next Figure 17 there is a presentation of typical RDF plant

Figure 17. Typical RDF technology

The RDF system is applicable for GHG gases reduction because all the carbon containing the waste instead of land filling is incinerated which has more reduction possibilities.

D.3. ILLEGAL LANDFILLS

According to the NWMP there are 1,000 wild landfills in the country. Based on NWMP1 (p.32) only 60 to 70% of the population is provided with waste collection services, which include 10% of the rural population. The other part of the population (30 to 40%) is applying the wild dumping of waste.

One of the mitigation activities against to the wild dump practice is providing of all the citizens of the country with waste collection and transportation systems. In this way there will be no more existence of illegal landfills without any environmental protection. This measure is related with introduction of the regional waste management systems and their implementation. These activities are in line with the adopted principle of universality of waste management services which is one of the principals adopted in the Law on waste management.

D.4 WASTEWATER FROM DOMESTIC HOUSEHOLDS

The mitigation measures for this type of waste generated in WWTP is generally support of construction of the new WWTP according to the National Strategy on Waters. The mitigation measures for this sector is developing of the new sewage systems, in the settlements that are not covered with organized collection of sewage and upgrading of the existing sewage systems. These measures are mainly driven by the Government policies, prioritization in municipalities and foreign funds (JICA, SDC, GIZ, ADA, etc.). Since they are not easily predicted, very costly (average 10 million $ USD) and can achieve only slight emission reduction, these measures are not analyzed further in this document.

D.5 WASTEWATER FROM INDUSTRIES

Mitigation measure is implementation of the Law on environment (53/05) which stipulates the industrial business under the IPPC licenses ordinance (89/05). The industrial WWTP are part of the IPPC requirements and they need to complete their applications by the year 2019. Since these emissions are 1.58% of total and depend on private investments of industries they are not considered as mitigation measures.

E. SCENARIOS FOR MITIGATION MEASURES FOR GHG GASES FROM THE WASTE SECTOR

In the text below there are measures (technologies) and scenarios used in this project:

Measures (technologies):

I. Existing non - compliant landfills

1. Closure and reclamation of the landfill sites
2. Collection and treatment of landfill gas
3. Collection, transportation and burning of the landfill gas (using the flare)

II. New regional landfills

1. Construction of the new regional landfills
2. Aerobic treatment of waste (composting)
3. Anaerobic treatment (digestion) with possible production of electricity
4. Production of Refuse Derived Fuel for cement industry

Comparable cases:

1. BAU scenario in which there are no investments for introduction of new technologies and there are only operational costs for the existing landfills.

2. Closure and reclamation of the existing landfills with burning of landfill gas and Introduction of the new technologies (aerobic and anaerobic treatment of biodegradable waste, RDF production) on the new constructed regional landfills which will reduce the production of GHG gases

The second case is combined in four scenarios:

a) Closure and reclamation of existing landfills with burning of the landfill gas on flare and introduction of MBT technology with composting

b) Closure and reclamation of existing landfills with burning of the landfill gas on flare and introduction of MBT technology using anaerobic digestion with production of electricity

c) Closure and reclamation of existing landfills with burning of the landfill gas on flare and introduction of MBT technology using anaerobic digestion with production of electricity and production of Refuse Derived Fuel (RDF) intended for cement industry (only for WMR1)

d) Closure and reclamation of existing landfills with burning of the landfill gas on flare and introduction of MBT technology with composting and production of Refuse Derived Fuel (RDF) intended for cement industry (only for WMR1)

Practically speaking we have 5 scenarios (BAU scenario plus 4 other scenarios) which are subject of analyzes done in this project.

All the calculations regarding the GHG emissions and investment and operational costs are done in Annex 2.

From 2019 there is a negative trend in population growth. Based on the available data there are three assumptions:

o The waste generation rate from 2007 to 2030 will grow with 1% annually. Year of 2007 is chosen because the data gathered from NWMP1 is reliable till 2006.

o The coverage of the population with waste collection for 2006 is 70%. It is assumed that this percentage will gradually grow to 100% till 2030. It means that all waste quantities, beginning from that year, will be landfilled in proper landfills.

o The calculations start from 1981 because it is assumed that quantities of landfill gas from this year will be active in referent year of 2009 (28 years of methane life span). Only for WMR1 the starting year (for quantities of landfill gas) is 1994 (the year of landfill commissioning).

E.1 PREDICTIONS FOR THE NEXT PERIOD 2013 – 2030

Assumptions and proposals:

o The country is divided on 5 waste management regions (WMRs).

o All the regions will introduce regional municipal waste management system through Public Private Partnership with exception of WMR 2 which is under IPA funding.

o All the technologies will be based on mechanical and biological treatment with aerobic or anaerobic treatment of biodegradable waste. Only WMR1 (Skopje region) will produce plus RDF for cement industry. This refers only to WMR1 because the cement factory is situated in Skopje. It is assumed that RDF from other WMR will be expensive because of the high transport costs to Skopje.

o All the WMRs will construct a new regional sanitary landfills (WMR 1 will upgrade the existing landfill Drisla).

o After the commissioning of the new regional landfills the closure and rehabilitation of the existing non-complying municipal landfills will start.

o There is no introduction of separate waste collection at source during the planned period.

Time frame of commissioning of new regional landfills and closure and reclamation of the existing landfills will be done by this dynamic:

WMR1 (Skopje region) start of the new landfill 2016

WMR2 (Northeast + East + Vardar region) start 2020

WMR 3 (Southeast region) start of the new landfill 2016

WMR4 (Pelagonia + Southwest region) start 2020

WMR5 (Polog region) start 2017

The time frame is proposed by expert taking in consideration the current situation and needed time for introduction of new infrastructure and equipment. From total amounts of municipal solid waste disposed at new regional landfills (shall be opened at different times) only 41.9% (garden waste, park waste or other non-food organic and food waste) shall be used for composting or for producing electricity. Garden and food waste are excluded after year 2016 in calculations of landfill emissions (with exception of BAU scenario).

