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# Strategic waste management study – Probolinggo, Indonesia

## Providing new economic opportunities and tackling environmental challenges

**Draft Final Report**

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** SWECO

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Probolinggo city has a long history of cooperation with Helsingborg city in Sweden.

**Responsibility for the information and views set out in this report lies entirely with the authors.**

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# Preface

Indonesia is facing a serious challenge in handling all the wastes generated in the country in a sustainable manner. Today much of the waste generated will end up in nature – either in rivers or at sea causing harm to fish and nature, or just dumped on land or burned. The situation has reached a point where the consequences of this informal and unsustainable waste management are resulting in economic losses in fishery and tourism industry but also in negative health impacts and environmental impacts.

Also the management of collected waste provide challenges. Many landfills in Indonesia are not properly managed adding to local environmental impacts both to air and water. People are finding their livelihoods in waste picking, which will expose them to a very hazardous working environment. Landfills in Indonesia today typically also emit large quantities of greenhouse gases adding to the global climate change. The Indonesian government has launched several initiatives linked to implement a 3R – reduce, re-use and recycle – waste strategy as well as developing the economy in a circular direction and also committed to ambitious targets to improve waste as well as ocean and habitat management.

The UN Agenda 2030 for Sustainable Development and the 17 Sustainable Development goals (SDG) links to the waste challenge. Good health and well-being (SDG3), clean water and sanitation (SDG6), sustainable cities and communities (SDG11) responsible consumption and production (SDG12), climate action (SDG13) and life below water (SDG14) are all challenged by the negative impacts from present situation. Solutions for sustainable waste management can potentially support reaching several of the SDGs mentioned above but also for example providing affordable and clean energy (SDG7).

The Swedish Energy Agency has cooperated with the Indonesian National Energy Council (NEC) in the field of supply of sustainable energy since December 2013. Several other projects focusing energy opportunities and challenges have been running parallel to this. In February 2017 a Memorandum of Understanding (MoU) was signed between Sweden and Indonesia on the issue of cooperation in the field of renewable energy (MEE and MEMR 2017) Sweden acknowledge the opportunities in combining proper waste management pursuing circular economy and reducing environmental impacts with building a strong and resilient renewable energy capacity.

This report is a case study of a medium sized city, Probolinggo, in Indonesia and the waste challenges experienced. The study propose a strategic route forward where improved waste management is received but also additional benefits linked to energy recovery from waste, improved recycling, reduce emission of greenhouse gas from the landfill and opportunities to increase collection of waste. Case studies are relevant to the studied object, but also provide information that is relevant to a general category.

This report is part Sweden's work to develop an action plan for strengthening position of Swedish waste management and waste to energy solutions and know-how in Indonesia (and later other countries, primarily in Asia).

*Paul Westin*

Country manager for Indonesia
Swedish Energy Agency

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# Abbreviations

| | |
|---|---|
| 3R | Reduce, re-use and re-cycle [waste] |
| APBD | Anggaran Pendapatan, dan Belanja Daerah, Eng. *Revenue and Expenditure Budget* |
| BAT | Best available technology |
| BLH | Badan Lingkungan Hidup Eng. *Environmental Department of the Probolinggo city council* |
| BPP | Badan Perencanan Pembangunan, Eng. *Planning Department of the Probolinggo city council* |
| FiT | Feed in Tariff |
| GOI | Government of Indonesia |
| HDPE | High-density polyethylene |
| IDR | Indonesian Rupiah |
| LLDPE | Linear Low Density Polyethylene |
| NDC | National Determined Contribution |
| $Nm^3$ | Normal cubic meter (gas volume) |
| O&M | Operation and maintenance |
| ORC | Organic Rankine Cycle |
| PLN | Perusahaan Listrik Negara |
| RT | Rukun Tetangam, Eng. *Neighborhood Association* |
| TPA | Tempat Pembuangan Akhir, Eng. *landfill* |
| TPST | Tempat Pengolahan Sampah Terpadu, Eng. *integrated waste management site* |

# Executive Summary

Probolinggo, a city with of 230,000 inhabitants found in East Java, Indonesia, is looking at how to solve and handle the waste generated in the city. As many cities in Indonesia, Probolinggo is dependent on traditional landfilling to handle and manage waste generated by households, institutions and industrial activities. There is a landfill site with two landfill cells where both cells have almost reached full capacity. Probolinggo has also a number of initiatives linked to reduce, re-use and recycle (3R) of generated waste. Examples are waste banks where citizens can hand in recyclable materials and composting of waste (biomass) from vegetable markets. Several people and companies are also involved in recycling via informal waste collection. The materials are collected from the waste bins, waste collections points or from the landfill of the city.

Several actions to plan long-term solutions to the waste management situation have been undertaken. There is a master plan developed by the city on options to handle the waste and to find long-term solutions. The implementation of this master plan has however been delayed and certain aspects of the plan (for example potential land areas for new landfill) has changed.

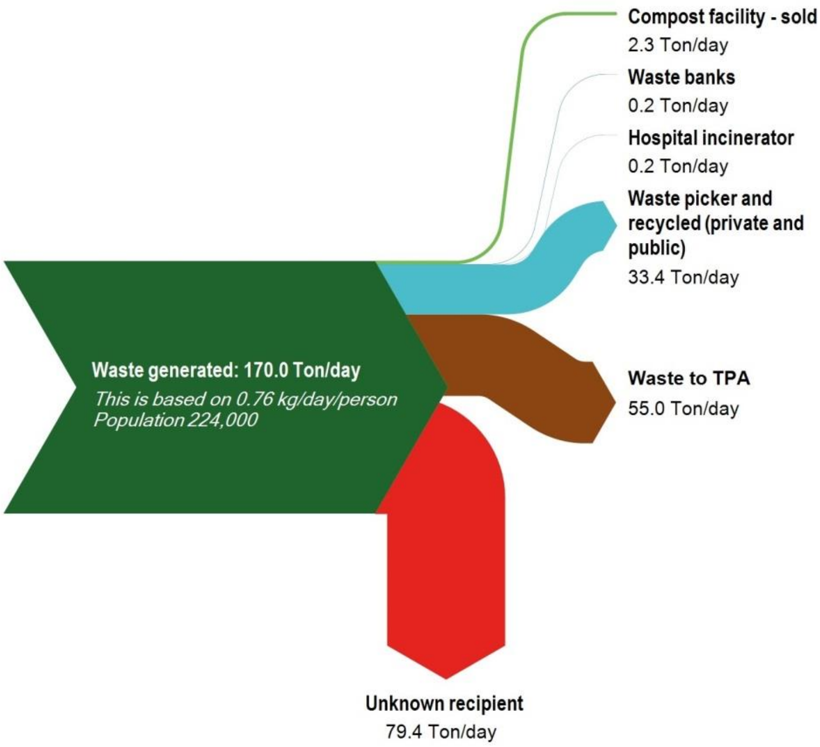



*Figure 1: Diagram illustrating the generation of waste and end-points of the waste streams. Data from 2016 (BLH 2018).*

The aim of the present report is to provide a proposal for a strategic plan for long term solutions to the waste challenges experienced in Probolinggo. Two main challenges are identified. First the challenge of landfill capacity and secondly to reduce the volume of waste that ends up in unknown recipient.

The report takes its point of departure in a framework to illustrate the suggested actions complexity of implementation vis-a-vis the time horizon for operationalisation. The complexity is not limited to technical complexity but include organisational and economical aspects as well. The approach was to suggest short-term actions that had a relatively low complexity, while long-term actions could include higher complexity.

The suggested solution narrative is divided into three time intervals; i) short term (1-3 years) actions, ii) medium term (3-6 years) actions, and lastly long term (6-10 years) actions. In Figure 2 the narrative is found in a graphic form and further explained below.


*Figure 2: Suggested strategic actions waste management in Probolinggo*

First actions is to ensure that a new landfill cell can be established that will ensure that waste generated in Probolinggo can be handled properly in a cost efficient way. The new landfill provides opportunities to plan and design a new landfill area that should provide opportunities for a long-term (+20 years) solution. A new integrated waste management site including waste to energy capacity provides a more resource efficient approach to waste management. This solution would provide one step up the waste ladder as energy recovery is introduced. In addition to this the solution would reduce emissions of greenhouse gases from the waste management and provide additional revenues to the city budget from sales of electricity. A sorting bay would be introduced at the landfill already as a medium term action in order to move waste pickers away from the landfill – reducing their exposure to unhealthy environment, but also improving covering and operation of the landfill in order to reduce environmental impacts.

In order to realise the integrated waste management site, planning and land acquisition needs to begin quite soon but already much work has been done and is found in the waste management master plan. These actions are all motivated by resource efficiency and reducing of waste problems, as well as providing modern infrastructure and healthy environment and financing via government channels should be feasible given options to include it in budgets and the strategic plans for Probolinggo.

In parallel to ensuring a new long-term solution for landfill capacity the already existing landfill cell 1 and parts of cell 2 should be closed down. The existing landfill gas equipment could be improved to further reduce emissions of greenhouse gases. Full scale landfill gas system would provide enough gas to be used in a genset and further provide revenue to waste management operations and reduce climate impacts from the waste management in Probolinggo.

Another action links to reduce the uncollected waste. Here the first steps are to understand and identify where these waste streams are and come up with appropriate actions. The long-term solution for landfilling waste should consider the real waste amounts that would also include the today uncollected amounts.

Actions to scale up existing activities on composting, recycling and awareness should be taken on. The activities on reduce, reuse and recycle material, along with increasing collection would probably support increased awareness and involvement in proper waste handling. These actions are ongoing and should be continued and supported, but priority should be on actions above.

The economic viability of these actions, illustrated as for example simple pay-back periods, is typically low. Reasons for this is found in relatively low feed in tariffs for generated electricity, and limited possibility to ensure gate fees for receiving at the landfill gate. Government initiatives on feed in tariffs for larger systems are presently in place, and actions to ensure gate fees and collection fees could be realised as part of long-term actions. The main source of funding for the proposed actions is suggested to be via governmental and regional budget allocations. In order to be successful in this approach good planning and proper preparations of background documents, as well as long-term commitment from political and public officials in Probolinggo will be required.

The strategic plan presented in this report suggests solutions to the main challenges linked with the waste management in Probolinggo. Still there are several unknown factors that should be studied further in order to provide additional directions for actions. One such area is to learn more on where the uncollected waste ends up, another links to the informal recycling sector.

Probolinggo has a reputation of being a green and clean city. The suggested actions would further strengthen this trademark and put Probolinggo as a role model for showcasing solutions for waste management challenges faced by many medium size cities in Indonesia today.

# 1 Introduction

Probolinggo is facing growing challenges with ensuring safe and efficient waste collection and management. The existing landfill is almost full and options for new landfill site requires time to be realised. Further challenges are found in that much of the generated waste is not collected. The opportunities to increase waste collection and decrease waste that ends up in the environment are there, but require strategic work with improving collection points, scaling up existing initiatives for reducing and re-using waste through waste banks, composting facilities and biogas installations. Probolinggo has good opportunities to take on a strategic work and take actions to improve already existing good waste management to more resource efficient, mitigate climate impacts, and supporting local industry and good livelihoods. This report provides a strategic plan that suggests actions on long-, medium and long short term time horizons. The actions that are proposed are all inter-linked and provide a string of actions that would lead to a waste management system that would provide a safe and environmentally sound waste management system in Probolinggo. Probolinggo can become a role-model in terms of action in tackling the waste challenge for medium size towns in Indonesia and Asia. The proposed approach would represent a unique case and solution-model for many other medium large cities in Indonesia. Probolinggo have a population of almost 230,000 in 2016 (BLH 2017) and is, as many Indonesian cities of this size, found on a relatively small land area. The options for sanitary landfills and other waste management options are thus somewhat restricted in terms of available land. This study also represents options for other cities in Indonesia with similar challenges as Probolinggo.

The central government in Indonesia is acknowledging the growing challenge in handling waste generated in the country. In 2013 it was assessed by IAHRD (2013) that about 70% of the waste was not handled or collected in a controlled way. The situation has led to increased attention from government and private sectors to find ways of tackling the situation. This is represented by the Government of Indonesia's (GOI) effort to promote waste incineration in 8-9 cities in Indonesia (PRI 2016) which was further expanded with three additional cities added to the priority list in 2018 (PRI 2018).

The existing waste management as a source for greenhouse gas emissions is identified in the first Indonesian National Determined Contribution (NDC) to reach the Paris agreement with the ambition to reduce the same (GOI 2016). President Joko Widodo have also said that Indonesia will reduce wastes via the 3R (reduce, re-use, recycle) strategy by 25% by 2025. Stakeholders in Indonesia are also looking at the opportunities to adjust to a more circular economy –

where waste needs to be turned from a problem to become a useful resource in the society.

One of the prime challenges in present waste management in Indonesia is to increase the collection rate and avoid un-controlled dumping or burning of wastes. This is also the case in Probolinggo. The practices of open-air burning and dumping garbage on land or in the sea or rivers are causing large costs for the society via negative environmental impacts, reduced attraction as a tourism nation and also via negative impacts on health and socio-economic situations of people exposed to leachate water, smoke and other consequences from the un-controlled waste handling.

The challenge is thus to *increase controlled collection of wastes*, and to bring these materials to best purposes and new uses in society. In cases where further use is not possible, the aim is to ensure that materials are deposited on landfill sites securely and in an environmentally safe way. To reach this situation will take time and a strategic plan presenting the different actions and potential synergies between different actions is a useful tool.

The aim of the present report is to provide a proposal for a strategic plan for long term solutions to the waste challenges experienced in Probolinggo. Two main challenges are identified. First the challenge of landfill capacity and secondly to reduce the volume of waste that ends up in unknown recipient. This plan would also provide a basis for business opportunities in the sector, and potential societal added values.

Probolinggo has since many years worked pro-actively to improve waste management and several initiatives to improve waste management are found (Mochtar *et al.* 2015; Bappeda 2016; BLH 2017; SW Indonesia 2017). These ongoing processes mean that stakeholders in Probolinggo and the Probolinggo city government are well acquainted with challenges and opportunities presented in improving waste management. This also suggests that there are studies and statistics found which can provide starting point of the suggested actions. The added value of the suggested actions is to further develop these ideas and also put it into a strategic context including the whole waste management sector in Probolinggo. The project will build on previous studies and provide new perspectives on achieving short- and long-term efficient and resource efficient waste management.

# 2 Probolinggo city – background

Probolinggo is a town with a population of about 230,000 persons. The city is found in the East Java Province, Indonesia, and is situated just at the coastline. The city of Probolinggo has an old history and much of the structure of the existing city can be traced back to the mid-19th-century when the city was a centre for sugar production. The old Dutch colonial administration planned the town according to colonial town planning rules for residencies (van Dun and Timmer 2015). Probolinggo has grown but the city still bears these historical imprints in the way transportation and parts of the infrastructure is organised. The city has only few tall buildings and availability of land is relatively restricted as land is already used for other purposes.

