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Kosovo Scenario for Mitigation of Greenhouse Gas Emissions from Municipal Waste Management

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Abstract: Solid Waste Management activities have a direct impact on GHG emissions arising from waste. Aim of this study is to calculate emissions from current municipal solid waste management in Kosovo and propose different scenarios for mitigation of GHG emissions from waste management. The IPCC model and SWM-GHG Calculator were used for the calculation of GHG emissions from different waste management options. The most favorable mitigation scenario was the Scenario 3, which considered an advanced solid waste management system. Having in the consideration the current situation, needs for the future, technical infrastructure and financial cost, the most realistic scenario for Kosovo was improved recycling and disposal of waste to sanitary landfill. The assessment presented in this paper is based on data for the year 2016.

Keywords: GHG emissions; municipal solid waste; landfill; mitigation; scenarios; Kosovo.

1. Introduction

Urbanization, rapid economic growth, rise in community living standards and lifestyle changes of the urban population result in increased generation of solid municipal waste[1),2)]. Before 2000, waste services from urban areas in Kosovo were not developed and most of the solid waste was deposited at unmanaged landfills. During the last two decades waste disposal infrastructure has improved with a shift from open dumping and unmanaged landfills to sanitary managed landfills. This improvement in waste collection service has led to increased amounts of waste disposed in landfills. However, the waste collection, separation, recycling and disposal infrastructure is not yet sufficient to serve the entire Kosovo territory. Actually, about 70% of total generated solid waste is disposed in sanitary landfills[3)]. As in other countries of the world, also in Kosovo the waste disposal sites are considered as common anthropogenic sources of greenhouse gases (GHG)[4),5),6)]. Methane (CH_4) emissions from landfills are increasing constantly due to increasing of population growth and increased waste generation. Landfills are ranking as the third-largest anthropogenic CH_4 source[7)]. CH_4 emissions from managed landfills accounts for 1.8% of total European Union GHG emissions in 2011, although there has been a decline by 47% between 1990 and 201. Reduction of the amount of biodegradable waste to landfills by 53% was a main driving force of CH_4 emission reduction[8)]. The GHG emissions from waste management in Kosovo represent around 4% of the total GHG national emissions[9),10),11)].

The total amount of waste generated in Kosovo in 2016 was estimated at 472,648 ton /yr, based on the resident population and per capita/day waste generation (1,798,506 residents' inhabitant's x 0.72 kg waste generation per capita per day)[12),13)].

2. Materials and methods

2.1. Location of the study area

The study was conducted in the Kosovo territory during 2017-2018, using relevant data on municipal solid waste management from central national institutions.

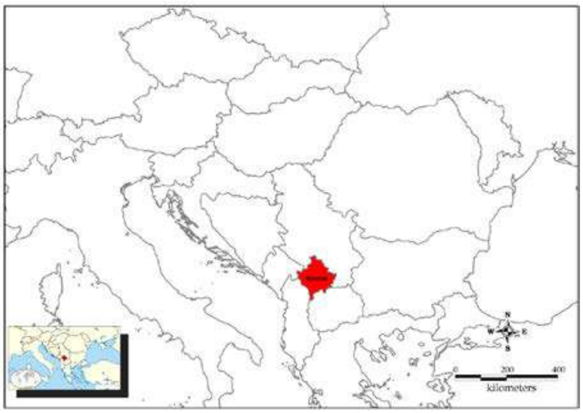

Fig. 1: Position of Kosovo in the map of Europe

2.2. Intergovernmental Panel on Climate Change 2006 Method

The IPCC Guidelines present methodology for the compilation of GHG inventory through empirical calculation. The guidelines include methodology for the calculation of GHG emissions from municipal solid waste[14),15)]. The IPPC 2006 software and IPCC Guidelines have been used for quantification of CH_4 emissions from waste management sector in Kosovo, using relevant data from relevant institutions.

The IPCC default method for calculation of methane emissions from waste based on the equation:

Methane Emissions = *Total amount of waste generated * Fraction of waste being disposed * Correction factor of waste fraction that generates methane gas for sanitary landfill * Fraction of biodegradable organic carbon * Fraction of biodegradable organic carbon that is readily available for degradation * Fraction of methane in biogas *16/12-R-Recovered CH_4)*(1-OX- Fraction of methane gas that is oxidized to carbon dioxide).*

2.3. Solid Waste Management Green House Gas (SWM-GHG) Calculator

The SWM-GHG Calculator is a tool for calculating of GHG emissions in Solid Waste Management. The Calculator developed by IFEU Institute allows for the estimation, calculation, and comparison of GHG emissions for different waste management policies at the first phase of the decision-making process[16)].

