

Article

Techno-Economic Feasibility and Greenhouse Gas Emissions Assessment of Composting Versus Biodrying in Mechanical–Biological Treatment: Case Study in Alexandria, Egypt

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Abstract

Egypt's municipal solid waste (MSW) sector faces persistent challenges due to increasing generation rates, limited recovery, and a high organic fraction, motivating the selection of appropriate biological treatment options within Mechanical–Biological Treatment (MBT) systems. This study compares composting-based MBT and biodrying-based MBT for a case application in Alexandria, Egypt, using an integrated techno-economic and greenhouse gas (GHG) assessment. Discounted cash-flow modelling was applied using defined CAPEX and OPEX, along with revenue from recovered products. GHG accounting used documented emission factors and activity data against an unmanaged landfill baseline representative of current disposal practices. The system boundary covers waste reception and mechanical processing, biological treatment, process energy use, and residual disposal. Results show that composting achieves higher financial performance (NPV USD 2.55 million) than biodrying (NPV USD 0.99 million), while delivering a 48.5% reduction in net system GHG emissions relative to the baseline. Sensitivity analysis indicates that the comparative ranking is primarily driven by electricity prices, revenue assumptions, CAPEX, and baseline-related emissions parameters. Under the defined assumptions, composting is the preferred MBT biological pathway for the analyzed case, and interpretations are limited to the evaluated boundaries.

Keywords: municipal solid waste (MSW); mechanical–biological treatment (MBT); composting; biodrying; greenhouse gas emissions (GHG); sustainable waste management



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1. Introduction

Uncontrolled municipal solid waste management has become a significant driver of greenhouse gas emissions in rapidly urbanizing economies, positioning the waste sector as a central climate policy challenge in Egypt. Rapid urbanization and population growth have transformed MSW management from a logistical concern into a critical environmental issue. Egypt currently generates approximately 74,816 tonnes/day of MSW, a volume that continues to rise alongside industrial and economic expansion [1]. This increase has direct implications for national climate objectives, as the waste sector represents a major

source of greenhouse gas emissions, particularly methane. Over a 100-year time horizon, methane exhibits a global warming potential that is 27 to 30 times greater than that of carbon dioxide [2]. According to Egypt's First Biennial Update Report, greenhouse gas emissions from the waste sector increased by approximately 71 percent between 1990 and 2022, with solid waste disposal remaining the dominant contributor, rising from 9858.12 to 16,852.03 gigagrams of carbon dioxide equivalent [3]. These trends underscore the role of organic-rich waste disposal as a key contributor to national emission growth.

Egypt's recent waste sector reforms have created a policy-driven need to evaluate treatment-based alternatives to conventional disposal, particularly in large metropolitan areas. In response to mounting environmental and climate pressures, Egypt Vision 2030 defines a strategic transition toward sustainability and resource efficiency, reinforced by the Waste Management Regulation Law, Law No. 202 of 2020 [4,5]. This legislative framework shifts the waste sector away from disposal-oriented practices toward controlled treatment, material recovery, and private sector participation. Within this transition, Alexandria represents a priority case due to its large waste volumes, coastal vulnerability, and reliance on predominantly mixed waste collection. According to the Waste Wise Cities Tool, Alexandria generates approximately 5134 tonnes/day of municipal solid waste (MSW). Despite relatively high collection coverage ($\approx 84\%$), material recovery remains limited, at only around 21%, underscoring the need for enhanced treatment and recovery infrastructure [6,7]. These figures indicate that improvements in collection alone are insufficient to achieve policy objectives without parallel investments in treatment capacity.

Within mechanical–biological treatment systems, the selection of the biological pathway represents a strategic trade-off between climate mitigation and resource recovery objectives. The climate relevance of Alexandria's waste challenge is intensified by waste composition, as organic materials account for approximately 63 percent of the MSW stream [7]. This high organic fraction substantially increases methane generation potential under anaerobic disposal conditions, making biological treatment a central determinant of environmental performance. In contexts where source separation remains limited, mechanical–biological treatment is widely applied as a scalable solution for residual MSW [8,9]. Composting-based systems prioritize aerobic stabilization and nutrient recycling, producing compost-like outputs whose quality and usability depend on feedstock purity and process control [9]. In contrast, biodrying-based systems focus on moisture reduction and energy recovery, enhancing the calorific value of the combustible fraction to produce refuse-derived fuel when regulatory and market conditions permit [10]. These approaches reflect competing objectives (soil restoration versus fuel substitution) that must be evaluated under local technical and market constraints.

Despite the widespread application of MBT, there remains a notable lack of comparative, data-driven assessments that jointly evaluate the techno-economic performance and greenhouse gas mitigation potential of composting-based versus biodrying-based MBT under Middle Eastern and North African conditions characterized by high organic content, mixed waste collection, and evolving regulatory frameworks. In Alexandria, the parallel availability of mixed MSW and relatively clean green waste introduces additional design considerations that can significantly influence product quality and system performance [11]. This study addresses this gap by evaluating the technical, financial, and greenhouse gas performance of two mechanical–biological treatment configurations, namely mechanical sorting combined with composting and mechanical sorting combined with biodrying, for a facility processing 350 tonnes/day of MSW alongside 100 tonnes/day of green waste. By integrating localized data with international best practices, the analysis provides a policy-relevant and evidence-based framework to support sustainable waste management decision making in Egypt and comparable urban environments.

2. Materials and Methods

This study adopts a comprehensive approach to evaluate the feasibility of establishing a Mechanical–Biological Treatment (MBT) plant for municipal solid waste management in a residential–commercial area of Alexandria, Egypt. The assessment is structured around three key aspects: technical feasibility, financial feasibility, and environmental feasibility. The technical evaluation examines the effectiveness and operational performance of the mechanical sorting process combined with two alternative biological treatment pathways for the MSW & Green Waste: composting to produce stabilized material as compost-like output (CLO) and biodrying to produce refuse-derived fuel (RDF). The financial analysis assesses the capital investment, operational costs, and economic returns within the framework of Egypt's regulatory and market conditions. The environmental assessment considers the potential impacts and benefits of the treatment processes, focusing on waste reduction, emissions control, and resource recovery. These aspects will be addressed in detail in the following sections.

2.1. Technical Analysis

2.1.1. Regulatory Framework and Infrastructure

As part of the methodological foundation for assessing the technical and financial feasibility of a Mechanical–Biological Treatment (MBT) facility in Egypt, this study integrates the national regulatory and institutional context that governs municipal solid waste management. Egypt's waste management challenges and regulatory frameworks are integral to the study. Law No. 202 of 2020 provides the legal foundation for municipal solid waste management, outlining responsibilities, planning mechanisms, and support for infrastructure development [12]. The Waste Management Regulatory Authority (WMRA), established by Prime Ministerial Decree No. 3005 of 2015 [12], plays a central role in overseeing implementation, setting technical standards, and providing localized data, such as waste composition figures used in this study, to support accurate modeling of material flows and treatment process.

In addition to structural governance, the methodology incorporates key regulatory incentives and market-specific policies. These include mandates for the use of Refuse-Derived Fuel (RDF) in industrial sectors like cement manufacturing, as well as government-backed tax exemptions for waste management projects [13]. Factoring these elements into the financial analysis ensures that the technical and economic evaluation is grounded in Egypt's current policy landscape and investment environment.

2.1.2. Mechanical Sorting and Biological Treatment

Mechanical sorting represents the first stage of the MBT process, offering a cost-effective means of segregating mixed waste streams into recyclable fractions, such as metals, plastics, paper and organic materials. Automated sorting technologies, including conveyors, magnetic separators, and optical sorters, are employed to ensure high recovery rates [14]. The organic fraction, which represents about 63% of the incoming MSW, is directed to one of two MSW treatment pathways depending on the scenario analyzed: (i) composting, producing a stabilized material as compost-like output (CLO) suitable mainly for landfill cover or restricted land-reclamation uses, or (ii) biodrying, producing RDF with enhanced calorific value.

Composting is applied in two distinct contexts in this study as shown in Figure 1. For mixed MSW, aerobic treatment stabilizes the organic fraction, reducing mass, yielding CLO that meets the quality requirements for landfill cover material or low-grade applications but is not intended for direct agricultural use due to contamination risks. In parallel, a separate line treats clean green waste collected from parks and agricultural sources; this

feedstock undergoes shredding, windrow composting, and screening to produce compost class A, suitable for agricultural applications [15,16]. Conversely, biodrying utilizes microbial activity to reduce the moisture content of the organic fraction, producing Refuse-Derived Fuel (RDF) with calorific values of 3000–3500 kcal/kg for high-grade RDF. Biodrying is faster than composting, requiring less space and achieving moisture reductions of approximately 40% [17]. Figure 2 illustrates the MSW mechanical sorting with biodrying workflow and subsequent routing of recyclables, RDF, and rejects.