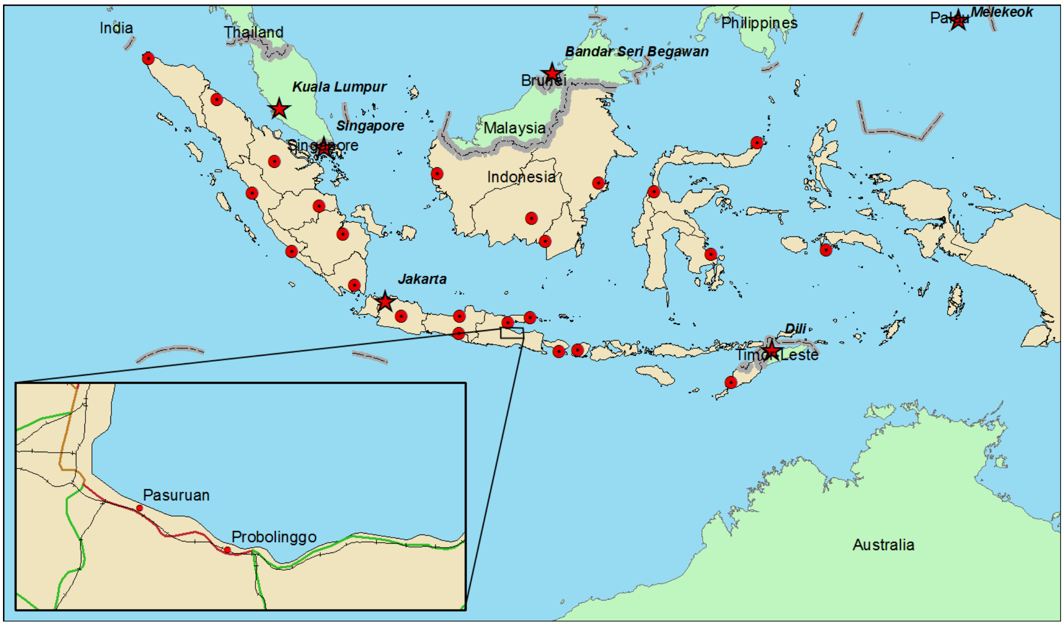



*Figure 3: Indonesia with the position of Probolinggo*

The population in the last census 2010 was 217,062 (BPS 2018) meaning that there has been a population growth of less than 1% per year over the last ten years[1]. Based on discussions with the planning department (in Indonesian *Badan Perencanan Pembangunan*, BPP) in Probolinggo there is no reason to believe that this pace of increase would drastically change in the coming years.

The city is divided into five districts which are all served by the Probolinggo city council. The central districts (in Indonesian *kecamatan*) Mayangan and Kanigaran

[1] According to UN (2018) population growth in Indonesia has decreased from 1.4% per annum in beginning of the millennia to about 1.25% in 2015.

are the most densely populated parts of Probolinggo while Kedopok district is more sparsely populated. In the latter district farming activities is more common and this is also the case for Kademangan district and Wonoasih district. Mayangan district and parts of the Kanigaran districts are the old parts of Probolinggo.

*Table 1: Probolinggo and data of the five districts (BLH 2017)*

| District | Area (km2) | Population | Density (pop/km2) |
|---|---|---|---|
| Kecamatan Kedemangan | 12.754 | 43,518 | 3,412 |
| Kecamatan Wonoasih | 10.981 | 33,380 | 3,040 |
| Kecamatan Mayangan | 8.655 | 62,162 | 7,182 |
| Kecamatan Kanigaran | 10.653 | 56,982 | 5,349 |
| Kecamatan Kedopok | 13.624 | 32,971 | 2,420 |
| ***Total*** | ***56.667*** | ***229,013*** | ***4,041*** |

Main occupations in Probolinggo are related to agriculture and selling these goods, manufacturing, trade and public services. There are a number of larger industries such as a wood board industry (Kutai Timber Indonesia), fish processing (e.g. Southern Marine Products) and adhesive industry (PT. Pamolite Adhesive Industry) and several smaller industrial and manufacture enterprises.

*Table 2: Number of people 15 years of age or higher and their main activity (BPS 2018).*

| Main industry | Person | Percentage |
|---|---|---|
| Growing of rice, roots and tubers | 8,153 | 9.2% |
| Growing of horticulture plants | 834 | 0.9% |
| Agriculture, estate or plantation | 59 | 0.1% |
| Fishing and aquaculture | 1,879 | 2.1% |
| Animal production | 1,149 | 1.3% |
| Other agricultural activities | 67 | 0.1% |
| Mining and quarrying | 115 | 0.1% |
| Manufacturing | 11,006 | 12.4% |
| Electricity and gas | 620 | 0.7% |
| Construction | 5,006 | 5.7% |
| Wholesale and retail trade | 20,550 | 23.2% |
| Hhotel and restaurant | 2,424 | 2.7% |
| Transportation and storage | 9,032 | 10.2% |
| Information and Communication | 695 | 0.8% |
| Financial and Insurance | 1,773 | 2.0% |
| Education services | 5,965 | 6.7% |
| Human Health | 1,415 | 1.6% |
| Public services and personal service activities | 16,177 | 18.3% |
| Others (real estate activities, water supplay etc.) | 1,515 | 1.7% |
| ***Total*** | ***88,434*** | |

The city has good transportation options with the National highway number one passing the city, railway connections and the city is close to Juanda international airport in Surabaya. There is also a harbour in Probolinggo mainly serving goods, but also some small ferries to neighbouring island and fishing vessels. Probolinggo is found on East-West transport corridor so there is a relatively high traffic on the highway passing Probolinggo. Distance from Surabaya is about 100 km. Tourist industry is mainly cantered around visits to Mount Bromo which is found on a distance of about 45 km from Probolinggo city. Mount Bromo is an active volcano with a height of 2,329 metres above sea level which is part of the Tengger massif in East Java.

Around the city of Probolinggo, the Probolinggo regency is found which covers a much larger land area (a total of 1,696 km$^2$) and with a population of more than 1.1 million people. The regency and the city of Probolinggo are from organisational point of view different entities. Even though both are part of the same regional planning, East Java region (in Indonesian *Jawa Timur*), most of the activities linked to waste management are done independently in each area.

## 2.1 Probolinggo – waste management

The current waste management system in Probolinggo is managed primary by the Badan Lingkungan Hidup (BLH, Eng. *Environmental Department of the Probolinggo city council*). This department is responsible from the day to day collection, transportation and upgrade, recycle operations and landfilling. There are a total of 204 staff (BLH 2017). Probolinggo has several initiatives to work along the 3R principles. There are initiatives on composting of organic wastes, waste banks and awareness campaigns. Apart from the formal waste management much of the recycling is managed by informal systems linked to waste picking along the collection chain which ends at the landfill. Existing waste streams can be visualised in a so called Sankey diagram. The amounts displayed here are based on number of people in Probolinggo and the typical generation of waste per person in Indonesia. The level of generated waste per person is based on the Indonesian standard No 3242 (SNI 2008). Amounts of wastes linked to compost facility, waste banks and hospital incinerator are actual tracked numbers from 2016 (BLH 2017). Amounts of waste collected via waste pickers and amounts recycled via other companies or stakeholders have been assessed based on follow-ups of waste picking and recycling activities.

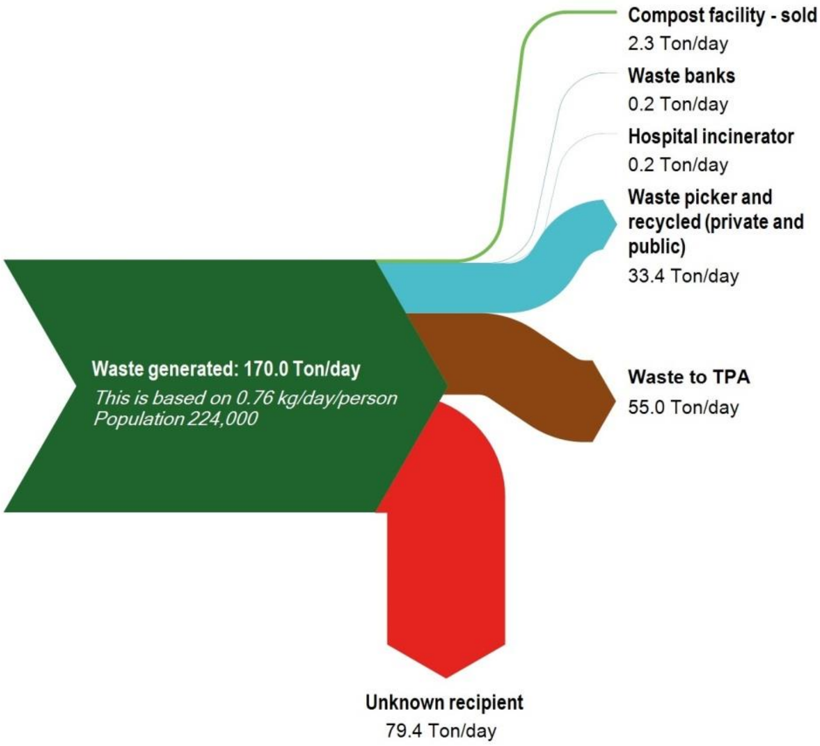



*Figure 4: Assessed and real amount of wastes generated and managed in Probolinggo, 2016 (BLH 2018)*

The amount of waste that ends up in in *unknown recipient* is assessed based on a gap analysis between the calculated generated waste and waste with known end-use. The total share is more than 45% of the generated waste which amounts to 79 ton/day. This waste would be dumped in rivers, reduced via open air burning, put on illegal dumpsites or other places. The amount of uncollected is high, but not uncommon for Indonesian conditions (see for example Prawiradinata 2017). The staff at the environmental department that we discussed this number with also agreed that the level of un-collected is probably in the range of 40-50%. The uncollected waste in Indonesia is adding to growing negative environmental impacts as well as negative socio-economic impacts and direct costs.

There is an impressive amount of waste that is recycled through waste pickers and other recycling initiatives. Waste materials that have an economic value will typically be sorted out from the municipal waste bins, different collection points or at the landfill and sold to companies that pay and sell these materials on trade the materials further to the industry. Plastic bottles, paper and carton, metal and textiles are materials collected. This collection and recycling is done informally. A formal initiative is a program run by the city called waste banks where citizens can bring recyclable materials and get refunds for it. So basically there are two routes for recycling – i) the households take recyclable materials to waste banks, or ii) the materials are picked up by the waste pickers either before the landfill, or on landfill. Still, substantial volumes of recyclable materials are deposited on the landfill.

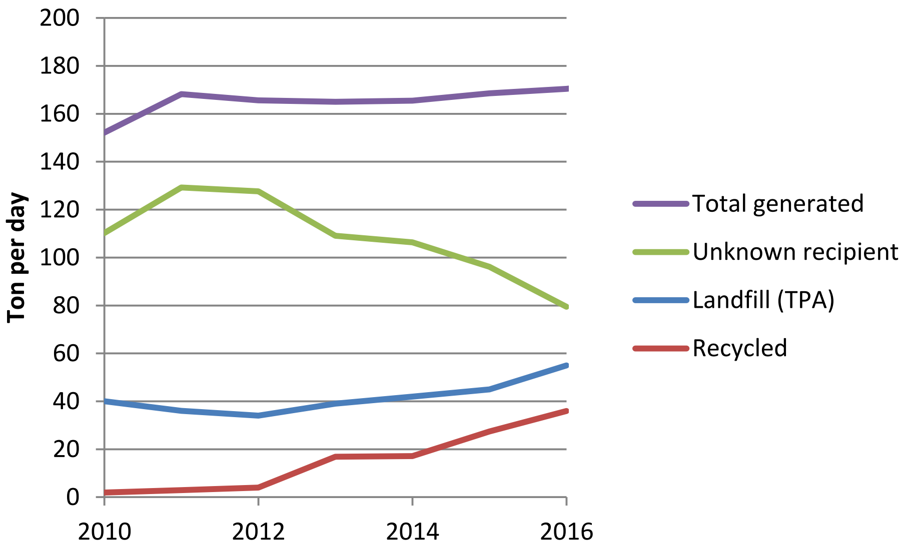



*Figure 5: Waste generated and where the waste ends up (BLH 2018)*

The materials that end up at the landfill consist to more than 60% (weight) by organic materials – 47% by organic materials from household waste, and 15% by garden waste. Plastics are about 17% by weight (Figure 6).

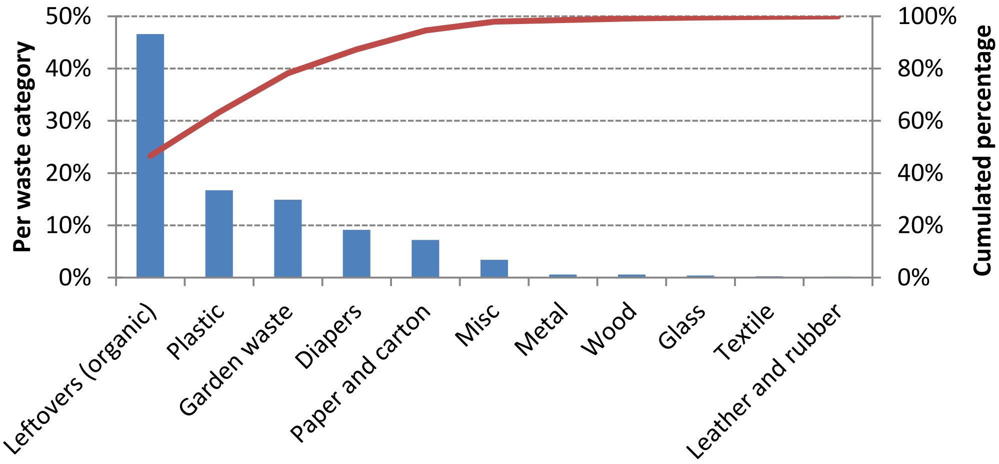
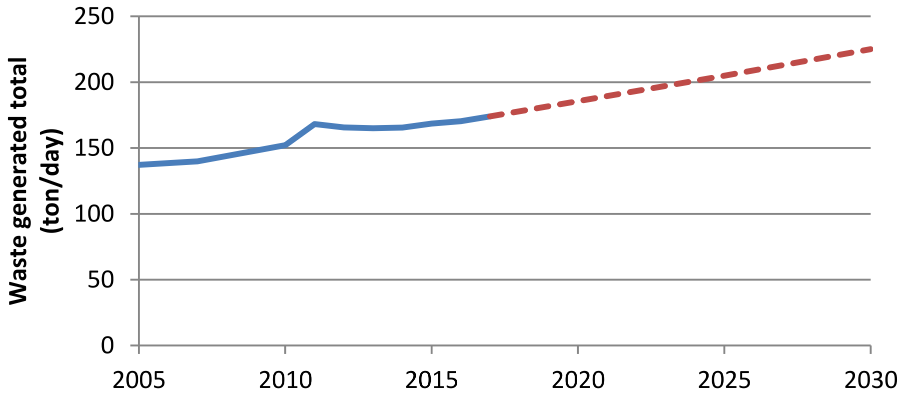



*Figure 6: Waste categories and percentage of what is put on the landfill (% of weight) (BLH 2017)*

The composition of the waste that ends up at the landfill is in line with reports from other locations in Indonesia and Asia (Rawlins *et al.* 2014; MEMR 2015; ESP3 2016; ADB 2017). The moisture content of the waste will differ depending on rains. As a consequence of relatively high level of waste that has an unknown recipient the design requirement of a new landfill is somewhat difficult to assess. The present waste stream to the landfill has been increasing over the years, but the main growth would be seen if waste stream now ending up in unknown recipient is re-directed to the landfill.

It is difficult to give a more exact estimate of the calorific value of the waste as this may vary largely between sites and between different seasons. Moisture content and variations over time may be a challenge in the Indonesian case. An estimate used in Indonesian case is 9.2 MJ/kg (Anshar *et al.* 2014) and 6 MJ/kg as reported in Rawlins *et al.* (2014). In China it was reported that waste had a calorific value of 4-6 MJ/kg with high (50%-55%) moisture content (Kalogirou 2018). In another case from India the reported energy content was about 6.9 MJ/kg (Kalogirou 2018). In urban African settings an average lower energy content of 9 MJ/kg was presented, though with variations of 6-14 MJ/kg reported (Scarlat *et al.* 2015). The energy content of the waste may also vary over time.

