Assessment of Greenhouse Gas Reduction Potential of Circular Economy Interventions in Manado City

Implementation of Pilot Project along the plastic value chain in Manado

Reduce, Reuse, Recycle, to Protect the Marine Environment and Coral Reefs (3RproMar)

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1 Background

Reduce, Reuse, Recycle to Protect the Marine Environment and Coral Reefs (3RproMar) is an ASEAN-German Cooperation project implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) and in coordination with the ASEAN Secretariat. This project aims to support ASEAN Member States, respective national partners in the four implementing countries: Cambodia, Indonesia, the Philippines, and Viet Nam, in increasing implementation capacity to reduce land-based waste leakage to protect the marine environment.

For Indonesia, in cooperation with the Ministry of Environment, Manado City was selected as a pilot municipality, reflecting its nature as a medium-sized remote coastal city with rich biodiversity. Marine plastic pollution is in particular harmful for its nearby wildlife, the local fishermen, and the inhabitants. As plastic waste entering our oceans continues to surge—currently estimated at 11 million tonnes annually—cities like Manado play a critical role in implementing local solutions that align with broader regional goals. By fostering local innovation, strengthening circular economy practices, and encouraging private sector participation, 3RproMar Manado supports the broader goal of protecting marine biodiversity, public health, and sustainable economic development through integrated regional cooperation. the pilot project includes four work areas, namely (1) Integrated Waste Management and Plastic Waste Management; (2) Strategy for Changing Patterns of Plastic Production and Consumption; (3) Collection and recycling of municipal solid waste with participation of the informal sector; (4) Social Behavior and Communication Changes in Waste Management at the community level.

The Greenhouse gas (GHG) reduction study is part of work area 1 and aims to address the task in the project Terms of Reference (TOR) to perform an assessment of the GHG reduction potential due to improved solid waste and plastic waste management and changed consumption/production patterns.

This assessment serves as a knowledge product to enable GIZ to understand the GHG reduction potential of local interventions in the plastic waste and circular economy sector.

2 Methodology for estimating GHG emissions

The baseline data for the municipal solid waste management (MSWM) system in Manado has been produced using the Waste Wise Cities Tool (WaCT) developed by UN-Habitat and the Waste Flow Diagram (WFD) methodology developed by GIZ. For assessing the overall impact of the MSWM system in Manado, a greenhouse gas (GHG) emissions estimation has been developed, using the SWM-GHG Calculator, developed by ifeu Heidelberg on behalf of GIZ in cooperation with KfW, with funds provided by the German Federal Ministry for Economic Cooperation and Development (BMZ).

The Calculator estimates the GHG emissions of solid waste management (SWM) systems and aids understanding GHG mitigation effects of different waste management options, as it can simultaneously calculate the emissions for a status quo scenario and 3 alternative scenarios. It determines the annual emissions of methane, nitrous oxide and carbon dioxide from the treatment and disposal of waste, presenting the total climate impact in CO_2-equivalent.

The methodology for estimating the GHG emissions resulting from the MSWM systems in Manado is described below, based on the different MSWM stages and as per calculations used by the Calculator.

The picture below illustrates which of the MSWM stages and activities were included in the GHG estimations or not, based on the tool and data availability.

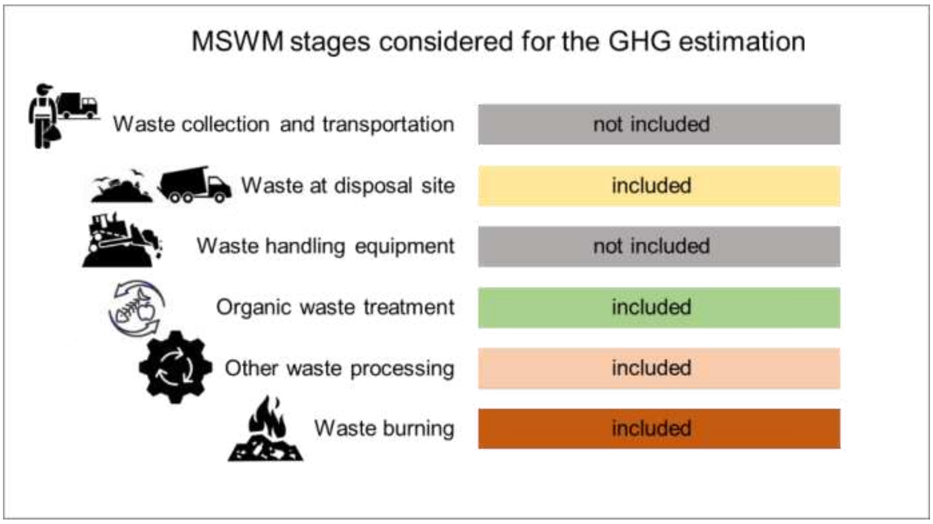


Figure 1 MSWM stages in Manado

GHG emissions resulting from the collection and transportation of waste, as well as from the operation of waste handling equipment at the disposal site, were not included in the current estimations, as these components fall outside the scope of the Calculator used in the assessment. The estimations focused primarily on MSW management in Manado and accounted for several key waste flows. This includes the MSW that is collected and transported to the Sumompo disposal site, along with emissions associated with waste treatment and the processing of all materials recovered within the city (including organic waste and recyclables). Additionally, the estimations considered uncollected MSW, which is typically either illegally dumped into the environment, including rivers, green spaces, or informal accumulation sites, thereby exacerbating both environmental degradation and health risks, or openly burned—contributing to air pollution and GHG emissions.

