# UNLOCKING PRIVATE CAPITAL FOR SUSTAINABLE PLASTIC WASTE REDUCTION IN INDONESIA

WASTE MANAGEMENT STRUCTURES OPTIMIZATION REPORT, FINDINGS, AND RECOMMENDATIONS

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## About the project

The Technical Assistance Partnership – Expert Deployment Mechanism (TAP-EDM) aims to increase the capacity of Global Affairs Canada (GAC) to provide demand-driven deployment of Canadian expertise abroad on priorities related to the Feminist International Assistance Policy (FIAP) in Overseas Development Assistance (ODA) eligible countries. TAP-EDM offers a toolkit of Technical Assistance (TA) activities and qualified expert resources to meet the expressed needs of National Government Entities (NGEs) that have been captured in a Technical Assistance Initiative (TAI). TAI activities may include a range of interventions such as training, advisory support, policy research, institutional development and technical visits in various domains. The project is implemented by Alinea International.

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## Acronyms

| | |
|---|---|
| ADB | Asian Development Bank |
| ASEAN | Association of Southeast Asian Nations |
| Bappenas | Indonesia's Ministry of National Development Planning |
| BOT | Build, operate and transfer |
| BPSR | *Balai Pengelola Sampah Regional* (Regional Waste Management Center) |
| CAPEX | Capital Expenditure |
| CMMAI | Indonesia's Coordinating Ministry for Maritime and Investment Affairs |
| $CO_2$ | Carbon Dioxide |
| GIZ | German Agency for International Cooperation |
| IDR | Indonesian Rupiah |
| JICA | Japan International Cooperation Agency |
| KfW | German Development Bank |
| kWH | kilowatt hour |
| MEMR | Indonesia's Ministry of Energy and Mineral Resources |
| MLP | Multi-layered Plastic |
| MoEF | Indonesia's Ministry of Environment and Forestry |
| MRF | Materials recovery facility |
| MSW | Municipal solid waste |
| NPAP | National Plastic Action Partnership |
| NGO | Non-governmental organization |
| NRE | New Renewable Energy |
| OECD | Organisation for Economic Co-operation and Development |
| OPEX | Operating expenditure |
| PET | Polyethylene terephthalate |
| PLN | Indonesia state-owned electric utility company (PT PLN) |
| PPA | Power purchase agreement |
| PPP | Public-private partnership |
| RDF | Refuse-derived fuel |
| SDG | Sustainable Development Goal |
| SNI | Indonesian National Standard |
| TPS3R | *Tempat Pengelolaan Sampah 3R* (Reduce, Reuse, Recycle at village level) |
| TPST | *Tempat Pengolahan Sampah Terpadu* (Integrated Waste Management Site) |
| TPA | *Tempat Pemrosesan Akhir* (Final Processing Site) |
| TPD | Tons per Day |
| UNOPS | United Nations Office for Project Services |
| WtE | Waste-to-energy |

## Executive Summary

For the initiative, *"Unlocking private capital for sustainable plastic waste reduction in Indonesia"* (TAI30-2021[1]), the TAP-EDM consultants (Consultants) were tasked to research, analyze and develop practical and realistic financial and technological waste management solutions that would help address Indonesia's significant build-up of marine plastic waste. At the request of Indonesia's Coordinating Ministry for Maritime and Investment Affairs (CMMAI), the scope of the initiative also included mixed solid waste management at three different levels[2]: the TPS3R[3] - village, TPST[4] – municipal, and TPA[5] - regency/major urban centre.

The project was implemented in two phases. From September to January 2022, the fact-finding phase included a technical visit, data analysis and a draft report. This was followed by a validation phase in March 2023, where the contents of the draft report (conclusions and recommended solutions) were presented to stakeholders for comments and feedback.

The fact-finding phase involved extensive consultations with both national and provincial governments in Jakarta and Badung Regency in Bali; private and public sector operators at the TPS3R, TPST, and TPA levels; NGOs; waste bank operators; and, the informal sector consolidators and aggregators. The Consultants researched and analyzed existing waste management approaches and recyclable material supply chain processes, including material pricing. Consultations with major industry developers including PT Sumber Organik[6], Chandra Asri, and Veolia provided valuable insights on the cost-benefit analysis required to structure viable projects at scale.

A key finding was that waste management must be integrated and structured at scale to be profitable and sustainable. Domestic and international private investment/financing interest in government waste management systems is higher once the minimum threshold of 1000 tons of solid waste per day is met. This is based on integrated waste collection and delivery to the plant gate.

The challenge is that Indonesia's current decentralized structure of waste management processes at the village, municipal and regency levels is well below this threshold. Consequently, there is little investment interest from private investors. Moreover, public funding allocations to waste management technology/services at each level (roughly 0.51% of the public budget) is insufficient and limits the economic and financial scope for technology investment at the small and even medium scale.

[1] This specific initiative collaborated closely with CMMAI, the Embassy of Canada to Indonesia, and the Canada-funded Indonesia/ASEAN Field Support Services Project, managed by Cowater.

[2] The function of each site is provided in the following reference: https://waste4change.com/blog/lets-get-to-know-the-functions-of-indonesias-waste-management-facilities-tps-tps-3r-tpst-and-tpa/?amp=1

[3] TPS3R, Tempat Pengelolaan Sampah 3R (Reduce, Reuse, Recycle)

[4] TPST, Tempat Pengolahan Sampah Terpadu (Integrated Waste Management Site)

[5] TPA, Tempat Pemrosesan Akhir (Final Processing Site)

[6] See Appendix C: Benowo WtE Plant in Surabaya

Only in higher income locations where the TPS3R or TPST may charge private user fees on waste collection is investment viable in a small materials recovery facility (MRF), biomass or pyrolysis (i.e., the revenue generated through waste collection from households, SMEs, hotels in these high-income areas may allow for capital and operating cost recovery).

The constraints are most significant at the TPST level, where incoming waste has been largely extracted of any value. The informal market has stripped out all high-value recyclable waste, including polyethylene terephthalate (PET) bottles, glass and aluminum, leaving behind a large proportion of organic waste. Therefore, while investment in a basic MRF may still be an option, a larger investment in a refuse-derived fuel (RDF) facility may only be viable if the processed waste products are sold as briquettes and used as fuel for the cement industry.

A more economically viable option is to integrate the TPST with a TPA to enable investment in a sanitary landfill, extract methane and reduce waste volume via incineration in either a waste-to-energy plant or pyrolysis. Discussions on the costs and benefits of each option are provided in the report.

This report focuses on technological solutions that have also been reviewed and discussed extensively by SistemiQ in collaboration with the Pew Foundation and the Ellen MacArthur Foundation[7]. It is understood that a holistic approach to solving plastic waste pollution requires both upstream and downstream solutions that are outside the range of this present report.

*Please refer to the appendices for detailed case study analyses presented at the workshops held in Bali and Jakarta. A summary of the two workshop findings are in Section II of the report.*



[7] https://www.systemiq.earth/wp-content/uploads/2022/04/ReShapingPlastics-v1.9.pdf

## Section I: Findings: September – October 2022 Technical Visit to Indonesia

### 1 Background

Indonesia hopes to reduce the estimated 1M tons of plastic that is currently "leaked" into the oceans and seas that surround the archipelago. To support this goal, the Government of Indonesia requested technical assistance from Canada via its TAP-EDM Project to analyze the marine plastic waste problem and provide viable technological and financial solutions to reduce the amount of "leaked" plastic. Two Canadian Consultants, a Public Finance Expert and a Waste Management Expert, were recruited to undertake the assignment.

Their work involved consultations, desk research, document review, data analysis and workshops including two technical visits to Indonesia. The purpose of the first technical visit was to collect information (September/October 2023). The purpose of the second visit (March 2023) was to validate the Consultants' findings and recommendations through two workshops.

Towards the end of the first technical visit of the Consultants, at the request of CMMAI, the scope was expanded to include the entire waste management and treatment system for all types of Municipal Solid Waste (MSW), not just plastics. This new scope of work required a complete review of the prevailing MSW collection, transfer and treatment systems in a targeted municipality. This included considering large-volume waste management /treatment based on internationally approved technologies, including waste-to-energy (WtE).

The Government of Indonesia has developed and implemented a waste management structure consisting of TPS3R, TPST, and TPA to enable a revenue stream for the informal sector (waste pickers) and for the village administration involved in managing the MSW and material recovery from it. However, this structure has limited scalability as compared to other waste management systems prevalent in the OECD and other emerging markets. In those examples, one entity collects and manages waste within a city/municipality, using facilities outside the city limits.

Initially, pyrolysis technology was considered the most viable option for treating mixed plastic waste. Pyrolysis allows high monetary yield with a fully circular economic future while providing useful resources (fuel) in the short term. However, given the above considerations related to MSW as a whole, the following technologies will be considered ("reviewed") based on the volume and type of waste at TPS3R, TPST and TPA: MRF; Biomass treatment to reduce organic waste movement/storage; WtE with or without RDF; and, Pyrolysis.

### 2 Review of TAP-EDM TAI30-2021 Technical Visit Findings - September - October 2022

Prior to the fact-finding technical visit, a desktop study was conducted as part of the development of an initiative work plan. Based on the experts' experience in other Asian countries with similar waste management challenges, as well as their review of current publications by members of the Indonesia National Plastic Action Partnership (NPAP), an initial hypothesis was formed suggesting that marine plastic waste was accumulating from terrestrial sources due to inconsistent management of municipal waste and the lack of market value attributed to non-PET[8], mixed plastic. The hypothesis was validated, and further insights were gained during this technical visit.

The technical visit included meetings and site visits with a wide range of stakeholders in Jakarta, Bali (Badung Regency) and Surabaya (see Appendix B). Visits to a wide range of waste management operators' sites/structures (e.g., TPST, TPS3R, TPA, WtE plant, mechanical recycling installations) revealed the following:

- The national policies introducing TPS3Rs in compliance with fiscal decentralization in Indonesia have devolved waste management to local governments at the village and small municipality levels.
- While some benefits have accrued to the informal waste sector, the waste management sector overall has been stymied from achieving the economies of scale required to manage the volume of municipal waste and stem the flow of plastics to the marine environment.
- The administrative structure of the TPS3R is causing fragmentation of the management of Mixed Solid Waste for the following reasons:
    - TPS3Rs bear the entire fiscal and management responsibility for managing Mixed Solid Waste. Operating expenditure (OPEX), however, is constrained by the highly restrictive budget allocated from the Regency's public budget (<0.51%) to waste management. Therefore, the effectiveness of each TPS3R is highly variable and is largely determined by each location's proximity to higher-value economic areas where additional private user fees may be levied.
    - TPS3Rs lack the infrastructure to deal with the large quantity of organic waste delivered, causing logistical and operational issues.
    - TPS3Rs are located in densely populated areas causing issues with access and resulting tensions over accumulated /malodorous waste. Waste management and treatment are usually located on the outskirts of urban centers.
    - TPS3R residues are transferred to TPSTs. However, the quality of the residue is much degraded as most valuable materials (PET, aluminum, and other higher-grade plastics) have already been removed by the informal sector. Removing these materials from Mixed Solid Waste also reduces its calorific and commercial value, thereby limiting the economic and financial value of an MRF at the TPST level.
    - The constraints for moving up the scale become more pronounced should a TPST consider a WtE plant. The low calorific value reduces the value of the MRF and RDF ultimately affecting the investment decision in a WtE plant as little value is to be gained from the feedstock.