E.2 INVESTMENT AND OPERATIONAL COSTS

All the prices used in this project for the calculation of investment and operational costs for closure of existing landfills, construction of the new landfills, introduction of landfill gas flaring system, MBT technologies with composting or anaerobic digestion and RDF production can be found in detail in Annex 1. On the next Table 20 there are accepted investment and operational costs together with the unit prices:

Table 20. Investment, operational and unit costs used in the project

facility	New regional landfill[1)]	Gas extraction and flare[1)]	Composting plant[2)]	Anaerobic digestion[2)]	MBT plant[1)]	RDF plant)1
Capacity	150,000 t/y	500 m^3/h	150,000 t/y mixed waste	150.000 t/y mixed waste	150,000 t/y	51,000 t/y selected waste
Investment costs (US$)	4,852,500	797,659	7,400,314	17,076,455	37,488,000	3,250,146
Operational costs (US$)	286,215	72,869	765,659	1,570,310	2,028,499	758,203
Investment unit price (US$/t)	32.35	5.31	49.33	113.86	249.92	21.67
Operational unit price (US$/t)	1.10	0.49	5.11	10.48	13.5	5.04

Source: 1) Drisla feasibility study

2) Own expert data

The investments of composting facilities are calculated together with investments for MBT technology. Data on investment and operational costs per ton of each measure are presented below -

enabled with GACMO model. MBT plant costs are highest, since it is the only precondition to have selection of different waste fractions by mechanical separation and only then can waste undergo biological treatment. On the next Table 21 there are investment and operational costs by the WMRs and starting year of each measure:

Table 21.Investment and operational costs, capacities and starting year for each WMR

Measure	Region	Investment unit price (US$/t)	Operational unit price (US$/t)	Capacity (tonnes)	Start year
Gas extraction and flare	WMR 1	5.31	0.49	172,767.6	2016
	WMR 2	5.31	0.49	202,455.9	2020
	WMR 3	5.31	0.49	175,37.82	2016
	WMR 4	5.31	0.49	179,249.5	2020
	WMR 5	5.31	0.49	95,180.59	2017
Composting plant	WMR 1	49.33	5.11	230,000	2016
	WMR 2	49.33	5.11	200,000	2020
	WMR 3	49.33	5.11	70,000	2016
	WMR 4	49.33	5.11	180,000	2020
	WMR 5	49.33	5.11	120,000	2017
MBT plant + construction of new landfills	WMR 1	282.27	9.57	230,000	2016
	WMR 2	282.27	9.57	200,000	2020
	WMR 3	282.27	9.57	70,000	2016
	WMR 4	282.27	9.57	180,000	2020
	WMR 5	282.27	9.57	120,000	2017
RDF plant	WMR 1	21.67	5.04	230,000	2016
	WMR 2	/	/	/	/
	WMR 3	/	/	/	/
	WMR 4	/	/	/	/
	WMR 5	/	/	/	/
AD treatment	WMR 1	113.86	10.48	230,000	2016
	WMR 2	113.86	10.48	200,000	2020
	WMR 3	113.86	10.48	70,000	2016
	WMR 4	113.86	10.48	180,000	2020
	WMR 5	113.86	10.48	120,000	2017

E.3 GHG EMISSIONS DEFAULT DATA

GHG emissions released with composting or AD treatment are calculated when emissions released during aerobic or anaerobic conditions (41.9% of total MSW disposed on a landfills) are added to emissions from decomposition of remaining 34% of waste disposed on a landfill without further treatment (wood waste, paper, textile). Methane emissions from different biological treatment options were calculated with Tier 1 methodology from 2006 IPCC Guidelines. Calculations of emissions from the biological treatments are based on the data presented on the Table 22 below:

Table 22. Methane emission factor for aerobic and anaerobic treatment of waste (Source: Volume 5: Waste: Chapter 4 Biological treatment of waste: 2006 IPCC Guidelines for National Greenhouse Gas Inventories)

Type of biological treatment	CH_4 Emission Factors (g CH_4/kg waste treated)
	on a dry weight basis
Composting-aerobic	**10** (0.08 - 20)
Anaerobic digestion -anaerobic	**2** (0 - 20)

E.4 REFERENT SCENARIO-BUSINESS AS USUAL

Reference scenario was developed and emissions are calculated using Tier 2 methodology and taking into account disposed waste from year 1981 onward. Assumption is that there will be no investment under "business as usual" in new landfills but sites shall have only maintenance costs that amount 4.79 US $/t on average. All the calculations can be found in more details in Annex 2.

Base year for prediction calculations is 2013. The GHG emissions by years are shown in the next Figure 18:

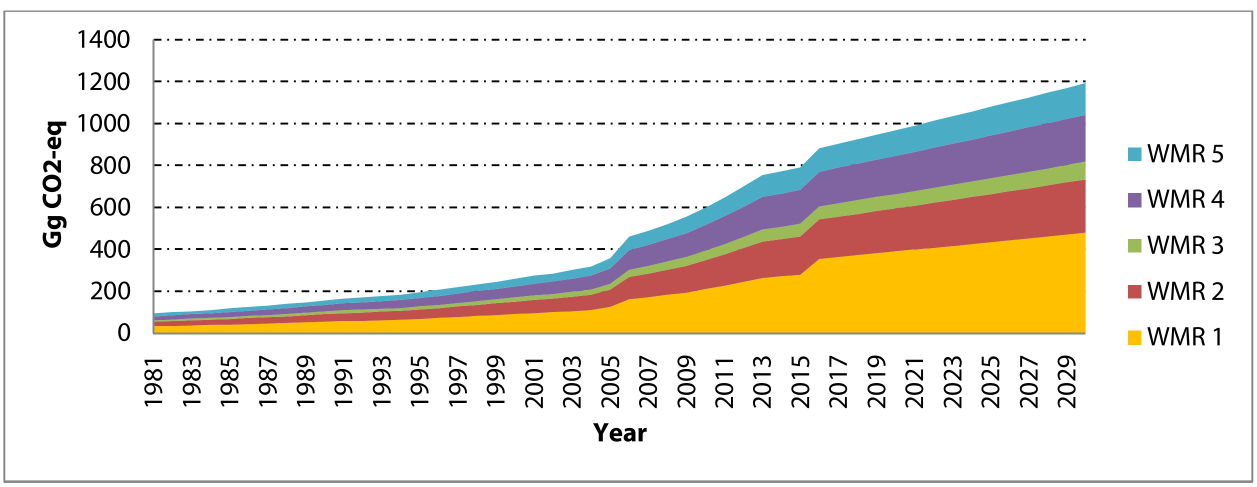


Figure 18. Emissions of CO_2eq in reference – BAU scenario by years

This scenario has the most generation of GHG gases as it is expected (1,193 Gg CO_2 eq. for 2030) and will serve as a baseline for emission reduction comparing. The total emission of GHG gases for this scenario is 26,679 Gg CO_2 eq. The impact of costs for this scenario is not taken in consideration to compare with other scenarios. This is simply done because the goal of this study is emission reductions, which are not the case with this scenario.