This method was used for the development of 4 scenarios in order to compare GHG emissions arising from different solid waste management options in Kosovo. Additionally, the SWM-GHG Calculator provides useful information and guidance on the costs of the planned policies or strategies with different waste management methods. In general, the calculation method used in the SWM-GHG Calculator follows the hierarchy of the waste management based on the Life Cycle Assessment (LCA) methodology. The calculator estimates the emissions of all types of waste management and calculates the total GHG emissions in CO_2 eq; include also all future emissions caused by treated waste streams[17)].

This method corresponds to the "Tier 1" approach described in IPCC 2006. In addition, the method allows creation of different emissions projections to archive the effects of changes in practice of waste management, such as increased use of sanitary landfills, waste recycling, or CH_4 recovery[18)].

Using the SWM-GHG Calculator, four different waste management systems have been calculated and compared.

2.4. Description of the scenarios

The Status Quo: Presents current situation of waste management in Kosovo, where limited sanitary waste management landfills are currently available. Different types of waste are treated and recycled by informal informal sector. Regular waste collection services do not yet operate in all municipalities and therefore do not yet cover the entire territory. Currently, 20% of the waste is dumped in unmanaged and uncontrolled landfills, 60% of the waste is disposed in sanitary landfills under semi-aerobic conditions without gas collections, 15% of waste is scattered and 5% is open burned.

Scenario 1: Improved recycling and disposal of waste: This scenario allows a higher recycling rate of waste streams, and partially collected and composted of organic waste. The waste is mainly disposed of to sanitary landfill with an efficiency of gas collection system up to 50%, used for electricity generation. Of the remaining municipal waste 10% is scattered, 2% is open-burned and 3% is disposed of in wild dumpsites, assuming that not all the rural areas have access to the sanitary landfill.

Scenario 2: Recycling and biological treatment of municipal waste*:* This scenario is the same as Scenario 1, however it is assumed that the municipal solid waste is no longer sent to landfill directly, but is pre-treated in a stabilization process, which minimizes the generation of methane emissions from landfill. Therefore gas collection is no needed. Waste recycling systems are similar to Scenario 1. In accordance with Scenario 1, 10% of the remaining residual waste is still scattered, 2% is open burned, and 3% is disposed of in wild dumpsites.

Scenario 3: Advanced solid waste management system: Represents an advanced management option. This scenario is categorized by high recycling rates for recyclable waste and high efficiency in the separate collection and composting of waste. Using mechanical, biological and physical methods for separation and treatment of the waste via stabilization producing a refuse derived fuel. All rural areas are part of the central waste management system.

3. Results and Discussions

The calculation of GHG emission from existing waste management practices, and development of different scenarios that are achievable, is an important step in development of policies for mitigation of GHG emission from Waste Management[19)].

GHG emissions for Status Quo

The results of GHG emissions for Status Quo scenario which represents the current situation on waste management are shown in Figure 2. The figure shows that total net emissions of GHGs from status quo was estimated at 537.5 Gg CO_2 eq/yr. Total emissions from disposal activities are estimated at 571.2 Gg CO_2 eq/yr, whereas the GHG emission reduction due to recycling were estimated at 33.7 Gg CO_2 eq/yr.