[8] PET resin used in fibres for clothing, containers for liquids and foods - especially, for the manufacturing of water bottles and other major non-alcoholic drinks.

## 3 Observations on the management of site-specific TPS3Rs

The Consultants visited a private and public TPS3R - both located in Badung Regency. It was clear that the location of each site was a significant determinant of the viability of each village-level waste processing facility.

***Location 1: Sekartanjung** - a public TPS3R managed with the support of Delterra, an international NGO.*

The Consultants visited the Sekartanjung TPS3R with the Director of Waste Management, CMMAI. They met with the administration, including the village leader and Delterra officials. During this visit, the following observations were made:

a) The slow composting process accumulated a large quantity of organic waste.
b) The volume of static waste constrained the overall operation of the TPS3R. It restricted the available area to develop value-added activities such as installing a material recycling or biomass facility.
c) Locating MSW processing facilities in densely populated/urban areas provoked tensions with neighbors due to odor and noise.
d) Locating MSW facilities in densely populated/urban areas constrains access for larger-scale collection equipment due to congested small roads and tight access.
e) Waste has low value-added potential.

<u>Suggested solutions:</u>

a) Deal with organic waste using bio-char production.
b) Introduce upgraded collection methods using compression garbage trucks and clear collection bags. This will also contribute to educating the householders to separate before introducing waste bins, leading to better quality waste contributing to OPEX revenues.
c) Develop a collection fee structure for householders, businesses, and other commercial entities (cannot exceed US$7/ton, prorated).
d) Technology: Collection trucks, small-scale MRF, shredding and baling facilities.

***Location 2: Seminyak** - private TPS3R*

The subdivision is in a high-density tourist area between Kuta and Canggu[9]. The many hotels, businesses and restaurants in this region have proactively coordinated with the privately owned TPS3R and pay for waste management to maintain a clean environment for its tourist clientele. Anecdotally, their total cost to run the site is between IDR100-180M per year.



[9] https://bali.com/map/

Seminyak maintains the following facilities and services:

a) Daily household collections using 25 trucks.
b) High-profile beach cleanup sponsored by Coca-Cola (since 2007).
c) 2 x loaders on TPS3R site for material handling.
d) On-site composting to process organic waste. Compost is sold to hotels for their in-house gardens.
e) On-site educational tours for school children to promote higher household collection rates and raise awareness of better waste management at the household level including the 3Rs (reduce, reuse and recycle).
f) MRF to add value to the incoming waste at the site.

Suggested solutions:

Undertake further study of this very successful TPS3R to create a business model that could be applied at other sites. Important data to collect from a prospective site includes:

a) Collection fee structure includes what they charge households, businesses (hotels, etc.) and other commercial entities.
b) Activities, related infrastructure, and equipment used for day-to-day operation.
c) Detailed list of operational staff required with salaries.
d) Utility costs.
e) Cost of equipment.
f) Weak points to address.

Location limitations:

In other areas, away from the income generation fostered by high-density tourism, or intensive commercial activity, residents may be unable to afford to pay for waste management, leading to the disuse of TPS3Rs. This leads to low household collection levels, resulting in open waste dumping and ultimate discharge into waterways and oceans (plastic leakage).

# 4 Proposed Value-Added Solutions – Our response to CMMAI's request for process improvement.

CMMAI requested a cost-benefit analysis of the option(s) to improve waste management at TPS3R and TPST levels to attract relevant technology and financing.

## 4.1 TPS3Rs - options for improved process and revenue generation

The primary purpose of structuring the TPS3Rs was to mitigate the cost of landfilling (tipping fees) by reducing the quantity of waste going to TPST. However, the Ministry of Environment has indicated that OPEX is the main issue in running the TPS3Rs and the TPSTs. Less than 0.51% of the regency budgets are allocated for waste management and in some cases, this also needs to cover the tipping fees at the landfill.

Despite the inefficiencies in the waste management structure caused by the TPS3Rs and the hurdles they created to scale up mixed solid waste collection and treatment, there are options to create value-addition.

#### *4.1.1 TPS3Rs as transfer stations*

TPS3R sites in low-income areas with limited budgetary capacity to process waste could act as mini waste transfer stations to support integrated waste management by a private operator/company. The company's compressor trucks would transport this waste from the TPS3Rs to the TPST - as in the case of Benowo in Surabaya.

#### *4.1.2 Materials Recycling Facility*

For those TPS3Rs located in higher income areas, with greater opportunities to levy private fees on waste collection, investment in a small MRF will enable cost recovery from waste management. The MRF would remove plastics and other recyclables such as paper, metals, glass, etc., leaving organic biomass. The MRF could thereby extract value from the incoming material and potentially generate additional revenue, over and above the service fees for waste collection, to meet OPEX requirements.

There would be two options for the remaining biomass: Transport to TPST, or Process at the TPS3R level. To implement either of the above, additional investments is required to upgrade transport systems. It is suggested that a waste compression truck make daily rounds at several TPS3Rs to collect waste material and remove the organics for delivery to the TPST for further processing/disposal.

#### *4.1.3 Biochar*

Organic waste disposal at a high volume TPS3R or TPST level can convert it to biochar (BESTON technology) or vessel-type fast composting, which significantly reduces the time of open-air composting. In the case of bio-char production, a fast process involving pyrolysis may also be considered. The product is a carbon-neutral fuel that reduces the volume of biomass. We recommend this type of plant for 2-3 contiguous TPS3Rs or at the TPST level.

Investments required[10]

Considering the small scale of the TPS3Rs in terms of mass flow and area, a small MRF would consist of the following:

a) Picking station for up to 4 pickers on a conveyor belt.

[10] These prices are to be verified by a tendering/RFP process, and are subject to change.

b) Small but robust baling press for the recyclables to produce standard bales.
c) Small loader to move materials around.
d) Small compression collection truck for MSW and delivering biomass to TPST[11]
e) Optional: biochar production; and, pyrolysis plant for mixed plastics.

The figures below are based on a processing capacity of about 5 tons per day.

| Item | Cost |
|---|---|
| Conveyor belts & Picking station (an MRF) | US$50,000 |
| Bio-char skid mounted | US$100,000 |
| Compressing truck x 2 | US$100,000 |
| Baling press | US$30,000 |
| Loader x 2 | US$60,000 |
| Optional: Plastic pyrolizer to produce oil | US$250,000 |
| Total | US$590,000 |

This investment of around US$590,000 would be the minimum required to support the TPS3R in processing the incoming waste and generating cash flow.

## 4.2 Improve TPST income streams.

### *4.2.1 Current constraints.*

The following factors challenge the economic and financial viability of TPSTs:

a) Low value of incoming waste. Waste pickers collect valuable plastic and other recyclable material from households for sale to consolidators. TPS3Rs and waste banks sort additional value from waste for consolidators and aggregators.
b) High volume of organic waste.
c) Low turnover of waste due to lack of resources (financial, technology, management).
d) Low tipping fees.

The above fosters a high leakage of low-value waste into the environment (plastic leakage).

### *4.2.2 Facilitate integration*

Global waste management is based on large volumes and value-addition to the waste to support financially viable operations. As such, most successful nascent waste management and treatment operations are based on long-term concessions and tipping fees: up to 5-10 years and US$40/ton, respectively.

[11] https://www.heil.com/bodies/non-cdl-mini-rear-load-garbage-trucks/

The waste management company appointed by the local government, primarily via open bidding, maximizes the quantity and quality of the waste stream by controlling the entire upstream and downstream waste supply chain - from collections at the household level to the integrated sorting and treatment of the waste to maximize efficiency and value.

To support integration, the following building blocks are required:

a. Organized household / SME collection system. It is important to give households and SMEs two clear bags so that the contents are VISIBLE to collectors.
    i. This 'trains' households and SMEs to separate the waste by WET (organic waste) and DRY (recyclables, e.g., plastics, glass, paper, cardboard, etc.).
    ii. Allows the collector to decide whether to collect or not.
    iii. Cheaper than providing bins.
    iv. Bags are recycled with recyclables.
b. Collection trucks with rear or side loading capability for clear collection bags. Clear collection bags enable the collector to determine whether the components are appropriately sorted. Collection trucks with rear or side loading enable prompt and efficient loading of bags and prevents loose garbage from falling into the environment.

A vital component for efficiency is the *weighbridge* at the TPST. Control and calibration of the weighbridge by a third party and independent operator is a key component for monitoring waste flow data and determining its value by the local government and TPST operator.

Once incoming waste value data are established, the TPST management, in coordination with the government, may review the calibration of tipping fees and consider the additional economic revenue streams derived from waste to support the financial viability of the TPST.

| **Item** | **Cost** |
|---|---:|
| Compressor Trucks (2 @US$50,000 each) | US$100,000 |
| Material handling equipment | US$60,000 |
| MRF | US$250,000 |
| RDF equipment | US$105,000 |
| Baling press | US$30,000 |
| Optional: Biochar | US$250,000 |
| Optional: Plastic pyrolizer to produce oil | US$3,750,000 |
| **Total Capital Expenditure (CAPEX)** | US$4,545,000 |



The operating expenses for the plant are set at US$40/ton. Based on a daily volume of 50 tons per day, annual operating expenses will be US$672,000, assuming the plant operates for 336 days per year. The estimated annual revenue for a TPST operating both biochar and pyrolysis is US$2.57 million. Therefore, this report strongly advocates considering investments in these technologies to complement the lower estimated revenue from RDF.

Revenue from RDF will fluctuate based on the tipping fee, which may be higher than US$7 per ton, where both the national and local governments expect the plant to generate a greater public good from municipal solid waste reduction.

## 4.3 TPAs

### *4.3.1 RDF project converted to WtE*

Briquette RDF are processed waste products used as fuel for the cement industry. They are a coal substitute for electricity generation.[12]

The West Java Provincial Government revised the waste processing in Legok Nangka from RDF to waste combustion via WtE. The reason being the waste volume from six cities/regencies in West Java had reached 1,820 tons per day. Therefore, the Common Secured Landfill Facility (SL) and waste processing into RDF reduced waste volume to 70 percent.

In January 2018, the regional solid waste treatment and final disposal site project at Legok Nangka were offered to investors via a public-private partnership (PPP) bidding process.

The project offer included the following[13]: (i) tipping fee set at a maximum of IDR 386,000 per ton or est. US$ 25.50 per ton, (ii) power purchase agreement (PPA) set at 13.44 cents per kilowatt hour (kWH). Construction of the WtE was set to begin in 2018.

The cost components in a TPA are as follows[14]: (i) Investment costs, which consist of land acquisition, planning, and construction of Regional TPA facilities, as well as final waste treatment and processing equipment, and (ii) Operational and maintenance costs, which consists of the costs of personnel, fuel, maintenance and maintenance of machinery, materials, building maintenance, overhead and administration.

Investment costs are sourced from the West Java Provincial Government. The operational and maintenance costs are usually the responsibility of service providers in waste-producing regions, namely: Bandung City; Cimahi City; Bandung District; West Bandung Regency; Sumedang Regency; and, Garut Regency.