E.5 FIRST SCENARIO

As discussed in Section C.2.1 for existing non-compliant landfills (excluding illegal dump sites) a **gas extraction with flaring** is the most suitable mitigation measure. So, this option is considered under all 4 scenarios.

To see the expected emission reductions achieved with implementation of a system for flaring will be possible when initially defined time frame is implemented.(see Table 21 above). For all regions are taken emissions at the opening of flaring-enabled are on site as of 1981, except for the Drisla landfill, which was opened in 1994. In order to get the amount of waste at the opening of the flaring system is used to dump the factors resulting from the distribution of emissions as in 2014 the amount of waste in 2014 when it gets $GgCH_4$ / t . The amount of methane in the period from 1981 until the opening of the flaring system is divide by this factor and obtained quantities of waste by regions. It is assumed that flaring-enabled to work 10 years and the total waste is divided by 10 to get investment for that technology. Using the formula $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ gets that reducing CO_2-eq will be 7.6 times.

In the first scenario (composting), the first important parameter is the year of the opening of the new landfill which should coincide with the opening of the system for flaring. The investment is calculated and based on the capacity of a region, and maintenance costs are changed by changing the amount of waste in a particular year. It is important to note that in the cost assumptions a discount rate of 6% was used (for all scenarios). The total amount of investment in the period from 2016 to 2030 plus the cost of maintenance for each year are discounted with a discount rate of 6% and are presented in 2012 dollars.
The process of composting produces compost that can be sold and therefore the installation of this technology will have certain financial benefits besides lowering emissions. It is assumed that 80,000 tonnes of biodegradable waste is necessary to produce 35,000 tonnes of compost. This relationship is used for calculating the amount of compost each year. It is also assumed that market price of the compost would be 16.17 US $/ t. The revenues from the sale are deducted from the investment.

The GHG emissions generated by closure of existing landfills in all regions and flaring and MBT with aerobic treatment-composting in the five regional landfills are shown on the next Figure 19:

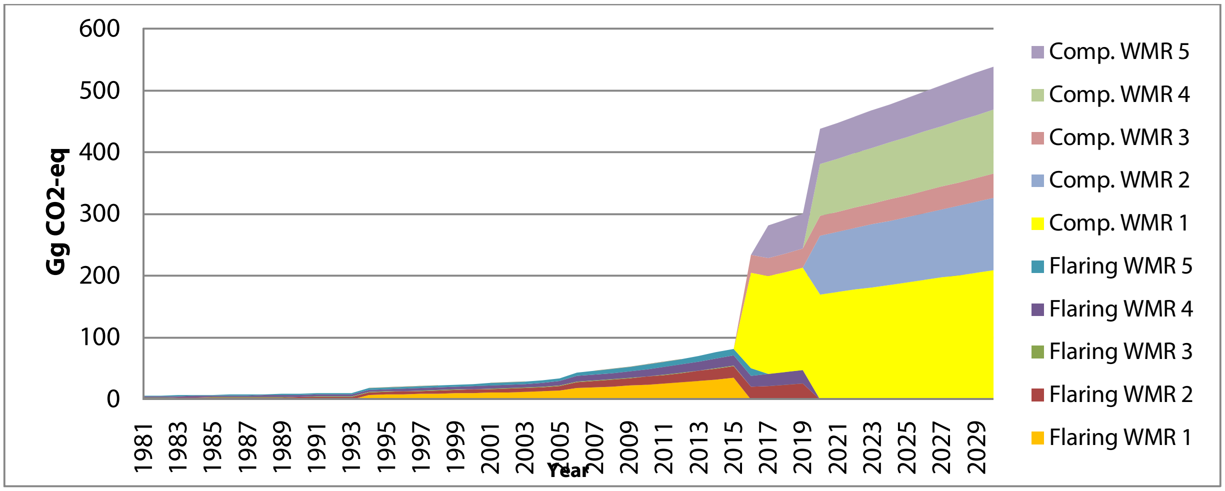


Figure19. Emissions of CO_2eq in the first scenario

It can be seen that introduction of the proposed technologies rapidly decreases the level of emitted GHG gases comparing with BAU scenario (539 Gg CO_2 eq. for 2030). The total emission of GHG gases for this scenario is 7,476 Gg CO_2 eq. with total emission reduction of 19,203 Gg CO_2 eq. The emission reductions of all scenarios are related with reduction of emitted GHG gases of analyzed scenario compared with GHG emissions of the reference scenario.

On the Figure 20 (so called Marginal Abatement Curve – MAC) it is presented the ratio between the costs and emission reduction for the first scenario:

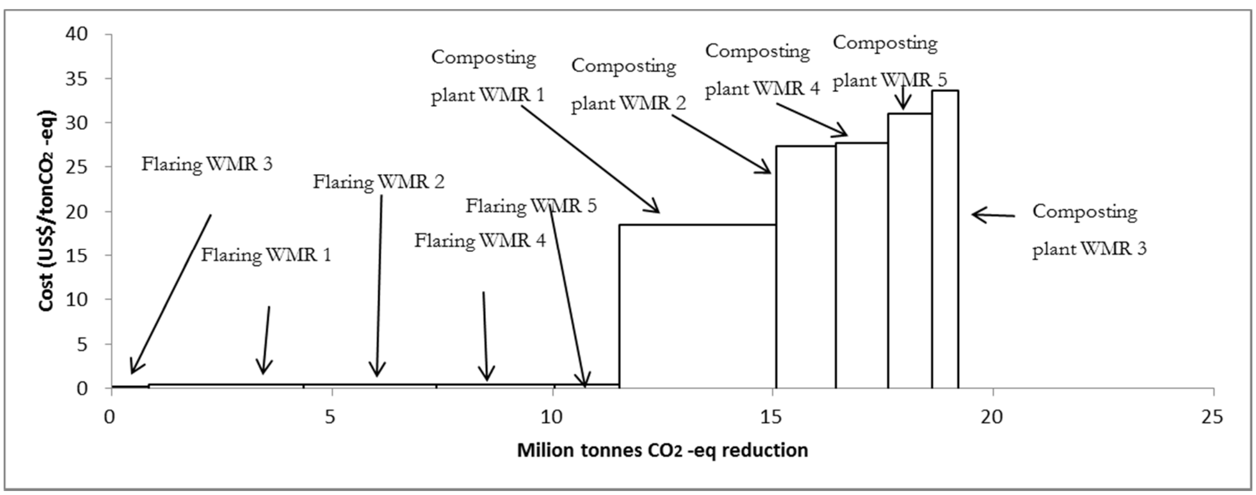


Figure 20 Ratio between the costs and emission reductions for first scenario

The Figure 20 shows that technology of landfill gas flaring is very cheap (0.16 US$/t CO_2 reduced– 0.45 US$/t CO_2 reduced) and is effective emission reduction technology (from 824,232 Gg CO_2 eq.– WMR 3 to 3,523,302 Gg CO_2 eq. – WMR 1) as well as the composting (18.50 US$/t CO_2reduced – 33.59 US$/t CO_2 reduced) with emission reduction (from 588,587 Gg CO_2- WMR3 to 3,537,134 Gg CO_2 – WMR1). It should be stressed that emission reductions refer to the existing municipal closed landfills (flaring) and the new opened regional landfills (composting).

E.6 SECOND SCENARIO

The emissions by the years generated by closure of existing landfills in all regions and flaring, MBT with anaerobic treatment – anaerobic digestion with electricity production at five new regional landfills are shown in the next Figure 21:.

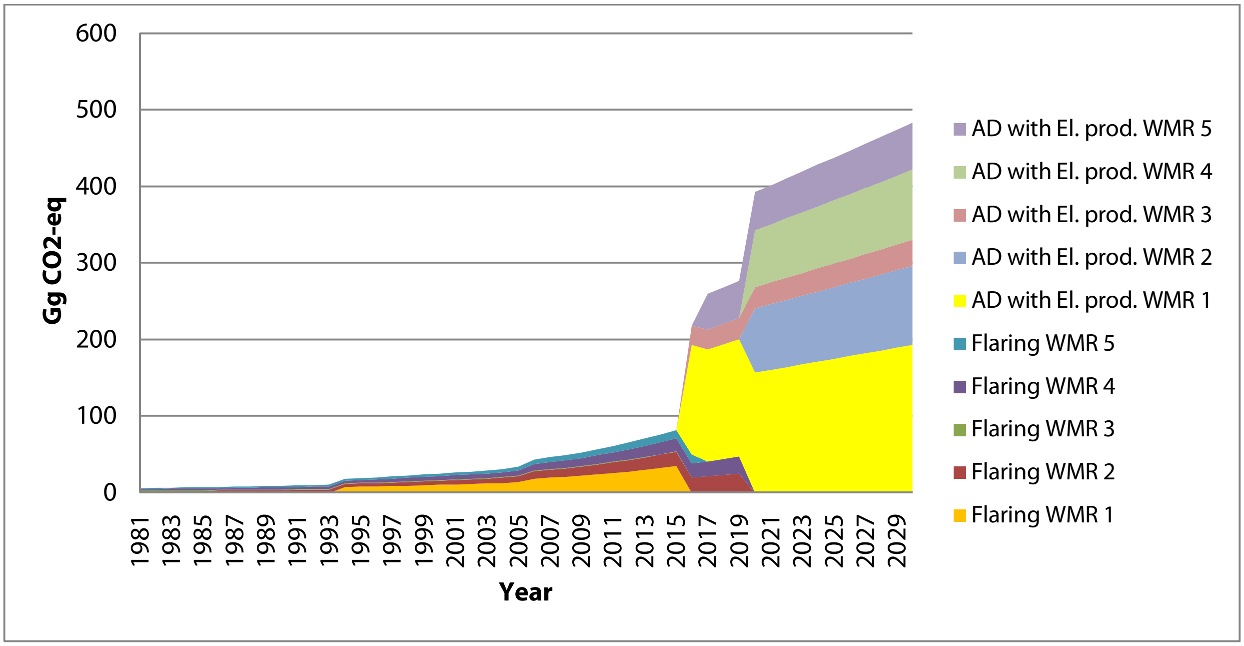


Figure 21. Emissions of CO_2eq in the second scenario by years

The second scenario assumed that all new landfills will produce electricity which is modeled in the same way as for composting. Here we have a financial benefit from the production of electricity from biogas which would be sold at a price defined by the current feed-in tariff from 23.3 dollar cent / kWh. It is also assumed that the technology will work with an efficiency of 80%.

Comparing with the first scenario, the above Figure 21 shows that emissions are lower (484 Gg CO_2 eq. for 2030) which means that anaerobic digestion as a technology produces lower GHG emissions than composting. The total emission of GHG gases for this scenario is 6,840 Gg CO_2 eq. and total emission reductions are 19,839 Gg CO_2 eq.

On the next Figure 22 it is presented the ratio between the costs and emission reduction:

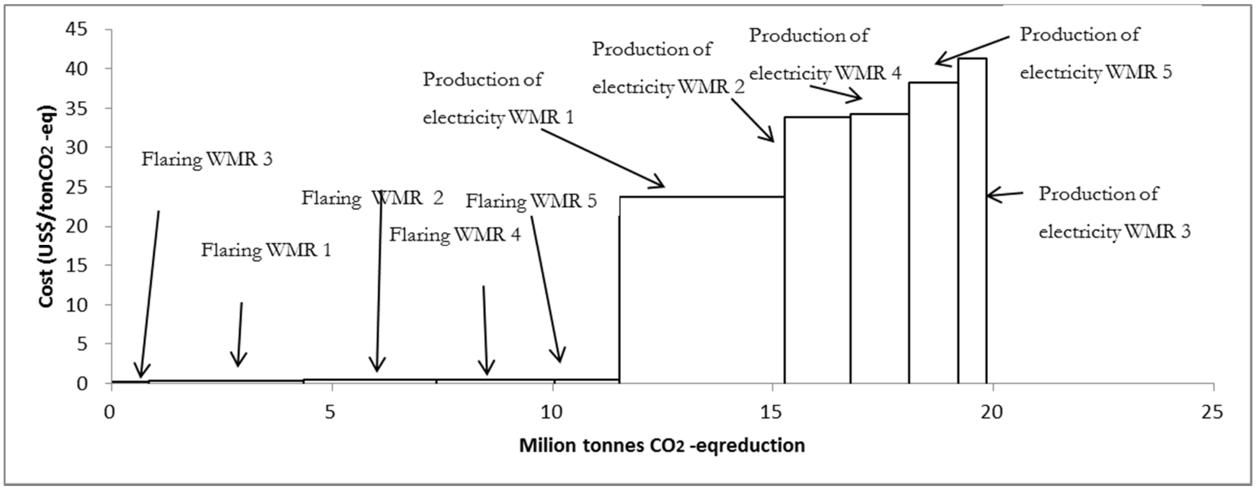


Figure 22. Ratio between the costs and emission reductions for second scenario

The analysis of the costs has shown that emission reduction per ton of CO_2 eq. are higher (23.73 US$/t CO_2 eq. reduced for WMR 1 - 41.26 US$/t CO_2 eq. reduced for WMR 3) than costs for composting. The impact of the sold electricity reduces the unit price for this scenario. The costs for flaring are the same for all the scenarios.

E.7 THIRD SCENARIO

The annual GHG emissions generated by closure of existing landfills in all regions and flaring, MBT with anaerobic treatment – anaerobic digestion with electricity production at five new regional landfills and additional RDF treatment at Drisla landfill (WMR1) are presented on the next Figure 23:

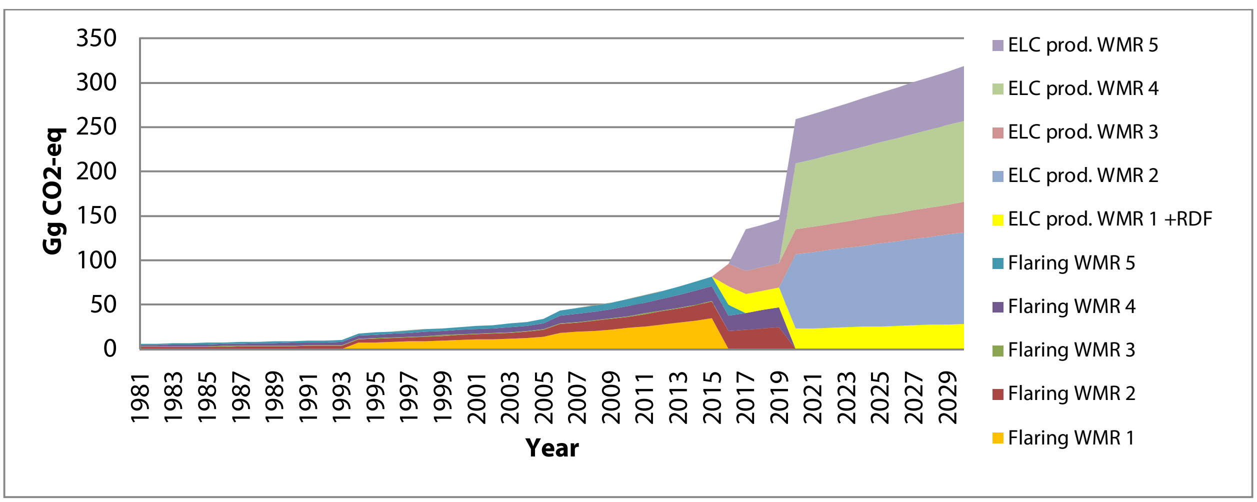


Figure 23. Emissions of CO_2eq in the third scenario by years

The third scenario assumes that all existing landfills will install a system for gas extraction and flare and the five new regional shall have an anaerobic treatment with option of producing electricity using, and landfill will install a system for RDF to be used by Cement factory TITAN AD Skopje or another company that has a furnace at high temperature near Skopje. RDF technology assumes that the remaining waste is studied (34%) and will burn. Due to lack of information on technology and emission reduction potential from RDF, it is assumed that this technology will reduce the same amount of emissions as flaring.

Here we have the lowest emissions from all the scenarios (319 Gg CO_2 eq. for 2030). The total emission of GHG gases for this scenario is 4,692 Gg CO_2 eq. with the highest total emission reduction of 21,987Gg CO_2 eq.

On the next Figure 24 it is presented the ratio between the costs and emission reduction:

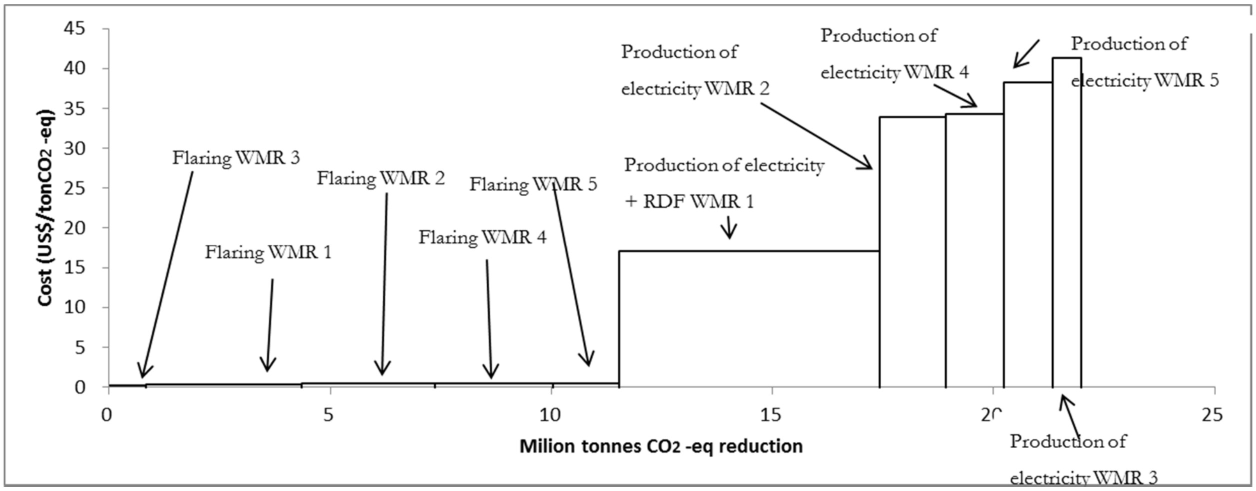


Figure 24. Ratio between the costs and emission reductions for third scenario

The third scenario has the same unit prices as second scenario with exception of WMR 1 where the costs in the second scenario are 23.73 US$/t CO_2 eq. reduced but the WMR 1 in third scenario has unit price of 17.06 US$/t CO_2 eq. reduced. The introduction of RDF production has positive impact on the costs and emission reductions. All these Figures can be seen in Annex 2.