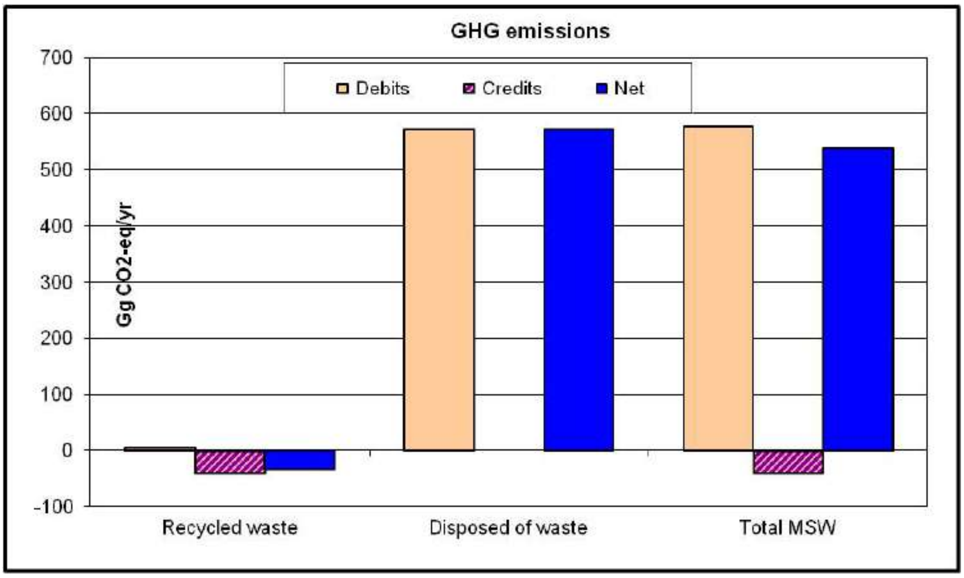

Fig. 2: GHG emissions for Status Quo

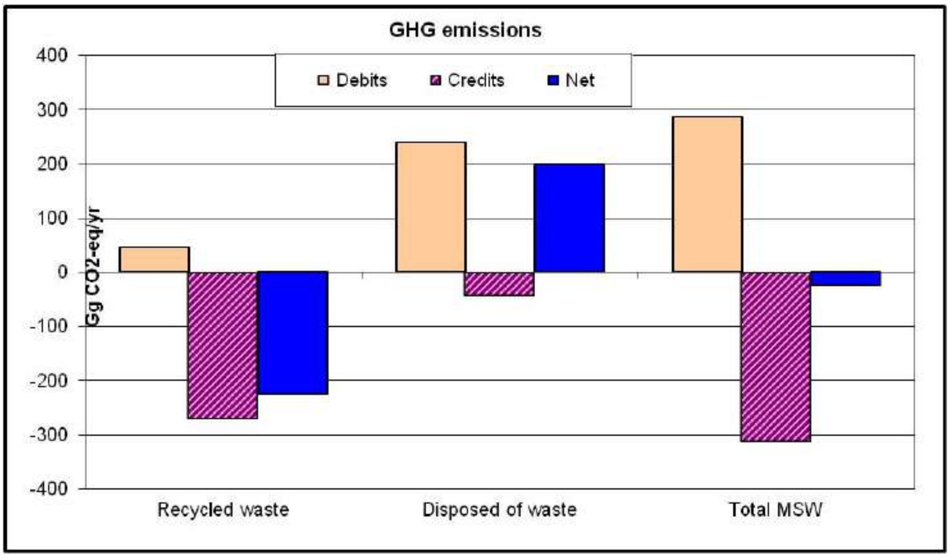

Fig. 3: GHG emissions for Scenario 1

GHG emissions - Scenario 1

GHG emissions estimates for Scenario 1, improved recycling and disposal of waste, are shown in Figure 3. The figure shows that total net emissions (net) from disposal activities are estimated at 199.5 Gg CO_2 eq/yr, whereas the total (net) GHG emissions reductions from recycling was estimated at 223.8 Gg CO_2 eq/yr. Total emissions (net) GHG reductions from this scenario were estimated at 24.3 Gg CO_2 eq/yr.

GHG emissions - Scenario 2

GHG emission estimates under Scenario 2, Waste management systems based on recycling and biological stabilization of remaining residual waste, are shown in Figure 4. The figure shows that total emissions (net) from disposal activities are estimated at 228.1 Gg CO_2 eq/yr, whereas the total (net) GHG emission reductions by recycling was estimated at 223.8 Gg CO_2 eq/yr. Total emissions (net) of GHG from this scenario was estimated at 4.3 Gg CO_2 eq/yr.