The management of the Legok Nangka Regional TPA is under the control of the Regional Waste Management Center (BPSR), which is a technical implementation unit (UPT) at the West Java Province Environmental Agency.



[12] Refer to the following article for additional discussion on decision-making process: https://ideas.repec.org/a/rnd/arimbr/v11y2019i1p1-12.html

[13] idem

[14] idem

### 4.3.2 Environmental and Climate Change Considerations of WtE

Untreated waste produces significant methane emissions[15] which increase GHG emissions. Globally, there are hundreds of WtE[16] plants operating worldwide, including approximately 500 in Europe, 75 in the United States, and over 400 in Asia. WtE encompasses a range of technologies some of which do not comply with the climate change goals, including $CO_2$ emission reductions targets of the Government of Indonesia[17]. However, where the appropriate and with the right WtE technology invested, it can used to manage large scale MSW, specifically pyrolysis or gasification in the context of mixed plastics and biomass and can be compliant with the Sustainable Development Goals (SDGs).

# 5 Badung Regency, Bali

The Consultants consider Badung Regency a compelling location for developing a pilot to upgrade waste management processes. This is due to its economic importance to the region and the value of its reputation as a major tourist site - particularly along the densely developed beaches.

However, there are several challenges:

- Suwung landfill in the South Denpasar district has reached its end-of-life and has entered a 'remediation' phase.
- Three new sites are being developed in Denpasar: (i) Kertalangu TPST, to accommodate 450 tons/day of waste, (ii) Tahura TPST, also expected to manage 450 tons/day of waste, (iii) Padangsambian Kaja TPST, to manage 120 tons/day.
- To manage a scalable waste treatment facility at Tahura or Kertalangu, investment is required in installing an MRF and a WtE via methane harvesting/incineration.
- Similarly, in Badung Regency, the expansion of 3 TPSTs in Mengwitani, including in Sangeh, is being considered for up to 300 tons/day capacity.
- Badung Regency has a master plan in line with World Bank requirements to implement WtE. However, there is currently limited scope to pay tipping fees beyond US$7/ton.



## 5.1 Needs Assessment for a WtE in Badung Regency [18]

WtE is an established technology to deal with MSW at scale. WtE involves the collection of unsorted MSW that is brought to a central facility such as an integrated TPST or TPA (In the case

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[15] Calculation of degradable organic carbon (DOC) states that 0.15 kg of methane (CH4) is produced by every 1 kg of dry waste and CH4 emissions of organic waste are 0.07 - 0.11 kg CH4 per organic waste dry weight (Intergovernmental Panel on Climate Change, 2007).

[16] WTE technologies use high temperatures for processing residual MSW. These treatment technologies may be used to recover useable energy (electricity and/or heat for district heating or industry) or produce fuels, including oils, chemicals, and/or char.

[17] For example, the Indonesia Just Energy Transition Partnership's Comprehensive Investment and Policy Plan (CIPP) includes a commitment to reduce Indonesia's power sector carbon emissions to a peak of 250M tons by 2030; increase the share of renewable energy generation to 44 percent by 2030; and, achieve net zero emissions in the power sector by 2050.

[18] Assumptions on WtE economic and financial viability were drawn from several academic journals. Principally from the following source: https://www.mdpi.com/2071-1050/13/13/7232

of Benowo). The waste is processed to be incinerated or gasified to produce heat, which produces steam for electricity generation. WtE is supported by Presidential Regulation no. 35/2018 related to establishing Waste-based Power Plants in Jakarta Province, Tangerang City, Bandung, Semarang, Surakarta, Surabaya and Makassar City.

To date, the only fully operational WtE plant in Indonesia is based on a Built Operate and Transfer (BOT) agreement between the Surabaya City Government and PT. Sumber Organik.

Analysis of WtE

In undertaking the analysis, the following assumptions will be maintained as constant:

(i) Tipping fee[19] is set to remain at US$7/ton for the next seven years.
(ii) Organic waste and mixed plastic waste will be set at a 70/30 ratio.
(iii) Daily waste input will be calculated at 750 tons/day and 1000 tons/day to verify economic and financial viability.
(iv) Interest rate on debt finance is set at 8 percent, based on current market indicators on corporate debt financing in Indonesia.

The Indonesian government, with a recommendation from the Minister of Environment and Forestry to the Minister of Finance, will provide a tipping fee subsidy to 12 local governments participating in the WtE project in accordance with Presidential Regulation no. 35/2018.

The requirements for receiving the tipping fee subsidy include, among others:

a) submitting an official letter from the region to the Ministry of Environment and Forestry;
b) already has Project Based Learning (PjBL);
c) tipping fee recommendations submitted; and,
d) assignment for submitting a tipping fee. This tipping fee subsidy is not provided for free but will be evaluated and monitored annually by Indonesia's Ministry of Environment and Forestry team. The results of this evaluation will affect the nominal subsidy that will be given to the Regional Government.

The assigned values for capital and operating expense - including the cost of feedstock, cost of technology, financing of plant and technology, processed waste product and indicative pricing

[19] Tipping fees are costs charged to local governments for collecting and processing waste from households, the amount of which varies depending on the type and capacity of the waste treatment site, with calculations based on operational and investment costs incurred by the waste management. Operational costs include the costs of collecting, transporting, sorting, processing and disposing of waste. Investment costs include costs for building, maintaining and repairing waste management facilities. Tipping fees are also influenced by government policies regarding subsidies, incentives, or taxes given to waste managers. For waste processing sites using waste-to-energy technology, the tipping fee is determined by the results of the investment auction using the government-business partnership (Kerjasama Pemerintah dengan Badan Usaha – KPBU or PPP) pattern.

were all drawn from the reviewed publication by members of the Department of Chemical Engineering, Faculty of Engineering, University of Gadjah Mada.[20]

Sensitivity analysis includes varying the assumptions on Indonesia state-owned electric utility company (PLN) off-take price agreements between US$ 0.09/kWh and US$ 0.1335/kWh. The price of recyclable waste is kept constant. Some variance is also introduced on debt financing, set at 30 percent and 50 percent of plant costs. The sensitivity analysis clearly demonstrates the most important factors driving the rate of return on plant investment. These are the consistent delivery of 1000 tons/day of waste and PLN off-take pricing, which highly impact the viability of the investment given high fixed capital and operating costs. A sensitivity analysis for the feasibility of a WtE plant with a capacity of 1250 tons per day is presented in Appendix C.

Financials of WtE

WtE plants involve high capital costs. CAPEX is expected to be nearly USD 90 million for a 1000 Tons Per Day (TPD) plant. However, if there are tipping fees and off-take agreements in place with PLN (USD 0.1335/kWh) and feedstock/land concessions for 20 years+, then projects are viable.

As a rule of thumb, the cost of these plants is based on kWh of installed power. Currently, it stands at around US$4000 per kWh installed.

### 5.2 Pyrolysis - recognizing the challenges of the volume of marine plastic waste.

The principal challenge in mitigating plastic waste leakage into the marine environment is developing a market value for Multi-layered Plastic (MLP), which consists of single-use sachets, noodle packets, plastic bags, and small plastic bottles, among other things. This material has little or no value due to absent demand as feedstock for recycling applications. In order to assign a value to MLP and other low-value plastics, a demand must be created for this material. For this to happen, a commercial product must be produced from this material, as a result of recycling. Furthermore, the recycling process must also comply with the SDGs (as mentioned under WtE) and the Circularity targets of the Government of Indonesia. Based on these factors, the Consultants explored the current implementation and use of pyrolysis technology in Indonesia.

Environmental considerations

Pyrolysis is a well-established technology used for centuries to produce charcoal. It is a heating process whereby a material, e.g., plastics, is transformed into fuel in the absence of oxygen (air). Hence, no oxidation of carbon occurs, and thus, no $CO_2$ is emitted. In the case of plastics, the polymers go through a depolymerization process and produce monomers and, if distilled, produce oil with similar properties to diesel or kerosene. This oil can be used as cooking fuel, low-speed diesel applications (such as farm machinery and boats using diesel engines), and diesel power generation.

[20] https://www.mdpi.com/2071-1050/13/13/7232

On a small scale, it is an ideal technology to remove low-value plastic waste from the environment and produce a useful and valuable resource, especially in rural and remote areas or where liquid fuels may be in high demand. It also provides residents of fishing communities with work in the off-season or stormy seasons when large volumes of plastics wash up on beaches and the fishermen are land bound. The alternate source of income is provided through the plastic that is collected and transformed via pyrolysis to produce fuel for own use (cooking, transport).

Indonesian context

The Consultants found many pyrolysis projects despite classification of pyrolysis as a "considered" technology by Indonesia's Ministry of National Development Planning (Bappenas)[21]. In the Guidebook "Waste to Energy" issued by Indonesia's Ministry of Energy and Mineral Resources (MEMR), pyrolysis is one of the options provided by the government for chemical and thermal-based intermediate waste processing facilities. The government's policy regarding processing waste into energy/electricity mandated through MEMR requires the technology to have proven effectiveness and safety in processing waste. Hence the term "considered". This does not rule out the possibility of pyrolysis being implemented in waste processing in Indonesia.

Purple Plastic[22] has an operational pyrolysis plant in Thousand Islands, where the village fishermen collect plastics and convert them into fuel for usage in cooking and boats. The system they have developed indigenously is low-cost and very well-suited for small-scale applications in rural and remote areas. This system can be enhanced and modified to increase the capacity to suit a bigger capacity to fit in with the TPS3R or TPST level. The Consultants met with Purple Plastic's CEO in Jakarta and he was confident that a local solution to deal with MLP could be developed, thus keeping the cost low.

Chandra Asri[23] is the biggest producer of virgin plastics from naphtha (crude oil), employing hydrocarbon cracking units at an industrial scale. They implement circular solutions whereby the monomers obtained by pyrolyzing mixed plastics can be refined and used as feedstock by them to produce virgin plastics. These are high-investment projects and potentially require hundreds of millions of dollars.

**Looking ahead**

In the short term, before meeting the SDGs and the Circularity targets, it is envisaged that pyrolysis oil will either be used as fuel (small scale) or have offtake agreements with large operators such as Shell, BP, etc., in Singapore for the pyrolysis oil, to be mixed with the feedstock to produce fuels.

[21] Platform Sistem Pengelolaan Sampah, September 2021

[22] https://purpleplastic.id/sumber-daya/

[23] https://www.chandra-asri.com

In the long term, all the oil from large-scale production of pyrolysis oil could be used as feedstock for refineries to produce virgin plastics.

*Urgency to resolve plastic waste*

The issue of plastic waste leakage poses an existential threat not just to the fishing and other marine-related industries in Indonesia but to the highly lucrative tourist industry, especially in Bali. Furthermore, potential locations for tourist destination development may face similar issues, as plastic waste in waters around Indonesia is a pervasive problem. Plastic discharge along the beaches was observed first-hand by the Consultants at the most popular beaches in Bali, such as Jimbaran and Sanur.

*Follow-on Steps for the TAP-EDM Mission in consultation with CMMAI*

The need for concerted action on both large-volume MSW and marine plastic waste pollution has become recognized at both the national level in Indonesia and the international level by the UN agencies and the OECD[24]. As a result, specific grant and multilateral assistance programs are available to develop sustainable projects.