The amount of waste assessed in this report is based on an assumed waste generation factor of 0.76 kg waste/person and day (2016). This factor is Indonesian standards (SNI 2008) and is in line with other assessments of waste generation in other Asian regions (Hoornweg and Bhada-Tata 2012; ADB 2017). There are good reasons to believe that the generation of waste in Probolinggo will grow. Looking at the generated municipal waste generated in Probolinggo up to 2030 it could look something like Figure 7.




*Note:* The waste generation increase from 0.76 kg/pers/day in 2016 to 0.9 kg/pers/day in 2030. The population in Probolinggo city in 2030 is projected to 250,000 persons.

*Figure 7: Diagram of assessed growth in total waste generation in Probolinggo based on assumed population growth and waste generation factor.*

The waste generation scenario in Figure 7 is based on a number of assumptions and may very but typically the waste generation per capita will increase with improved incomes in the households something that is foreseen in Probolinggo in the years to come. Indonesia is showing an economic growth and this would typically lead to higher consumption and thus also an increase of generated waste. In addition to this the actual waste that needs to be taken care of by the municipality and put on the landfill would also have to consider the need to improve efficiency in collection and reduce un-collected waste volumes. The data collection in Probolinggo is very good and there are track records of waste management and collection, including production of compost, recycling via waste banks and also waste pickers going back several years. One parameter that could be further investigated is the waste generation factor which is now based on a combination of default value from Indonesian standard (SNI 2008). *It is strongly suggested that planning any long-term solution the input data (generated waste, need to put waste on landfill etc.) are investigated and verified.*

The waste management is part of the yearly city budget. The city budget is to a great extent based on transferred resources from the central and provincial governments. In 2014 the transferred budget made up to 84% of the total city budget of 872.8 billion IDR (about 74 million USD, 2014*). This reflects the high dependency that the city have on government transfers, but also reflects the need to consider potential of government support in financing any infrastructure projects.* The situation found in Probolinggo is not unique and is expected to be similar in many other Indonesian cities.

Looking specifically at the waste management there are potential revenues from waste collection at different points. There are also potential revenues from waste collection fees at households on the one hand and industrial and commercial activities on the other.

Collection of household waste is done on the local level by an assigned person from the Rukun Tetangga (RT) which basically is a number of households organised together. This person will take the waste to collection points where from which the waste is then transported to transfer points and then from these transfer points to the landfill (TPA, Tempat Pembuangan Akhir,). Waste collection from the households is made manually, typically using a hand cart. The person responsible for the collection will have the opportunity to pick recyclable materials from the waste. The level of fee that each household is paying is about 12,500 IDR/month (0.9 $USD_{2017}$)[2]. This monthly fee is paid to the person collecting the waste, and does not reach the revenue stream of the city. There are about 200 waste collectors in the city and the collection interval is between one and three days depending on location and type of client (CDIA 2016; BLH 2017).

Wastes from commercial and public activities are collected in a similar manner but depend on the size of operation. Larger industries will have to ensure that their waste is managed in a proper way. Industries would typically try to minimize the waste for deposition via selling or letting it to other activities. For example the fish processing industry would sell fish offal and scales to fodder industry.

A collection point is typically made up by a smaller container where the waste is put and then taken to a transfer points. There are 18 collection points and a total of four transfer stations. There are also transfer depos that are open or closed masonry buildings. The transport from the temporary stations to the landfill is done by lorries.

There are fee levels for a number of different commercial activities. These fee levels were set already in 2011 and have not changed since then.

[2] The exchange rate between Indonesian rupee (IDR) and United States dollars (USD) used in this report is 13,380 IDR/USD which should represent an average exchange rate of 2017.

*Table 3: City fees for solid waste management for different consumers in the city. Fee within brackets indicates the corresponding cost in $USD_{2017}$.*

| Consumer/client of solid waste management | Fee per month, IDR/month ($USD_{2017}$/month) |
|---|---|
| 1. Trading | |
| a. Street vendors | 1,000 (0.1) |
| b. Stand or stall | 7,500 (0.6) |
| c. Large I | 75,000 (5.6) |
| 2. Hotel | |
| a. One star hotel | 150.000 (11.2) |
| b. Hostel | 125,000 (9.3) |
| c. Inn/lodging | 50,000 (3.7) |
| 3. Restaurant | |
| a. Restaurant | 100,000 (7.5) |
| b. Cafe | 75,000 (5.6) |
| c. Stall / depot | 50,000 (3.7) |
| 4. Public places, recreation and sports and other entertainment | |
| a. Movie theatre | 50,000 (3.7) |
| b. Billiard house | 50,000 (3.7) |
| c. Beauty salon | 50,000 (3.7) |
| d. Barbershop | 15,000 (1.1) |
| e. Train station | 100,000 (7.5) |
| f. Bus station | 200,000 (14.9) |
| 5. Other business place | |
| a. Workshop company | 75,000 (5.6) |
| b. Traditional workshop company | 15,000 (1.1) |
| c. Car showroom | 75,000 (5.6) |
| d. Warehouse, goods storage | 100,000 (7.5) |
| e. Grinding/drying company | 15,000 (1.1) |
| f. Public transportation/travel agency garage | |
| - Bus | 150,000 (11.2) |
| - Truck | 100,000 (7.5) |
| - Travel . | 50,000 (3.7) |
| 6. Office | |
| a. Government institution | 150,000 (11.2) |
| b. BUMN, BUMD and Bank | 200,000 (14.9) |
| 7. Company | |
| a. Small company | 50,000 (3.7) |
| b. Medium company | 100,000 (7.5) |
| c. Large, | 150,000 (11.2) |

* Source: Local regulation of Probolinggo city No 3/2011 about cost recovery cited from CDIA (2016)

The efficiency in collecting set fees is relatively low. According to CDIA (2016) substantial part of the running costs for the waste management in Probolinggo city could be covered by these revenues. *Increasing the collection rate would require substantial dissemination of information and supporting activities in order for inhabitants and companies to agree and support these steps.* It should be stressed that this is *not* a unique situation for Probolinggo but rather the usual situation in Indonesian cities.

# 3 Probolinggo's two waste management challenges

The waste management in Probolinggo is well-organised and relatively efficient but also facing challenges. There are several initiatives that have been implemented to reduce and recycle waste such as composting, recycling and waste banks. There already exists a master plan for the waste handling (Bappeda 2016) in which a new landfill is presented. This plan provides details on waste streams, projected increase of waste generation and also review of several options for treating waste in a long time perspective. One challenge has been to acquire/get access to land where the landfill can be situated. There are people staying on the proposed land area, as well as there are some economic activities taking place. *One challenge in long-term planning is to build commitment among decision makers, stick to the plan and to ensure that also other stakeholders and planning and development initiatives align with the plan.*

Apart from the master plan there has also been a major study on potential of a regional landfill (CDIA 2016). This project was implemented by international consultants and studied the opportunities for a regional landfill that would serve both the Probolinggo city and the Probolinggo regency. The conclusion was that certain barriers for implementation were found in order for this to happen, and these were mainly found in low interest and structural challenges of regional cooperation and also weak economic results of the project.

There are two main challenges linked to the waste management in Probolinggo.

1. The existing landfill is full and the plans for a long-term solution as presented in the master plan will not be ready in time.
2. There is a high level of uncollected waste that impact people, scenery and the environment.

This report provides a strategic approach to how Probolinggo can arrange a long-term efficient waste management system, with high resource efficiency, low environmental impacts and a system that provide jobs and incomes. Based on discussions and interviews with stakeholders in Probolinggo and the regional planners in Surabaya it becomes clear that options and solutions that are based on adjusting tariffs in order to finance the initiatives are not viable at this time. Probolinggo city is not against regional cooperation but express that in order to tackle the two waste challenges the city must find solutions to its own problems. *In the long run further efforts to ensure high efficiency in collecting waste collection fees from households, industries and other institutions would seem a good practice. Apart from generate revenues to the operation of the waste management in Probolinggo it* *would also show on leadership and formalise proper management of waste streams in the city.* In terms of financing there are opportunities to seek funding from government for improving infrastructure and tackle waste challenges via APBD (Anggaran Pendapatan, dan Belanja Daerah, Eng. *Revenue and Expenditure Budget*). *Provision of funds via this channel does take some time, as the activities and investments must be included in city plans and budgets, and then granted upwards in the system.* Some items, like heavy trucks, cannot be financed via this channel.

The budget in Probolinggo is heavily dependent on revenues transferred from central government and other outside funds. According to CDIA (2016) local revenues is about 16% of the total revenues in city budget, while transferred is about 84%. This is no unique case for Probolinggo but a relatively common situation. *In a long-term perspective it would be strategic to increase revenues from the waste management. This could include selling products such as landfill gas, electricity but also scaling up existing revenues from recyclable materials, and compost. This could also include actions to ensure that fees and charges defined in regulations are collected* but these actions are sensitive and in order to avoid backlashes it will require ample time to plan and implement.

Waste handling in Probolinggo is mainly aimed at providing a service where the waste is taken care of – the waste is a problem and solving the problem costs money. Looking at international best practice on solving waste problems these are often based on economically viable solutions where revenues comes from those generating the waste collection fees and other revenues such as from generated electricity sales. *It is not realistic in a short-, or medium term to form such solutions in Probolinggo as the risk of increasing waste amounts that are not taken care of would be very high.*

Probolinggo have already initiatives that aim to reduce, re-use and re-cycle (3R) waste streams. The waste banks and large volumes of recycled materials are good initiatives. Composting is another example where waste is turned into a resource. The scale of the composting does at present not offer any net profit to the city. The revenues from waste fees are low and do not cover the operation and required maintenance. Even though the perspective to view waste as a resource rather than a problem is known, it has not been operationalised in the day to day activities. This study suggests that as a long-term goal making this shift could be achieved and the waste management could increase revenues streams and gradually start covering operational costs. *This transition will take time and changes will have to come gradually and be supported with information and long-term commitment among politicians and officials in the city.*

## 3.1 Strategic framework of this study

The situation in Probolinggo was presented to the project team as urgent considering that the existing landfill was full, and alternative landfill sites would require substantial time to realise. Another clear message was that all too often solutions presented to the decision makers would include activities that would be very complicated or presently unrealistic to realise in the local context. So in terms of any suggestions we assumed that there was a low-complexity – high-complexity dimension, and a short-term – long-term activities dimension. The solution for a new landfill needed to be short-term and with low complexity.

In Figure 8 the framework is presented and the required conditions for the short-term solution to the challenge of the full landfill are presented as well as an indication on the requirements for a long-term solution. It is believed that the level of complexity is needed to be kept at a moderate level especially for the short term actions in order for it to be realistic. One approach to avoid higher complexity is to opt for solutions that the city of Probolinggo has the mandate to control itself. In addition the suggested approach does not include increased fees, or need for regional solutions which will keep complexity to reasonable levels. Any larger initiative would still include a need for strategic planning and ensuring that the plans are followed through.

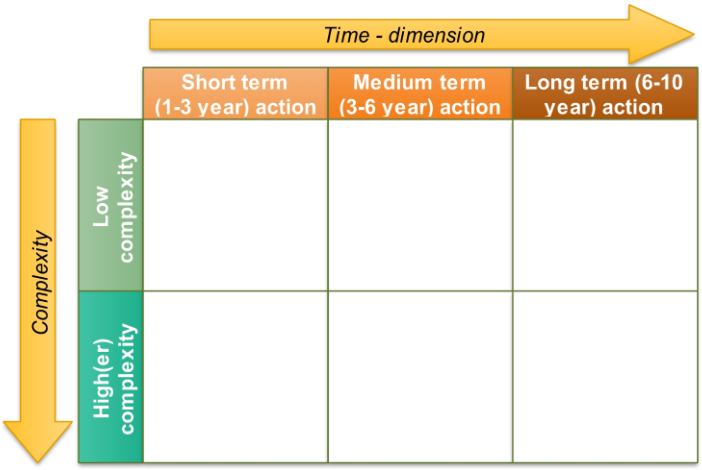



*Figure 8: Study framework of complexity and timeline*

The level of complexity is not static – as time pass the complexity will typically decrease as planning, experience and information is accumulated. In addition it should be pointed out that there is no actual problem of high level of complexity but it indicates that planning and preparations will be even more important. But also that long-term commitment towards a certain solution will facilitate a successful process. The complexity includes several dimensions such as complexity of technology, financing opportunities, or organisational complexity. This report suggest that main complexity will be found in deciding on the route forward, plan for this pathway and design solutions and act and operationalise activities according to the plan in the years to come. The technical complexity is there in many of the suggested actions but will typically not be the most complex item considering all aspects of the initiative.

The framework suggested in this report links to considerations brought forward in the Master plan for solid waste management (Bappeda 2016). In that document four different time horizons are discussed (short term 2016-2020, medium term 2021-2025 and long term 2026-2030 and 2031-2035). In the perspective of the waste management challenges seen there is need to establish a solution in the next ten years that will cope with the waste generated in Probolinggo for many years to come. *We conclude that based on the situation there is need to have a functional system in place by 2030 and beyond that continue work on reduce, reuse and recycle (3R). Further actions on ensuring low levels of uncollected waste will also be required. The 3R concept will thus also include actions to increase the efficiency in collection of waste.*

## 3.2 Suggested solution narrative

The strategic plan to scale up existing initiatives and improve waste management in Probolinggo will have to be made in a number of steps. The immediate problem of existing landfills that are almost full needs to be handled in quick actions, while long-term solutions will have to be planned, designed and operationalised with a longer time span in consideration. Still it is extremely important that these actions, although separate, are seen as a part of the ambition to solve and improve waste management and work for the 3R principle including reducing waste that ends up in unknown recipient.

The suggested solution narrative is divided into three time intervals; i) short term (1-3 years) actions, ii) medium term (3-6 years) actions, and lastly long term (6-10 years) actions. In Figure 9 the narrative is found in a graphic form and further explained below.


*Figure 9: Suggested strategic actions waste management in Probolinggo*

*First actions is to ensure that a new landfill cell can be established that will ensure that waste generated in Probolinggo can be handled properly in a cost efficient way.* The new landfill provides opportunities to plan and design a new landfill area that should provide opportunities for a long-term (+20 years) solution. A new landfill together with waste to energy capacity provides a more resource efficient approach to waste management, one step up the waste ladder via energy recovery, and would also reduce emissions of greenhouse gases from the landfill but also provide additional revenues (from electricity). This would be an integrated waste management site. In order to realise this, planning and land acquisition needs to begin quite soon but already now much work has been done and found in the existing waste management master plan (Bappeda 2016). These actions leading towards a long-term solution are all motivated by resource efficiency and reducing of waste problems, as well as providing modern infrastructure and healthy environment. Additional benefits are reduction of greenhouse gas emissions and turning towards a circular economy. Financing via government channels should be feasible given the national high priority given to all these impacts but will require options to include it in budgets and the strategic plans for Probolinggo.

*In parallel to ensuring a new long-term solution for landfill capacity the already existing landfill cell 1 and parts of cell 2 should be closed down.* The existing landfill gas equipment could be improved to further reduce emissions of greenhouse gases. Full-scale landfill gas system would provide enough gas to be used in a genset and further provide revenue to waste management operations and reduce climate impacts from the waste management in Probolinggo.

