

Environmental and Economic Assessment of GHG Emissions Mitigation through Improved Waste Management in Jordan

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Introduction

Jordan, as a signatory to the Paris Agreement, is committed to reducing greenhouse gas (GHG) emissions. In 2017, total emissions were 32,646.79 Gg CO₂eq, with the waste sector contributing 4,046.37 Gg CO₂eq, making it the second-largest source after energy (Jordan Ministry of Environment, 2022). Solid waste generation reached 3.7 million tonnes in 2020, increasing at 5% annually (Jordan Ministry of Environment, 2022). Dumping and landfilling are the dominant disposal methods that are driving sectoral emissions. Although no national waste characterization study has been conducted, estimates suggest that 54% of waste is biodegradable, while recycling rates remain low (7-10%), primarily driven by the informal sector (Abu Qdais et al., 2019). To improve Solid Waste Management (SWM) and reduce emissions, Jordan plans to close dumpsites, develop sanitary landfills with gas collection, generate electricity from landfill gas, and promote composting. By 2030, at least four composting plants with a combined capacity of 200 tonnes per day are expected to be operational. This paper aims to evaluate waste management strategies in Jordan to improve the system and reduce GHG emissions cost-effectively.

Methodology:

This study assesses waste sector emissions using the SWM-GHG calculator (ifeu, 2023) and evaluates if Jordan can meet its targets. The tool applies a life cycle assessment (LCA) approach with four data input sections, namely waste generation and composition, recycling (baseline vs. alternative scenarios, including composting and biogas utilization), treatment and disposal (landfill operations, MBT, and gas efficiency), and cost assessments.

Three alternative scenarios were compared to the 2017 baseline using national data and expert evaluations. Scenario 1 (S1) represents current conditions in 2025, assuming composting facilities operate at full capacity. Scenario 2 (S2) reflects a near-future scenario where the second largest landfill in the country (Al-Akeeder) is upgraded to sanitary standards, and some open dumps are converted into controlled landfills. Scenario 3 (S3) includes mechanical-biological treatment (MBT) to recover recyclables and stabilize organic waste before disposal, aligning with the ongoing construction of a 300-tonne-per-day MBT facility in Amman. All scenarios assume proper landfill coverage with a 10% oxidation rate and methane recovery at 25%, considering that excessive organic waste can clog gas collection systems.

Table 1. Assumptions for Scenario Development in the LCA Tool

Waste management options			Status Quo	Scenario 1	Scenario 2	Scenario 3
Dry material (recycling)	Paper, cardboard		3%	3%	3%	3%
	Plastics		6%	6%	6%	6%
	Glass		0%	0%	0%	0%
	Ferrous metals		1%	1%	1%	1%
	Aluminum		0%	0%	0%	0%
Organic waste (recycling)	Food waste		0	4%	4%	4%
	Garden and park waste		0	2%	2%	2%
Type of primary waste treatment and disposal	Wild dumps/unmanaged disposal site		100%	25.0%	5.0%	5.0%
	Controlled dump/landfill without gas collection		0	25.0%	15.0%	15.0%
	Sanitary landfill with gas collection		0	50.0%	80.0%	52.0%
	MBT aerobic + further treatment		0	0	0	25%

For the cost analysis, we opted for software-generated values and used available data. The cost of sanitary landfilling in Amman is 41% higher than that of the controlled dumpsite in Irbid (Abu Qdais et al., 2023). Since 20 euros per tonne is the maximum cost provided in the software for a controlled dumpsite, we adopted this value, while 34 euros per tonne was considered for the sanitary landfill. The estimated cost of waste pretreatment is 25 euros per tonne, and composting costs are 15 euros per tonne.