The scale of plastic waste is well documented internationally. International foundations, including the Ellen MacArthur Foundation, together with the Pew Foundation, have coordinated with a group of international public and private industry and investor stakeholders on identifying the pathway to circularity. The collaborative report published by SistemiQ in 2022 identifies the four major pathways to Reshaping Plastics and Achieving the Pathways to a Circular Climate Neutral Plastics System in Europe. The report clearly identifies the need for a holistic approach that addresses both upstream and downstream challenges. It also reviews the application of specific technologies including MRF as well as Chemical Recycling (pyrolysis and WtE)[25].

The Consultants have presented these technologies during stakeholder meetings in Bali and Jakarta – with a focus on investment opportunities and discussions on pathways to support circularity.

The short-term mission conducted over the period of October 2022 – March 2022, focused on pragmatic solutions to address the volume reduction of MLP and MSW. The technology solutions consider the existing fiscal and institutional constraints in Indonesia, which presently restrict the scale of subsidies or grants available in the waste sector. While the limited fiscal space for providing grants or subsidies may create a deterrent for structuring public-private solutions at small

[24] https://www.oecd.org/newsroom/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm

[25] Refer to page 40 of Systemic report "ReShaping Plastics" (2022) for a presentation on the Four Systems Intervention. Refer to pages 47-49 for a discussion on methods to expand mechanical recycling. Refer to pages 50-52 on Scaling Chemical Recycling Capacity. https://www.systemiq.earth/wp-content/uploads/2022/04/ReShapingPlastics-v1.9.pdf

and medium scale, opportunities exist for attracting investors to the most profitable sites where feedstock of both MLP and MSW are readily available at scale and delivered at plant gate at a minimum of 1250 tons per day.

## Section II: Findings of March 2023 TAP-EDM Mission (Feedback from Bali and Jakarta Workshops and Site Visits)

At the request of CMMAI and with the ongoing support of the Embassy of Canada in Indonesia, the objective of the second mission was to present a series of technology and finance case studies to stakeholders in Bali and Jakarta. The detailed case studies enabled focused discussions on the options for the government, national and local, as well as the donor community to consider the sustainable investment opportunities to manage MSW and MLP waste.

The case studies presented in the final appendix shared the following assumptions:

I. Public financing of MSW, including MLP, is limited to 0.51% of the public budget – hence the maximum tipping fee paid by the government to a waste processor is limited to USD 7 per ton (compared to USD 40 per ton prevailing internationally);
II. PPP project development opportunity will be determined by the project's internal rate of return, i.e., the ability to generate project cash flow from value-added waste products and possibly, direct service fees (households, SMEs, enterprises);
III. PPPs require specific management and contractual agreements guided by best international practices in enterprise management.
IV. Technology needs to be carefully targeted to geographical location, type and volume of waste, volume and consistent quality of waste feedstock delivered to plant gate;
V. Financing will be conditional on risk mitigation of all major factors guiding investment decision – these are, among others:
    a. structuring a reliable supply chain with upstream / feedstock and downstream / offtake agreements,
    b. land and tax concession agreements,
    c. environmental safeguards,
    d. independent audit procedures,
    e. cost of financing and type (debt and equity),
    f. foreign / majority ownership,
    g. political support at the local level for the type of technology investment and investment cost recovery schedule,
    h. management structure and qualifications of CEO, CFO, plant manager(s),
    i. labor standards and dispute settlement procedures.

The workshops in Bali and Jakarta prompted discussion on widely divergent levels of constraints and opportunities.

# 1 Bali Workshop results

The workshop held on March 9, 2023 was attended by representatives of the Denpasar, Badung and Gianyar regency from the departments of public works, environment and home affairs as well as representatives from the Bali provincial government. Major international NGOs active in Badung Regency in the waste management sector were also represented, including Delterra. Given Indonesia's highly decentralized nature of waste management, the views and feedback received from the regency-level officials were most helpful in guiding opportunities to identify investment options.

The most relevant and immediate feedback focused on the emergency related to waste disposal following the closure of the Suwung landfill. New TPSTs are coming on stream in Tahura, Kertalangu, Padansambian, and Mengwitani. However, the current daily flow and waste volume has led some regencies to move forward with open incineration.

Furthermore, some competition for feedstock between the government-managed TPST and the private sector-led TPST, in a contiguous location will need to be managed more strategically if additional technology investment is to be facilitated in an area such as Mengwitani.

Major takeaways to support new technology investment relate to the following:

→ Need to tighten the supply chain and ensure just-in-time delivery of value-added waste / feedstock to the TPST plant gate in order to enable additional investment in technology.
→ TPS3Rs need to act as transfer stations and deliver MSW and MLP via compressor trucks to TPST plant gate.
→ TPST to process between 50-350 tons per day and extract value via biochar, RDF or pyrolysis investment.
→ WtE requires large volumes of MSW – at a minimum of 1000 tons per day if tipping fees will remain at USD 7/ton.

Concerning the above, Bali stakeholders indicated the following:

→ Acknowledgement of the need to manage volume waste more effectively – including support for investment in compressor trucks at the TPS3R level, provided existing truck operators support new investment;
→ Backward integration is underway between Kertalangu TPST and 17 TPS3Rs with an expanded agreement across 40 TPS3Rs being envisaged in the coming 24 months
→ RDF is the prevailing technology for TPSTs in Bali – the reason being, the briquettes are widely used by the hotel association members to generate steam and certify sanitary standards for laundry.
→ Biochar – a strong interest in this technology to process the high volume of organic waste and move the waste from TPS3R to TPST to enable scale production.

→ Interest in pyrolysis as a separate, foreign-invested plant. Discussions focused on the need to maintain TPST activity focused on RDF and possibly biochar, with a separate offtake agreement potentially structured between TPSTs and a new pyrolysis plant for MLP. This is to support GHG compliance by TPST operators producing MLP-free briquettes.

## 2 Jakarta workshop results

The workshop held on 14 March 2023 brought together a very different set of stakeholders. The Embassy of Canada, with the agreement of CMMAI, invited all the major donors and government ministries focused on waste management and plastic waste reduction in Indonesia. The attendees included the World Bank, the Asian Development Bank (ADB), Danish Government, German Development Bank (KfW), German Agency for International Cooperation (GIZ), Japan International Cooperation Agency (JICA), United Nations Office for Project Services (UNOPS), Bappenas, PLN, and major NGOs such as NPAP, Oceans Integrity, Minderoo Foundation, as well as senior academics from Gajah Mada University.

The case studies on each technology drew animated discussion on the following:

→ Recognition of public finance constraints – the government can only afford US$7 per ton tipping fee. All donors and government agencies fully agreed regarding this constraint and advocated the need for public-private solutions to enable volume MSW and MLP disposal.

→ WtE represents the opportunity to absorb large volumes of MSW and MLP at a minimum of 1000 tons per day. However, there is limited opportunity in Bali and Java to offtake this coal-equivalent feedstock.

Based on PLN’s assessment, Java and Bali's densely populated provinces currently experience excess electricity generation capacity. Therefore, the implementation of Regulation 2018 whereby the national government advocates WtE to dispose of municipal waste across Indonesia’s twelve major urban centres is not enforceable in Bali or Java. According to PLN, the underlying economics of electricity generation do not support additional investment in WtE. Based on this assessment, PLN does not favor providing the required 13.335 cents per kilowatt hour to justify the capital investment in a coal-equivalent energy plant in Java or Bali.

According to PLN, the less populated provinces of Sumatra, Sulawesi and Kalimantan are underserved in terms of access to electricity. These provinces represent a more viable economic rationale for the guaranteed PPA of 13.335 cents per Kilowatt hour that would attract international project investment in WtE.

→ RDF – given the low tipping fee and low market value of the waste-derived product, investment in RDF is highly dependent on location and effective plant management. The coal-equivalent product needs to be competitively priced relative to subsidized coal in the market – therefore, an RDF plant needs to be located near the off-takers (cement plants, WtE plants or other industries to produce heat) to reduce transport costs. To ensure the profitability of the low-margin product, an RDF plant manager needs to ensure predictable and reliable volume delivery to customers, as per contract stipulation.

Most mid-size to large TPSTs met by the Consultants produce RDF. While the Consultants could not confirm the exact tipping fees, the amounts may vary based on the location and size of the TPST and the national government's willingness to create an added incentive for province-specific investment.

→ Biochar – strong interest was expressed in this higher value process – particularly in Bali, where a large volume of biomass waste is generated. The opportunities for investment at the TPST level will be greatly determined by structuring a supply chain of biomass feedstock, on a contractual basis, with participating TPS3Rs.

→ Pyrolysis – both the Bali and Jakarta workshops expressed a high level of concern over marine plastic waste and the need to identify a technology solution to address the volume of marine plastic and MLP in municipal waste. Given low tipping fees, investment in a pyrolysis plant will require volume feedstock delivery at the plant gate and an offtake agreement for the high-value diesel fuel. The economics of plant efficiency need feedstock inputs of 150-300 tons per day to generate the output of diesel fuel required to support the internal rate of return on investment.

Within the Association of Southeast Asian Nations (ASEAN), plastic waste is processed using pyrolysis technology in Thailand and Vietnam, while the technology is well-established in China and Japan. In Canada, a substantial investment in pyrolysis technology is being implemented in the province of Quebec. Canadian pyrolysis technology is also being deployed in Japan.

## Section III: Final Recommendations and Next Steps

CMMAI is considering the above technologies and has requested that the Consultants identify opportunities for blended finance to scale up the processing of MSW and MLP. Based on the fiscal constraints of the government of Indonesia, PPPs offer a viable opportunity to implement the appropriate technology in a given geographical area. To structure a project that responds to both public constraints as well as the pressing public need for a solution, a follow-on pre-investment study is required to scope out project feasibility in a given geographical area.

Based on this study and various meetings with private and public parties, the Consultants strongly recommend that CMMAI consider the option for a 300 TPD plastic pyrolysis plant investment. An approximate timeline of 18 months is considered necessary for the technical, financial, governance and environmental due diligence.

### 1 Next Steps: Pyrolysis

(i) Consider establishing a pyrolysis project outlined in this report, along with the financial contribution.
(ii) A project proponent needs to be identified with the following credentials:
   a. Strong financial record in Indonesia or internationally, verified by any of the big four accounting firms.
   b. Appetite for PPP-type arrangement in the project.
   c. Willing and capable of being an equity partner in the project.
   d. Technically aware and committed to the aims and objectives of CMMAI and sustainability framework.
(iii) An appropriate location must be identified with access to the MLP feedstock generation areas and aggregators. Political and other considerations are to be at the forefront of this decision.
(iv) Start negotiations with the regency.
(v) Identify an off-taker and start negotiations to put an MOU or binding contract in place.
(vi) Start negotiations with suppliers of MLP to establish a supply chain.
(vii) Prepare a FEASIBILITY STUDY based on the above.
(viii) Start implementing the project on the ground.
(ix) 2-3 year implementation timeframe before pyrolysis-derived oil starts to be produced.