Another action links to reduce the uncollected waste. Here the first steps are to understand and identify where these waste streams are found and end up and based on this information develop and design appropriate actions. The long-term solution for landfilling waste should consider the *real* total waste amounts which would also include the today uncollected amounts.

*Actions to scale up existing activities on composting, recycling and awareness should be taken on.* The activities on reduce, reuse and recycle material, along with increasing collection would probably support increased awareness and involvement in proper waste handling. These actions are ongoing and should be continued and supported, but priority should be on actions above.

Taken all these actions into consideration a scenario for the waste management in 2030 can be made. Taking the point of departure in the representation of waste streams in 2016 (see Figure 5) and adjusting for population growth, increased waste generation factor as a consequence of economic development, the total waste generation in Probolinggo in 2030 would be around 212 ton/day. Composting, recycling and reducing waste is assumed to increase but main focus should be on reduce the waste stream that ends up in unknown recipient. Based on a scenario for 2030 it would mean about 160 ton waste per day with the destination landfill (Figure 10).

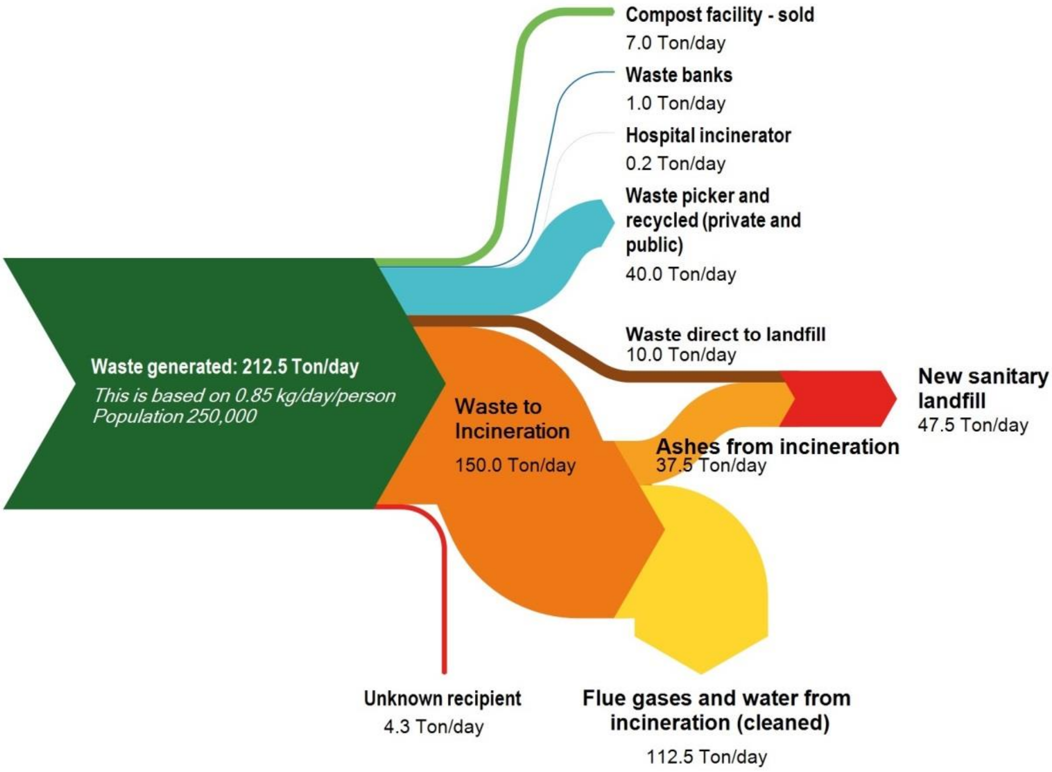



*Figure 10: Future waste scenario Probolinggo, new sanitary landfill with incineration capacity*

Introduction of an integrated waste management site with sorting bay, incineration capacity and expanded landfill capacity will provide opportunities for a long-term solution for management of generated waste in Probolinggo. One key-component is the incineration plant which will *reduce volume (and weight) of the waste to be put on the landfill considerably.* The energy recovered from the waste will be used to generate electricity sold to the grid providing additional revenues to the city's waste management budget. T*he incineration plant should be equipped with international standard flue gas and water cleaning equipment in order to ensure that high standard of environmental concerns is upheld.*

# 4 Suggested solution – establish long-term landfill solution Probolinggo

The two existing landfill cells serving Probolinggo city are almost full. The existing master plan for waste management includes plans for extending the area of the landfill in order to facilitate a long-term solution to the waste disposal challenge in Probolinggo (Bappeda 2016). The realisation of the plan will take time and short term actions are needed to solve the immediate problem of finding areas for waste disposal.

The long-term solution would benefit from introducing waste to energy options that would reduce the volume of waste as well as climbing one step up the waste ladder. Additional benefits are reduced greenhouse impacts as landfill gas is collected, and incineration will reduce landfilled organic materials. The suggested approach includes actions to improve working conditions for waste pickers on the landfill and increase recycling. We suggest that the approach should be seen in three different steps where we have indicative time periods from the starting point. The three steps are interlinked and there is no final/complete solution achieved only by pursuing the first or second step.

## 4.1 Short term (1-3 years) actions

Short term actions are considered such actions that could be done within the period of about one to three years. It is also suggested that full focus is to solve current predicament with restricted landfill capacity and thus few additional activities are suggested. We strongly suggest that planning and decisions on the future actions are commenced as soon as possible in order to facilitate and support a resilient implementation of the action plan.

### 4.1.1 New landfill to tackle short term needs

We suggest that the new landfill cell (referred to here as cell 3) is located on the premises of the existing TPA (Tempat Pembuangan Akhir, *Eng. landfill*) at the Bestari Landill. The proposed location of the new cell 3 would be between the current cell 1 and cell 2 (Figure 11).

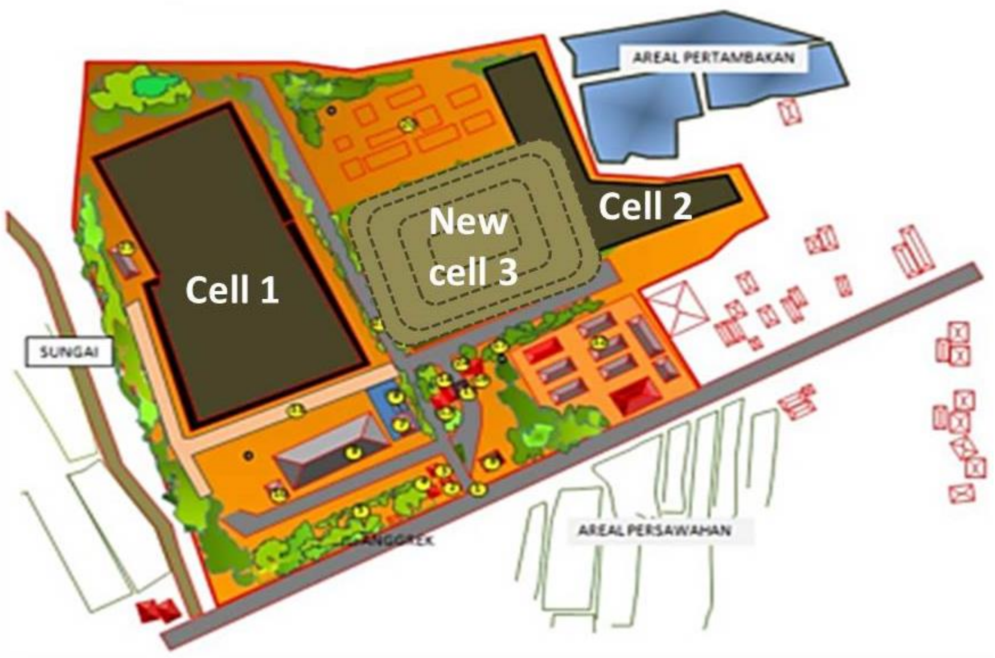



*Figure 11: Suggested location of new landfill cell 3*

The proposed land area to be covered by cell 3 is today a green park, built upon an old dump site. The land area does not have an active use at present but is just referred to as a green area. The new cell 3 should be connected to existing cell 2, which makes cell 2 and cell 3 one entity. This would provide opportunities to increase the total volume of the combined cells as compared to two individual cells (Figure 12).

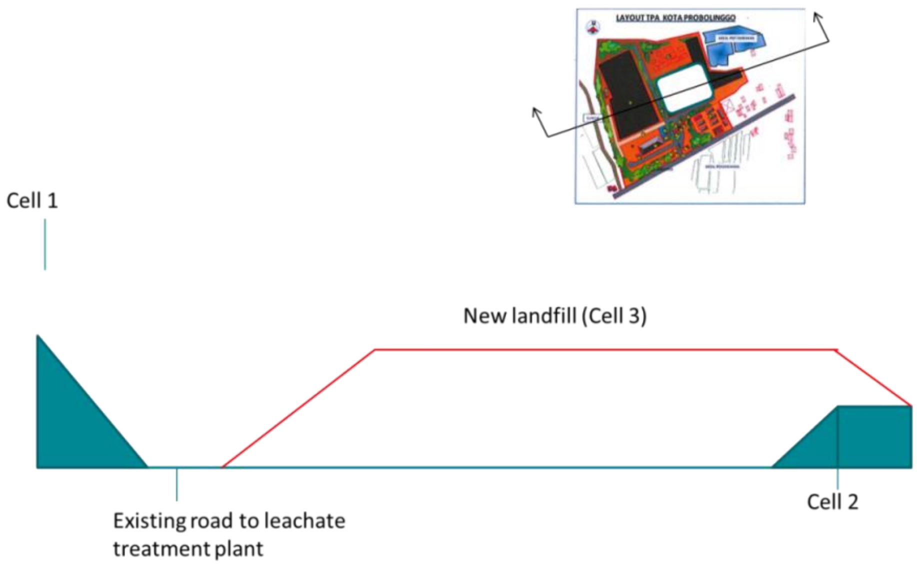



*Figure 12: Section of new landfill showing cell 1, cell 2 and new suggested cell 3.*

The design of the new cell is restricted in all four directions by:

- NNW (north-north-west): the leachate treatment plant
- WSW (west-south-west): a connection road to the leachate treatment plant
- ENE (east-north-east): landfill cell 2. The new landfill cell 3 can be built partly above cell 2.
- SES (south-east-south): the road to cell 2 and to the east part of the Bestari landfill.

This results in a rectangle shape of about 90 meter times 70 meters.

The suggested position of the new landfill cell would, according to our assessment, be a solution with relatively low complexity as it is on premises in control of the city. Know-how of how to construct a landfill should be available either locally or regionally as cell number 2 was recently built. This would mean opportunity to operationalize this solution in a relatively short time span. (Figure 13).

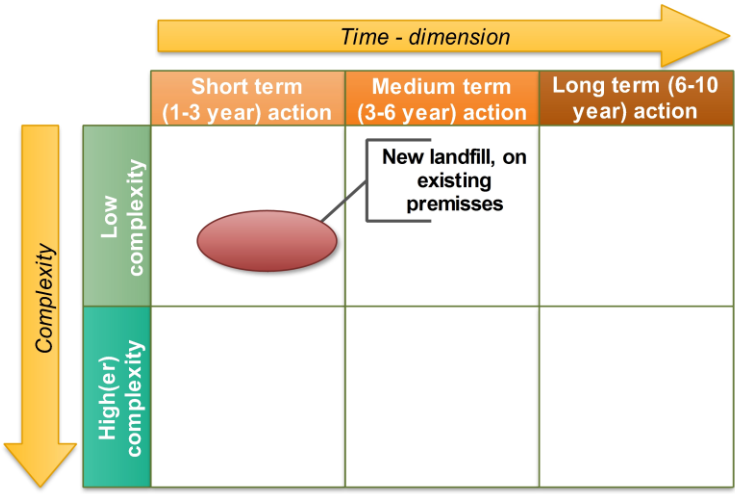



*Figure 13: New landfill site, assessment of complexity and timeline*

The capacity of the new cell 3 is estimated to hold at least 2 – 3 years of wastes, based on about 60 tones waste/day. *As this is only a temporary solution it will be crucial to commence planning for the long-term solution once the construction of new cell 3 has started.*

#### 4.1.1.1 Design and performance

The ground is smoothed down and levelled out. If necessary a layer of structural fill (compacted soil and rocks) are placed on the surface. The surface should be slightly sloping (slope at least 2:100 to 5:100) to one or several low points where the leachate can be collected.

The size of the landfill cell depends on the more specified design but considering priority to maximize the volume it should be possible to establish a rectangle of maximum 90 m between existing road east of cell 1 towards cell 2 and 70 m between existing leachate treatment system and road linking entrance and recycling and composting areas.

There are some basic design approaches for landfill sites (see for example Letcher and Vallero 2011; Munawar and Fellner 2013; Townsend *et al.* 2015; Youcai and Ziyang 2017). The exact design will depend on a number of variables including but not limited to temperature, rainfall and expected moisture, the ground where the landfill is positioned. Below is a presentation of a basic design approach.

Above the prepared ground is put a double liner system (Figure 14):

- Bottom: natural clay, compacted, 0.2 – 0.3 m thick, or geo-synthetic clay liner or bentonite liner.
- Top: Textured High-density polyethylene (HDPE) liner >1.5 mm. The HDPE sheets/rolls shall be overlapping and the seams shall be welded.

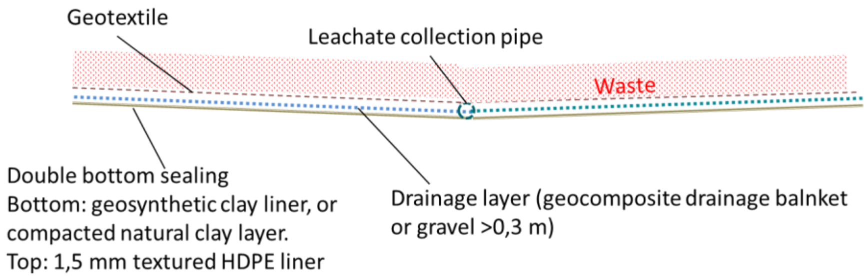



*Figure 14: Design of bottom sealing system.*

Above the HDPE sheet is put a drainage system, ether gravels (c. 0.3 m height of the layer) or a geo-composite drainage blanket. Above the drainage layer is put a geo-textile cloth (to protect the drainage layer from the waste).

The bottom shall be slightly sloping or inclined to one or several low points where perforated pipes collect the leachate water and conduct the leachate water to the existing leachate treatment system.

Embankments should be installed round the cell (Figure 15). The embankment should also connect to the cell 2, and the bottom sealing should overlap to cell 2 in accordance with the figure.

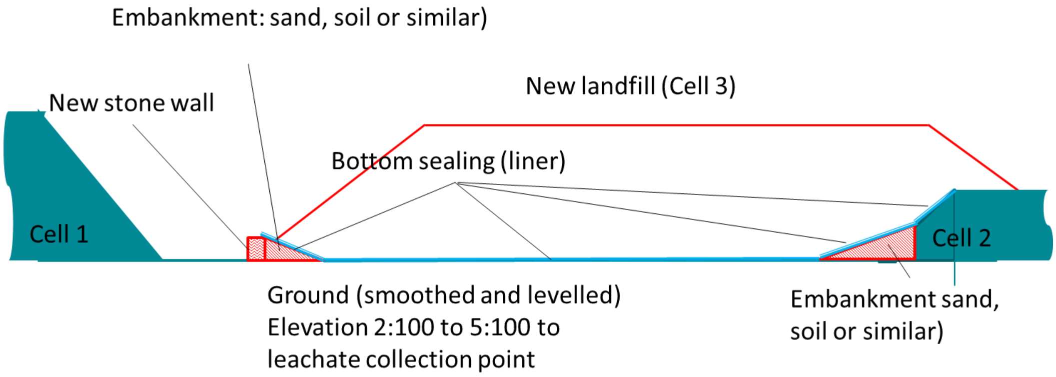



*Figure 15: Construction of landfill cell 3.*

The capacity of the leachate treatment system should be reviewed as part of connecting another landfill cell to it. At present the leachate treatment system is apart from treating the leachate from cell 1 and cell 2 also treating some sewage transported to the landfill with trucks. Assessing the capacity in order to ensure that substance levels are not exceeded should be made.