E.8 FOURTH SCENARIO

The annual GHG emissions generated by closure of existing landfills in all regions and flaring, MBT with aerobic treatment – composting at five new regional landfills and additional RDF treatment at Drisla landfill (WMR1) are presented on the next Figure 25:

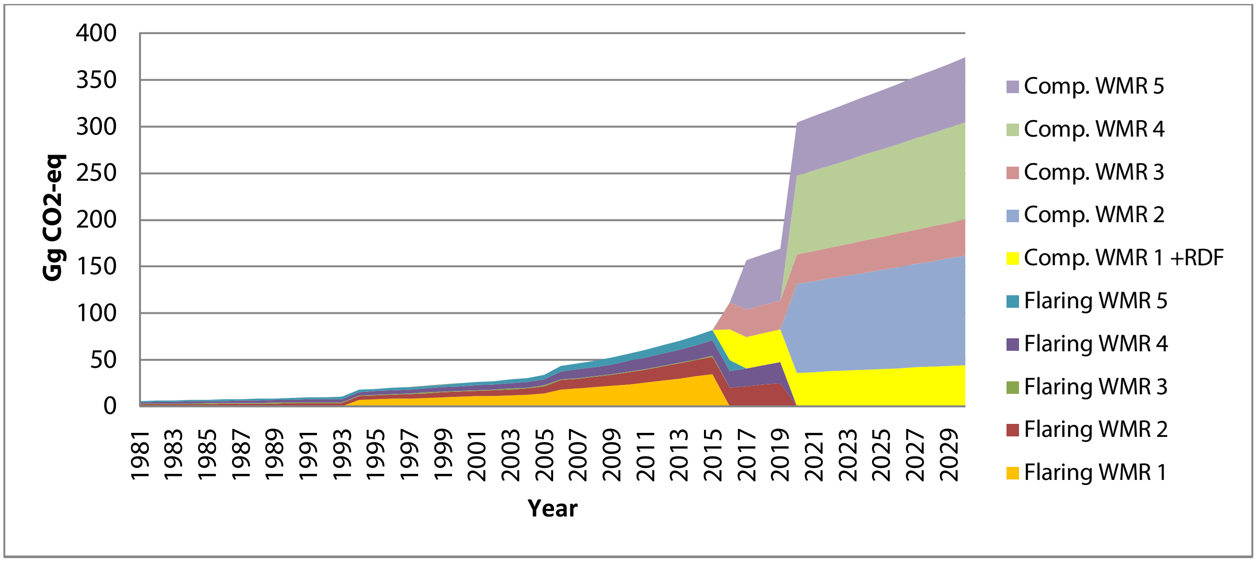


Figure 25. Emissions of CO_2eq in the fourth scenario by years

The fourth scenario assumes that all existing non-compliant landfills will install a system for gas extraction and flare and the five new regional landfills will be open to the option of composting waste. On Drisla landfill will be installed RDF system and the products will be used by Cement factory TITAN AD Skopje or another company that has a furnace at high temperature near Skopje. The GHG emissions in this scenario are between second and third scenario (374 Gg CO_2 eq. in 2030). The total emission of GHG gases for this scenario is 5,328 Gg CO_2 eq. with total emission reduction of 21,351 Gg CO_2 eq.

On the next Figure 26 it is presented the ratio between the costs and emission reduction:

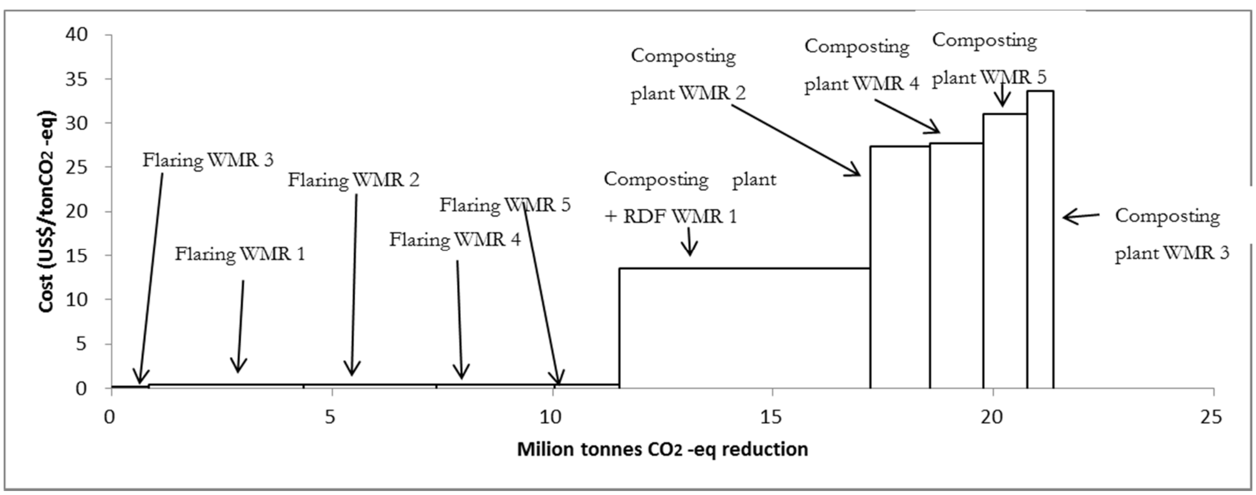


Figure 26. Ratio between the costs and emission reductions for fourth scenario

The costs are lower than the previous two scenarios (from 13.56 US$/t CO_2 eq. reduced to 33.59 US$/t CO_2 eq. reduced) which means that this scenario has the best ratio between the economic and environmental benefits.