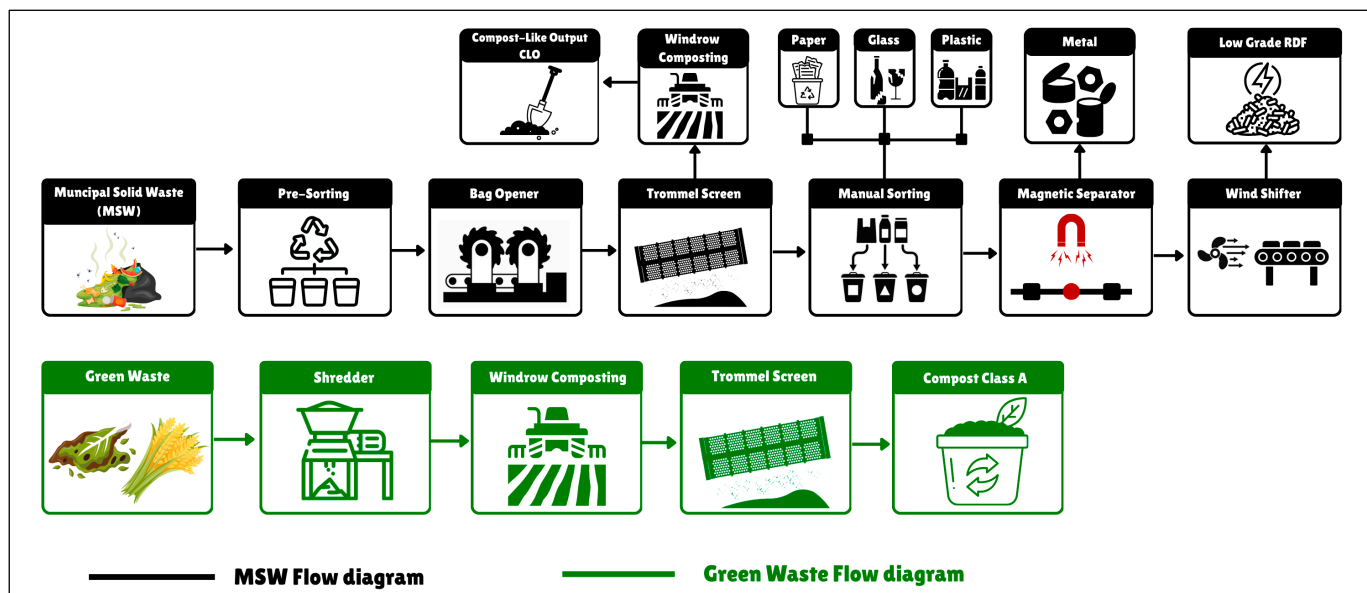


Figure 1. Flow diagram for composting processes. Source: Drafted by authors.

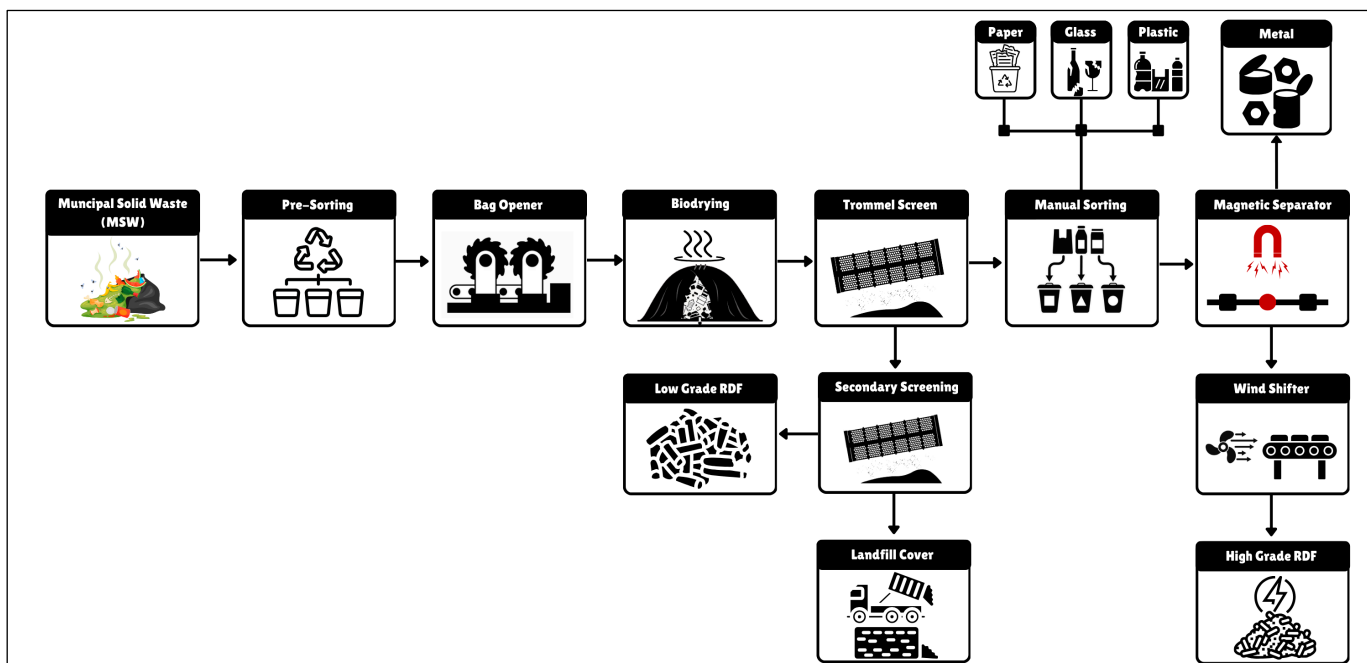


Figure 2. Flow diagram for biodrying processes. Source: Drafted by authors.

2.1.3. Site and Operational Assumptions

The proposed MBT plant is assumed to be situated on an 8-feddan site, strategically located to minimize transportation costs while complying with environmental regulations. Proximity to waste sources, transportation networks, and landfill sites is optimized to en-

sure efficient waste flow. The plant design includes facilities for waste reception, sorting, composting or biodrying units, and administrative operations. Operational assumptions include a plant efficiency of 85% and continuous operations (365 days/year), reflecting real-world performance benchmarks for MBT facilities [18]. It is further assumed that an efficient waste collection and transportation system is in place to deliver MSW from residential and commercial areas to the plant. Transportation distances, fleet requirements, and logistics operations are optimized to ensure uninterrupted waste flow and minimize operational costs.

2.1.4. Mass Balance and Process Design

The mass balance framework for the proposed MBT plant quantifies the input and output streams at each stage of waste processing, ensuring a comprehensive understanding of material flows. The plant is designed to process 350 tonnes/day of municipal solid waste (MSW) alongside 100 tonnes/day of green waste, with 63% organic content and 12% recyclables extracted through mechanical sorting. The comparative assessment is between MSW composting and MSW biodrying within the MBT system. At the same time, green waste is composted in a dedicated line in both configurations to produce Class A compost to avoid clean biomass loss. These outputs are evaluated for their market potential and environmental impact [19]. The mass balance model was parameterized using site-specific waste composition data and performance factors for MBT unit operations (mechanical sorting, windrow composting, and biodrying) derived from published MBT case studies and technical guidance documents [20–22]. Model verification focused on internal consistency and was performed by enforcing mass closure across all process blocks (incoming MSW and green waste, recovered recyclables, RDF fractions, compost/CLO, rejects, and process losses). Key output fractions were benchmarked against ranges reported for comparable full-scale MBT facilities treating mixed MSW, confirming that model outputs fall within reported values [21].

2.2. Financial Analysis

The financial evaluation employs discounted cash flow (DCF) analysis to assess the economic viability of two mechanical–biological treatment (MBT) configurations: mechanical sorting combined with aerobic composting and mechanical sorting combined with biodrying. The methodology follows international project finance standards established by the World Bank and International Finance Corporation for infrastructure feasibility studies [23], adapted to Egyptian regulatory and market conditions. The analysis spans a 12-year project lifecycle, consisting of a 2-year construction period during which capital expenditures will be disbursed, followed by a 10-year operational period during which the project will generate revenue and recover costs. This timeframe aligns with typical Egyptian waste management concession agreements while remaining conservative relative to the lifespans of physical infrastructure (20–35 years for civil works and buildings) [24].

All financial assumptions applied in the discounted cash-flow analysis are aligned with international guidance for infrastructure and Egyptian Public–Private Partnership (PPP) appraisal guidelines issued by the Ministry of Finance [24]. Capital and operational cost structures reflect MBT facilities of comparable scale and technology, as reported in recent international case studies and regional feasibility assessments. The real discount rate is derived from a nominal weighted average cost of capital (WACC) calibrated to Egypt's macroeconomic conditions, incorporating a CAPM-based cost of equity, sovereign risk premium, and after-tax cost of debt. Inflation effects are treated consistently using the Fisher equation (Full parameter values, sources, and derivation steps are provided in Supplementary Methods S1).