#### *4.1.1.2 Economic assessment of new landfill site (cell 3)*

Assessing the costs for this new short-term solution landfill cell is difficult as much of the work and expertise for construction can be found in Indonesia. Recent experience exists as cell 2 was recently commissioned. Possibly some expertise will be required to make the more detailed technical designs of the landfill. A similar construction in Europe would be around 2 million USD, but this is considered much higher than would be expected in the case considered in Probolinggo.

### 4.1.2 Landfill gas collection - Cell 3

The new landfill cell 3 should be equipped with system to capture the emitted methane from the landfill. This is motivated by the ambition to bring waste management in Probolinggo up to high international standard. Ensuring capture of emitted methane from a landfill  is good practice and will reducing impact on climate as greenhouse gases emitted from the landfill are captured (see for example ADB 2017; GIZ 2017) and will also provide revenues to the city budget.

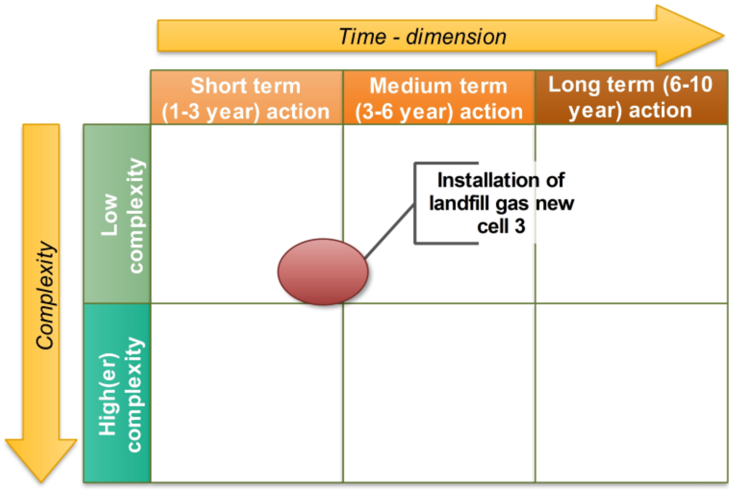



*Figure 16: Installation of landfill gas new cell 3, assessment of complexity and timeline*

The new landfill cell (cell 3) should be equipped with a gas recovery system where consideration of potential uses should be made. A fully functional system can provide revenues to the landfill operation in terms of electricity sold to the grid, or via using gas for other purposes such as cooking gas. Depending on the end use a functional landfill gas recovery system can be designed. Further consideration should be given to the added landfill gas capacity that is foreseen to be installed on the closed cell 1 and 2 as part of medium term actions (see Close existing landfill cell 1 and partially close cell 2).

#### 4.1.2.1 Landfill gas

In an ordinary landfill the organic material is degraded by anaerobic processes. A landfill gas with 50 – 60 % of methane $CH_4$ and 40 – 60 % of carbon dioxide $CO_2$ is produced in practically all landfills with organic waste. The degradation is slow and methane emissions from a landfill can go on for 25 – 50 years (MEMR 2015; GIZ 2017). The emissions of especially the methane but also the carbon dioxide will add to the negative impacts linked to the greenhouse effect.

Landfill gas can be extracted and used as an energy source providing revenues along with reducing negative climate impacts. The gas can be collected by inserting perforated pipes in the landfill, and then transport the gas in a pipeline to a gas combustion plant. The efficiency of collection can under optimal conditions reach 85% or above (EPA 2011) but less than 50% is common if the systems are not properly designed and operated (GIZ 2017). The gas can be used as fuel in a gas engine (typically a converted diesel engine) connected to an electrical generator. The investments are relatively low, and the incomes from selling electricity can pay the investment within a few years.

Methane has an energy content of 47 MJ/kg or 22.6 MJ/Nm$^3$. The landfill gas with 50 – 60 % by volume of methane has an energy content of 11 – 16 MJ/m$^3$ (Markgraf and Kaza 2016)

The gas production can be expected to be 5 – 10 $m^3$ of landfill gas (with 50 – 60 % methane) per year and per ton of landfilled waste during at least five years, and after that the gas production will slowly decline. The total accumulated amount of collected landfill gas can often be 50 – 400 $m^3$ per tonne landfilled waste, distributed over 10 – 20 years (from the moment the waste has been landfilled).

The landfill gas contains up to 50 % carbon dioxide. The untreated landfill gas can be used in combustion plants without further treatment. However, it is possible to remove the carbon dioxide to get a more methane rich gas with 95 – 99 % by volume of methane. This upgraded gas can be used as fuel for busses, trucks and cars.

Recovery of landfill gas *does not decrease* the amount of landfilled waste, but it will change the status of the landfill from a "disposal site" to an "electricity production site" and *landfill gas recovery is an integrated part of any sanitary landfill*.

The basic idea is to insert several perforated pipes in the landfilled waste to collect the gas, and the perforated pipes is connected to a pipe system that brought the gas from the perforated pipes to a kind of gas treatment plant. There are two basic designs of landfill gas recovery systems; i) vertical pipe system or ii) horizontal pipe system. The basic idea is to insert several perforated pipes in the landfilled waste to collect the gas, and the perforated pipes is connected to a pipe system that brought the gas from the perforated pipes to a kind of gas treatment plant. There are two different ways to apply the perforated pipes in the landfill.

Horizontal collection is an option for installation during the landfill operation phase, while vertical systems can easily be installed at landfill that are filled up, but more difficult to install during the operation phase (Figure 17).

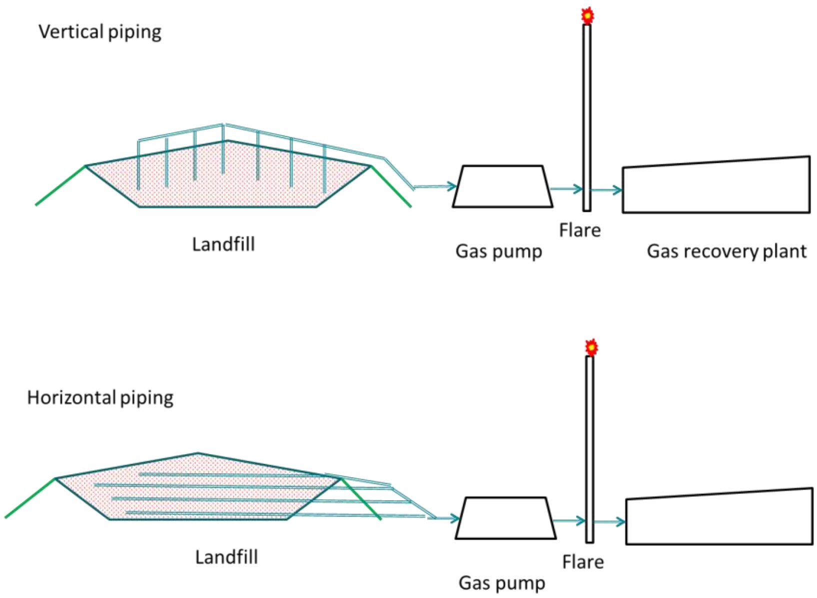



*Figure 17: Principle of vertical gas collection pipes and horizontal collection pipes*

Usually a gas pump is connected to the system to create a slight under-pressure in the landfill to transport the gas out of the landfill. The pump speed must be balanced to so the pumped speed is balanced to the actual production rate of the gas. If the pump speed is too high, air will sucked into the landfill and into the landfill gas. If the pump speed is too low there is a risk that landfill gas will leak out from the landfill. In connection with the pump, usually before the pump, a water condensation system to separate off the moisture in the gas is found. The raw gas from the landfill may contain 20 – 25 % of water.

A horizontal system can be installed also in landfills that are under operation (ISWA 2005). There is need to carefully ensure that the gas collecting pipes are not damaged during operation of the landfill. Example of the principle construction of horizontal landfill gas collecting is shown in Figure 18.

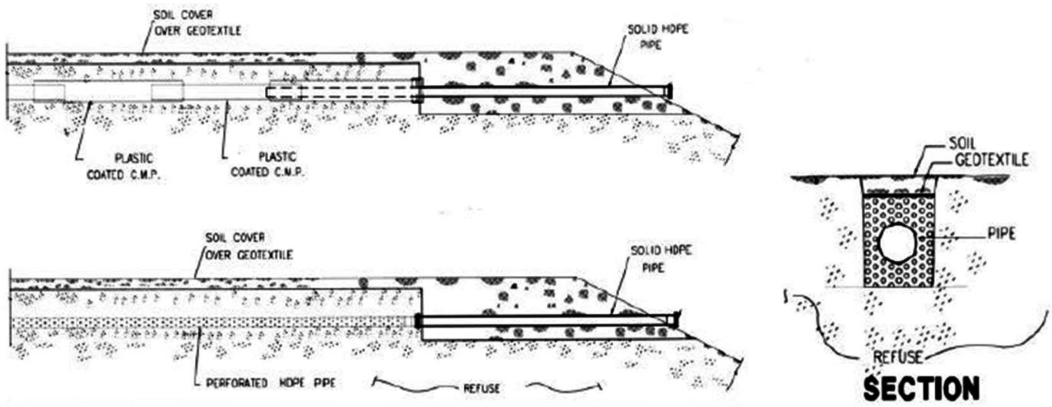



*Figure 18: Construction of horizontal gas collectors*

Figure 18 illustrates that there is a zone in the landfill where no gas will be collected. It is crucial for safe and efficient operation to ensure that no oxygen from the surrounding atmosphere is sucked into the landfill. This zone also defines the active volume of a landfill from which the landfill gas will be collected. If the outer zone is relatively gas-tight the zone could be relatively thin, while if more porous this zone must be wider in order to avoid oxygen to be sucked into the active area of the landfill from which the gas is collected.

A vertical system is similar in design as the horizontal system but the gas pipes are drilled down into the landfill creating a number of gas wells that collect the generated landfill gas from a certain area around the pipe. The gas well design will define how large area will be covered by one gas well. Figure 19 illustrates how a vertical bas collector can be designed.

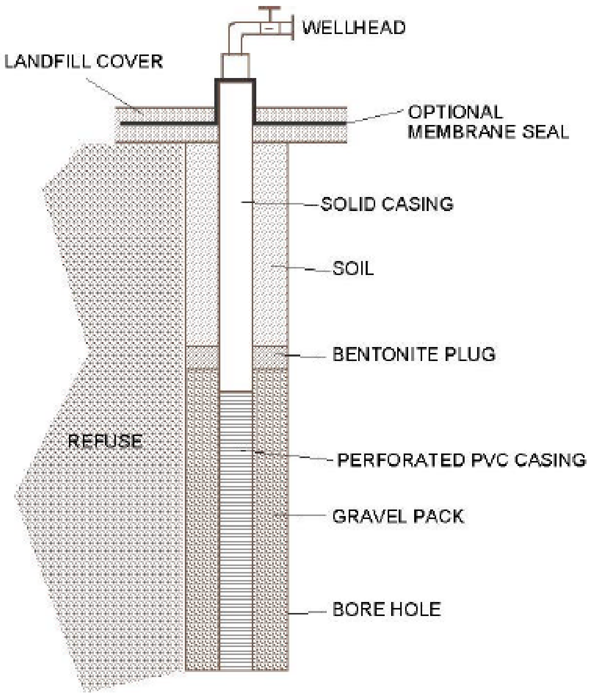



*Figure 19: Construction of vertical gas collectors (ISWA 2005)*

The pros and cons of vertical versus horizontal systems will have to be considered when opting for different solutions. In the case of landfills that are closed down the vertical system have certain advantages, while horizontal systems can be applied also during operational phase of a landfill.

*Table 4: Table from GMI (2012, table 3-1) summarizing advantages and disadvantages of landfill gas recovery systems*

| **Vertical wells** | | **Horizontal wells** | |
|---|---|---|---|
| *Advantages* | *Disadvantages* | *Advantages* | *Disadvantages* |
| Minimal disruption of landfill operations if placed in closed area of landfill<br>Most common design<br>Reliable and accessible for inspection and pumping | Increased operation and maintenance required if installed in active area of landfill<br>Availability of appropriate equipment<br>Delayed gas collection if installed after site or cell closes | Facilitates earlier collection of LFG<br>Reduced need for specialized construction equipment<br>Allows extraction of gas from beneath an active tipping area on a deeper site | Increased likelihood of air intrusion until sufficiently covered with waste<br>More prone to failure because of flooding or landfill settlement |

The suggested landfill gas system to be installed in cell 3 should be either horizontal or vertical. There are reasons to consider a horizontal system as the preferred choice, as it will be installed already when the landfill is operated. *For any system solution chosen the supplier should be able to provide evidence of systems performance in terms of efficient operation and long-term technical life considering operational parameters on-site in Probolinggo.*

A gas pump is required to create a slight under-pressure in the suction pipes in the landfill and to transport the gas out of the landfill. The pump speed must be balanced to the actual production rate of landfill gas. Today there are online systems that monitor and regulate these systems. The monitoring also serves to ensure other operational parameters.

The landfill system requires an option to flare excessive gas. Flaring gas, instead of emitting it, would ensure that carbon dioxide is emitted instead of methane with a 25 times stronger climate impact factor. There is a flaring station at Bestari landfill but this could require shifting depending on the design volume of gas collected. A principle design of a flaring solution is found in Figure 20.

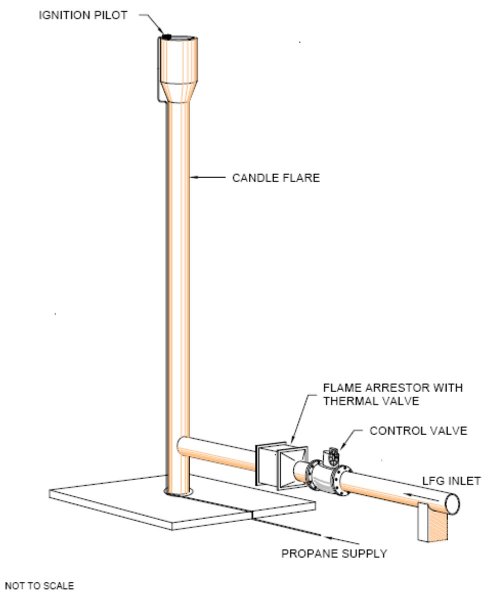



*Figure 20: Flaring of excess landfill gas*

Landfill gas recovery is a mature technology but successful operation will depend on the design in consideration with how the landfill is operated. As presented above wear and tear of the system might be substantial but operational approaches can reduce these impacts. It is suggested that any installation or system opted for should provide reference case installation where a operational track record can be provided.

#### 4.1.2.2 Assessment of gas production – cell 3

Based on design parameters and general knowledge on the organic content of the waste it is possible to present an indication of the gas production when the landfill is full and eventually covered. The numbers are only indicative and would be affected by a number of variables linked to operational parameters (e.g. added waste per day, organic fraction of waste, compactness of landfill), but also waste parameters such as organic fraction, any chemical disposals etc.