E.9 RESULTS OF THE ANALYSIS

Results from the cost-benefit analysis of each scenario, including investment and operational costs and expected GHG emission reduction in each WMR are presented below:

The investment costs for each WMR and for all scenarios are presented on the Table 23:

Table 23.Investment costs by each WM region and scenario

Scenarios	WMR(s)	Mill. 2012 US$
Reference	WMR 1	9.77
	WMR 2	8.58
	WMR 3	2.85
	WMR 4	7.60
	WMR 5	5.12
First scenario	WMR 1	74.41
	WMR 2	42.87
	WMR 3	22.14
	WMR 4	38.40
	WMR 5	35.28
Second scenario	WMR 1	97.88
	WMR 2	56.55
	WMR 3	29.17
	WMR 4	50.60
	WMR 5	46.52
Third scenario	WMR 1	109.52
	WMR 2	56.55
	WMR 3	29.17
	WMR 4	50.60
	WMR 5	46.52
Fourth scenario	WMR 1	86.05
	WMR 2	42.87
	WMR 3	22.14
	WMR 4	38.40
	WMR 5	35.28

On the Table 24 there are presented total investment costs for implementation of all scenarios including reference scenario.

Table 24. The total investments costs by scenarios

Investment costs	Mill. 2012 US$
Reference	34
First scenario	213
Second scenario	281
Third scenario	292
Fourth scenario	225

Normally, the reference scenario has the lowest costs and the third scenario has the highest investment costs which refer on highest (reference scenario) and lowest (third scenario) GHG emissions.

On the Figure 27 the costs for implementation of each scenario are presented (related to Table 24). The minimum cost has the reference scenario (BAU scenario) and the highest cost has the third scenario (MBT with anaerobic digestion and RDF production).

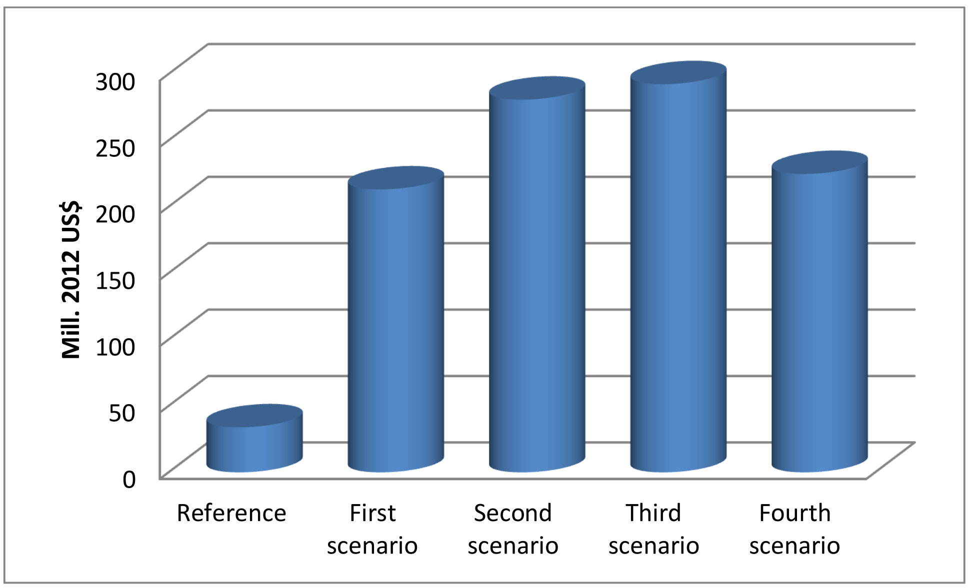


Figure 27. Costs for implementation of the scenarios

On the Figure 28 there are presented the generated emissions of each scenario. The worst case is reference scenario (with 26.679 Gg CO_2 eq) which is normal because there is no application of any technology. The best is third scenario (with 4.692 Gg CO_2 eq). Combination of anaerobic digestion and RDF production is the best technology taking in consideration the GHG emissions. The other three scenarios are closed to each other in GHG emissions which means that introduction of any technology will significantly reduce the BAU emissions.

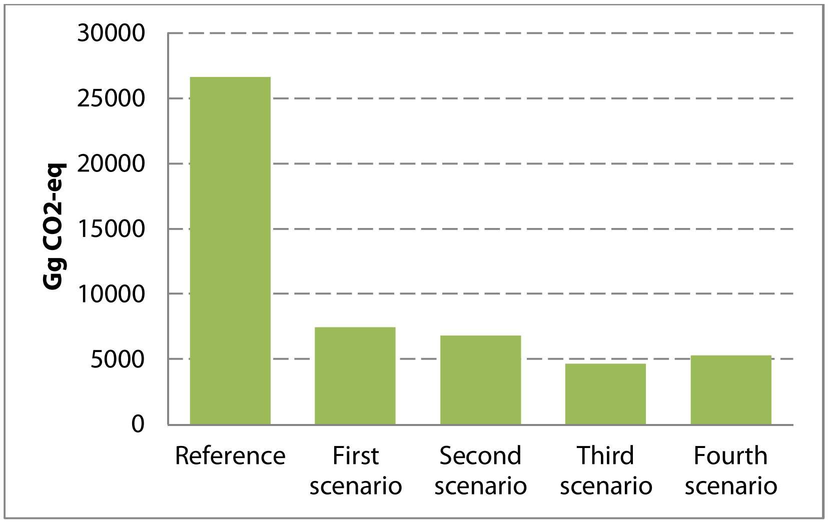


Figure 28. Generation of CO_2 eq by the scenarios

On the next Figure 29 there is presentation of the emission reductions caused by each scenario. The best scenario is third (the highest amounts of GHG emissions reduction correlated with the lowest amount of generated GHG gases shown in previous Figure 28) and the worst is the first scenario (technology of composting).