2.1 Disposal site

Methane (CH_4) emissions from disposal sites rely on the First Order Decay (FOD) method, as per the IPCC Methodology. This approach operates on the assumption that the degradable organic component in waste decays slowly over several decades, during which CH_4 and carbon dioxide (CO_2) are generated. Assuming that conditions remain constant, the rate of CH_4 production depends solely on the remaining amount of carbon in the waste. Consequently, CH_4 emissions from waste placed in a disposal site are highest in the initial years after deposition, and then gradually decline as the degradable carbon in the waste is consumed by the bacteria that facilitate decay[1].

The Calculator estimates the methane generation potential based on the IPCC methodology.

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

Where:	L_0	=	CH_4 generation potential, Gg CH_4
	$DDOC_m$	=	mass of decomposable DOC (degradable organic carbon in the year of deposition), Gg
	F	=	fraction of CH_4 in generated landfill gas (volume fraction)
	16/12	=	molecular weight ratio CH_4/C (ratio)

According to the IPCC Methodology: The basis for the calculation is the amount of Decomposable Degradable Organic Carbon ($DDOC_m$), which is the part of the organic carbon that will degrade under the anaerobic conditions in disposal sites. $DDOC_m$ equals the product of the waste amount (W), the fraction of degradable organic carbon in the waste (DOC), the fraction of the degradable organic carbon that decomposes under anaerobic conditions (DOC_f), and the part of the waste that will decompose under aerobic conditions (prior to the conditions becoming anaerobic) in the disposal sites.

The Calculator uses the default value of 0.5 for the fraction of the degradable organic carbon that decomposes under anaerobic conditions (DOC_f), the recommended value for bulk waste, as per the IPCC Methodology (IPCC 2019, V5, Chapter 3, Table 3.0).

The calculation methodology applies a Methane Correction Factor (MCF) which reduces estimated methane generation based on the degree to which aerobic conditions occur at the disposal site. It depends significantly on variables such as landfill management practices, the use of daily cover layers, compaction ratio, depth, height and shape of the disposal site.

For the modelling of the GHG emissions for the MSWM system in Manado, two different Methane Correction Factors (MCFs) were applied, based on the final disposal conditions of the waste. For the fraction of MSW that is collected and transported to the Sumompo disposal site, an MCF of 0.8 was used. This corresponds to the IPCC default value for an unmanaged disposal site with a depth of 5 meters or more, reflecting the likely anaerobic conditions that contribute to higher methane generation. In contrast, for the portion of waste that remains uncollected and is either dumped in the environment or accumulates in shallow, informal sites, a lower MCF of 0.4 was applied. This value aligns with the IPCC default for wild dumps or unmanaged shallow disposal sites (less than 5 meters deep), where the conditions for methane production are less favorable due to greater exposure to oxygen. These differentiated factors ensure a more accurate estimation of methane emissions based on the specific waste disposal scenarios present in Manado.

As the CH_4 is not recovered at the disposal site, it is subject to oxidation in the solid waste disposal site cover layer. Rates of oxidation of uncollected methane in cover soils of disposal sites depend on cover soil type and thickness, climate, and the rate of methane flux to the cover soil per unit area. The calculator uses the IPCC default value of 0% for managed uncovered sites, unmanaged or uncategorised disposal sites.

The calculation methodology also accounts for the composition of landfill gas by assuming that 50% of the generated gas is methane (CH_4), in line with the IPCC guidelines. This assumption is represented by the FCH_4

[1] 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5 Waste, CHAPTER 3 SOLID WASTE DISPOSAL, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

factor (Fraction of CH_4 in generated landfill gas), and reflects the typical composition of biogas produced from the anaerobic decomposition of organic waste in solid waste disposal sites. According to the IPCC, most waste in such sites generates landfill gas composed of approximately 50% methane and 50% carbon dioxide, making this a standard and widely accepted parameter for estimating methane emissions from landfills..

Table 1 shows the parameters values used in the Calculator to determine GHG emissions at disposal site.

Table 1 Parameter values used in the calculation model

Parameter	Value	Source
DOC_f Fraction of degradable organic carbon which decomposes for different waste types	0.5	IPCC (2019, V5, Ch3)
MCF – methane correction factor – Wild dumps/unmanaged disposal site, shallow (<5m) used for uncollected MSW	0.4	IPCC (2019, V5, Ch3)
MCF – methane correction factor – Unmanaged disposal site, deep (>=5m), used for collected and disposed MSW at Sumompo disposal site	0.8	IPCC (2019, V5, Ch3)
Oxidation factor – Managed uncovered with aerated material, unmanaged and uncategorized SWDS	0	IPCC (2019, V5, Ch3)
FCH_4 – Fraction of CH_4 in generated landfill gas	0.5	IPCC (2006, V5, Ch 3.2.3)

For additional details, please refer to **Annex 1 SWM-GHG Calculator Excel file**.

2.2 Uncollected municipal solid waste

The Calculator assumes that uncollected waste is dumped on landscape, scattered in the environment and it decomposes under aerobic conditions, thus not causing methane emissions.