*Table 5: Assessed potential of landfill gas production in new cell 3*

| | **Tot landfill volume** [$m^3$] | **Density** [$ton/m^3$] | **Weight** [ton] | **Gas prod** [$Nm^3/h$] | **Pot electr generation** [$kW_{el}$] |
|---|---|---|---|---|---|
| Cell 3 | 81,900 | 0.6 | 49,140 | 19 | 35 |

The collected gas could be used for several purposes. We suggest that consideration is made to have a genset that is operated on gas from all the three cells.

Gas production will take place also up to the closing point in an increased level as the system is evolved. Possibly the full operation of the landfill gas system on cell 3 will only happen after closing of cell 1 and partial cell 2 has happened. The landfill gas from cell 3 should be tapped into the landfill gas recovery system build as part of closing cell 1 and cell 2. The additional landfill gas from cell 3 will strengthen the business case and sharing equipment will lower subsequent costs. See section 4.2.3 for further information on landfill gas system on cell 1 and cell 2.

The reduction of greenhouse gas emission from the new landfill cell 3 would be about 1,000 tonne $CO_{2eq}$ per year based on recovered volume of 19 $Nm^3$ biogas per hour, and an assumption that the recovered gas is burned in a genset[3].

## 4.2 Medium term (3-6 years) actions

The medium term actions will be concentrated on planning and preparing for the long term actions, but also to ensure that closing cell 1 and partially close closing cell 2 at the Bestari landfill is strongly motivated from environmental and climate perspectives. The actions links to improving the capacity to collect emitted methane from the landfill via landfill recovery system and to cover and close cell 1 and close the parts of cell 2 that are not part of new cell 3.

### 4.2.1 Planning and preparations for long-term solution with integrated waste management site, including new landfill area and possible incineration

Based on the experiences and present situation it is crucial that actions are taken as soon as possible (could also be during short term actions) to revise, assess and initiate activities around the long-term action plan on establishing a sanitary landfill in Probolinggo. As suggested in this report the landfill area could be further equipped with incineration capacity in order to reduce volumes of waste to be landfilled and also avoid landfilling organic material and thus avoiding methane emissions to the atmosphere.

Actions to be considered here are establishing political commitment to the long-term action plan, further detailing the land acquisition details and forming an action plan for implementation. *We would recommend further assessing the actual waste situation in Probolinggo in order to provide background information. In terms of new sanitary landfill further details on the investment costs and possible budget alternatives should be made.*

### 4.2.2 Close existing landfill cell 1 and partially close cell 2

Cell 1 and cell 2 at the Bestari landfill has, as mentioned, reached its full capacity and the cells should be closed in order to ensure low environmental impacts in

[3] This calculation does not consider impact from replacing existing electricity production in Indonesia which is predominantly based on fossil resources.

the future. Cell 2 is considered to be merged together with new landfill cell 3 and thus parts of cell 2 cannot be closed. Below presentation is mainly focused on actions linked to cell 1.

This action is considered to have a relatively low complexity (Figure 21).

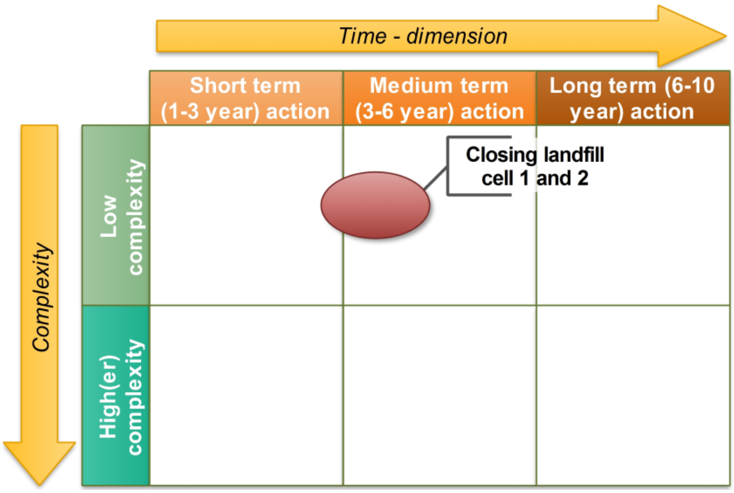



*Figure 21: Assessment of medium term solution closing of existing cell 1 and cell 2.*

A landfill's design should limit water from entering into the landfilled waste to reduce leachate generation. When the landfill is full, it is important to put a cover over the landfill to minimize the leachate production in the future. There are different techniques available to cover or cap landfills, and the technique depends on the climate conditions. In Indonesia resistance against monsoon rains may be an important factor in the design. *Consideration of possible future climate changes is strongly recommended to be included as considerations in the design process.*

A possible design of a landfill cap, adapted for Indonesia, is shown in Figure 22.

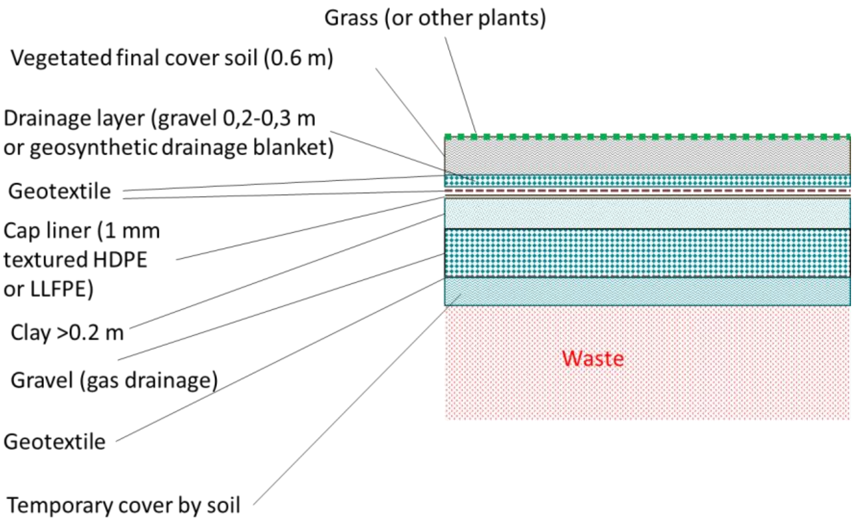



*Figure 22: Suggested design of landfill capping*

The waste should be compacted, and the landfill should be consolidated before the capping starts. A preliminary cover of soil should be put above the waste when the no more waste is put into the landfill.

Above the soil cover is put a geo-textile cloth, and on the cloth is put a 0.2 m layer of gravel (size 25 – 50 mm). The function of the gravel layer is to lead off gases from the landfill (gases that are not collected by the landfill gas system). The function of the geo-textile cloth is separate the gravel from the soil layer.

Above the gravel is put another geo-textile, and a layer of clay. The layer should be 0.2 – 0.3 m thick with permeability of less than $10^{-9}$ m/s. As alternative to natural clay, it is possible to use pre-fabricated geo-synthetic clay liner.

Above the clay, or geo-synthetic clay liner, is put a cap liner, 1 – 1.5 mm thick of textured HDPE or Linear Low Density Polyethylene (LLDPE).

The plastic liner is protected by a geo-textile cloth or geomembrane, and above that is put a drainage layer by gravels. The layer should be 0.2 – 0.3 m thick and the gravel size about 25 – 50 mm. As an alternative pre-fabricated geo-synthetic drainage blanket can be used.

The drainage layer is protected by another geo-textile cloth, and above it is put a soil layer. The soil layer should be at least 0.6 m thick. On the soil grass and other low growing plants can be sowed.

It should be mentioned that the gas recovery system can continue to be in operation also after the capping, as long as there is a landfill gas production. There may also be a small leachate production so some kind of leachate control system should be present.

The closure of cell 1, according to the above, should start when the new cell 3 is in operation. Cell 3 is partly built upon cell 2, and the open parts of cell 2 should be preliminary covered with soil until the closure of cell 3 begins.

When the landfill is closed and capped the land area could be used for different purposes. One option is to place solar PV cells on the surface to support further low carbon emitting energy production and show case additional renewable energy opportunities.

#### *4.2.2.1 Economic assessment*

The cost for closure of cell 1 is preliminary estimated to maximum 80,000 US$. This assessment is based on costs typically found in Europe and from the Indonesian case this would typically be lower.

### 4.2.3 Improve efficiency of landfill gas collection in closed cell 1 and cell 2

Bestari landfill cell 1 and cell 2 have a basic landfill gas recovery system installed. This system is based vertical pipes drilled down in the landfilled waste. The landfill gas is extracted from using 4 meter PVC pipe perforated at the bottom, and put down in the landfill 5 – 10 meters. The landfill gas is led by smaller pipes to a simple gas cleaning unit. After cleaning the landfill gas, it is distributed to nearby private houses where the gas is used for cooking. There are currently 9 families that can use the gas.

*Figure 23: Existing landfill gas recovery system on cell 1. This system is a vertical system.*

The existing landfill gas system was build and designed as a local initiative. It is very impressive and a good case of the ambitions of the staff at the environmental department, Probolinggo city. The installation has created know-how on operation and maintenance of these types of systems. An updated system would increase the gas collection and provide both economic revenues as well as reduce environmental and climate impacts from the landfill cell.

In order to capture a high percentage of the produced landfill gas a new landfill gas system should be installed. As cell 1 and parts of cell 2 would be closed the installation of vertical system is possible and a recommended choice. A supplier should be able to provide reference cases of similar installations before choosing system design and supplier. The activity is consider slightly more complex to achieve not so much due to technical reasons but the action will require additional budgeting to happen, and thus required to be integrated into city plans and budgets communicated with central authorities.

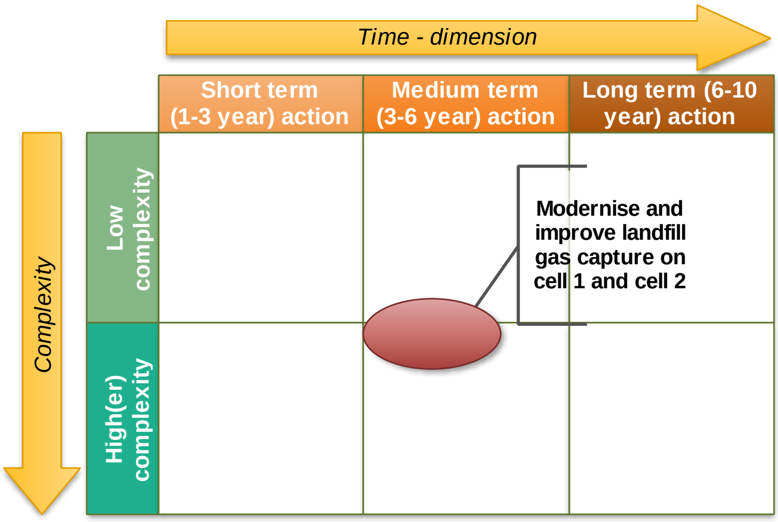



*Figure 24: Assessment of medium term action on modernising and improving landfill gas capture on closed cell 1 and partial on cell 2.*

The gas potential can be assessed applying a low and a high case. In any actual implementation it is strongly recommended that test wells are made to ensure gas production and assess the quality (amount of methane, oxygen etc). The difference between these two cases is mainly found in how large the active landfill volume will be. In the high production case it is assumed that only 1 meter from the surface is needed as a barrier, while in the low production case 3 meters are needed as a barrier to prevent oxygen penetration. From experience the actual situation would be found between these two cases.

*Table 6: Assessed potential of landfill gas production in cell 1*

| | **Active landfill volume** [$m^3$] | **Density** [$ton/m^3$] | **Weight** [ton] | **Gas prod** [$Nm^3/h$] | **Pot electr generation** [$kW_{el}$] |
|---|---|---|---|---|---|
| Cell 1 (low case) | 84,360 | 0.6 | 50,616 | 19 | 35 |
| Cell 1 (high case) | 124,800 | 0.6 | 74,880 | 28 | 53 |

* 1 $Nm^3$ landfill gas = 4.7 kWh; electric efficiency in genset set to 40%

The gas production will be between 19 and 28 $Nm^3/h$. The strategic plan also considers that cell 3 should include landfill gas recovery with gas provision of about 19 $Nm^3/h$ at the time when the cell is full. This gives a few options for gas use. Obviously there is room to use parts of the gas for cooking, but preferred option is to run a gas powered genset. Based on gas yields a first installation of a 50 $kW_{el}$ genset would be appropriate. As recovered gas increase additional gensets can be added to the system creating a redundancy.

The investment cost of an international best practice landfill gas system, including all equipment, a 50 $kW_{el}$ genset, installation and training would be about 8,800 million IDR (635,000 USD). This is a rough estimate not considering options to reduce costs by applying local production of certain materials etc.

Revenues from the electricity generation will be from selling electricity to the grid, a possibility strongly supported by present government (PRI 2016; MESM 2017). Electricity would be sold to the power company Perusahaan Listrik Negara (PLN) for further distribution to other end users on the network. The tariffs that are offered on waste-to-energy projects from PLN are rather complex but government are supporting that new renewable energy capacity is introduced to the grid and feed in tariffs (FiT) are in place. But the question is if this small installation would qualify in these programs due to size.

The average production cost of East Java is set to 914 IDR/kWh (6.83 US cent/kWh)[4], which is slightly lower than the average Indonesian electricity production cost (MESM 2018). The production cost is a key variable in defining the level of the tariff offered. There is an option for negotiating the tariff offered from PLN for electricity. The level indicated above is thus a minimum tariff.

Based on these premises a simple calculation of the revenues from the operation can be made (Table 7).

*Table 7: Revenues from operation of landfill gas system (cell 1)*

| Item | Amount |
|---|---|
| Installed electric capacity | 50 $kW_{el}$ |
| Operational availability | 95 % |
| Electricity generated per year | 410 MWh |
| Tariff | 6.83 US cent/kWh<br>(914 IDR/kWh) |
| Revenue per year | 28,003 USD/year<br>(374,740,000 IDR/year) |

At present the pay-back time of this installation would be very long. Capture of the methane that is emitted from the landfill is a priority and integrated part of a modern landfill.

The reduction of greenhouse gas emission from the closed landfill cell 3 would be 1,000 up to 1,600 tonne $CO_{2eq}$ per year based on recovered volume of 19 $Nm^3$ to 28 $Nm^3$ biogas per hour, and an assumption that the recovered gas is burned in a

[4] Decree No. 1772 K/20/MEM/2018 dated 29 March 2018. There is also a feed in tariff (TiF) discussed for waste to energy installations in Indonesia. PRI (2018) stipulates that PLN should purchase electricity from waste to energy installations with a capacity below 20$MW_{el}$ at a rate of 13.35 US cent/kWh.

genset[5]. Opportunities for revenues via climate emission reductions have not been considered here.

### 4.2.4 Ensuring safe working conditions including waste pickers

Presently there are around 60 persons involved in collecting sellable items at the landfill site. There is no formal agreement that these people are allowed to find their livelihood on the landfill this fills the purpose of further collect reusable and recyclable items. These persons are exposed to a hazardous working environment. The income levels from selling the collected items are reported to be about 50,000-100,000 IDR per day (3.7 – 7.5 USD/day). Waste pickers are found along the waste stream, from the source all up to the landfill. They all fill an important part in ensuring the level of recycling of materials that are seen in Probolinggo.

The existing informal work force, that the waste picker today form, could very well receive a more formal role in the work with 3R:s at the landfill in the future. The existing waste pickers are a group with experience and also knowledge in these issues that could be utilised to further act for reducing waste amounts.