2.2.1. Cost and Revenue Estimation Methodology

Capital Expenditure (CAPEX) encompasses land acquisition, site infrastructure, buildings, machinery and equipment, vehicles, furniture and fixtures, and pre-opening expenses including design, licensing, and site preparation. Cost estimates derive from multiple sources:

- Vendor quotations for major mechanical equipment (imported biodrying system, composting machinery)
- Egyptian Central Agency for Public Mobilization and Statistics (CAPMAS) construction cost indices for buildings and infrastructure
- Real estate market surveys for peri-urban Greater Cairo land values

Operational Expenditure (OPEX) comprises raw materials, labor, utilities, maintenance, transportation, landfill disposal fees, and indirect administrative costs. Cost structures are based on:

- Raw materials: 14.9% of annual revenue
- Labor: 4.3% of revenue, supporting 85 full-time equivalent positions
- Maintenance: 1.4% of fixed asset value annually
- Utilities: 1.8% of revenue

These parametric relationships derive from benchmarking analyses of operational Egyptian waste treatment facilities and are adjusted for site-specific conditions including local labor rates, regulated energy tariffs, and regional input material costs [25].

Revenue Projections are structured around three product categories with distinct pricing mechanisms:

- Recyclable Materials (aluminum, ferrous metals, plastics, glass, paper and carton): Priced according to Cairo Metal Exchange quotations and negotiated offtake agreements with recycling industry participants [26,27].
- Refuse-Derived Fuel (RDF): Priced at USD 25/tonne equivalent based on cement industry alternative fuel market conditions.
- Compost Products (Class A agricultural grade and Compost-Like Output): Priced at USD 10/tonne and USD 3/tonne respectively, aligned with Egyptian Standard ES 8079/2023 quality specifications and prevailing organic fertilizer market rates [28,29].

2.2.2. Sensitivity Analysis Protocol

This study assesses the financial resilience of the MBT facility through a univariate sensitivity analysis calibrated to prevailing economic conditions in the Egyptian market. Variance bands of ± 10 percent and up to ± 20 percent were applied as structured stress tests within the financial model. The ± 10 percent range represents typical inflationary pressures on capital expenditures (CAPEX) and operating expenditures (OPEX), while the higher ± 20 percent range, applied selectively to revenues and utility costs, reflects historically observed volatility in recyclable material prices and potential adjustments to national energy subsidies.

The analysis evaluates seven distinct scenarios to examine the sensitivity of key financial indicators, including Net Present Value NPV, Internal Rate of Return IRR, Benefit–Cost Ratio BCR, and Payback Period, to these variations. The scenarios encompass isolated increases in CAPEX and OPEX, a combined inflationary scenario, and targeted cost escalations of up to 20 percent in labor, utilities, and maintenance. These assumptions explicitly address the risks associated with currency depreciation and the availability of imported spare parts. By varying each parameter independently while holding others constant, this analysis identifies the most critical risk factors and confirms the project’s resilience against the economic instability characteristic of the region.

2.3. Environmental Impact and GHG Emissions Assessment

2.3.1. Greenhouse Gas Emission Calculation Methodology

The greenhouse gas (GHG) assessment framework is constructed based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [30], the GHG Protocol Corporate Standard [31], and the UNFCCC EXACT analytical tool [32]. All emissions are quantified in carbon dioxide equivalents (CO₂e) over a 100-year temporal horizon. In compliance with the IPCC Fifth Assessment Report (AR5), the Global Warming Potentials (GWPs) utilized are 34 for CH₄ and 298 for N₂O [33].

The assessment adopts an operational system boundary, extending from waste reception at the MBT facility to the production of stabilized outputs, including recyclables, refuse-derived fuel (RDF), compost-like output (CLO), and Class A compost. Included emission sources comprise: (i) Scope 1 emissions from on-site diesel combustion in loaders, tractors, and windrow turners; and (ii) Scope 2 emissions from off-site electricity generation associated with mechanical sorting, biological treatment processes, and ancillary facility operations. Avoided emissions are defined as the reduction in GHG emissions relative to a baseline scenario in which all incoming waste is disposed of in an unmanaged landfill without gas capture, consistent with IPCC default assumptions for mixed municipal solid waste in warm climates [30]. Avoided emissions account exclusively for methane emissions prevented through the diversion of organic waste from landfills. Downstream processes, including RDF combustion, infrastructure construction, and long-term soil carbon sequestration from compost application, are explicitly excluded from the system boundary to maintain methodological consistency across scenarios (Detailed equations, emission factors, and activity data are provided in Supplementary Methods S2). Model parameters are derived from a combination of IPCC default values and Egypt-specific National Inventory Reports (NIR), as summarized in Table S1.

2.3.2. System Boundary and Emissions Scope

The system boundary encompasses all operational processes from the receipt of mixed municipal solid waste (MSW) and green waste at the MBT facility through the generation of final treatment outputs (recyclables, RDF, Class A compost, and CLO). Included processes consist of waste transport from collection zones to the facility, mechanical sorting, biological treatment via composting and biodrying, operation of on-site mobile equipment, and electricity consumption within processing units and the administrative building.

In line with the GHG Protocol Corporate Standard, the study quantifies only Scope 1 and Scope 2 emissions. Scope 3 emissions are excluded, including upstream equipment manufacturing and facility construction, downstream RDF combustion in cement kilns, and long-term soil carbon sequestration or fertilizer substitution effects from compost application. The exclusion of Scope 3 may lead to underestimation of both positive and negative life-cycle effects: for composting, soil carbon sequestration and mineral fertilizer substitution would further improve its climate performance, whereas for biodrying, fossil fuel substitution in cement kilns would add additional GHG savings beyond the operational boundary. Because both pathways share similar sorting infrastructure and differ mainly in biological and downstream energy-use stages, the relative comparison between composting and biodrying remains robust, although absolute life-cycle impacts are conservative [34].

3. Results

3.1. Technical Evaluation

3.1.1. Regulatory Compliance and Implementation Feasibility

The feasibility of composting and biodrying facilities in Egypt was evaluated in accordance with Law No. 202 of 2020 and its Executive Regulations, particularly Articles 4, 5, 15,

24, and 30, which establish the national waste management hierarchy and treatment priorities. Article 4 prioritizes biological treatment, especially composting, for organic waste and sets technical requirements related to waste input control, odor and leachate management, and product quality. Article 5 promotes energy recovery from non-recyclable waste through biodrying to produce Refuse-Derived Fuel (RDF), supporting national policies aimed at reducing fossil fuel consumption in energy-intensive industries such as cement manufacturing. In contrast, Article 15 incentivizes cement plants to substitute coal with RDF. Article 24 provides fiscal incentives for waste treatment projects, including exemptions from customs duties and VAT on capital equipment, reducing capital costs by approximately 10% and improving project viability. In addition, Article 30 facilitates access to the National Waste Management Fund, enabling co-financing, grants, and public–private partnership models. The proximity of the Alexandria MBT facility to major cement plants ensures a stable RDF off-take market, further enhancing the technical and economic feasibility of biodrying within the national regulatory framework.

3.1.2. Overview of Composting and Biodrying Pathways

This study evaluates the feasibility of integrating composting and biodrying within a Mechanical–Biological Treatment (MBT) facility designed to process 350 tonnes/day of municipal solid waste (MSW) and 100 tonnes/day of green waste. Both composting and biodrying are biological treatment processes aimed at reducing landfill dependency and enhancing resource recovery; however, they differ significantly in terms of process intensity, energy demand, and environmental performance. In the composting pathway, the organic fraction of MSW undergoes aerobic stabilization using open windrow systems with periodic turning, which represents the prevailing operational practice in Egypt. Aerobic conditions are maintained through natural or passive aeration with limited mechanical assistance. Moisture control is required to sustain biological activity, resulting in an average water demand of approximately 60 L/day. Under these operating conditions, composting achieves a mass reduction of approximately 30–50% over a residence time of 6–12 weeks. The treated MSW organic fraction yields compost-like output (CLO), which is suitable for restricted applications such as landfill cover or land reclamation. In parallel, composting of green waste produces Class A compost suitable for agricultural use [35,36].

In the biodrying pathway, the organic fraction of MSW is treated in enclosed reactors equipped with fully controlled forced aeration systems. The process exploits microbial heat generation to enhance moisture evaporation, resulting in rapid drying over a typical processing period of 7–15 days. Biodrying does not require external water addition. Following biological treatment, the material undergoes mechanical separation to produce refuse-derived fuel (RDF) fractions. Depending on process configuration and input waste characteristics, RDF calorific values range from approximately 1500–1750 kcal/kg for low-grade fractions to 3000–3500 kcal/kg for high-grade fractions. Biodrying systems require higher electricity input due to intensive aeration and ventilation requirements. The two biological treatment pathways differ primarily in terms of residence time, aeration intensity, water demand, energy consumption, and spatial requirements. These technical differences form the basis for the comparative mass balance, financial, and greenhouse gas emissions analyses presented in subsequent sections [17].

3.1.3. Operational Challenges and Design Considerations

Operational challenges for composting include high land requirements, the need for adequate odor and leachate management systems, and sensitivity to climatic conditions that may affect microbial activity. Composting also requires regular turning of windrows with specialized machinery, increasing maintenance requirements. Biodrying's primary

operational challenges include higher energy demands for forced aeration, skilled labor requirements for process optimization, and potential emission controls to manage VOCs and particulates. The study emphasizes the importance of equipment reliability and robust staffing to address these challenges. The MBT facility design incorporates advanced mechanical sorting, ensuring high recovery rates for recyclables.