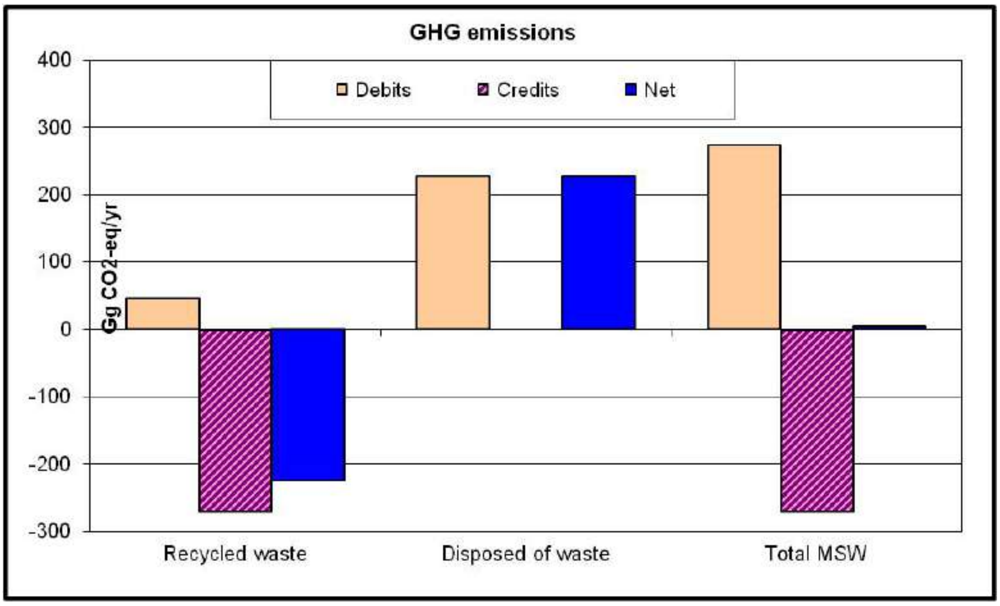

Fig. 4: GHG emissions for Scenario 2

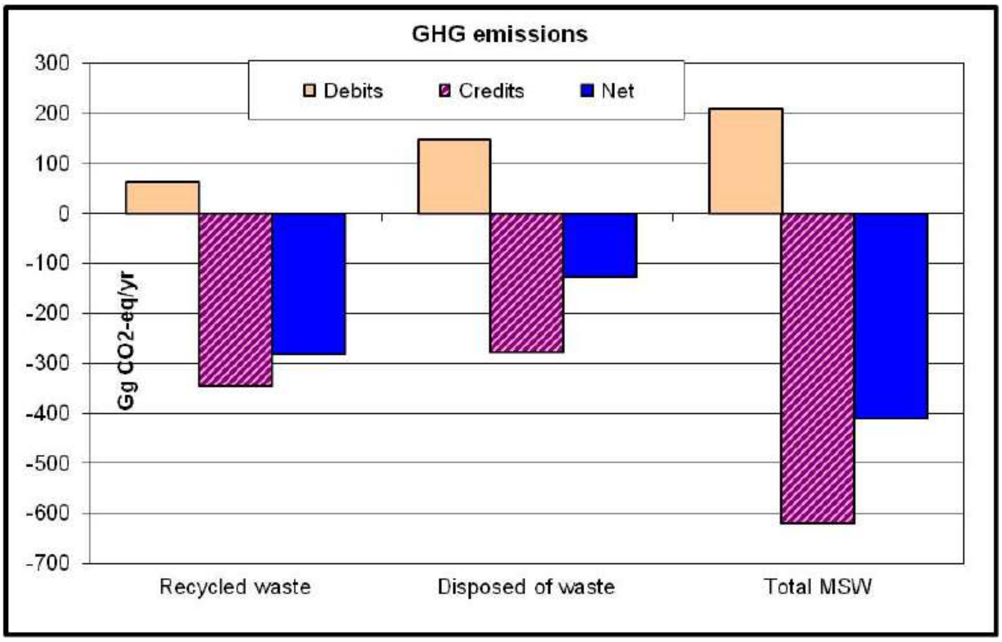

Fig. 5: GHG emissions for Scenario 3

GHG emissions - Scenario 3

GHG emission estimates for Scenario 3, advanced solid waste management system, are shown in Figure 5. The figure shows that total emissions reductions (net) from disposal activities are estimated at 127.7 Gg CO_2 eq./yr, whereas the total (net) GHG emissions reductions by recycling was estimated at 282.2 Gg CO_2 eq/yr. Total emissions (net) of GHG from this scenario were estimated at minus 409.9 Gg CO_2 eq/yr.

GHG emissions and cost for all scenarios

Figure 6 shows the estimated GHG emissions under all calculated scenarios illustrating the differences in debits and credits between scenarios. The emission reduction scenarios give emissions reductions 4.3 Gg CO_2 eq/yr for Scenario 2, -24.3 Gg CO_2 eq/yr, to Scenario 1 and -409.9 Gg CO_2 eq/yr to Scenario 3, compared to the 537.5 Gg CO_2 eq/yr of the Status Quo. Each scenario is considered one mitigation option compared with Status Quo.