As part of further modernising and streamlining the final waste management at Bestari landfill actions should be taken to ensure safe working conditions for all at the landfill. It is not advisable to have people at the actual landfill site as it will inevitably directly and indirectly affect the way that compactors and dumpsters are moving on the landfill. As a result it is advisable to find other options to safeguard that existing waste pickers are not forced away from their existing livelihoods. To simply not allow waste pickers at the Bestari landfill site would not be a pro-active action as it would reduce the amount of recycled materials.

One of the most attractive options to consider is to have a transfer station and sorting bay at the landfill premises where the waste pickers could ensure that valuable and recyclable material are taken out from the waste stream to be put on the landfill. A transfer station with a sorting bay would ensure that compacting and building the actual landfill site including covering with soil etc can be more efficient[6]. In addition the risk for accidents and exposure to health hazards be reduced and potentially also improve recycling and re-use of materials by improving the conditions for the waste pickers to actually find and locate valuable materials.

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[5] This calculation does not include additional greenhouse gas reductions from replacing existing electricity production in Indonesia which is predominantly based on fossil resources.

[6] The issue of landfill waste pickers and their role in waste management has received attention in literature (see for example Marello and Helwege 2014; Dias 2016; Colombijn and Morbidini 2017; de Bercegol *et al.* 2017). The situation in Probolinggo, with the majority of waste picking taking place before waste is reaching the landfill, is somewhat different from many studies where focus is mainly on the waste pickers on the landfill.

The actual design of the sorting facility should be studied in more detail in order to find a suitable solution for the Probolinggo case. Conveyor belt solution with manual picking, and some automated assistance (such as magnetic and eddy-current separator) is one option and tested on several places in Asia and elsewhere.

*It is strongly advisable that that design of these measures includes participation of the affected people (waste pickers at the landfill) in order to avoid unnecessary tensions or backlash in the form of non-compliance of leaving the landfill.*

Operational costs and investment costs would be required to realise the sorting bay. The motivations are found in working conditions, social aspects and realising a sanitary landfill. The sorting bay would provide certain revenues as separated materials can be sold. We cannot judge at this point the magnitude of revenues that could be obtained.

## 4.3 Long term (6-10 years) actions

The long-term solution for Probolinggo will have to include a new site for future landfill cells. This report also suggest that this new landfill site is combined with a small scale incineration plant which would reduce volume of waste to be landfilled, but also reduce the organic materials in the landfill and thereby reducing emissions of methane from the landfill. The suggested approach builds on the existing master plans (Bappeda 2016) with some additional suggestions to further reduce climate impacts, and ensure a long operational life. The integrated waste management site (*Tempat Pengolahan Sampah Terpadu,* TPST) would become an Indonesian showcase illustrating how a medium size city in practice can tackle and solve the problems arising from waste handling, and at the same time providing new jobs, reduce health risks and working for reducing waste ending up in nature and the ocean. This will happen at the same time as maximizing recycling.

### 4.3.1 New integrated waste management site, including pre-treatment, incineration capacity and new landfill

The suggested new cell 3 will only have a capacity that will cover a few years of operation, and a long-term solution of the landfill problem will be needed. As no more space is found on the existing premises of the Bestari landfill site new land areas will have to be acquired. Based on discussions in Probolinggo it is preferred to expand the existing area rather than opting for a new location. In the Probolinggo waste master plan (Bappeda 2016) the idea of an integrated waste management site was launched and presented in detail. This strategic plan supports this and adds on some details.

The *technical* complexity of the suggested solutions is relatively low as much of these systems are based on proven technologies. Still, the assessment of total complexity of realizing this will be a relatively high level of complexity. This is mainly due to need for ensuring financing, as well as safeguarding that there is a commitment from the different city bodies and politicians in opting for this solution (Figure 25).

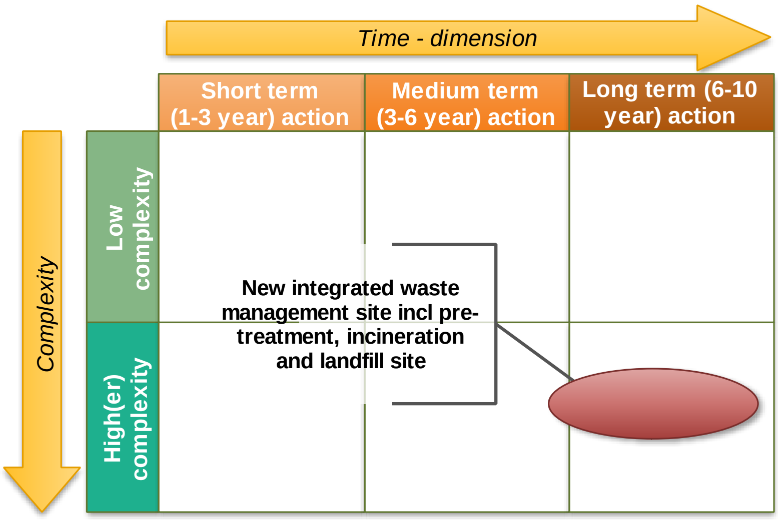


*Figure 25: Assessment of long term action on establishing integrated waste management site including pre-treatment, incineration and landfill capacity.*

This action will depend on successful implementation of planning and preparation during the short and medium term actions. The successful implementation of this new integrated waste management site would result in a long-term solution in Probolinggo.

#### 4.3.1.1 New area for operations

For the future needs the area north-east of the current landfill cell 2 is recommended. Today there are fishponds and some commercial buildings as well as houses there. According to CDIA (2016) study the actions to start building the new landfill was to begin already in 2011 but has been delayed. As a consequence new buildings and activities has begun in the area.

The waste management master plan (Bappeda 2016) provides a good approach of the needed actions. Considering the challenges that land acquisition will, and has proved to be, there are reasons to look for options that do not include the areas marked as "presently occupied" in Figure 26. The other land area marked "potential land for new landfill" can still be part of the plan.

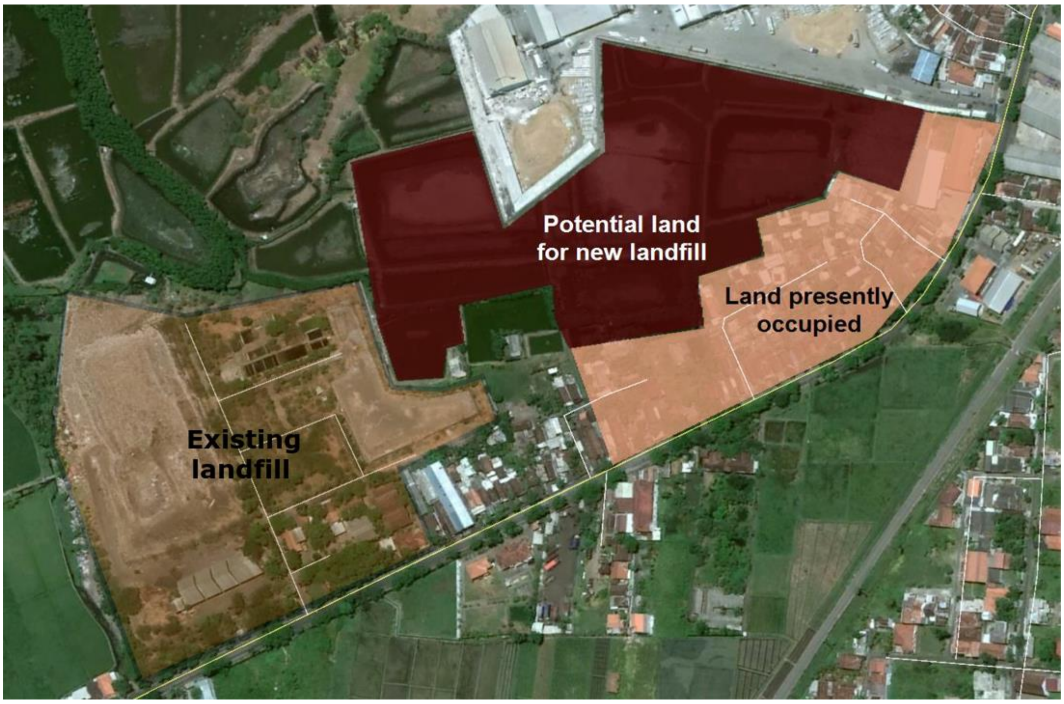


*Figure 26: Potential area for landfill expansion (source: google earth, CDIA 2016, assessment of land use).*

In the Master Plan there is already a preliminary description of the performance of the new landfill, where the landfill is planned to be built in three successive cells. There are alternative ways of design, which was suggested for new cell 3 where European standard has been applied.

The design of the new landfill site follows the approach for the short-term action to establish landfill cell 3. The ground is smoothed down and levelled out. If necessary a layer of structural fill (compacted soil and rocks) are placed on the surface. The surface should be slightly sloping (slope at least 2:100 to 5:100) to one or several low points where the leachate can be collected.

Above the prepared ground is put a double liner system:

- Bottom: natural clay, compacted, 0.2 – 0.3 m thick, or geo-synthetic clay liner or bentonite liner.
- Top: Textured HDPE liner >1.5 mm. The HDPE sheets/rolls shall be overlapping and the seams shall be welded.

Above the HDPE liner, a drainage system is built, either gravels (c. 0.3 m height of the layer) or a geo-composite drainage blanket. Above the drainage layer is put a geotextile cloth (to protect the drainage layer from the waste).

The bottom shall be slightly sloping or inclined to one or several low points where perforated pipes collect the leachate water and conduct the leachate water to the existing leachate treatment system.

Embankments should be installed round the cell, see Figure 27. The embankment should also connect to the cell 2, and the bottom sealing should overlap to cell 2 in accordance with the figure.

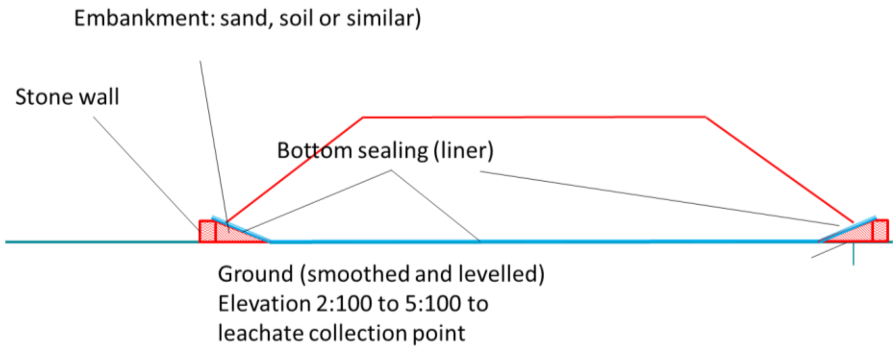


*Figure 27: Principle construction of future landfill cell.*

The future landfill cell should be equipped with a gas recovery system based on horizontal pipes, which are inserted in the landfill during the fill-up. Horizontal collection is an option for installation during the landfill operation phase, while vertical systems can easily be installed at landfill that are filled up, but more difficult to install during the operation phase.

The new gas collection system should be connected to the suggested gas recovery systems from cell 1, cell 2 and cell 3. Additional generator capacity could be considered depending on gas generation foreseen.

The leachate treatment system should be reviewed in order to ensure proper functionality. If needed additional capacity should be added to ensure that there is no harmful discharge of substances to the recipient.

#### 4.3.1.2 Waste to energy - Incineration plant providing opportunity for energy recovery from waste

At present there is about 20,000 tonnes of waste for the landfill per year[7]. A long-term possibility to develop the waste management and reduce landfilling is to implement an incineration plant for energy recovery from the waste. The incineration plant will produce electricity that can be sold to the electricity company. Possibly also steam may be generated and sold to a steam-needing industry close to the incineration plant.

[7] In Johansson and Warren (2015) they define a small scale waste to energy system as a plant that treated less than 100,000 tonnes per year of waste.

The waste stream that is found in Probolinggo will not be enough to motivate a large scale incineration systems operating on super-heated steam, while options using an Organic Rankine Cycle (ORC) turbine would be more feasible. The ORC technology is based on using an organic working fluid with a lower boiling point than water. This will provide opportunities to utilise heat at lower temperatures and by this find new opportunities for design. The down-side is that the efficiency of an ORC system is around 25% which is lower than conventional large scale systems where efficiency may be around 30%[8].

A typical design of a smaller waste incineration site would include a receiving bay where also sorting can be made. Drying is needed to ensure that the waste to be fed into the boiler is not too wet. By both sorting and drying the waste received the incineration process can be controlled which also ensures that any harmful compounds in the flue gases can be held within the permits. The heat energy from the boiler is then used in the turbine to generate electricity that is fed out to the grid. Heat can be used in the drying of the waste and also sold to customers if there is a demand. Heat exchangers are used to cool excess heat to the air or to a stream (Figure 28).

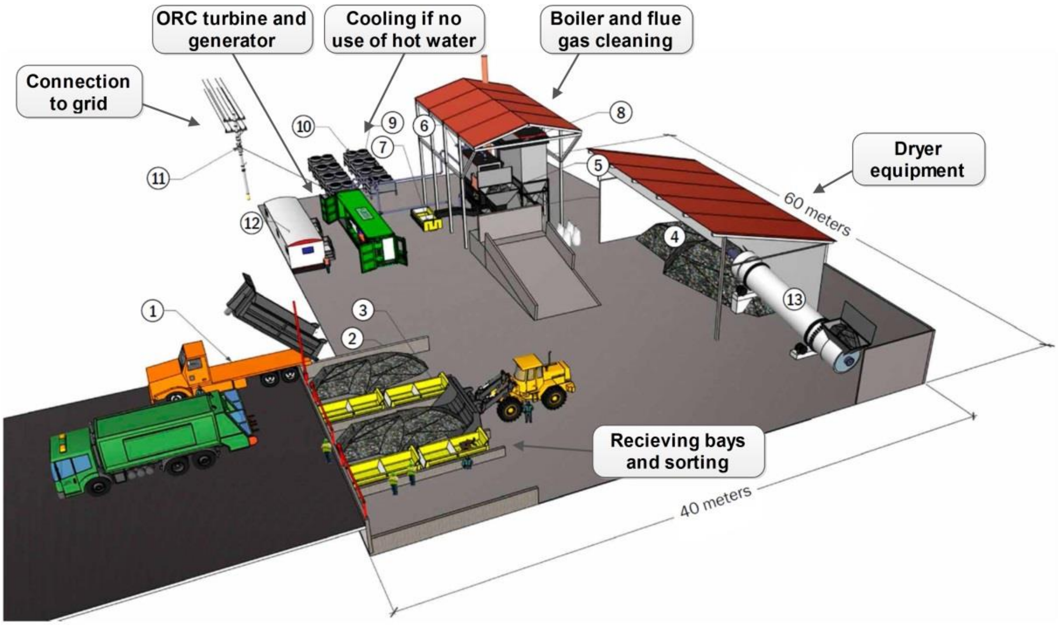


*Figure 28: Outline of incineration plant (source: Againity layout)*

Using thermal treatment, steam and electricity are produced and the weight of MSW is reduced by up to 70%–80%, whereas the volume is reduced by up to

[8] The efficiency of 30% can be increased if further energy recovery in the process is made. For example with flue gas condensation electric efficiency may reach 35%. In cases where the heat can be utilized the total efficiency (including both electricity and heat recovery) can reach above 90%. The business case for these latter cases is of course much better than if the heat will have to be cooled off.