Alexandria generates over 5134 tonnes/day of MSW, with a composition that supports integrated waste treatment solutions, as shown in Figure 3. Approximately 63% of this waste stream consists of organic material, making it highly suitable for composting processes aimed at producing soil conditioners and reducing reliance on landfills. Additionally, 27% of the waste comprises non-recyclable combustible fractions, which are ideal for biodrying and the subsequent production of Refuse-Derived Fuel (RDF). The biodrying facility would not only align with national waste management priorities but also enhance resource recovery and support the energy needs of local industries, particularly cement plants seeking alternative fuel sources [7].

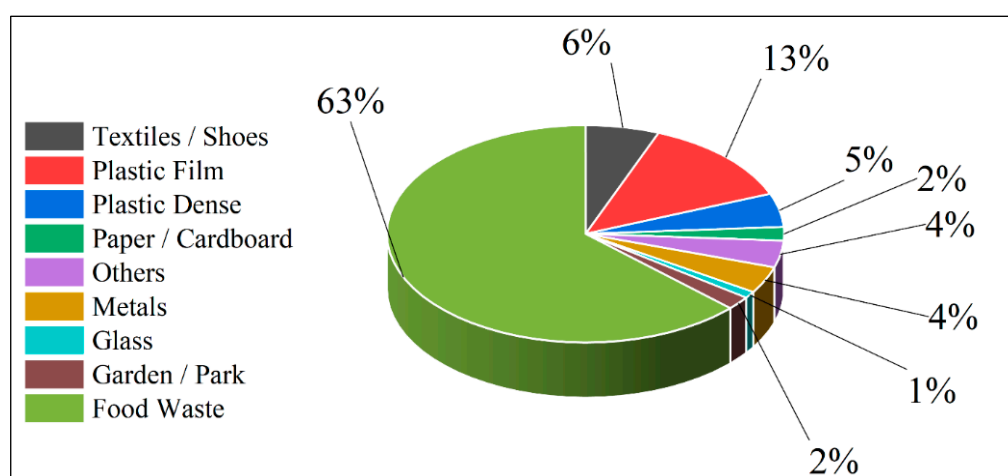


Figure 3. Waste composition of Alexandria's municipal solid waste [7]. Source: Drafted by authors).

The mass balance and process flow diagrams clearly illustrate the separation between the municipal solid waste (MSW) treatment line and the dedicated green waste composting line, as shown in Figure 4. In the MSW line (top portion of Figure 4), waste enters pre-sorting and mechanical separation steps, with approximately 63% of the input identified as organic material. This organic fraction is routed through windrow composting and trommel screening (15 mm), and yields around 41% stabilized compost-like output (CLO), which is primarily used for landfill cover, landscaping, or land reclamation due to quality restrictions. Throughout the MSW processing, there is a cumulative mass loss of 20% during composting and a 2% reject stream following trommel screening. Additional sorted MSW fractions include 12% recyclables (paper, plastics, glass, and metals) and significant portions channeled to low-grade RDF production (15%), as well as 22% non-recyclable residues that are further managed via wind shifting and disposal.

In the green waste line (bottom portion of Figure 4), clean biomass collected from parks and agricultural sites is first shredded, then subjected to windrow composting and trommel screening. This pathway results in a notable 30% mass reduction during composting, followed by a 2% reject stream after screening, ultimately producing about 68% high-quality compost suitable for agricultural and soil amendment applications. Figure 4 demonstrates that the parallel green-waste line is entirely distinct from the MSW line, ensuring that only clean green waste produces marketable Class A compost. At the same time, the MSW fraction yields CLO for non-agricultural use. This separation supports both effi-

cient landfill diversion from mixed MSW and safe nutrient recycling from green sources, in accordance with best practice and Egyptian regulatory standards.

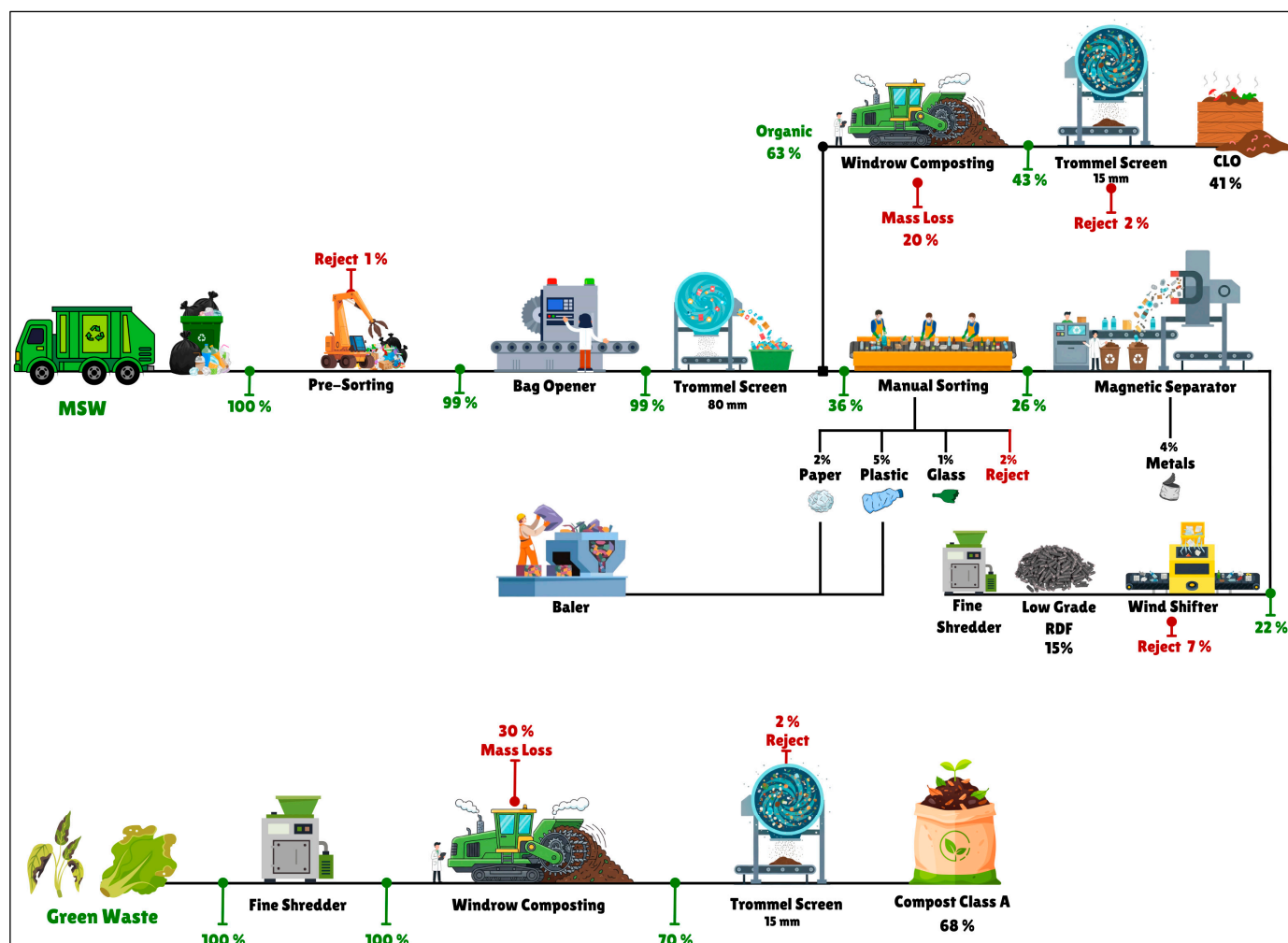


Figure 4. Mass Balance of MBT with composting (MSW line & Green Waste). Source: Drafted by authors.

The composting pathway generates high-quality by-products, producing approximately 680 kg of Class A compost per tonne of green waste and 410 kg of Compost-Like Output (CLO) per tonne of municipal solid waste (MSW) processed. This output supports agricultural sustainability by improving soil quality while also strengthening local market opportunities for organic soil amendments. In addition, the facility demonstrates efficient resource recovery performance by extracting approximately 12% recyclable materials and converting a substantial share of the organic fraction into stabilized compost products, while limiting landfill-disposed residues to less than 10% of the total input waste stream. These performance indicators highlight the project's substantial contribution to circular economy principles and align with Egypt's Vision 2030 objectives for sustainable waste management and resource efficiency.

In the biodrying pathway (as shown in Figure 5), the organic fraction of municipal solid waste (MSW) is first subjected to biodrying. This process rapidly reduces moisture using microbial heat and forced aeration. After biodrying, trommel screening, and additional mechanical separation, the process yields approximately 17% high-grade RDF and 13% low-grade RDF, both of which serve as alternative fuels, mainly for cement kilns and industrial energy markets. Manual and magnetic sorting during the process allow further recovery of valuable recyclables such as paper, plastics, glass, and metals. The proposed

processes produce RDF with the following properties in Table 1. The reported calorific values reflect the energy content of the RDF fractions under their processed conditions. The lower calorific value of the low-grade RDF is primarily attributed to its higher organic content. Previous studies have shown that RDF produced after mechanical separation and biological processing typically exhibits lower heating values within similar ranges due to the influence of waste composition and organic content, with lower values associated with higher organic fractions and less combustible material [37].