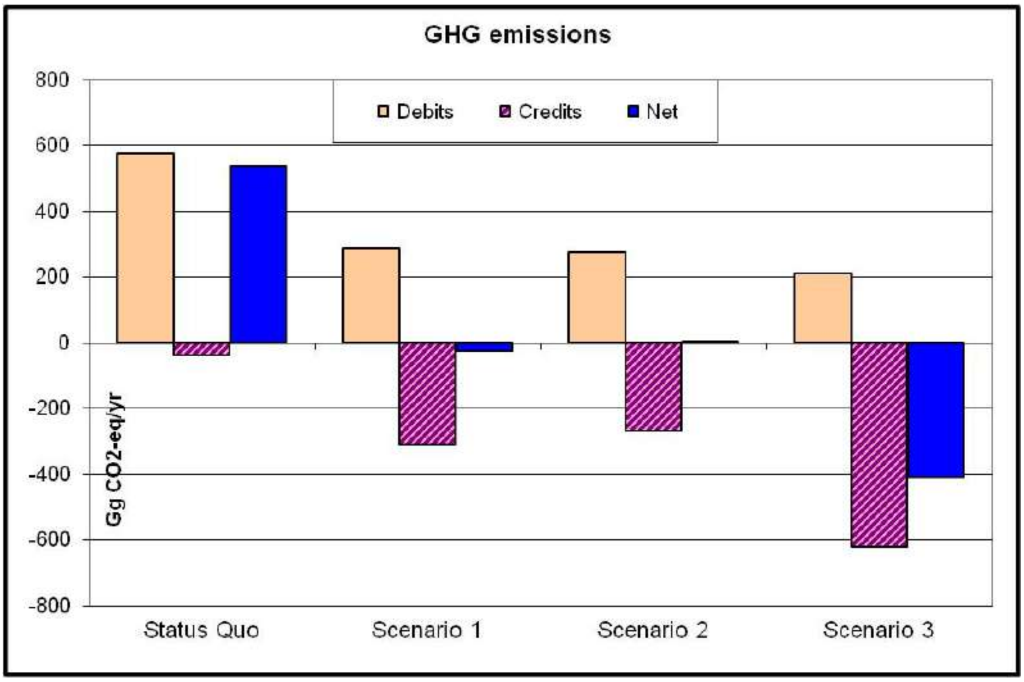

Fig 6: GHG emissions for all scenarios

Table 1 shows estimated total costs for all calculated scenarios. According to the cost calculations Scenario 1 was amounted to 7.2 million Euro/yr (8.15 million US$ equivalent), Scenario 2 was amounted to 8.8 million Euro/yr and Scenario 3 was amounted to 28.5 million Euro/yr, compared to 1.45 million Euro/yr of the Status Quo.

The mitigation costs of scenarios comparison to Status Qou are presented in the Table 2. The results show that the mitigation cost for Scenario 1 was amounted to 10 Euro/ton CO_2 eq/yr, Scenario 2 was amounted to 14 Euro/ton CO_2 eq/yr and Scenario 3 was amounted to 29 Euro/t CO_2 eq/yr.

The most favorable mitigation scenario was Scenario 3, advanced solid waste management system.

Taking into the consideration the current situation, needs for the future, technical infrastructure and financial cost, the most feasible and realistic scenario for implementation in Kosovo is found to be the Scenario 1. This scenario represents an improved recycling system and disposal of municipal waste to sanitary landfill, where a higher recycling rate can be realized. The scheme of the Scenario 1 is presented in Figure 7.

The integral part of this scenario is that collected gas is utilized for electricity generation. Energy recovery provides important energy sources and helps to improve the cost-efficiency of waste management, therefore are significant for the economic potentials of waste management systems[20),21)].

Collection of the methane gas represents one of the most cost effective methods to reduce greenhouse gas emissions from landfills[22)].

Collection of the gas during the operational lifetime of the landfill will capture between 60% and 90% of the methane emitted by landfill, depending on type of the design and operating system[23)]. Collecting landfill gas for energy use conserves other energy resources, reduces the rate of global climate change from GHG emissions, and provides financial benefits for the community[24)].

Increasing waste-to-energy capacity provides a significant potential for mitigation future methane emission from waste disposal[25)].