Results:

Baseline scenario net emissions were estimated at 3,305.48 Gg CO₂eq, 19% lower than Jordan's reported emissions. The results indicate that S1 leads to a 6% reduction, while S2 achieves an 11% reduction, though partial dumpsite closures temporarily increase emissions. In S3, emissions are reduced by 31%, assuming at least 28% of total waste is processed via MBT. A sensitivity analysis excluding composting and organic waste recycling (0%

diversion) showed reductions of 4% in S1, 10% in S2, and 30% in S3, confirming that organic waste diversion has a minimal impact compared to landfill upgrades and MBT. However, its influence is more significant in S1 and S2, where MBT is absent.

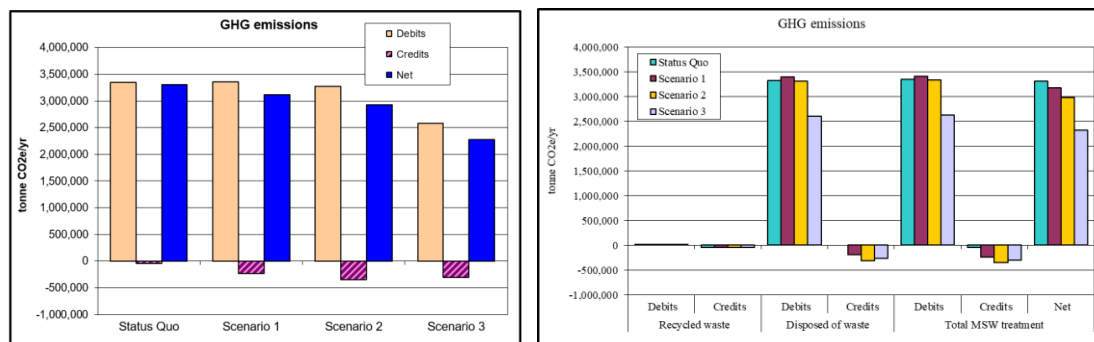


Figure 1. GHG emission from different scenarios

The comparison of mitigation costs per tonne of GHG emissions across the three scenarios versus the status quo scenario shows that while improving the waste management system increases total costs, it reduces the mitigation cost per tonne of CO₂ equivalent. Among the scenarios, the MBT-based third scenario incurs the highest total cost but achieves the lowest mitigation cost compared to the baseline scenario.

Table 2. results of cost analysis for different scenarios

	Scenario 1	Scenario 2	Scenario 3
Total costs in euro/yr	68,997,440	94,328,224	86,543,642
Difference GHG compared to SQ in t CO ₂ e/yr	-186,777	-379,303	-1,027,730
Difference costs compared to SQ in euro/yr	68,997,440	94,328,224	86,543,642
Mitigation costs in euro/t CO ₂ e	369	249	84

Discussion:

The solid waste sector in Jordan contributes to 12% of the total GHG emissions of the country. Such a percentage is higher than the global average of 5%. With international support, the country has improved SWM by upgrading dumpsites and promoting composting. The sanitary landfill in Amman generates an average of 106 MWh per day of electricity. Composting efforts have been less successful. Six pilot composting plants were established but mostly operate below full capacity. Diverting organic waste is crucial. In the short term, separate collection from households is unfeasible, but organic waste from markets and hotels presents a low-hanging fruit opportunity. Municipalities should be legally required to offer separate collection systems for such bulk generators.

Upgrading dumpsites to landfills has already increased financial pressure on the waste management system. Operating a sanitary landfill in Amman costs 41% more than a controlled dumpsite in Irbid. Composting remains a cheaper option to mitigate GHG, as waste currently undergoes no partial pretreatment before disposal. A scenario incorporating MBT at landfills could help Jordan achieve its 31% GHG reduction target, but MBT remains the most expensive option. In the short term, expanding composting plants and ensuring full operation using organic waste from commercial sources is a more feasible approach. In addition, conducting a national waste characterization study would provide critical insights into waste composition across sectors, improving national waste management strategies and enhancing GHG inventory accuracy. The findings of this study are relevant for policymakers, waste management authorities, and international funding agencies, providing data-driven insights into the economic and environmental trade-offs of different MSW strategies.

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