As there are still several illegal waste dumps in Manado, it has been assumed that 40% of the uncollected waste is scattered through environment while 60% of the uncollected waste is found in small, illegal waste dumps. The methodology to account for the emissions of MSW disposed of in small, illegal waste dumps is following the one used for accounting the GHG emissions at the disposal site, as per the subchapter above.

2.3 Organic waste treatment

For the organic waste treatment, composting, the Calculator assumes that 50% of the composting is done through open windrow composting and 50% is done through encapsulated composting plants. Open composting is managed with diesel-engine machinery, and the diesel demand was calculated as 1.5 l/t organic waste. The GHG emissions from composting are dominated by the methane and nitrous oxide (N_2O) emissions from the composting process. CO_2 emissions from electricity and diesel demand are of minor importance. The Calculator uses the default emission factors for CH_4 and N_2O emissions for biological treatment of waste, as per the IPCC 2006 Methodology.

The calculation methodology considers that the end products of composting consist of one-third immature compost, primarily used in agricultural applications. For mature compost, two thirds of the end product, about 30% is utilized in agriculture, while 3% is employed as substrate material for land recultivation. The remainder is used for gardening in both professional and recreational settings, or as a substrate. The specific application of compost determines the type of primary material it replaces. In agriculture, compost substitutes mineral fertilizers based on its nutrient content. When used as a substrate or humus supply, it replaces peat and/or bark humus, depending on its organic matter content. However, when compost is used for recultivation, no primary materials are substituted, as waste materials are typically employed for this purpose.

As the Calculator is estimating the climate impact through an LCA type of accounting, organic waste composting emissions also included diesel demand for open composting, electricity demand for encapsulated composting plants and emissions resulting from compost application.

In Manado, approximately 2.6 tonnes of organic waste are recovered daily by informal waste pickers living near the Sumompo disposal site and used as animal feed. Since the calculator does not include a specific option for this type of waste utilization, the recovered organic waste was subtracted from the initial total MSW generated. Consequently, the waste generation rate was recalculated, and the composition adjusted accordingly. As a result, the generation rate decreased from 0.61 kg/cap/day to 0.604 kg/cap/day, accounting for the organic waste diverted for animal feed.

2.4 Other waste processing

In order to quantify the impact of recycling other materials, the Calculator considered default emission values as detailed below. The emissions were calculated taking into account the emission factors for emissions (debits) and for the saving potential (credits).

$E_x = M_x * EF_{emissions,x} + M_x * EF_{saving\ potential,x}$

Where: E_x = emissions resulted from recycling of material, kg CO_2eq

x = material which is recycled

$EF_{emissions,x}$ = emission factor for emissions (Debits) for material x, kg CO_2eq/t waste

$EF_{saving\ potential,x}$ = emission factor for saving potential (Credits) for material x, kg CO_2eq/t waste

Table 2 Recycling emission factors (EF) used in the Calculator

Recycling emission factors	EF emissions - Debits	EF saving potential - Credits	Source
Plastics kg CO_2eq/t waste	550	1070	Vogt et al. (in publication); rounded values
Fe metals kg CO_2eq/t waste	22	1500	Vogt et al. (in publication); rounded values
Glass kg CO_2eq/t waste	20	500	Prognos/IFEU/INFU 2008
Paper, cardboard kg CO_2eq/t waste	180	630	Vogt et al. (in publication); rounded values

2.5 Open burning of waste

The emissions occurring from waste burning are estimated based on the amount of kg of waste burned in Manado multiplied with the emission factors. The Calculator estimates open burning as complete oxidation of the fossil carbon contained in the waste. Considering the uncertainty of the quantities burned in the open and because the incompletely burned remains will decompose over time this is an insignificant simplification. Based on the IPCC 2019 Methodology (Ch 5, V5), the calculation method uses a default CH_4 emission factor of 6500 g / t MSW wet weight.

The percentage of MSW which is being openly burned by residents in Manado was considered to be equal to the percentage of plastic waste being openly burned, which was estimated using the WFD tool. According to the Baseline report, 3% of the total plastic waste generated is being openly burned. For GHG calculations, it has been assumed that 3% of the MSW generated is being openly burned in Manado.

3 Associated emissions for MSWM operations in 2023

Based on the methodology outlined in the previous chapter and using the GIZ Calculator Tool, the total associated emissions from MSWM operations in Manado for 2023 are estimated to 87,878 tonnes of CO_2 equivalent. Of this total, 84,236 tonnes CO_2eq result from the disposal of waste at the Sumompo disposal site, 1,346 tonnes CO_2eq are attributed to open burning, and 3,597 tonnes CO_2eq are linked to uncollected waste that is illegally dumped in small accumulations. Additionally, an emissions offset of -1,301 tonnes CO_2eq is credited to the recycling of materials.

The graph below shows the total CO_2eq associated emissions estimated for the MSWM operations in 2023 in Manado, per MSWM process.