Pyrolysis technology is not only useful to reduce waste that otherwise becomes a landfill burden but also to produce alternate material to fossil fuels for power plants and cement factories. As a fuel for fishing and motorcycles, pyrolysis-derived fuel reduces reliance on hydrocarbons. Currently, there is quite a lot of use of pyrolysis technology to process waste in Indonesia, both at a small scale ranging from 10 – 20 tons/day at the island level and waste banks, to internal corporations. This shows promising results in the context of reducing waste, particularly MLP. Most waste banks and even recycling collectors in Indonesia rule out collecting MLP from both households and landfills because they are considered to have no economic value.

The attention of the Government of Indonesia in supporting waste management and the use of thermal technology such as pyrolysis to treat waste already exists and is set forth in various regulatory policies and derivative regulations in the form of decisions, including:

i. Regulation of the Minister for the Environment No. 13 of 2012 concerning Guidelines for the Implementation of Reduce, Reuse and Recycle through Waste Banks;
ii. Regulation of the Minister of Environment and Forestry No. P70/2016 which regulates the Emission Quality Standards for Businesses and/or Thermal Waste Treatment Activities;
iii. Regulation of the Minister of Energy and Mineral Resources Number 5 of 2021 concerning Standards for Business Activities and Products in the Implementation of Risk-Based Business Licensing in the Energy and Mineral Resources Sector and its derivatives in the form of Decree of the Director General of New, Renewable Energy and Energy Conservation Number (5.K/EK. 05/DJE/2022 concerning Standards and Quality (Specifications) of Bio-Diesel Biofuels as Other Fuels Marketed Domestically.

Projects for utilizing pyrolysis in processing waste with a scale of 50 – 200 tons/day have also started in several areas, including on a small scale at the Kedungrandu TPST, Banyumas Regency, Central Java which is managed by the local non-governmental organization, KSM. For a larger scale at the sub-district level, it has started in Sangatta Regency, East Kalimantan with a waste processing capacity of 50 tonnes/day. Meanwhile, for a larger city scale of 120 tons/day, construction of a processing facility has begun in Tebet District, South Jakarta. Another area that is starting to be interested in utilizing pyrolysis technology is the Province of Yogyakarta which is currently negotiating a waste treatment at the Piyungan landfill of 200 tonnes/day with a CAPEX (not including land) of around IDR70 billion. All of these projects involve community activities at the waste bank. These are valuable opportunities to sensitize the community to environmental issues and how they can play a positive role, including by seeing previously neglected plastic waste as a raw material for processing in pyrolysis facilities. The support provided was obtained from the Ministry of Environment and Forestry[26] which stated that pyrolysis technology is more environmentally friendly.

There are numerous international pyrolysis technology providers. The scale of available plastic feedstock, delivered to potential plant gate, will determine the investment. In the context of Badung Regency, Bali, which has a 2023 APBD target of IDR 6 trillion, the budget enables investment in pyrolysis-related waste processing.



## 2 Next Steps: WtE

(i) Consider establishing a WtE project outlined in this report, along with the financial contribution.
(ii) Identify the project proponent, as per the following:
   a. Track record of developing WtE projects.

[26] https://mediaindonesia.com/humaniora/87913/teknologi-pirolisis-lebih-ramah-lingkungan

b. Strong financial record in Indonesia or internationally, verified by any of the big four accounting firms.
c. Appetite for PPP-type arrangement in the project.
d. Willing and capable of being an equity partner in the project. Either self-financed or backed by an appropriately sized project developer.
e. Technically aware and committed to the aims and objectives of CMMAI and sustainability framework.

(iii) Identify and select a location with the help of CMMAI. Location to be one of the twelve earmarked cities benefiting from the presidential decree No. 35 of 2018.
(iv) Open negotiations with the regency to secure concession agreement for a minimum of 20 years along with gate fees (not expected to be more than US$7/ton).
(v) Open negotiations with PLN to establish interconnection and PPAs.
(vi) Prepare feasibility based on the above.
(vii) Secure finance and start implementation.
(viii) 3–5-year timeframe before power gets delivered to the grid.

## 3 Next Steps: A third option to develop co-firing capability and capacity for RDF offtake.

A third option based on RDF is also being trialed in one of PLN coal-fired power plants already. RDF is a low-intensity investment with big potential if there are off-takers of RDF in the vicinity. This has been a challenge for waste managers because they have identified cement plants as the main off-taker of RDF.

However, if an existing coal-fired plant can be modified to use RDF as a substitute for coal, a ready offtake for RDF will be available across Indonesia. This will avoid placing an undue burden on the electricity grid as PLN will not be required to accommodate additional net power generation infrastructure, as in the case of a new WtE plant. Accommodating a new energy plant may explain the reticence of PLN to sign new PPAs with potential WtE proponents. It would also explain why a single WtE plant (Benowo) was established to date since the presidential regulation was passed to encourage WtE in the twelve cities.

MEMR has already done significant work in developing regulations on RDF with specifications and standards for WtE and cement plants already in place[27]. The referenced document states, "The government has prepared a draft Ministerial Regulation related to the biomass and co-firing program in RDF-fired power plants by utilizing biomass as a coal substitute. This program is carried out to achieve the New Renewable Energy (NRE) target of 15% by 2025." This comes under Regulation 35 (2018) and could further help the project proponent establish this type of project. While waiting for the issuance of the relevant ministerial regulations, the use of RDF in cement factories still refers to the Technical Specification Guidelines for Refuse-Derived Fuel (RDF) as an Alternative Fuel in the Cement Industry published by the Center for Research and Development of Green Industry and the Environment, Research and Development Agency Industry, Ministry of Industry of the Republic of Indonesia, 2017.



[27] https://ipen.org/sites/default/files/documents/ipen-rdf-pef-indonesia-v1_5aw-en.pdf

Advantages:

1. The national grid may need more capacity to absorb or handle the additional power generated by the WtE plants proposed for the twelve cities under the presidential decree. Using RDF at existing coal plants would overcome this issue.
2. No need to negotiate a complicated PPA with PLN paving the way for developing RDF capacities nationwide.
3. A package can be designed to replicate with the appropriate technology upstream (MSW management to produce consistently high-quality RDF) and downstream (upgrades to co-fire RDF with coal) at the power plant level.

Other Considerations:

RDF could be considered a useful alternative fuel as long as the production site is close to a cement factory or a WtE facility. Consideration to produce RDF can be carried out among the 52 points of PLN's coal-fired power plants which require pellet/RDF raw materials from waste raw materials. The standard specifications set by PLN for RDF refer to the Indonesian National Standard (SNI) 8966:2021[28] for Solid Fuel. In addition, choosing a location near the cement industry which has 34 kilns can also absorb RDF production from waste with a minimum calorific value specification of 2,500 kcal/kg[29]. RDF is also being used as an energy source in high volume tourist areas by hotels managing large laundry facilities.

The application of Refuse-Derived Fuel (RDF) technology is one of the strategies implemented by the Indonesian Government in the cement industries and power plants, to utilize the energy content of domestic waste and industrial solid waste. The technology's objective is to support efforts to conserve natural resources such as fuel, reduce $CO_2$ emissions, and contribute to overcoming waste problems. Law Number 3 of 2014[30] encourages the development of Green Industries to increase the efficiency and effectiveness of sustainable use of resources that preserve the environment and benefit society. The cement industry is one of the industrial subsectors that is considered ready to implement the Green Industry concept.



[28] SNI 8966:2021 Bahan bakar jumputan padat untuk pembangkit listrik

[29] Standard alternative fuel from solid waste, Semen Gresik - Rembang Factory.

[30] UU No. 3 Tahun 2014 tentang Perindustrian

## Appendix A: Conclusion: Can Private Capital be Unlocked?

Unlocking private capital outside the 12 priority cities.

1. Risk factors for large WtE and pyrolysis plants. The major risk factor for an investor, outside the 12 priority cities, will be the just-in-time delivery of up to 1250 tons of waste per day, at a plant site located in a more remote area. Therefore, the more remote the location, the higher the risk of investment which will require careful risk management with governments at municipal, regional and national level and likely, a higher corresponding subsidy. These will need to be in the form of grant financing, tipping fee and feed-in-tariff subsidy in a WtE investment, and contractual off-take agreements for pyrolyisis-derived fuel.

2. Risk factors for mid-sized RDF plants. The location of these plants, processing between 500-1000 tons of waste per day, will be key to their profitability. Therefore, an RDF plant located close to an off taker whether this be a cement plant, high volume heat facility such as hotel laundry facilities, or a WtE plant, will be a key determining factor in attracting private investment and corresponding professional, management structure.

3. Risk factors for small village-level biomass. As indicated in the report, location and most critically, management ability, play a significant role in enabling multiple revenue stream generation at TPS3R level. The Consultants met with the operator of the TPS3R in Seminyak where the biomass facility is operated on a commercial basis, supported by annual financial statements. In addition to the revenue streams derived from the sale of composted biomass product to the various hotel establishments, the TPS3R also derives income from the sale of biochar to enterprises and households and collects multiple user-based fees to support annual capital investments and operating costs. Where location does not enable multiple revenue stream generation for a TPS3R, the report strongly advocates the integration of TPS3Rs, on the basis of contractual feeder stations, to TPSTs.

Options for blended finance

The use of blended finance in waste management has been implemented in OECD economies. A key factor has been the expanded public budget geared to support investment in efficient waste management. The improved investment environment and resulting improved waste management, has also been achieved through the privatization of waste collection and processing, as well as PPP agreements facilitating investments in major waste processing plants. The OECD provides an overview of the major areas of policy action enabling investment in waste management through public, private, and blended finance.[31]

In Indonesia, the low level of public budget dedicated to waste management will require time to be adjusted. In the interim, the most viable option for policymakers is to enable private investment



[31] https://www.oecd-ilibrary.org/sites/1f4e61ee-en/index.html?itemId=/content/component/1f4e61ee-en

within proximity to major urban areas. The prevailing government regulations recognize this reality and have created the opportunity for investment in the major 12 cities.

The report identifies the viability of large scale WtE and pyrolysis investment, as well as RDF and biomass processing - based on location. The initial review of the profitability of these investments, will enable the consideration of financing options by national and municipal governments with both national and international investors. Investors may range from private corporates, bilateral financial institutions as well as multilateral financial institutions (MFIs). MFIs have started to structure Special Purpose Vehicles to catalyze large scale investments in major public-private waste processing sites.

Solutions for more remote areas

Small scale projects are inevitably higher risk given their location and the more intensive due diligence required in verifying project administration. In these areas, the expertise of established Indonesian NGOs is most valuable. The Consultants met with Delterra and they benefited from their presentation on clustering TPS3Rs in Badung Regency. The Consultants also met with PURPLE plastic[32] who have pioneered pyrolysis of ocean-derived plastic for use as fuel by the fishing communities. The viability of these projects merits further consideration for replication in Indonesia.