EU Landfill Directive guides help member state countries to achieve targets on greenhouse gas emissions reductions, through methane recovery and diversion of organic municipal waste from landfills[26)]. It's calculated that 1 ton of waste is equivalent to 670 kWh of electricity generation. As well 10% of the electricity produced is spent of waste treatment. The cogeneration energy from landfills would be suitable for Kosovo for district heating systems[27)].

Key mitigation strategies and measures projected to be commercialized before 2030 in the waste management are landfill CH_4 recovery, energy recovery from waste incineration, waste composting, improvement of the wastewater treatment plans, recycling of the waste streams, and minimisation of the waste generation, to optimize CH_4 oxidation[28)].

Table 1: Total cost for all scenarios (Euro/yr)

	SQ Euro/yr	S 1 Euro/yr	S 2 Euro/yr	S 3 Euro/yr
Recycled waste	50,464	444,851	444,851	619,443
Composted organic waste	0	229,600	229,600	459,201
Municipal waste to landfill/dumpsites without gas collection	1,404,723	0	0	0
Municipal waste to sanitary landfill with gas collection	0	6,521,606	0	0
Municipal waste to sanitary landfill	0	0	8,152,007	0
Mechanical, biological and physical waste co-processing	0	0	0	27,437,238
Total	1,455,188	7,196,057	8,826,458	28,515,881

Table 2: Mitigation cost for all scenarios (Euro/yr)

	SQ	S 1	S 2	S 3
Total GHG in Gg CO2 eq/yr	537.5	-24.3	4.3	-409.9
Total costs in eq/yr	1,455,188	7,196,057	8,826,458	28,515,881
Difference GHG compared to SQ in ton CO2 eq/yr	0	-561,907	-533,241	-947,486
Difference costs compared to SQ in eq/yr	0	5,740,869	7,371,270	27,060,694
Mitigation cost in euro/t CO2 eq/yr	-	10	14	29

Fig. 7: Scheme of the Scenario 1

Collection of the gas during the operational lifetime of the landfill will capture between 60% and 90% of the methane emitted by landfill, depending on type of the design and operating system[23]. Collecting landfill gas for energy use conserves other energy resources, reduces the rate of global climate change from GHG emissions, and provides financial benefits for the community[24]. Increasing waste-to-energy capacity provides a significant potential for mitigation future methane emission from waste disposal[25].

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Alternative energy sources are potential sources that can increase the level of energy production in a national scale and provide appropriate standards in the protection of the atmosphere and the entire natural environment against pollution as well as to create new jobs[29)30)].

A practical example of alternative energy technologies in the Kosovo is use of solid waste as energy recourse. Some of pilot projects for implementation in Kosovo municipalities may include installations of plants for biological and physical treatment of solid waste, treatment of organic waste and plants for recycling of plastic waste[31)].

The issue of climate change is inevitable and must be addressed sustainably and appropriately[32)]. Climate change can be limited by suitable adaptation and mitigation measures creating public awareness from various institutions local, regional, national and global levels[33)].

The measures for mitigation of climate change should be interconnected with the green economy model and sustainable development projects. The Western Balkans countries should be oriented to adopt national policies that encourage a green economy, sustainable development and climate change adaptation projects[34)]. Solving the issue of PET recycling, and reducing the PET that ends in the landfills, would increase the lifetime of the landfills for 5 to 10 years[35)].

4. Conclusions

Taking into account the current waste management system in Kosovo and possibilities for improvement, 3 scenarios were proposed. Estimation of the reduction of the GHG emissions, and cost of each scenario were calculated. Based on the results the most favorable scenario was proposed for implementation in further national policies on waste management and climate change mitigation.

The method used for estimation of the GHG emissions from different scenarios helps to identify mitigation policies, measures, instruments and opportunities for GHG reductions, using waste treatment technologies, and therefore has a significant potential to provide benefits from methane gas collecting from landfills and energy production.

An advanced waste management system is the most appropriate way to address the reduction of GHG emissions from the waste sector, including strategies and measures oriented to landfilling with gas recovery, alternative technologies for the solid waste composting and waste treatment.

Moreover, principles of circular economies for solid waste, including waste prevention, waste minimization, material recovery, recycling and re-use represent a potential opportunity for indirect reduction of GHG emissions through reducing the need for raw material consumption and energy demands from fossil fuels.

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