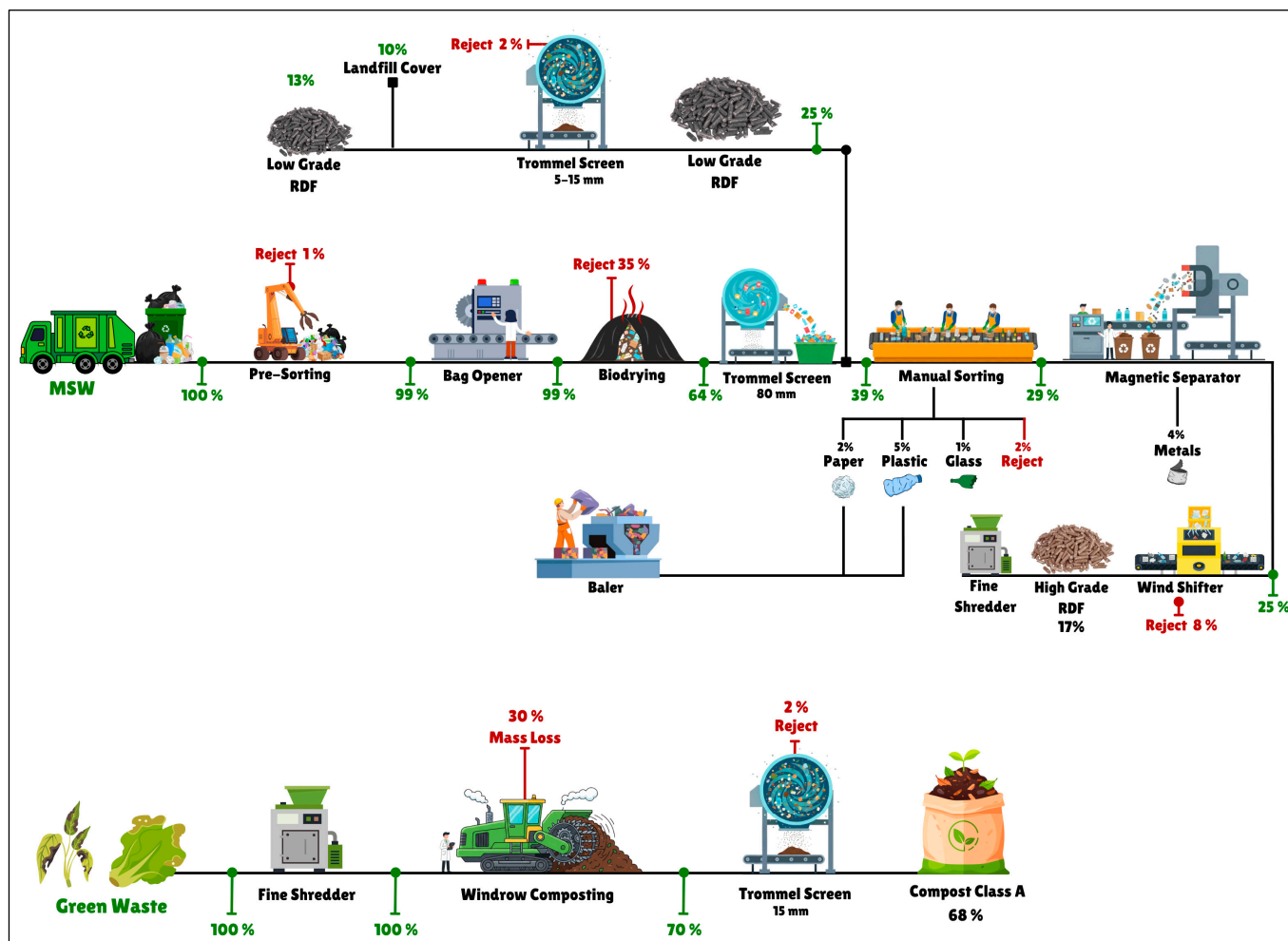


Figure 5. Mass Balance of MBT with Biodrying of MSW. Source: Drafted by authors.

Table 1. Parameters of RDF produced by the MBT.

Parameter	High-Grade RDF	Low-Grade RDF
Daily Quantity	17% of plant input	13% of plant input
Particle Size	50–80 mm	5–15 mm
Water Content	<30%	<30%
Calorific Value	3000–3500 Kcal/kg	1500–1750 Kcal/kg

This interpretation is consistent with municipal solid waste characterization studies conducted in Egypt, which report a dominant organic fraction and wide variability in calorific values depending on waste composition and moisture content. For example, characterization of MSW generated in Greater Cairo showed calorific values ranging from 4360 to 12,277 kJ/kg, reflecting the strong influence of organic content and material heterogeneity on energy potential. These findings indicate that organic-rich waste streams, when

subjected to limited separation or biological processing, are expected to yield RDF fractions with relatively lower calorific values, consistent with the low-grade RDF reported in this study [38].

Further support is provided by Egypt-based studies on RDF and biomass-derived fuel preparation for cement industry applications, which demonstrate that improved screening and removal of undesirable fractions significantly enhance fuel quality. In these studies, calorific values increased from approximately 3359–3620 kcal/kg in unscreened RDF and biomass mixtures to values as high as 3851 kcal/kg after optimized screening. This confirms that RDF fractions with limited screening or higher organic content exhibit lower calorific values, whereas more intensively screened fractions approach higher energy content suitable for industrial co-processing [39].

3.1.4. SWOT Analysis

The viability of composting and biodrying within the Egyptian context is evaluated through a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, as illustrated in Table 2. This strategic framework incorporates quantitative benchmarks and international insights to provide a systematic comparison of the two technologies based on their internal operational characteristics and external environmental influences. The SWOT analysis was conducted in strict accordance with the ISO 31000:2018 risk management framework [34], ensuring that strategic strengths, weaknesses, opportunities, and threats were evaluated through a systematic risk-based lens [40]. As demonstrated in the analysis, composting has several fundamental strengths, including its status as a proven technology with low greenhouse gas (GHG) emissions and the production of nutrient-rich compost. These attributes align with significant opportunities to support sustainable agriculture and contribute to a circular economy. However, composting faces notable weaknesses, such as high land requirements and sensitivity to weather conditions, while remaining vulnerable to threats related to odor resistance and leachate impacts.

Table 2. SWOT Analysis for composting and biodrying.

SWOT Category	Composting-Based MBT	Biodrying-Based MBT
Strengths	- Proven, widely implemented for organic stabilization - Produces nutrient-rich compost/compost-like output (CLO) - Lower methane emissions than landfilling - Supports nutrient recycling and circular economy [41]	- Produces RDF/SRF with higher calorific value via moisture reduction [10] - Shorter processing cycles compared to composting [42]
Weaknesses	- Large land footprint and long residence times - Sensitive to feedstock quality and climatic variation - Potential GHG/VOC emissions and odor if poorly managed [43]	- High energy input for forced aeration [10] - Increased electricity demand and operational costs - Partial stabilization of organic matter
Opportunities	- Aligns with circular economy goals via nutrient recycling and soil amendment - Reduces landfill burden and promotes sustainable agriculture [41]	- Growing demand for alternative fuels in cement and energy-intensive sectors - Policy support for RDF as a fossil fuel substitute [44]

Table 2. Cont.

SWOT Category	Composting-Based MBT	Biodrying-Based MBT
Threats	- Community resistance due to odors - Limited market value for low-grade CLO - Regulatory constraints on compost quality standards [45]	- Stricter emissions and fuel standards - Need for skilled operators - Competition from direct incineration or other MBT pathways

In contrast, biodrying excels in its strengths of fast processing and the production of Refuse-Derived Fuel (RDF) with high calorific value. The technology benefits from opportunities driven by the growing demand for RDF in energy sectors. Nevertheless, the implementation of biodrying is constrained by weaknesses, including high energy demand and elevated capital expenditure (CAPEX). Furthermore, it faces external threats from tightening emission regulations and a potential shortage of skilled labor required for specialized operations.

3.2. Financial Evaluation

This section synthesizes the financial performance of the two MBT configurations by integrating capital and operational cost structures, revenue composition, and discounted cash-flow indicators. Rather than presenting individual metrics in isolation, results are interpreted in terms of capital efficiency, risk exposure, and sensitivity to key economic drivers under Egypt-specific market and regulatory conditions. This evaluation integrates detailed financial metrics, sensitivity analyses, and a comparative analysis of both technologies, providing actionable insights for stakeholders.

3.2.1. Expenditures and Revenue Streams

Capital Expenditure (CAPEX)

The total capital investment for the proposed MBT facility is estimated at USD 10.150 million for the composting plant and USD 12.513 million for the biodrying plant. CAPEX covers land acquisition, construction, machinery, vehicles, and pre-opening expenses. Notably, machinery costs for biodrying are significantly higher due to imported technology and energy-intensive equipment [46].