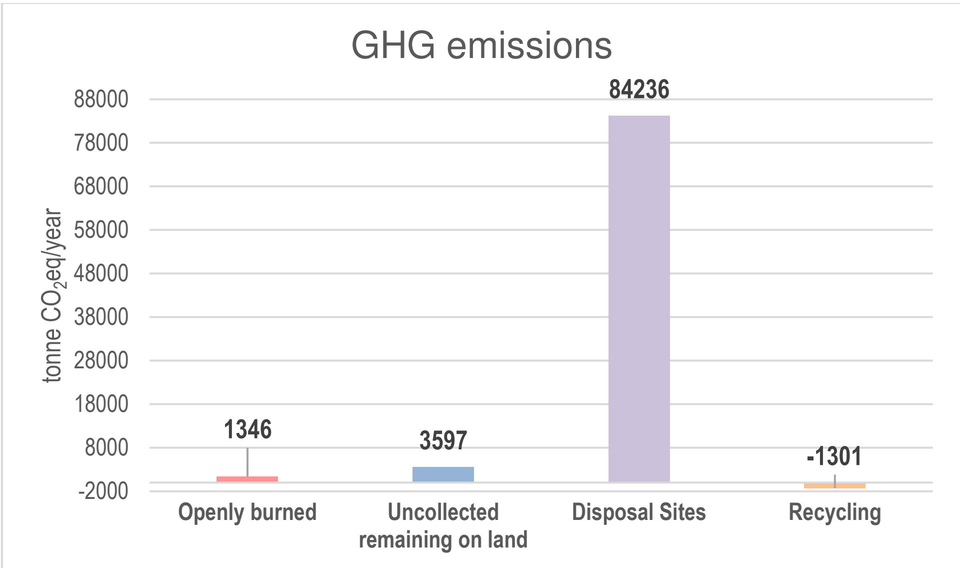
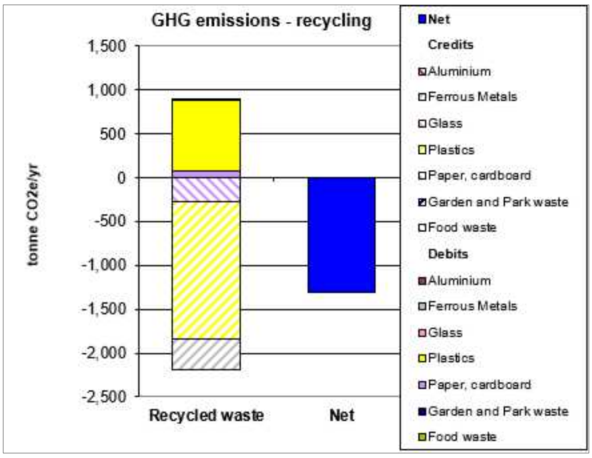


Figure 2 Total CO_{2eq} associated emissions estimated for the MSWM operations in 2023 in Manado

The total offset emissions due to recycling of materials was -1,301 tonnes of CO_2eq in 2023. A total of 2,136 tonnes of materials were recycled in Manado, comprising 436 tonnes of paper and cardboard, 1,470 tonnes of plastics, and 231 tonnes of metal. These recycling activities resulted in an estimated emissions offset of -196 tonnes CO_2eq for paper/cardboard, -764 tonnes CO_2eq for plastics, and -341 tonnes CO_2eq for metals. The figure below details the emissions from recycling processes in 2023, broken down by material type and total contribution.



Recycled Waste	Emissions	Emission savings potential	Net results
	tonne $CO_{2\text{-eq}}$	tonne $CO_{2\text{-eq}}$	**tonne $CO_{2\text{-eq}}$**
Paper, cardboard	78.46	-274.61	**-196.15**
Plastics	808.38	-1572.66	**-764.28**
Ferrous Metals	5.02	-345.81	**-340.79**
Total	**891.86**	**-2193.08**	**-1301.22**

Figure 3 GHG emissions from recycling of materials. Extract from the SWM - GHG GIZ Calculator (left); emissions broken down by material type and contribution (right).

The table below details the estimated emissions of the MSWM processes in 2023, by source of emission, while also highlighting the amount of waste which was treated per each process type.

Table 3 Estimated emissions of the MSWM processes in 2023, by source of emission, and amount of MSW treated

Source of emission	Amount of MSW treated (tonnes/year)	Value (tonne CO_2eq/year)
Open burning of MSW	3,076	1,346
Uncollected MSW remaining on land	11,831	3,597
MSW at Disposal Sites	83,108	84,236
Recycling	2,136 (out of which 436 paper/cardboard, 1,470 plastics, 231 metal)	-1,301

4 GHG Emissions Reductions with Project Implementation

To estimate the total emissions generated by the MSWM system in Manado after project implementation, two calculation models were developed:

1. **Overall Manado Model**: This model considered all MSWM activities in Manado, excluding the plastic waste recovered and sent for co-processing in cement factories, which amounted to 413 kg/day. This quantity was subtracted from the total waste generated in the city, leading to a recalculated waste generation rate and composition. Additionally, the plastic waste avoided through the use of reusable tumblers in schools (389 kg/day) was also deducted from the total plastic waste generated.
2. **Co-Processing of Recovered Plastic Model**: Since the Calculator is designed to estimate emissions based on the treatment of the entire MSW stream—including all waste fractions—for all processes except for recycling, it does not allow for the specification of a partial flow, such as only a percentage of plastic waste being co-processed in cement factories. Additionally, the available treatment options are limited to Mechanical-Biological Treatment (MBT) under aerobic or anaerobic conditions of the overall MSW. To accurately capture the emissions specifically from the co-processing of plastic waste in cement factories, a separate model was developed, which considered plastic being processed through MBT under aerobic conditions, as per the Calculator's options. This dedicated model focuses solely on the plastic fraction, allowing for a more precise estimation of emissions from this specific treatment route..