[32] https://purpleplastic.id/https-purpleplastic-wordpress-com-join-us/

## Appendix B: Stakeholder Meetings (September – October 2022)

Jakarta 1:

- Ministry of Public Work and Housing – Directorate of Sanitation
- MoEF - Directorate General of Waste and Hazardous Materials Management (PSLB3)
- Multi-stakeholder kickoff meeting hosted by CMMAI
- Ministry of Industry - Directorate of Downstream Chemical and Pharmaceutical Industry
- IFC representative
- World Bank representative - Environment & Natural Resources
- ADB representatives
- JICA representatives
- Pak Agus Sari, Founder of PURPLE
- Ministry of Industry - Standardization Agency and Industrial Services Policy
- Indonesia Canada Chamber of Commerce

Bali:

- Reciki Solusi Indonesia
- PT. Systemiq Lestari Indonesia
- Plastic Bank
- Environmental and Cleanliness Agency of Denpasar City Regency (DLHK Denpasar)
- P.T. Bali CMPP (TPST Operator at Tahura), together with the Director of Waste Management, CMMAI and the Deputy Minister for Environmental and Forestry Management, CMMAI
- Delterra
- Environmental and Cleanliness Agency of Badung Regency (DLHK Badung)
- Public Works and Spatial Planning Agency of Badung Regency
- Pak I Komang Ruditha Hartawan, TPS3R Seminyak.
- Circulate Capital
- Digital Central Waste Bank in Gianyar Regency - Griya Luhu

Surabaya:

- Reciki Solusi Indonesia
- Central Waste Bank in Surabaya - Yayasan Bina Bhakti Lingkungan
- Environment Agency of Surabaya City (DLHK Surabaya)
- Visit to Benowo WtE Facilities (facilitated by DLHK Surabaya)
- Second Muse
- Visit to Veolia RPET plant in Pasuruan

Jakarta 2:

- PT SMI - SDG Indonesia One
- Chairperson of Indonesia NPAP
- Chandra Asri (Pilot pyrolysis project in Central)

## Appendix C: Benowo WtE Plant in Surabaya

At present, one plant in Benowo deals with 1000 TPD running under a PPP model between Surabaya Regency and Pt. Sumber Organik. The following are the details[33]:

a. Benowo WtE is based on gasification technology supplied by SINOMAC[34].
b. Benowo landfill has an area of 37-hectares and a WtE power plant comprising waste disposal capacity ranging from 1,300 to 1,500 tons daily.
c. It has a 1.6 MW methane plant based on methane extracted from a landfill.
d. It also has a 9 MW standard gasification WtE plant dealing with the daily incoming waste.
e. It was completed and inaugurated in 2021 by President Joko Widodo at an indicated cost of US$49.86M[35].
f. All the electricity produced is sold to PLN for US$0.01335/kWh.
g. There is also a tipping fee of US$7/ton controlled via a weighbridge at the entrance and controlled by Surveyor Indonesia[36] operating on contracts of 3 years to maintain transparency and best value to the City of Surabaya.

Management of Waste Treatment in Surabaya City[37]:

"Surabaya produces up to 1,600 tons/day from the activities of three million citizens. Based on the data from the Surabaya City Government, the waste generated daily is also contributed by the high level of non-resident activities in Surabaya. Garbage in Surabaya consists of at least 31 types, of which around 60-70% is wet waste. The Surabaya City Municipal Government has implemented a zero-waste policy through the Waste Bank program to carry out 3R activities (reduces, reuses, and recycles). This process has succeeded in reducing around 30- 40% of the waste before being sent to the Final Management Site (TPA), so it is expected to reduce the amount of landfill in TPA. In managing its waste, the City Municipal Government involves the role of the private sector through an auction process. Based on a memorandum of understanding (MoU), the current corporate selected by the Surabaya City Government to run waste management in TPA Benowo is PT. Sumber Organik has had a system of build, operate and transfer (BOT) since 2011 for a period of 20 years.

Waste management in Surabaya uses a sanitary landfill system by the provisions in *Law No. 18 of 2008 concerning Waste Management*. The Benowo landfill area is around 37.4 Ha. The Surabaya City Government owns the survey results to TPA Benowo; Surabaya shows that the Surabaya City Government has truly involved the role of the private sector through such actions. The Surabaya City Government invested Rp336 billion in this cooperation to provide 18 hectares of land. At the



[33] Additional details on subsidies provided by the Government are to be found in: https://ideas.repec.org/a/rnd/arimbr/v11y2019i1p1-12.html

[34] https://www.sinomach.com.cn/en/MediaCenter/News/202101/t20210127_269831.html

[35] https://www.gatra.com/news-467191-Technology-surabaya-to-generate-electricity-from-waste.html

[36] Data needs checking.

[37] The full discussion of the Benowo WtE plant is found in the following publication: https://ojs.amhinternational.com/index.php/imbr/article/view/2841/1848

same time, the waste management in Surabaya City Government paid a tipping fee to PT. Sumber Organik of Rp119,000 / ton for the first year. The tipping fee increased by 7% per year in the first ten years; in the second 10 years there was a 3% increase per year. For 2016, 2017 and 2018, the (respective) tipping fees are Rp155,985 per ton, Rp166,904 per ton, and Rp.178,587 per ton.

In accordance with the MoU between the Surabaya City Government and PT. Sumber Organik, from TPA Benowo, PT Sumber Organik uses methane gas produced from landfill to be used as electricity through biogas technology facilities. Since 2015 WtE Benowo plant has produced electricity of around 1.5 MW per day by processing methane gas produced by landfills at the Benowo landfill.

The electricity produced is sold to PT. PLN with a price of around 18.77 cents USD / kWh refers to MEMR Ministerial Regulation (*Permen ESDM) No. 44 of 2015.* The income from the sales of electricity generated from WtE Benowo plant is entirely the income of PT. Sumber Organik. At present the Surabaya Municipal Government and PT. Sumber Organik is studying landfill processing in the Benowo landfill with thermal or combustion technology. It is intended to take advantage of the large amount of existing landfill and also the increasing supply of waste. If the above discourse comes to an implementation agreement from Benowo Landfill, it is estimated that the electricity of 9 MW output can be produced.

There are ongoing discussions around the utilization of the processing and burning of methane gas in landfills, which is regulated under Presidential Regulation No. 35 of 2018 *concerning the Acceleration of Development of Waste to Electrical Energy Processing Installations Based on Environmentally Friendly Technology*. This 2018 regulation replaces the previous Presidential Regulation No. 18 of 2016 concerning *Acceleration of WtE Development*. The 2018 regulation designate 12 cities as priority locations for WtE.

The previous 2016 regulation made a reference to thermal technology in waste processing. The new regulation does not specifically mention the type of technology (e.g. thermal) that must be used, however it does include requirements for machines/equipment to be used that can process waste into electrical energy, and reduce the volume and time of waste processing significantly through environmentally friendly and proven technology that meets quality standards in accordance with statutory provisions.

Regarding cooperation in waste management through the WtE project, the tipping fee paid by the regional government is very much needed as an incentive to invite investment. This is to support the operational costs and maintenance of high WtE technology facilities. An offer from a number of investors who state their readiness to do waste management without the need for tipping fees with electricity rates of US$0.1877/kWh, the credibility and readiness of such investors need to be identified further, given the record that cooperation in the construction of WtE involving such investors could not be carried out until now. With the abundant amount of waste supply from the city of Surabaya to Benowo landfill of 1,600 tons/day, 1,000 tons of which will be processed through technical sanitary landfills which can later produce methane".

## Appendix D: Prerequisites on Recommended Options

The Bali and Jakarta workshops identified the preliminary investment and management costs relating to the proposed technologies at small (TPS3R), medium (TPST) and large scale (TPA). The revenue streams of each waste management site need to be supported by consistent user fees from households and enterprises, particularly in low-income areas.

Prerequisites for Private Investment - large just-in-time volumes delivered at plant gate, in urban areas.

In order to attract private investment to the MSW and MLP sector, the investment needs to be profitable. The opportunity for profitable investment lies in the ability to structure scale economies - via integrated supply chains and large-scale waste processing at a specific site outside a densely populated urban area.

At the Jakarta workshop, the consultants presented the viability of either a WtE plant or pyrolysis plant, at 1250 tons of MSW and MLP, per day. The major assumptions are: PLN feed-in tariff at 11 cents/kWh; tipping fee at $7.00/ton[38]. Findings indicated that the higher the volume of mixed waste and/or MLP waste, the higher the opportunity to ensure profitable returns to a private investor.

The sensitivity analysis demonstrated that investment profitability is largely determined by the scale of just-in-time daily supply of waste to the plant gate. The assumptions maintain existing tipping fee structures, as well as marginally higher feed-in-tariff to PLN. The Consultants, therefore, consider the viability of private investment in either a WtE or pyrolysis plant at 1250 tons per day - in a densely populated urban area in Indonesia.

The Sensitivity Analysis presented during the Jakarta Workshop figures were remodeled with adjusted assumptions with an added loan to partially fund plant and equipment. See tables[39] below:



[38] Developed by Iqbal Bhatti and Madeleine Varkay (TAP-EDM)
[39] Developed by TAP-EDM consultants

## For Base lines figures MDPI's [1] Annual Operating Expenses and Operating Income report for a hypothetical plant were used

PoT 3.44 years IRR 25.59%

| Assumed Operating Costs | Specific Value | | US$ per annum | Percentage |
|---|---|---|---|---|
| Pretreatment costs | USD 6.76 | Per ton waste | 2,466,216.22 | 20.37% |
| Employee salaries | USD 46,047.30 | Per month | 552,567.57 | 4.56% |
| Maintenance costs | 2% | Fixed capital | 2,044,601.47 | 16.89% |
| Plant Supplies | 15% | Maintenance costs | 306,690.22 | 2.53% |
| Royalties and patent | 1% | Sales | 292,603.45 | 2.42% |
| Utilities | 100% | Maintenance costs | 306,690.22 | 2.53% |
| **Direct Operational Cost** | | | 5,969,369.14 | 49.30% |
| Payroll overhead | 15% | Salary | 82,885.14 | 0.68% |
| Laboratory | 10% | Salary | 55,256.76 | 0.46% |
| Plant overhead | 50% | Salary | 276,283.78 | 2.28% |
| **Indirect Operational Cost** | | | 414,425.68 | 3.42% |
| Depreciation | (Capital-Salvage Value)/(Plant Lifetime) | | 3,680,282.64 | 30.39% |
| Property taxes | 1% | Fixed capital | 1,022,300.73 | 8.44% |
| Insurance | 1% | Fixed capital | 1,022,300.73 | 8.44% |
| **Fixed Operational Cost** | | | 5,724,884.11 | 47.28% |
| **Operational Cost** | | | 12,108,678.92 | 100.00% |

Assumed Operating Costs

| Income | Value per Day | Specific Value | Amount (in USD per Year) | Percentage |
|---|---|---|---|---|
| Electricity | 473,958.33 kWh | USD 0.1335/kWh | 23,094,804.69 | 55.53% |
| Tipping fees | 1000 ton | USD 33.78/ton | 12,331,081.08 | 29.65% |
| Recyclable waste | 250 ton | USD 0.02/kg | 6,165,540.54 | 14.82% |
| **Total (in USD per year)** | | | 41,591,426.31 | 100% |

Note 1: A Techno-Economic Evaluation Of Municipal Solid Waste (MSW) Conversion to Energy in Indonesia September 2021: Muhammad Mufti Azis, Jonas Kristano Universitas Gadjah Mada