Figure 6 summarizes CAPEX allocation for both pathways, emphasizing the cost disparity between the two technologies. A comparative analysis indicates a significant difference in capital intensity, with the biodrying configuration requiring an 18.9% higher investment than composting. Machinery and equipment constitute the primary cost driver; biodrying requirements total USD 3.470 million, which is 102% higher than the USD 1.714 million required for composting. This pronounced variance originates from the imported biodrying system, valued at approximately USD 2.096 million, which incorporates proprietary forced-aeration technology and automated control systems. Conversely, composting technology relies upon standard mechanical equipment manufactured by Egyptian or regional suppliers, which is procured at substantially lower cost points without significant import premiums. Building and structural infrastructure also demonstrates a 20% cost premium for biodrying facilities due to the necessity of hermetically sealed structures and sophisticated odor treatment systems. Consequently, the elevated biodrying contingency reserve—which is 44% higher than that of composting—accounts for risks associated with specialized equipment installation and the limited availability of local technical expertise for troubleshooting [46]. The CAPEX comparison highlights a clear divergence in capital intensity between the two pathways. Biodrying requires approximately 18.9% higher upfront investment than composting, driven primarily by imported proprietary equipment and enclosed reactor infrastructure. This higher capital burden is not offset

by proportional revenue gains, indicating lower capital productivity for biodrying under the analyzed conditions.

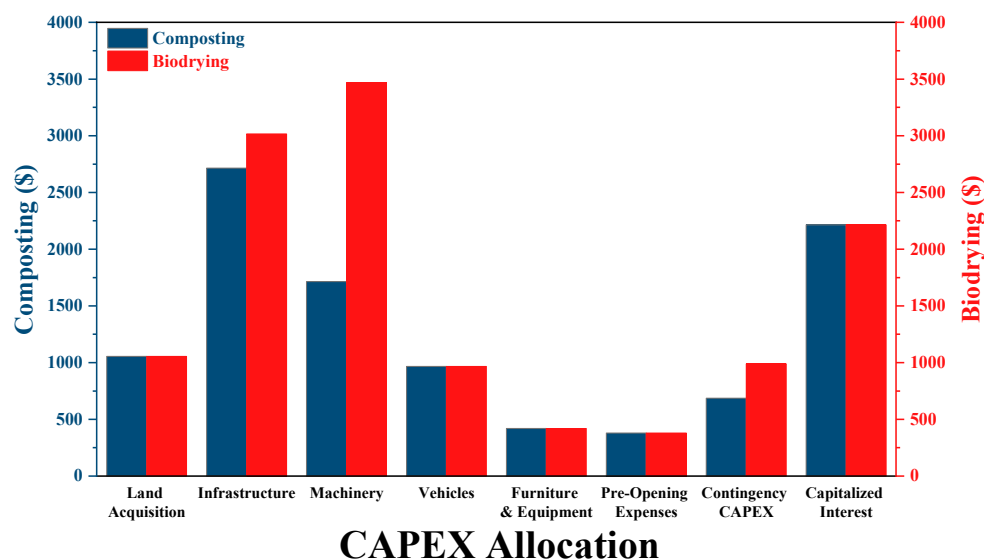


Figure 6. Summary of CAPEX Allocation. (Source: Drafted by authors).

Operational Expenditure (OPEX)

Annual operating expenditure (OPEX) is estimated at USD 1.795 million for the composting configuration and USD 2.231 million for the biodrying configuration. These costs comprise raw material and waste procurement, landfill disposal fees for rejects, personnel expenses, transportation, maintenance, spare parts, utilities, marketing, and indirect administrative overheads, as shown in Table 3. In both cases, raw material and waste procurement constitute the largest single cost item at USD 768,000/yr, reflecting the baseline input and service payments required to sustain the facility's designed processing capacity. These values align with international benchmarks for waste-to-energy logistics and disposal fees for medium-scale facilities [47].

Table 3. Annual operational expenditure (OPEX) breakdown (USD/yr).

Cost Category	Composting (USD)	Biodrying (USD)
Raw Materials	768,000	768,000
Landfill Costs	84,845	84,845
Salaries and Wages	296,400	296,400
Transportation	151,893	151,893
Maintenance	78,950	102,344
Spare Parts	98,400	334,710
Utilities	154,806	330,666
Marketing	26,000	26,000
Indirect Costs	135,758	135,758
Total Operational Costs	1,795,052	2,230,616

Logistics and disposal costs represent a further significant share of the operating budget. Transportation for waste collection and transfer is budgeted at USD 151,893/yr, while landfill fees for non-recyclable rejects amount to USD 84,845/yr, values that are consistent with reported ranges for medium-scale waste treatment facilities in comparable settings. Labour and administration likewise play a central role in ensuring reliable operation: direct salaries and wages total USD 296,400/yr, supplemented by USD 135,758/yr in indirect costs associated with management, administrative staffing, and office operations, and USD 26,000/yr allocated to marketing to support product offtake and market development.

The main divergence in OPEX between the two technological options is driven by maintenance, spare parts, and utilities, reflecting the higher energy demand and technological complexity of the biodrying line. While maintenance rises from USD 78,950/yr (composting) to USD 102,344/yr (biodrying), the increase is far more pronounced for spare parts (from USD 98,400/yr to USD 334,710/yr) and utilities (from USD 154,806/yr to USD 330,666/yr), owing to the greater reliance on specialised electromechanical components and intensive forced-aeration systems in biodrying. Consequently, biodrying incurs approximately USD 0.44 million/yr in additional operating costs relative to composting, despite identical expenditures for raw materials, landfill fees, labour, transportation, marketing, and indirect costs [48].

Revenue Stream

The revenue structure of the proposed Mechanical–Biological Treatment (MBT) facility is dominated by the recovery and sale of high-value recyclables, with additional contributions from RDF and compost products, as shown in Figure 7. Under the baseline assumptions, projected Year-1 revenues amount to USD 5.55 million for the composting configuration and USD 5.42 million for the biodrying configuration, rising to approximately USD 25.465 million and USD 25.904 million, respectively, by Year 10. This growth trajectory is consistent with Egypt’s urbanisation and income trends and is supported in Alexandria by a steadily expanding population of roughly 5.5–5.8 million inhabitants (annual growth 1.1–2.0%) and increasing per-capita MSW generation of about 0.9–1.0 kg·capita^{−1}·day^{−1}, as reported in recent sector assessments [49].

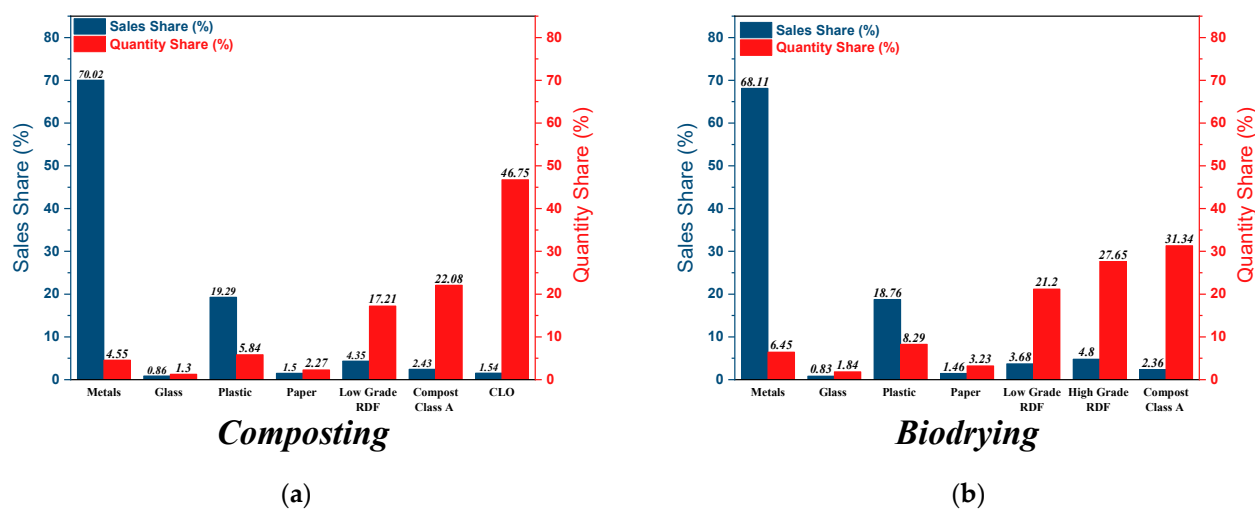


Figure 7. Financial and Material Output Analysis of (a) Composting and (b) Biodrying Pathways. (Source: Drafted by authors).

Recovered recyclables constitute the principal revenue stream in both MBT configurations, accounting for 91.67% of total sales in the composting option and 89.17% in the biodrying option, despite representing only 13.96% and 19.82% of total output, respectively. In physical terms, both configurations recover 15,695 tonnes/year of recyclables, with metals providing the most significant financial contribution (70.02% of sales in the composting case and 68.11% in the biodrying case, corresponding to 5110 tonnes/year). Plastics contribute 19.29% (composting) and 18.76% (biodrying) of total sales at 6570 tonnes/year. In comparison, paper and glass provide smaller but stable revenue shares: paper accounts for 1.50% (composting) and 1.46% (biodrying) at 2555 tonnes/year, and glass for 0.86% (composting) and 0.83% (biodrying) at 1460 tonnes/year.