More details on the input data used in the GHG models can be found in Annex 2. The final results accounted for emissions from both models.

The intervention measures implemented through the project have contributed to positive climate impact. The rehabilitation of the TPS3R facilities in Cempaka and Malendeng, along with support for waste collection in the Malalayang area, enabled the separate collection of waste and improved overall MSW collection. As a result, more materials were recovered, and the volume of MSW openly burned was reduced. Specifically, the amount of waste openly burned in Manado decreased from 3,076 tonnes/year to 2,441 tonnes/year following project implementation, resulting in a 22% reduction in associated emissions. In addition, activities such as the installation of NTTI river traps and regular beach clean-ups, together with the previously mentioned activities helped reduce the amount of uncollected waste remaining in the environment by approximately 900 tonnes per year, leading to an 11% decrease in related emissions. Additional efforts to expand MSW collection, promote plastic reduction, and enhance material recovery—such as the DSG school project, the Satu Tampa reverse vending machines (RVMs), and the establishment of drop-off points—further contributed to increased recycling. These initiatives led to a 7% increase in emissions offset through recovered and recycled materials.

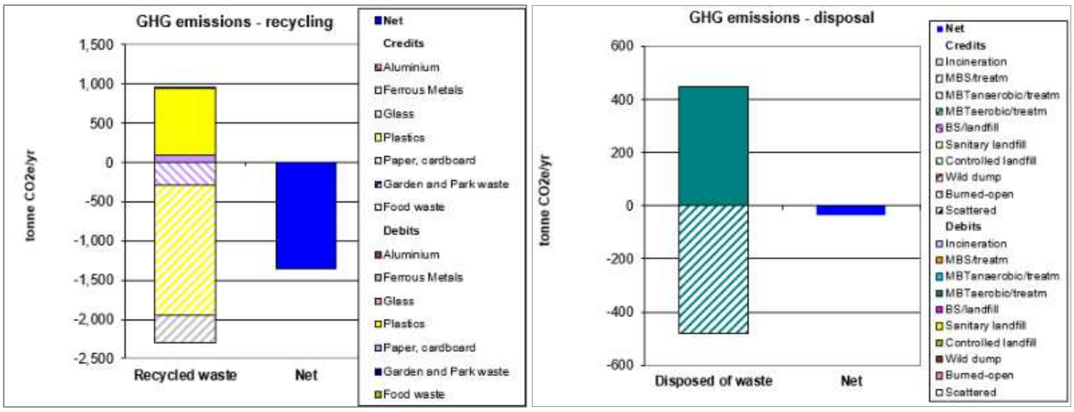
Using the GIZ Calculator Tool, the total associated emissions estimated for the MSWM operations in Manado with the 3RPromar project activities implemented, are estimated to 89,005 tonnes of CO_2eq. Of this total, 86,153 tonnes CO_2eq result from the disposal of waste at the Sumompo disposal site, 1,048 tonnes CO_2eq are attributed to open burning, and 3,201 tonnes CO_2eq are linked to uncollected waste that is illegally dumped in small accumulations. Additionally, an emissions offset of -1,396 tonnes CO_2eq is credited to the recycling of materials and co-processing of plastic in cement factories.

Table 4 Estimated emissions of the MSWM processes in Manado with the 3RPromar project activities implemented, by source of emission, and amount of MSW treated

Source of emission	Amount of MSW treated (tonnes/year)	Value (tonne CO_2eq/year)
Open burning of MSW	2,441	1,048
Uncollected MSW remaining on land	10,492	3,201
MSW at Disposal Sites	84,723	86,153

Source of emission	Amount of MSW treated (tonnes/year)	Value (tonne CO_2eq/year)
Recycling	2,247 (out of which 465 paper/cardboard, 1, 547 plastics, 235 metal)	-1,360
Co-processing	151 (plastics)	-36

The total offset emissions due to recycling of materials was -1,396 tonnes of CO_2eq. A total of 2,247 tonnes of materials were recycled in Manado, comprising 465 tonnes of paper and cardboard, 1,547 tonnes of plastics, and 235 tonnes of metal. These recycling activities resulted in an estimated emissions offset of -209 tonnes CO2eq for paper/cardboard, -805 tonnes CO2eq for plastics, and -347 tonnes CO2eq for metals. Additionally, 151 tonnes of plastics were processed through co-processing in cement factories, resulting in an estimated emissions offset of -36 tonnes CO2eq. The figures below detail the emissions from recycling processes in Manado, with the 3RPromar project activities implemented, broken down by material type and total contribution.



	Emissions	Emission savings potentia	Net results
Recycled Waste	**tonne CO_{2eq}**	**tonne CO_{2eq}**	**tonne CO_{2eq}**
Paper, cardboard	83.66	-292.82	**-209.15**
Plastics	851.02	-1655.63	**-804.61**
Ferrous Metals	5.11	-351.78	**-346.67**
Co-processed waste			
Plastics	446.14	-482.06	**-35.92**
Total	**1385.94**	**-2782.29**	**-1396.35**

Figure 4 GHG emissions from recycling of materials (up left) and from co-processing of plastic in cement factories (up right – through MBT option in the GHG Calculator). Extract from the SWM - GHG GIZ Calculator (up); emissions broken down by material type and contribution (down).

The table below details the estimated emissions of the MSWM operations in Manado with the 3RPromar project activities implemented, by source of emission.