**We remodeled the figures with revised assumptions and added a loan to partially fund plant and equipment…**

| Operational Expenses (Fixed Assumptions) | |
|---|---|
| **Base Assumptions** | **Adjusted Assumptions** |
| • Cost of land was set at US$42.1 million. Amount of land with estimated cost not indicated.<br>• Cost of capital is land plus Plant and Machinery (US$102million | • Amount of land 14.5[2] hectares @ US$2million per hectare<br>• Capital cost thus reduced US$89 million |
| • Property Tax (land and Building) 1% of total fixed capital | • Property tax 0.5% of total cost of capital (Property Tax (land and Building) maximum 0.5% of the regional government-determined market value )[1] |
| • Depreciation. As per MDPI | • Straight line over 20 years (For tax / cash flow purposes acerated depreciation) |
| **Operational Expenses** | |
| • No financing of plant and equipment | • Initially loan for 50% of the cost of plant and equipment at 8%p.a. |
| **Operating Income** | |
| • Tipping Fee US$33.78 | • Tipping Fee US$7.00 – US$11.00 |
| • Recyclable waste 25% of daily tonnage | • Recyclable waste 10% of daily tonnage |

It is also imperative that until daily tonnage is weighed in at 1,000 TPD, the electricity price be maintained at minimum US13.35 cents/kWh. Once daily tonnage weighs in at 1,250 TPD, electricity offtake pricing may be reduced to approx. US10.00 cents/kWh, to maintain IRR

## Required Electricity Payment at 1000 Tons per day

| OPERATING COSTS | | | | | | |
|---|---|---|---|---|---|---|
| | | Specific Value | | | | |
| Operating costs | Cost | Description | Driver | amount | Annual Cost | % |
| Pretreatment cost | 6.76 | per ton | 1000 | 360,000 | 2,433,600 | 19.59% |
| Employee Salaries | 46,047.30 | per month | | 12 | 552,568 | 4.45% |
| Maintenance | 2% | Of capital | | 89,135,337 | 1,782,707 | 14.35% |
| Supplies | 15% | Of Maintenance | | 1,782,707 | 267,406 | 2.15% |
| Royalties / patents | 1% | Of sales | | 24,649,200 | 246,492 | 1.98% |
| Utilities [3] | 15% | Of Maintenance | | 1,782,707 | 267,406 | 2.15% |
| **Direct Operational Costs** | | | | | **5,550,178** | **44.67%** |
| Payroll Overhead | 15% | Of salary | | 552,568 | 82,885 | 0.67% |
| Laboratory | 10% | Of salary | | 552,568 | 55,257 | 0.44% |
| Plant Overhead | 50% | Of salary | | 552,568 | 276,284 | 2.22% |
| **Indirect Operational Costs** | | | | | **414,426** | **3.34%** |
| Depreciation | | | | | 3,006,767 | 24.20% |
| Property tax | 0.5% | Of total foxed capital | | 89,135,337 | 445,677 | 3.59% |
| Insurance | 1% | Of total Equipment | | 60,135,337 | 601,353 | 4.84% |
| Interest | 8% | 50% | | 30,067,669 | 2,405,413 | 19.36% |
| **Fixed Operating Costs** | | | | | **6,459,210** | **51.99%** |
| **Operational Costs** | | | | | 12,423,814 | 100.00% |

| OPERATING INCOME | | | | | | | |
|---|---|---|---|---|---|---|---|
| Electricity | MWh per day | 474 | Tons per year | 360,000 | price per KWh | 0.1300 | 22,183,200 |
| Tipping | Fee per ton | 7.00 | Tons per year | 360,000 | | | 2,520,000 |
| Recyclable was | per day | 100 | Tons per year | 36,000 | price per ton | 68.50 | 2,466,000 |
| **Total Annual Income** | | | | | | | **27,169,200** |

| | |
|---|---|
| POT yrs | 6.04 |
| IRR (10 years ) | 10.4% |

## Required Electricity Payment at 1250 Tons per day

| OPERATING COSTS | | | | | | |
|---|---|---|---|---|---|---|
| | | Specific Value | | | | |
| Operating costs | Cost | Description | Driver | amount | Annual Cost | % |
| Pretreatment cost | 6.76 | per ton | 1250 | 450,000 | 3,042,000 | 23.35% |
| Employee Salaries | 46,047.30 | per month | | 12 | 552,568 | 4.24% |
| Maintenance | 2% | Of capital | | 89,135,337 | 1,782,707 | 13.68% |
| Supplies | 15% | Of Maintenance | | 1,782,707 | 267,406 | 2.05% |
| Royalties / patents | 1% | Of sales | | 24,412,500 | 244,125 | 1.87% |
| | 15% | Of Maintenance | | 1,782,707 | 267,406 | 2.05% |
| **Direct Operational Costs** | | | | | **6,156,211** | **47.25%** |
| Payroll Overhead | 15% | Of salary | | 552,568 | 82,885 | 0.64% |
| Laboratory | 10% | Of salary | | 552,568 | 55,257 | 0.42% |
| Plant Overhead | 50% | Of salary | | 552,568 | 276,284 | 2.12% |
| **Indirect Operational Costs** | | | | | **414,426** | **3.18%** |
| Depreciation | | | | | 3,006,767 | 23.08% |
| Property tax | 0.5% | Of total foxed capital | | 89,135,337 | 445,677 | 3.42% |
| Insurance | 1% | Of total Equipment | | 60,135,337 | 601,353 | 4.62% |
| Interest | 8% | 50% | | 30,067,669 | 2,405,413 | 18.46% |
| **Fixed Operating Costs** | | | | | **6,459,210** | **49.57%** |
| **Operational Costs** | | | | | 13,029,847 | 100.00% |

| OPERATING INCOME | | | | | | | |
|---|---|---|---|---|---|---|---|
| Electricity | MWh per day | 474 | Tons per year | 450,000 | price per KWh | 0.1000 | 21,330,000 |
| Tipping | Fee per ton | 7.00 | Tons per year | 450,000 | | | 3,150,000 |
| Recyclable was | per day | 125 | Tons per year | 45,000 | price per ton | 68.50 | 3,082,500 |
| **Total Annual Income** | | | | | | | **27,562,500** |

| | |
|---|---|
| POT yrs | 6.13 |
| IRR (10 years ) | 10.1% |

## Appendix E: Further Considerations

Waste management requires the processing of large volumes of differentiated waste categories on a given day. To prevent waste leakage in the land-based and marine environment, waste needs to be managed on the basis of consistent administration, financial planning and technology to ensure adequate capital and operating expenses at each site. Several scenarios and simulations were carried out based on the experience of the Consultants.

As is generally known, there are three main aspects of waste management namely 1) Collection; 2) Consolidation; and, 3) Processing and/or disposal.

In the Indonesian context, the central government sets the policy on waste management infrastructure and devolves to the City/Regency the responsibility for operational costs. Given the absence of supporting operational business plans, many of the structures have fallen into disuse. This resulted in MSW being mismanaged and often led to "open dumping" resulting in undesirable effects on the environment such as plastic leakage into the ocean. In Indonesia this is particularly troublesome as it is an island nation with relatively low land depth and high precipitation rates.

The proposed consideration for waste management and processing is to provide and maximize the following facilities:

<u>TPS3R – expand their potential transfer stations</u>

TPS3R is the first point of MSW collection, both collected from TPS and from households. Tricycles and small trucks with a carrying capacity of up to 1 ton can bring waste to TPS3R. By way of example, in Badung, Bali, there are 17 TPS3Rs that can be utilized as feeders for materials needed by a TPST. Therefore, it is suggested that the TPS3R be enhanced and used as a transfer station rather than a processing site. Some TPS3Rs may also provide a pick-up service to householders and charge them a fee. This scheme requires an offtake material agreement between a TPS3R and TPST to ensure the continuity of waste processing operations.

In some instances, consideration may also be given to the use of Pyrolysis technology at the TPS3R level.  Large volumes of organic waste may be transformed into biochar and sold, particularly in tourist areas, to generate revenue to cover operating expenses.

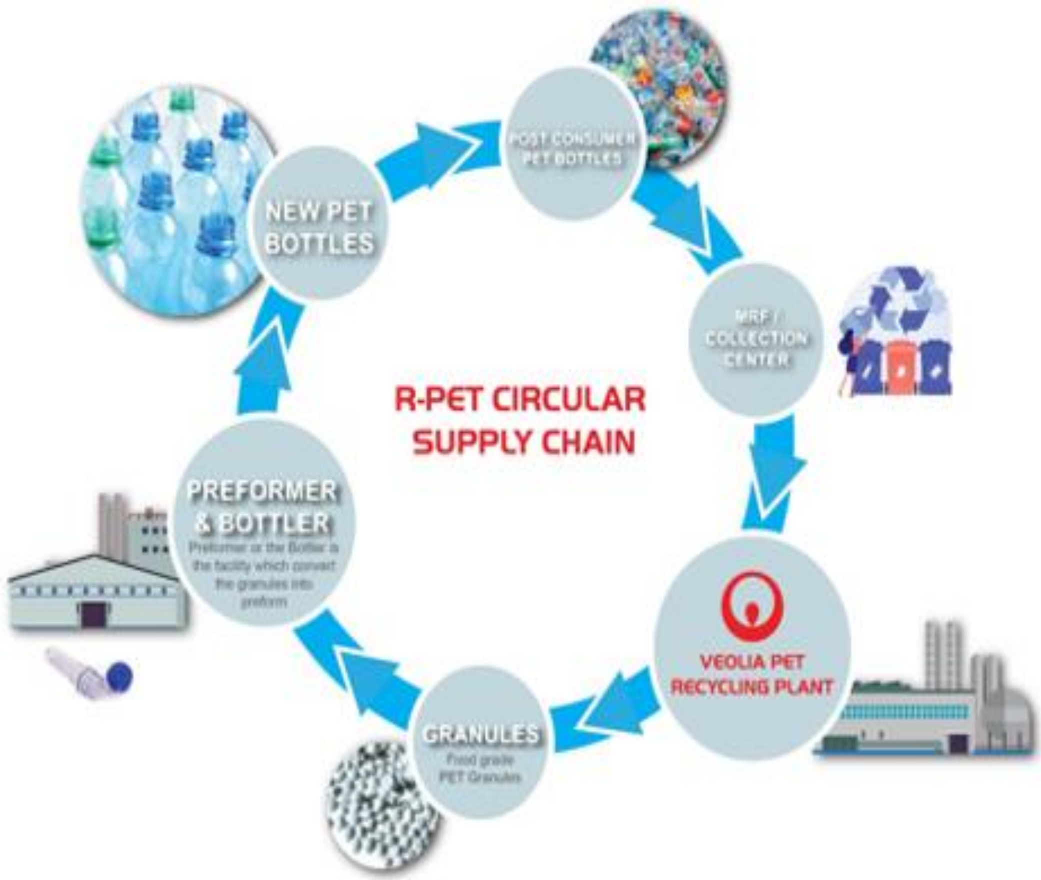
<u>TPST – expand public-private sector joint ventures</u>

The Consultants visited several public and well as public-private, TPST sites in East Java and Bali. Those managed on the basis of commercial principles, with appropriate investment in infrastructure, technology and human resources training, are used as final disposal site and waste treatment. The capital and operating expenses are based on the input of daily waste volume and revenue generation from processed waste. The effectiveness of an expanded public-private TPST scheme will also require a waste delivery agreement contract with several TPS3Rs to ensure operational continuity. By optimizing the functions of TPS3R and TPST at the city/district level, dependence on disparate landfills will be reduced and sanitary landfills will only be a place for collecting waste residues. It is suggested that the improved consolidation between TPS3Rs and TPSTs will reduce reliance on unregulated landfills and facilitate the predictable disposal of hazardous waste at TPA level.