RDF generates an energy-oriented revenue stream that, in monetary terms, remains secondary to recyclables. In the composting configuration, low-grade RDF reaches 19,345 tonnes/year (17.21% of total output) and contributes 4.35% of sales. In the biodrying configuration, RDF production is diversified into low-grade RDF (16,790 tonnes/year; 21.20% of output; 3.68% of sales) and high-grade RDF (21,900 tonnes/year; 27.65% of production; 4.80% of sales), reflecting the higher-quality fuel fraction attainable under biodrying conditions; regulatory requirements for cement plants underpin this stream to source 20% of their fuel from alternative sources, including RDF.

Biological outputs account for a substantial share of the mass balance but contribute only modestly to revenue. For the composting option, Class A compost amounts to 24,820 tonnes/year (22.08% of output) and contributes 2.43% of total sales, while compost-like output (CLO) reaches 52,560 tonnes/year (46.75% of production) and contributes 1.54% of sales. In the biodrying option, Class A compost remains at 24,820 tonnes/year (31.34% of output) and contributes 2.36% of sales. Overall, non-recyclable products account for 8.33% of sales and 86.04% of the production in the composting configuration, compared with 10.83% of sales and 80.18% of output in the biodrying configuration, underscoring the strong economic dependence of both options on recyclable material recovery. Despite differences in biological treatment, both configurations remain economically dependent on recyclable recovery, which accounts for nearly 90% of total revenues. RDF and compost products contribute marginally to cash inflows, implying that improvements in biological processing primarily influence cost efficiency and risk profile rather than revenue maximization.

3.2.2. Economic Performance Metrics

A comparative analysis of cash flows over 12 years highlights key differences in the financial performance of composting and biodrying pathways. As shown in Figure 8a, composting exhibits a more favorable trend, with significant cash inflows beginning in the third year and steadily increasing over time. Initial outflows are high in the first two years but decrease sharply afterward, leading to a sustained positive net cash flow. In contrast, Figure 8b illustrates the biodrying pathway, which also begins generating inflows from the third year but at slightly lower levels compared to composting. Moreover, biodrying maintains higher operational outflows throughout the evaluation period. These financial patterns suggest that composting provides a more economically sustainable approach, with higher returns and lower long-term costs, making it a more attractive option for resource recovery from organic waste.

Key financial metrics validate the economic viability of the MBT facility, as shown in Table 4. A discounted cash flow (DCF) assessment was undertaken to compare the composting and biodrying configurations over a 12-year project lifecycle, comprising a 2-year construction period followed by a 10-year operating period, using a 14% real discount rate. Across all key financial indicators, composting exhibits superior performance, including higher Net Present Value (NPV), higher Internal Rate of Return (IRR), a shorter payback period, and a slightly higher Benefit–Cost Ratio (BCR). Although both pathways satisfy the financial acceptability criterion of achieving an IRR above the real discount rate, composting offers a more attractive investment profile in terms of value maximization and capital efficiency.

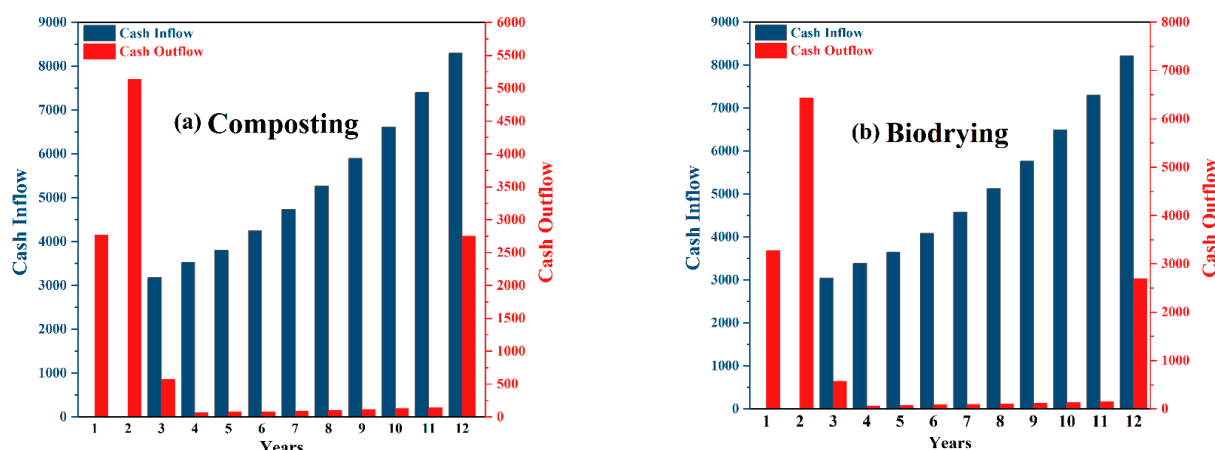


Figure 8. Annual cash inflow and outflow for (a) the composting and (b) biodrying pathways. (Source: Drafted by authors).

Table 4. Key financial indicators.

Performance Metric	Composting Pathway	Biodrying Pathway
Net Present Value (NPV)	USD 2.55 Million	USD 0.99 Million
Internal Rate of Return (IRR)	37%	29%
Payback period	3.8 years	4.9 years
Benefit–Cost Ratio (BCR)	1.6	1.5
Total CAPEX	USD 10.15 Million	USD 12.51 Million
First-year revenue	USD 5.55 Million	USD 5.42 Million
NPV/CAPEX ratio	0.25	0.08

NPV results underscore the stronger value creation associated with composting. The composting configuration generates an NPV of approximately USD 2.55 million, compared with USD 0.99 million for biodrying, corresponding to an absolute differential of about USD 1.56 million. While these NPVs represent a moderate share of total capital costs, the magnitude and robustness of the differential are decision-relevant, particularly under conditions of elevated financing costs and macroeconomic uncertainty. In such contexts, a higher NPV not only indicates greater expected surplus over the cost of capital but also provides a wider buffer against adverse deviations from base-case assumptions.

The financial advantage of composting is driven primarily by differences in capital intensity rather than by revenue potential. Total CAPEX for composting is lower than for biodrying, with the latter requiring 18.9% higher investment, mainly due to more expensive machinery and specialised infrastructure. By contrast, Year-1 revenues are broadly comparable—USD 5.55 million for composting and USD 5.42 million for biodrying—indicating that the additional capital deployed in the biodrying option does not translate into proportionally higher cash inflows. This divergence is reflected in the NPV-to-CAPEX ratio, which is substantially higher for composting, signalling markedly stronger capital productivity.

Return metrics reinforce this interpretation. Composting achieves an IRR of around 37%, compared with 29% for biodrying, yielding an 8-percentage-point advantage. Although both models exceed the 14% hurdle rate and therefore indicate financial feasibility, the higher IRR for composting implies a larger return margin and, consequently, greater resilience to downside risks such as construction delays, operating cost escalation, or weaker-than-expected market uptake of outputs. In project finance settings, this margin also enhances bankability by supporting stronger debt-service capacity and reducing sensitivity to unfavourable financing terms. Liquidity and timing indicators further differentiate the

two options. The payback period for composting is estimated at 3.8 years, compared with 4.9 years for biodrying, thereby shortening the duration of capital exposure during the early operational phase when technical and market risks are typically most pronounced. This faster capital recovery is particularly relevant for private investors and PPP structures that prioritise early cash recovery as a practical risk-management criterion.

Cost-benefit analysis is consistent with the DCF findings. Both pathways yield BCR values above unity, confirming that discounted benefits exceed discounted costs; however, composting attains a marginally higher BCR than biodrying, in line with its superior NPV and capital-efficiency indicators. Under a financing structure with a 50:50 debt-equity split, the lower CAPEX of composting translates into a smaller absolute equity requirement than biodrying, while simultaneously delivering greater net value. Integrated financial indicators consistently favor the composting-based MBT configuration. Higher NPV, IRR, and a shorter payback period collectively indicate stronger value creation and faster capital recovery, which are critical under high discount rates and macroeconomic uncertainty. The markedly higher NPV/CAPEX ratio for composting underscores superior capital efficiency rather than superior revenue generation.

3.2.3. Sensitivity Analysis

The sensitivity analysis evaluates the robustness of the financial model for the proposed MBT facility under different scenarios involving variations in key financial and operational parameters. The study reveals that a 20% reduction in revenue poses the most significant risk, lowering the Net Present Value (NPV) to USD 445,080, reducing the Internal Rate of Return (IRR) to 28%, and extending the payback period to 5.1 years. This scenario emphasizes the critical importance of maintaining projected revenue levels to safeguard financial viability.