Table 5 Estimated emissions of the MSWM processes in Manado in 2023 and with the 3RPromar project activities implemented, by source of emission

Source of emission	Value 2023 Baseline (tonne CO_2eq/year)	Value Project implemented (tonne CO_2eq/year)	Value difference
Open burning of MSW	1,346	1,048	-298 tonne CO_2eq/year 22.2% reduction
Uncollected MSW remaining on land	3,597	3,201	-396 tonne CO_2eq/year 11% reduction

Source of emission	Value 2023 Baseline (tonne CO_2eq/year)	Value Project implemented (tonne CO_2eq/year)	Value difference
MSW at Disposal Sites	84,236	86,153	1,917 tonne CO_2eq/year 2.3% increase
Recycling	-1,301	-1,360	59 tonne CO_2eq/year 4% increase of offset
Co-processing	0	-36	36 tonne CO_2eq/year

The figure below details the GHG emissions by source of emission, for the 2023 Baseline and with the 3RPromar project activities implemented.

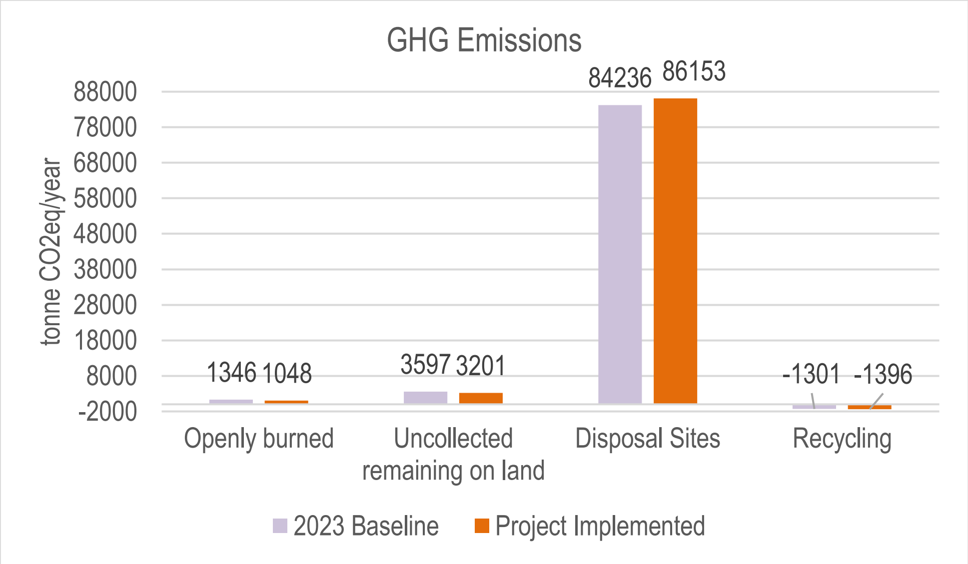


Figure 5 GHG emissions by source of emission in Manado, for the 2023 Baseline and with the 3RPromar project activities implemented; Recycling for the scenario with the 3RPromar project activities implemented also includes the offset emissions from co-processing of plastic

Although there is a slight overall increase in total GHG emissions (1.3%), this is primarily due to a 2.3% rise in emissions at the disposal site, reaching 86,153 tonnes CO_2eq/year. This increase reflects the higher waste collection rate and disposal at the Sumompo disposal site, including the deposition and anaerobic decomposition of organic materials. However, emissions from open burning have decreased significantly by 22.2%, dropping to 1,048 tonnes CO_2eq/year, due to improved waste management practices and the expansion of collection services in previously underserved areas. Additionally, emissions from uncollected waste have declined by 11% to 3,201 tonnes CO_2eq/year. Enhanced recycling efforts and co-processing of plastic waste have also contributed to substantial offsets, reaching -1,396 tonnes CO_2eq/year—an increase of 7% compared to the baseline.

5 Recommendations

3RProMar project in Manado has primarily targeted the reduction of unmanaged plastic waste, aiming to decrease plastic leakage into the environment and waterways, while improving overall waste management practices. While the interventions have led to improvements in plastic waste recovery and a reduction in open burning, to maximize the climate benefits of these interventions and further reduce GHG emissions, a more integrated approach is essential..

Critically, increasing waste collection alone—without parallel efforts to recycle materials and divert organic waste from disposal sites—can unintentionally increase emissions. When more waste is collected but sent directly to unmanaged landfills, especially without separating organics, methane emissions from anaerobic decomposition rise. Therefore, the most effective strategy for reducing emissions and environmental pollution lies in implementing these measures in a coordinated manner: improving waste collection, scaling up recycling and material recovery, and prioritizing the diversion of organic waste from final disposal.

The following recommendations outline key strategies to optimize waste management, enhance material recovery, and promote sustainable waste treatment solutions, while reducing the associated GHG emissions for the MSWMS in Manado, when implemented together.

Enhancing Organic Waste Diversion

Organic waste is a major contributor to methane emissions when disposed of in unmanaged landfills. Diverting organics from the waste stream not only reduces emissions but also creates valuable by-products like compost and animal feed.