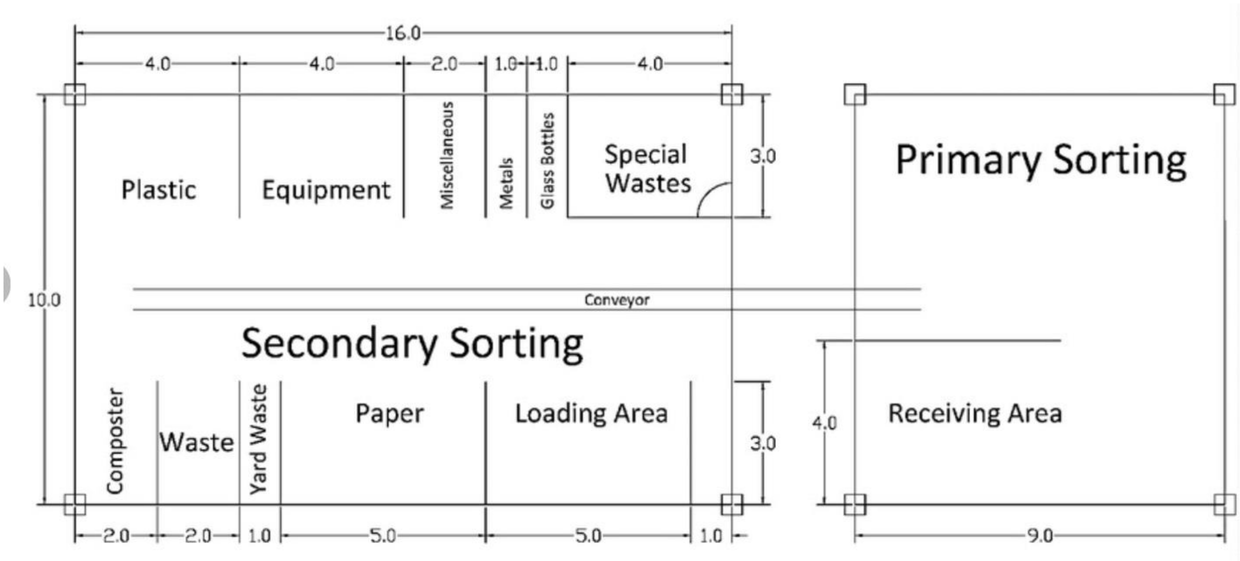
TPA

This is a large landfill structure (engineered or otherwise). In city/regency where a TPA exists, the large-scale investments in WtE and Pyrolysis should take place at this level.

## Appendix F: Veolia PET Collection Flowchart



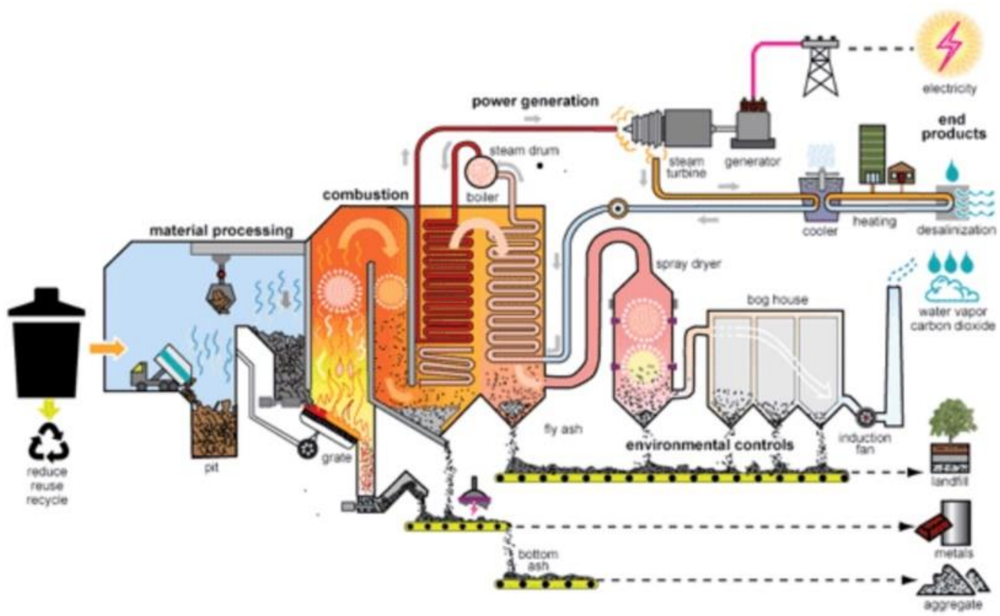
## Appendix G: Proposed layout for MRF[40]




Proposed layout for the Materials Recovery Facility (in meters)

[40] https://www.researchgate.net/figure/Proposed-layout-for-the-Materials-Recovery-Facility-in-meters_fig1_335980404

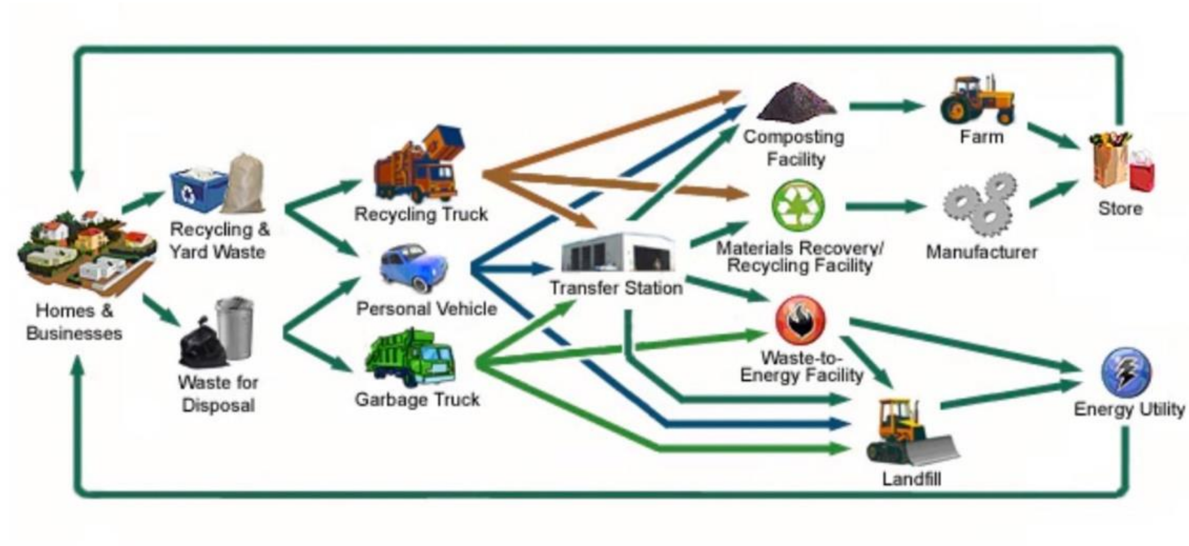
## Appendix H: WtE Process Flow[41]




A mass-burn waste-to-energy plant

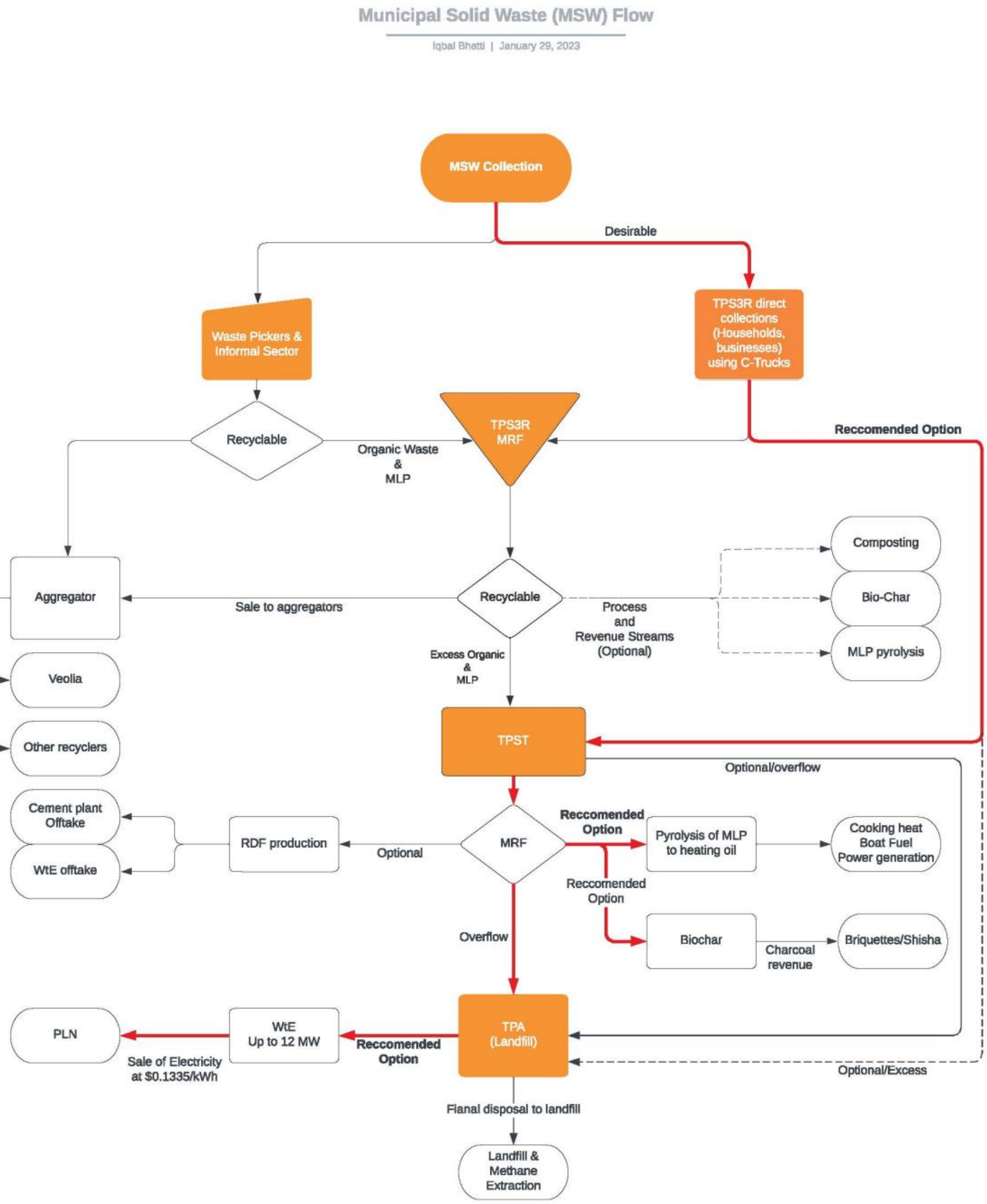
41 https://www.eia.gov/energyexplained/biomass/waste-to-energy-in-depth.php

## Appendix I: MSW Mass Flow (OECD general)[42]




42 https://www.mass.gov/guides/municipal-waste-combustors

## Appendix J: MSW (Indonesia Structure)[43]




[43] Developed by TAP-EDM Consultants

www.tap-pat.ca