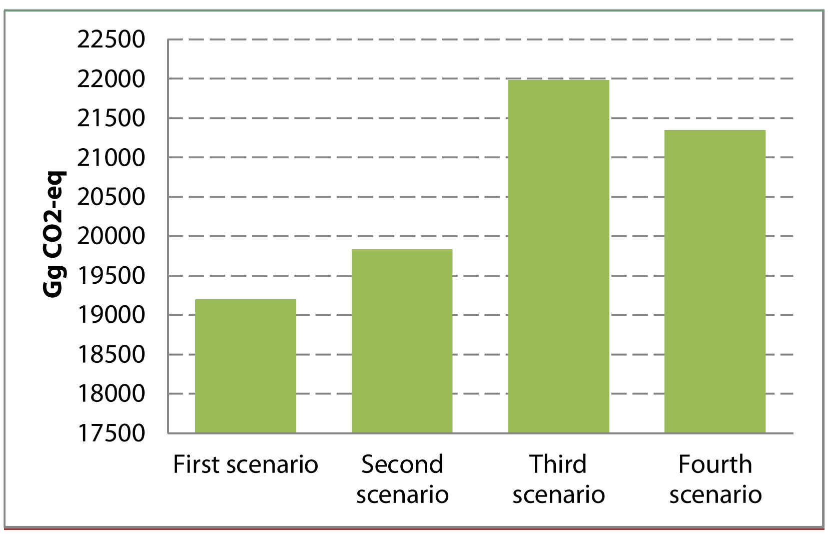


Figure 29. Reduction of CO_2eq by the scenarios

The summary of all above Figures is presented on Table 25.

Table 25. The summary of costs, emissions, reduced emissions and overall cost-effectiveness of all scenarios

Scenario	Costs Mill. 2012 US$	Expected emissions Gg CO2-eq	Cumulative emissions reduced Gg CO2-eq	Overall cost-effectiveness US$/kt CO_2 eq. reduced
Reference-BAU	34	26,679	/	/
First scenario	213	7,476	19,203	9.33
Second scenario	281	6,840	19,839	12.44
Third scenario	292	4,692	21,987	11.75
Fourth scenario	225	5,328	21,351	8.94

It can be concluded that fourth scenario has the best position even the reductions of GHG gases are not the best one. The difference of emission reductions between the third and fourth scenario is 636 kt CO_2eq, reduced, which is 3% of the best reducing scenario. But the overall costs of third scenario are 8.94 US$/kt CO_2eq, which is the best option. The third scenario has 11.75 US$/kt CO2eq which is 31% higher than fourth scenario.

So, the combination of landfill gas burning and MBT plant with selection of recyclables, composting of biodegradable waste and production of RDF intended for cement industry (only for WMR 1) is the best option for the country. If there are possibilities in the future to produce RDF for thermo power plants in other regions, the situation will be even better.

F. PRIORITIZATION OF THE MITIGATION STRATEGIES

The prioritization of the mitigation strategies should not be based only on two parameters like environmental and economic effectiveness which are presented in the previous chapter. The involvement of the stakeholders is very important because they can estimate whether the proposed strategies are good or not. Based on this way of thinking, the workshop for all the relevant stakeholders of the country was organized on 27.08.2013.

During the workshop the stakeholders estimated five criteria for prioritization of the mitigation strategies. The criteria and the results of the estimations are presented on Table 26.

Table 26. Estimation of the five criteria for prioritization of the mitigation strategies

Criterion		Weight
C1 Economic effectiveness		0,22
C2 Environmental effectiveness		0,22
C3 Feasibility		0,21
C4 Measurability		0,16
C5 Co-benefits		0,19
	Σ	**1**

The estimation confirmed that first three criteria have the main and equal importance.

After this work, the next form (Table 27) was given to the stakeholders to evaluate the value of mitigation strategies against each criterion and mark with 1 (lowest) to 5 (highest):

Table 27. Evaluation form of mitigation strategies against each criterion

Mitigation scenario	C1	C2	C3	C4	C5
Composting					
Anaerobic digestion					
Anaerobic digestion + RDF					
Composting + RDF					

The aim of this evaluation was to define the importance of each criterion towards the proposed mitigation strategies.

The result of this examination is presented on the next Table 28.

Table 28. Ranking of the mitigation scenarios

Mitigation scenario/Rank	Score	Rank
Composting	**3.78**	**2**
Anaerobic digestion	**3.45**	**4**
Anaerobic digestion + RDF	**3.76**	**3**
Composting + RDF	**4.35**	**1**

In the end the results of the workshop regarding the best mitigation strategy were the same with the results from the previous chapter which means that the chosen fourth scenario is real and implementable.

G. CONCLUSIONS

G.1 Summary of main findings

- The introduction of MBT technology as a measure for achieving the IPCC goals and EU standards is the best option for the country

- Inclusion of composting instead of anaerobic digestion in MBT technology is better solution especially if we take in consideration that there is no separate collection of biodegradable waste in the country. This is precondition for successful implementation of anaerobic digestion.

- If it is feasible the production of RDF in all WMR(s) will increase the level of GHG emission reductions

G.2. Policy recommendations

The expert recommendations for the policy are the same with the already accepted waste management policy expressed in the national waste management documents. Introduction of MBT technology with aerobic treatment of the waste will fulfill the requirements of EU directives related to waste management (no untreated waste on the landfills), save the landfill space, open new jobs and in the same time significantly reduce the GHG gases released in the atmosphere. It is also recommended to the MOEPP to assist the regions in finding of the available international financial sources.

G.3 Follow up

Follow up of this study should be investigation on waste composition for the whole country done on the scientific base and providing relevant data on types, quantities, generation, recycling and other information regarding the waste management in the country. This data will serve as a base for implementation of Tier 2 methodology by which there will be more accurate data on GHG emissions in the country.

References:

1) National Waste Management Strategy 2008-2020
2) National Waste Management Plan 2006-2012
3) National Waste Management Plan 2009-2015
4) Law on waste management
5) National environmental investment strategy
6) Feasibility study for Drisla (2011)
7) State of environment Report, MOEPP (2011),
8) Building capacities for implementation on EU Landfill directive, closure of non-compliant landfills and inspection, MOEPP (2011)
9) Environment situation in the Former Yugoslav Republic of Macedonia, DG Internal Policies (2008)
10) Revised IPCC Guidelines (1996), Good Practice Guidelines, sector: Waste (2000) and IPCC Guidelines (2006)
11) Analysis of biodegradable waste treatment in order to reduce quantity of disposed waste, Bojana Tot et al, *32nd annual meeting of the international association for impact assessment* (2012)

12) Cost-effectiveness of GHG emission reduction measures and energy recovery from municipal waste in Croatia, Daniel Rolph Schneider, Mislav Kirac, Andrea Hublin, Energy 48 (2012), p. 203-211

13) ISWA paper “Approximate cost functions for solid waste treatment facilities”, authors: Konstantinia Tsilemou and Demetrios Panagiotakopoulos, 2006

14) Refuse Derived Fuel – Case Study of Waste as Renewable Resource