- **Promote decentralized and home composting** by establishing decentralized community-based composting facilities and provide training and support for household-level composting initiatives (especially in areas with available space) to reduce the amount of organic waste reaching the disposal site.
- **Develop partnerships with agricultural and livestock sectors** to repurpose organic waste as compost or animal feed, offering a sustainable alternative to landfill disposal and reducing methane emissions from anaerobic decomposition.
- **Extend source-segregation of waste** in households, schools, and businesses to ensure clean streams for composting and other treatments.

Scaling Up Recycling and Material Recovery

Recycling plays a crucial role in reducing the environmental and climate impact of waste by offsetting emissions from virgin material production and lowering the volume of waste sent to landfills.

- **Support the informal waste sector's role** in collecting and recovering recyclables, including plastics, metals, and paper, by providing incentives to their Cooperative and engaging with informal waste pickers to join the Cooperative.
- **Expand materials recovery facilities** and introduce sorting stations in strategic locations to improve operational efficiency and boost the quantity and quality of recovered recyclables.
- **Encourage businesses and industries to adopt circular economy practices,** including increased use of recycled materials, phasing out single-use plastics, and designing products for reuse and recyclability..

Improving Waste Collection

Effective waste collection is the foundation of a functional MSWM system. However, it must be designed to support material recovery and organic waste diversion—collecting more waste without segregation can exacerbate emissions.

- **Establish community-based collection points** to improve accessibility and encourage source-segregated waste collection.t6

- **Expand source-separated collection systems** in areas currently relying on mixed waste collection. Provide households with separate collection bags and require businesses to store different waste types separately at the source. This will enhance material recovery by reducing contamination and improving the quality of recyclables.
- **Enforce local regulations on waste separation** at the household and business level, supported by public education and consistent monitoring.

Improve Sumompo Disposal Site Operations

The current unmanaged conditions at the Sumompo site contribute significantly to GHG emissions and pose environmental risks. Upgrading site operations is essential for minimizing these impacts.

- **Improve landfill compaction and daily cover practices** to minimize odors, control pests, and reduce fire risks.
- **Establish a Mechanical Biological Treatment (MBT) station** to reduce the organic amount of waste sent for final disposal, and to recover valuable materials..
- **Retrofit the site with a landfill gas collection system** using a series of vertical gas wells connected into a manifold system and associated vacuum pumps. Utilise the gas for local heating such as cooking food scraps for animal feed supply or simply flaring to oxidise the methane component into carbon dioxide.
- **Introduce waste screening measures at the disposal site** to prevent the dumping of recoverable or hazardous materials, ensuring better segregation and recycling.
- **Implement leachate management systems** to prevent groundwater contamination and improve environmental protection as part of a broader strategy
-

Awareness Raising and IEC

Community participation is vital to the success of any waste management system. Public awareness and education can drive behavioral change and improve the effectiveness of technical interventions.

- **Promote Source-Separated Waste Collection** byconducting community education campaigns and distribute clear sorting guidelines to households and businesses, ensuring better material recovery and reducing contamination of recyclables.
- **Encourage Organic Waste Composting** by organizing workshops and provide instructional materials on home and community composting techniques to minimize organic waste disposal and promote soil enrichment.
- **Raise public awareness of the informal sector's role** in recycling, and provide training and support to help integrate informal waste pickers into formal systems.
- **Provide targeted training for informal waste pickers** on the environmental and climate impacts of solid waste management practices, including awareness of how their recycling activities contribute to GHG emissions reduction, the importance of proper waste segregation, and safe handling practices. Empowering informal workers with this knowledge not only enhances their role in the waste value chain but also strengthens their contribution to climate mitigation and environmental protection.
- **Use social media, schools, and local influencers** to educate the public on sustainable waste practices, the importance of reducing single-use plastics, and the environmental consequences of unmanaged waste.

Annex 1 SWM-GHG Calculator Excel files

6. Solid Waste Disposal **IPCC guidelines default values**

DOCf
Fraction of degradable organic carbon which decomposes for different waste types
IPCC 2019, V5, Ch3, Table 3.0

Type of waste	Recommended Default DOCf	Remark
Less decomposable wastes e.g. wood, engineered	0,1	
Moderately decomposable wastes e.g. paper, textil	0,5	
Highly decomposable wastes e.g. food wastes, gra	0,7	
Bulk waste	**0,5**	**Default value used for calculations**

MCF
SWDS classification and methane correction factors
IPCC 2019, V5, Ch3, Table 3.1
Note: "While there is not any periodical monitoring or relevant information for management status of SWDS, it should be treated conservatively as poorly managed."

Type of site	MCF default values
Managed - anaerobic	1
Managed well - semi-aerobic	0,5
Managed poorly - semi-aerobic*	0,7
Managed well - active aeration*	0,4
Managed poorly - active-aeration*	0,7
Unmanaged - deep (>5m waste) and/or high water	0,8
Unmanaged - shallow (<5m waste)	0,4
Uncategorized SWDS	0,6

*new with IPCC 2019; (not considered in calculations in IPCC 2019 Tool)

OX
Oxidation factor (OX) for SWDS
IPCC 2019, V5, Ch3, Table 3.2

Type of site	OX default values	Remarks
Managed*, unmanaged and uncategorized SWDS	0	Managed but not covered with CH4 aerated material
Managed* covered with CH4 oxidizing material	0,1	Examples: soil, compost