Conversely, a 10% increase in Capital Expenditure (CAPEX) or Operating Expenditure (OPEX), as well as a combined increase of both, has a relatively minor impact on financial metrics. These scenarios result in IRRs above the discount rate of 29%, and the Benefit-Cost Ratio (BCR) remains favorable. Increases in operational variables such as salaries, electricity costs, and maintenance expenses (up to 20%) also show negligible impacts, with IRRs consistently above the discount rate and payback periods remaining within acceptable limits. This highlights the model's resilience to cost fluctuations compared to revenue changes.

The findings underscore the need for strategic efforts to protect and optimize revenue streams. By focusing on revenue stability through market strategies and regulatory support, stakeholders can ensure the long-term sustainability of the project. The detailed sensitivity results are summarized in Table 5.

Table 5. Sensitivity analysis results.

Scenario	NPV (USD '000)	IRR	BCR	Payback Period (Years)
Baseline Scenario	2550	37%	1.5	3.8
Revenue Reduction (20%)	445	28%	1.1	5.1
CAPEX Increase (10%)	2109	34%	1.5	4.2
OPEX Increase (10%)	2100	33%	1.2	3.9
CAPEX & OPEX Increase (10% each)	1773	32%	1.3	4.3
Salaries Increase (20%)	2389	36%	1.4	4.1
Electricity and Fuel Cost Increase (20%)	2471	37%	1.5	3.8
Maintenance and Spare Parts Cost Increase (20%)	2513	37%	1.5	3.8

3.2.4. Limitations and Recommendations

The financial analysis acknowledges certain limitations, including potential variations in waste composition, fluctuations in market demand for by-products, and regulatory changes affecting RDF use. Future research should explore advanced composting techniques to improve product quality and investigate emerging RDF production technologies to enhance calorific value. Stakeholders are advised to focus on operational efficiency, strengthen market demand through policy advocacy, and invest in advanced sorting technologies to minimize waste losses.

3.3. Environmental Impacts and GHG Emissions

The greenhouse gas (GHG) performance of three waste management scenarios was evaluated: (i) a business-as-usual baseline in which all waste is disposed of in an unmanaged landfill without gas capture; (ii) a mechanical–biological treatment (MBT) configuration incorporating composting of the municipal solid waste (MSW) organic fraction and green waste; and (iii) an MBT configuration employing biodrying for refuse-derived fuel (RDF) production. For each pathway, annual GHG emissions and emission intensity ($\text{kg CO}_2\text{e}\cdot\text{tonne}^{-1}$ waste) were quantified following the methodology presented in Section 2.3, enabling direct comparison with published MBT case studies from comparable climatic and operational contexts.

3.3.1. Annual and Normalized Emissions

Both MBT configurations substantially reduce GHG emissions relative to the landfill baseline, with the composting pathway demonstrating superior climate performance. Annual emissions from the baseline scenario total 55.4 million $\text{kg CO}_2\text{e}\cdot\text{year}^{-1}$ due to uncontrolled methane formation in unmanaged disposal sites without landfill gas capture. The composting-based MBT pathway achieves 28.5 million $\text{kg CO}_2\text{e}\cdot\text{year}^{-1}$ (48.5% reduction), while the biodrying-based pathway yields 39.6 million $\text{kg CO}_2\text{e}\cdot\text{year}^{-1}$ (28.5% reduction) (Figure S1).

Normalized emission intensities further highlight these differences and enable benchmarking against international MBT applications. The landfill baseline exhibits an emission intensity of 303.4 $\text{kg CO}_2\text{e}\cdot\text{tonne}^{-1}$ waste, which lies within IPCC default ranges for unmanaged landfills receiving organic-rich MSW in warm climates and aligns with values reported for comparable developing-country settings. The composting-based MBT pathway reduces emission intensity to 156.1 $\text{kg CO}_2\text{e}\cdot\text{tonne}^{-1}$ (48.5% reduction), whereas the biodrying-based pathway achieves 240.9 $\text{kg CO}_2\text{e}\cdot\text{tonne}^{-1}$ (20.6% reduction) (Figure 9). Emission intensity thus emerges as a robust primary indicator for international MBT benchmarking and supports direct comparison with facilities documented in the peer-reviewed literature and operational databases.

3.3.2. Emissions Breakdown by Source

Process emissions from biological treatment dominate the GHG profiles of both MBT configurations, whereas operational emissions contribute only a minor fraction of total impacts. In the composting-based pathway, methane and nitrous oxide from biological treatment account for 24.3 million $\text{kg CO}_2\text{e}\cdot\text{year}^{-1}$, corresponding to 92.7% of total emissions; in the biodrying-based pathway, the analogous process emissions reach 37.5 million $\text{kg CO}_2\text{e}\cdot\text{year}^{-1}$, or 94.6% of total emissions. Operational emissions—including transportation (0.6 million $\text{kg CO}_2\text{e}\cdot\text{year}^{-1}$), sorting line electricity (0.4 million $\text{kg CO}_2\text{e}\cdot\text{year}^{-1}$), electricity for biological treatment equipment (0.2–0.5 million $\text{kg CO}_2\text{e}\cdot\text{year}^{-1}$), and diesel use in mobile equipment (0.5–0.6 million $\text{kg CO}_2\text{e}\cdot\text{year}^{-1}$)—collectively represent only 7.3% and 5.4% of pathway-level emissions for composting and biodrying, respectively, as detailed in Supplementary Table S2.

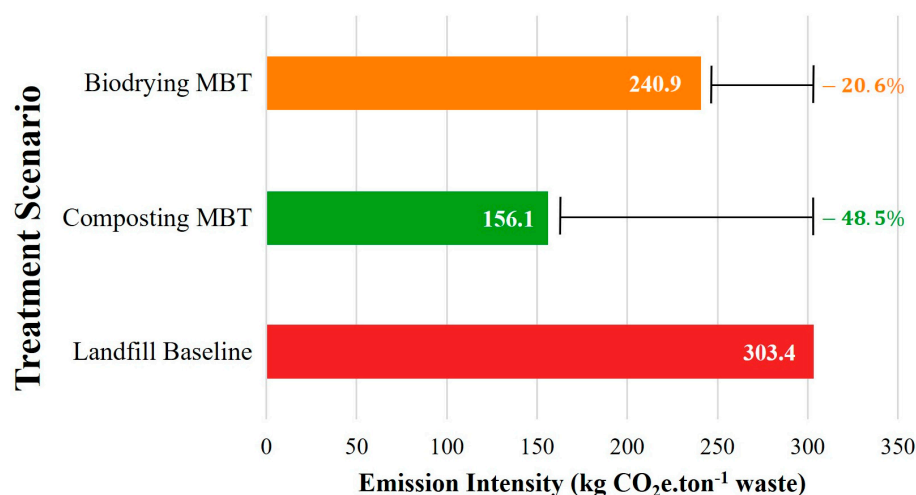


Figure 9. Normalized GHG Emissions Intensity. (Source: Drafted by authors).

Biodrying requires higher electricity consumption for biological treatment equipment than composting due to the use of forced aeration systems; however, this difference accounts for less than 2% of total pathway emissions. This finding indicates that process-related emissions dominate the greenhouse gas profiles of both MBT pathways. Accordingly, meaningful emission reductions are more likely to result from optimization of biological process parameters such as aeration intensity, residence time, and moisture temperature control rather than from incremental improvements in equipment energy efficiency.

4. Conclusions

For the Alexandria case, this study compared composting-based and biodrying-based mechanical–biological treatment (MBT) configurations using an integrated techno-economic (discounted cash-flow) and greenhouse gas (GHG) assessment within clearly defined system boundaries. Under the stated assumptions, the composting pathway exhibited stronger financial performance than biodrying, with a net present value of USD 2.55 million compared to USD 0.99 million, and achieved a 48.5% reduction in net system GHG emissions relative to a baseline unmanaged landfill. Sensitivity analysis confirmed that the relative ranking of the two pathways is primarily influenced by electricity prices, revenue assumptions for recovered products, capital expenditure levels, and baseline-related emissions parameters. Based on these results, composting is identified as the preferred biological treatment option for the analyzed MBT configuration in Alexandria. These findings are specific to the defined assumptions, system boundaries, and local conditions, and should not be generalized beyond the evaluated case.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su18031350/s1>, Figure S1. GHG Emissions Comparison by Treatment Method. Table S1. Emission factors used in the GHG assessment. Table S2. GHG Emissions Breakdown by Source (Composting vs Biodrying). Refs. [23,30,32,50–58] are cited in Supplementary Materials.

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Abbreviations

The following abbreviations are used in this manuscript:

MSW	Municipal Solid Waste
GHG	Greenhouse Gas
MBT	Mechanical–Biological Treatment
NPV	Net Present Value
IRR	Internal Rate of Return
RDF	Refuse-Derived Fuel
SDGs	Sustainable Development Goals
CE	Circular Economy
SCF	Segregated Combustible Fraction
SRF	Solid Recovered Fuel
WMRA	Waste Management Regulatory Authority
CAPEX	Capital Expenditure
OPEX	Operational Expenditure
PBP	Payback Period
BCR	Benefit–Cost Ratio
PPP	Public–Private Partnership
VOC	Volatile Organic Compound
CLO	Compost-Like Output
SWOT	Strengths, Weaknesses, Opportunities, and Threats

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