FCH4
IPCC 2019, V5, Ch3, Appendix 3A.2

	Default value
Fraction of CH4 in generated landfill gas	0,5

Dry matter and carbon content
Default dry matter content, DOC content, total carbon content and fossil carbon fraction of different MSW components
IPCC 2006, V5, Ch2, Table 2.4; no refinement in IPCC 2019

MSW component	Dry matter content in % of wet weight	DOC content in % of wet waste		DOC content in % of dry waste		Total carbon content in % of dry weight		Fossil carbon fraction in % of total carbon	
	Default	Default	Range	Default	Range	Default	Range	Default	Range
Paper/cardboard	90%	40%	36-45%	44%	40-50%	46%	42-50%	1%	0-5%
Textiles	80%	24%	20-40%	30%	25-50%	50%	25-50%	20%	0-50%
Food waste	40%	15%	8-20%	38%	20-50%	38%	20-50%		
Wood	85%	43%	39-46%	50%	46-54%	50%	46-54%		
Garden and park waste	40%	20%	18-22	49%	45-55%	49%	45-55%	0%	0%
Nappies	40%	24%	18-32%	60%	44-80%	70%	54-90%	10%	10%
Rubber and leather	84%	39%	39%	47%	47%	67%	67%	20%	20%
Plastics	100%					75%	67-85%	100%	95-100%
Metal	100%					NA	NA	NA	NA
Glass	100%					NA	NA	NA	NA
Other, inert waste	90%					3%	0-5%	100%	50-100%

Values for calculation

C total in % wet waste	C fossil in % of total carbon
Default	Default
0,414	1%
0,4	20%
0,152	0%
0,425	0%
0,196	0%
0,28	10%
0,5628	20%
0,75	100%
0	0%
0	0%
0,027	100%

Methane recovery (Gg)	R

"The default value for CH4 recovery is zero. CH4 recovery should be reported only when references documenting the amount of CH4 recovery are available."
"Indirect methods might be based on the number of SWDS in a country with CH4 collection or the total capacity of utilisation equipment or flaring capacity sold."

20%	Default when CH4 recovery is estimated on the basis of the number of SWDS with landfill gas recovery
35%	When the amount of CH4 recovered is based on the total capacity of utilisation equipment or flares sold -->35% of the installed capacitites

Annex 2 Input Data for the Calculator model

Table 6 Input Data for the Calculator model

Parameter	Value Baseline	Value Project Implemented	Comment / Source
MSW generated	100,151 tonnes/year		Baseline data (recovered organic waste for animal feed was deducted from the total amount of MSW generated). Project Implemented data (recovered organic waste for animal feed was deducted from the total amount of MSW generated; amount of plastic waste avoided through use of tumbler in schools was deducted from the waste generated)
Composition of MSW	Food waste 41.4% Garden and park waste 9.1% Paper, cardboard 10.1% Plastics 16.2% Glass 2.0% Ferrous Metals 1.0% Aluminium 0.0% Textiles 1.0% Rubber, leather 1.0% Nappies (disposable diapers) 0.0% Wood 2.0% Other, inert waste 16.2%	Food waste 41.6% Garden and park waste 9.1% Paper, cardboard 10.1% Plastics 15.9% Glass 2.0% Ferrous Metals 1.0% Aluminium 0.0% Textiles 1.0% Rubber, leather 1.0% Nappies (disposable diapers) 0.0% Wood 2.0% Other, inert waste 16.2%	Baseline data – the composition was recalculated to account for the recovered organic waste deducted from the total MSW; textiles and rubber was divided equally between the two categories). Project implemented data – the composition was recalculated to account for the plastic waste avoided through the reuse of the tumbler in schools and the plastic treated through co-processing in cement factories.
Classification of water content	High water content	High water content	Based on INDONESIA location
Country-specific GHG electricity emission factor	675g CO2e/kWh	675g CO2e/kWh	Default value provided by the Calculator
Materials recycled as share of the total MSW composition	Paper, cardboard 4.3% Plastics 9% Glass 0% Ferrous metals 22.8% Food waste 0%	Paper, cardboard 4.6% Plastics 9.7% Glass 0% Ferrous metals 23.2% Food waste 0%	As provided by the Calculator Instructions, this represents the share of the total waste composition, per material, meaning that the remaining is either disposed or remaining in the environment. The recovered organic waste for animal feed was already accounted for.
Type of waste treatment and disposal (the remaining residual waste, besides the recycled materials)	Scattered waste not burned 4.83% Open burning of waste (incl. landfill fires) 3.14% Wild dumps/unmanaged disposal site 7.24% Controlled dump/landfill without gas collection 84.79%	Scattered waste not burned 4.3% Open burning of waste (incl. landfill fires) 2.5% Wild dumps/unmanaged disposal site 6.45% Controlled dump/landfill without gas collection 86.76%	Calculated based on Baseline data.
Methane correction factor (MCF)	Wild dumps/unmanaged disposal site – 0.40	Wild dumps/unmanaged disposal site – 0.40	

Parameter	Value Baseline	Value Project Implemented	Comment / Source
	Controlled dump/landfill without gas collection – 0.80	Controlled dump/landfill without gas collection – 0.80	
Output fractions MBT aerobic	n.a.	RDF for co-incineration (cement kiln) – 100%	The model only considered the plastic waste which is sent for co-processing in cement factories.
RDF from aerobic MBT	n.a.	Fossil carbon content – 75% Net calorific value – 31.5%	The model only considered the plastic waste which is sent for co-processing in cement factories.

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