90%. (Kalogirou 2018). The ash amount depends on the composition of the waste, but a preliminary estimate show that an input of 60 tonnes per day of waste to the incineration plant will produce up to 12 tonnes of ash per day, which may correspond to 10 – 14 $m^3$ of ash per day. These numbers are given by the composition of the waste and may thus vary somewhat[9]. The incinerated waste will result in an ash residue that has to be taken care of in a controlled manner. Sometimes the ash may be used for construction material, but landfilling is probably the most probable disposal method. One important difference between the ash and the solid waste presently landfilled would be that the ash is an inert material with no organic materials.

Perhaps most important in the context of considering a waste incineration plant inside Probolinggo is to ensure that the cleaning and treatment of flue gases and condensation liquid from the flue gases, are according to high international standard. Waste incineration is a mature technology and the track record of ensuring environmentally safe operation is long. The limit values for polluting substances have been adjusted to best available technology (BAT) and industrial standards in order to ensure safe operation, but also ensuring that these installations can be positioned closed to towns and cities without problems[10].

*Table 8: Thresholds for daily average emissions limit values of polluting substances in flue gases, EU levels (European Parliament 2010) and Indonesian levels (MLHK 2016)*

| **Component** | **EU legislation** | **Indonesia legislation*** |
|---|---|---|
| Total particular [mg/Nm3] | 10 | 120 |
| Suplhur dioxide ($SO_2$) [mg/Nm3] | 50 | 210 |
| Nitrogen (NO and $NO_2$) [mg/Nm3] | 200 | 470 |
| Hydrogen chloride (HCl) [mg/Nm3] | 10 | 10 |
| Mercury (Hg) [mg/Nm3] | 0.05 | 3 |
| Carbon monoxide (CO) [mg/Nm3] | 50 | 625 |
| Hydrogen fluoride (HF) [mg/Nm3] | 1 | 2 |
| Dioxins and Furans [ng/Nm3] | 0.1 | 0.1 |

Note: Thresholds for other intervals than daily average also applies, these are some examples.

The construction and operation of a waste to energy plant in Probolinggo will require strategies to ensure public acceptance of this new technology. Health

[9] As a consequence of reduced volumes one option is to build the incineration plant in connection to the Bestari landfill utilizing connections to grid (via the proposed landfill gas system), existing sorting bay and other infra structure and then transport *the resulting ashes* to a new landfill site. The volume of ashes is much reduced.

[10] Historically (in the 80's) there were problems with high content of dioxins in the flue gases. This problem was tackled by new cleaning approaches, changing operational parameters in the boilers and other measures and the levels were drastically reduced. Dioxin and Furan levels can now be held at a very low level if operation and equipment is in place and working correctly.

impacts are today experienced from open air burning and it is important to point out that a controlled modern waste to energy incineration plant will be far from uncontrolled burning. There is no analogy between these two and in fact the waste to energy plant will support reducing the open air burning in favour of controlled energy recovery from waste, with cleaning of flue gases and any other emissions. As a consequence of introduction of a waste to energy system in Probolinggo, an *improved* environmental status of air and water could be achieved. *Participatory planning approaches together with providing information to citizens are advisable and these activities should be initiated already in early stages of planning (see section 4.2.1).*

Any waste to energy plant solution considered should be able to provide evidence and guarantees to adhere to strict environmental conditions of the flue gases and condensate and leachate water. *It is strongly recommended that levels according to best international practice, as for example illustrated by the limit values in EU regulation, are applied in order to safeguard against risks of increase exposure to substances damaging to health and/or environment (HPA 2009). Any installation that cannot guarantee these operational parameters should not be considered further.*

Some basic pre-treatment will be needed in order to ensure safe and efficient operation. By pre-treatment a basic refuse-derived fuel (RDF) is created where the risk that concentrations of hazardous compounds in the flue gases are outside the given permissions and thresholds will be reduced. The pre-treatment is based on two steps: i) sorting of waste and ii) drying.

A sorting bay is proposed to be initiated which is found in connection to the tipping point where waste trucks and other vehicles arriving with waste for the landfill is tipping their waste. Initiate a sorting bay is part of medium term actions aiming for initiate sanitary landfill operation of cell 3 and improving working conditions (see section 4.2.4).

The waste in Probolinggo is often wet, and in order for the incineration process to be efficiency and controlled the waste has to be pre-treated (dried) before energy recovery can be undertaken. A drier should be incorporated in the incineration plant design, and should make optimal use of excess heat from the incineration process which will reduce the need of other conventional fuels such as gas or oil.

As was noted in section 2.1 energy content of the waste may vary rather significantly. A further investigation of the energy content will be required as part of the steps towards realising the long-term solution. *This investigation should apart from energy content define in more detail the content of the waste entering to the landfill. A special attention should be given to any hazardous waste entering the landfill and the sources of these compounds.*

The design of the waste to energy plant should be done taking into consideration possible increase in waste generation by the population of Probolinggo, but also the increase of waste as a result of actions to reduce the amount of waste that today has an unknown recipient. It is often a good approach to start with a unit where full operation can be upheld and expand with a second unit if there is a basis for that. In such a case the second unit would profit from certain infrastructure already found for the first unit and thereby reducing costs.

*Table 9: Summary of indicative numbers for installation of ORC waste to energy plant*

| Size boiler | Generator | Waste capacity | Investment (see note) |
|---|---|---|---|
| 2.3 MW | 240 kW electricity | 1.2 ton/h | 4.0 million USD |
| 4.5 MW | 470 kW electricity | 2.4 ton/h | 6.5 million USD |
| 9.0 MW | 950 kW electricity | 4.8 ton/h | 12 million USD |
| ***Included:*** waste incinerator, flue gas cleaning (electrostatic filters and other filter), ORC turbine and generator, transport, installation, commissioning and training of staff<br>***Excluded:*** roofs, stairs, office, connection of water, electricity and sewage, concrete foundations and a 50x50 flat space. | | | |

The time from order of plant (first down-payment) to operational waste to energy plant at site is about 12 months. The actual construction and building is not very complicated but proper design requires good knowledge of the details of waste composition, moisture content and similar variables.

Reduced greenhouse gas emissions will be result of the proposed action. We have not calculated the resulting impact at this stage but this impact will also add motivation to make this action.

### *Economic assessment of incineration option*

The economic assessment of an incineration capacity as part of an integrated waste management site would provide triple benefits – provide revenues from operation, reduce climate impacts and reduce waste volumes required to be landfilled. The required total investment includes incinerator, dryer, pre-treatment (dryer, sorting etc) and site preparation. One key aspect is to ensure that contractual agreement has been arranged with organisation purchasing the power (in Probolinggo case PLN). Necessary permits and ensuring monitoring routines are in place will also be required.

The daily waste stream to the landfill in Probolinggo is presently about 55 ton/day. The volume is expected to grow, but at this point of time 55 ton/day would be the most appropriate design volume. A 4.5 MW boiler capacity is needed linked to a 470 $kW_{el}$ generator resulting in an indicative investment of about 7.0 million USD (Table 10).

*Table 10: Indicative budget of waste to energy plant, 55 ton/day capacity*

| | |
|---|---|
| Incinerator, incl turbine, flue gas cleaner, cooler etc | 6.5 million USD |
| Site preparation, connection to grid etc | 0.5 million USD |
| **Total** | **7.0 million USD*** |

*Bappeda (2016) provide an indicative investment range of 0.9-13.6 million USD for an incineration plant with corresponding size. The span illustrates the need to ensure clear specifications on operational parameters and environmental performance.

Operation and maintenance (O&M) cost will include personnel cost, fuel for front loader and maintenance of the waste to energy plant. These costs are part of the operation of the total integrated waste management site and will have to be assessed in more detail depending on the route decided. Revenues from plant could come from sales of; i) electricity, ii) heat (warm water or steam) and iii) selling of recyclable product. At this point the electricity is the main revenue to consider as demand and willingness to pay for heated water or steam is unsure. The recycling bay is already considered in earlier activities and these revenues are thus already accounted for (section 4.2.4). There is also indirect revenue as the landfill will not be filled as quickly as before. Other possible revenue could be from $CO_2$ emission credits as an integrated waste management system with incineration capacity would reduce emission of greenhouse gases (these are not considered here).

There is presently FiT stipulated for the prioritised waste to energy projects listed in PRI (2018, chapter V, article 11.1.a) setting it to 13.35 US cent/kWh[11]. This tariff is possibly not applicable to any waste to energy installations installed in Indonesia but only to installations in the short-listed cities. The higher FiT can be contrasted to the level defined in MESM (2018) where purchase price of electricity to the grid is set to 6.83 US cent/kWh (914 IDR/kWh). It is however well worth considering that this provides leverage for further discussions and suggestions to the government of Indonesia.

[11] This level is set for waste to energy plants with a capacity up to 20MW. Larger plants (>20MW) have a FiT level stipulated via an algorithm where installed capacity is playing a role (chapter V, article 11.1.b)

*Table 11: Revenues from sale of electricity to the grid – waste to energy system (high and low case)*

| **Item** | **Amount** |
|---|---|
| Installed electric capacity | 470 kW |
| Operational availability | 95 % |
| Produced electricity per year | 3,910 MWh |
| Tariff (low) | 6.83 US cents/kWh<br>(914 IDR/kWh) |
| Tariff (high) | 13.35 US cents/kWh<br>(1,786 IDR/kWh) |
| Revenue low | 267,053 USD/year<br>(3,573,169,000 IDR/year) |
| Revenue high | 521,985 USD/year<br>(6,984,159,000 IDR/year) |

Consideration of O&M costs should be given in the more detailed feasibility study of this alternative. Consideration of access to spare parts and technical support should be included in final decision of system.

In many cases the business case for a waste to energy plant would include revenues from gate fees. The new regulation to support establishment of waste to energy in 12 cities in Indonesia (PRI 2018) include certain provision for securing the revenue from gate fee. *As this is a long-term action there is room to lobby toward regional and government level to ensure a level playing field between cities that are looking to ensure that waste management is done in a resource efficient, environmentally safe and cost-effective way.*

The pay-back for the waste to energy site is long. Still the business as usual alternative will result in continuing challenges for waste management, costs caused by environmental degradation and risk of health problems caused by uncontrolled waste disposal. So a strong motivation to opt for an integrated waste management site is to find a long term solution for the waste management in Probolinggo – and show-case a modern and safe solution for a medium sized city in Indonesia.

# 5 Suggested solution – increase the share of collected waste

Substantial efforts and actions in short-, medium and long-term will be needed in order to increase collection of the waste that today ends up in unknown recipients. Several of these actions will be interlinked and reductions in waste via a certain measure may create positive impacts on other areas. Experience also shows that when people perceive that their environment becomes cleaner it will support positive behavioural changes in terms of trying not to litter in the same way.

The lack of capacity in the landfill is presently a barrier to develop and implement actions to collect larger amounts of waste as there is no place to put it. With the suggested new landfill cell a temporary solution will be in place awaiting the long-term solution. Thus the actions here to increase share of collected waste go hand in hand with actions on ensuring landfill capacity and integrated waste management as discussed in chapter 4.

## 5.1 Systematic review of amounts and end-of-life of uncollected waste

The data of waste streams in Probolinggo is very good and detailed. There are comprehensive data compilations for the waste streams handled by the city and via other formal systems. The problem is though that the waste that ends up in unknown recipients is by obvious reasons tracked to a lesser degree. The amount of un-collected waste is based on providing a factor of generated waste per person in the city and retracting all the known waste streams ending up with a substantial volume of waste with an unknown recipient.

In order to design an action plan for decreasing the amount of un-collected waste further detailed information is needed. Recipients of this un-collected waste are today open-air burning in the city and else-where, dumping in streams or the sea, or other informal dumpsites. It would be useful to have further detailed information on origin and amounts for this waste, and where it ends up in order to develop a good action plan.

Based on this information waste scenarios can be formed that will provide input in the design and planning of the long-term solution for waste management in Probolinggo. The Probolinggo waste management master plan (Bappeda 2016) includes projections for the future. In the present report a basic scenario to illustrate the integrated waste management site (Figure 10) solution is given. *It is* *further suggested that data on the informal waste recycling is covered in order to verify information on existing levels of collection.*

## 5.2 Review existing collection and approach

The collection system can be improved. Instead of putting the waste onto the ground, different kind of plastic bins can be used. The bins have to be of enough capacity to store the expected amount of waste (so waste is not put on the street). The bins will require special trucks for collection, so the driver or collection personnel do not have to lift or carry the waste. The size of the bins depends on the amount of waste on each collection point. There are plastic bins from for example 500 – 1,000 litres volume and more. There are also metal containers with 5 – 10 $m^3$ volume that also may be used if there are large volumes of waste. It can be advantageous to collect industrial dry wastes in big containers and collect the containers maybe once a month, while bins in housing areas should be collected at least once or twice a week. The containers should be covered with lids. The containers need appropriate collection trucks, for example the 500 – 1,000 litres plastics bin are collected by special designed back-loading trucks.

Probolinggo has already acquired a number of plastic bins, but has no trucks that can handle the containers. Sourcing funds for larger vehicles is different from sourcing funds for investments in waste management equipment and plants. *In the medium- to long-term actions on procuring more efficient and adapted vehicles should be made.*

## 5.3 Illegal dumpsite

According to CDIA (2016) four illegal dumping sites were found on the harbour road. These were operated based on opportunities to profit from recyclable materials and not primary as a consequence of not too high costs for tipping it at the city landfill. This illustrates that there is a livelihood to be made on recycling and there are several people that have knowledge in what can be re-sold.

These illegal dumpsites could or should be closed in order to avoid environmental problems etc. But another option could be to ensure that the dumpsites are operated with permits and proper environmental control system and evolve them into recycling businesses. The sorted waste should then be transported to the landfill for proper end-of-life treatment.

Problem here is that these recycling stations are made outside the formal control systems and may cause environmental problems. The operation illustrates the opportunities that are found in recycling and sorting waste in Indonesia.

The actions on this item are in the short- and medium-term and strongly linked to the actions taken at establishing a sorting bay at the Bestari landfill station. *It seems important to ensure that a participatory approach can be initiated and that the* *positive aspects of know-how, entrepreneurship etc among the waste pickers is acknowledged in forming an action plan.*

## 5.4 Continue work on dissemination of information on good practice and understanding of waste management

*Information aimed towards the population and visitors to Probolinggo on good practice and the problems waste can cause aimed towards the population and visitors to Probolinggo should continue.* There are already many initiatives providing information and this should continue. It is advisable to link campaign towards the activities in short-, medium and long-term actions in order to have the support from the public.

Information aiming at up-scaling the activities linked to further scale up activities in the waste banks is one example, other are opportunities to acquire compost from the composting sites to be used in farming and plantations.

Information on good-practice will support a process to make Probolinggo a cleaner city by reduce littering on the roads and public areas but also support a process to increase collection of waste. Reducing the un-collected waste will be a key challenge in improving the waste management in Probolinggo. Information campaigns towards school children, offices employees, industries, private households and in public areas are some examples. The second challenge is to create acceptance for the solutions sought by the city to improve waste management. One specific item here is to ensure that diapers are not thrown in the river, despite knowledge about incineration[12]. Changing behaviour and beliefs will take time and long-term action on this item will be required.

As part of this action it would be advisable to look at opportunities to increase fee collection and increasing revenues in the waste handling. Information on why proper waste management is needed, why citizens need to pay for it and the benefits (clean environment) could be first steps. Some actions on this could possibly be taken in medium- to long-term action and any actions taken will need proper planning in order to avoid backlash from client negative responses.

## 5.5 Increase monitoring of industries waste management according to permits

Industries are responsible to ensure proper handling of waste resulting from their operations. It is advisable to ensure that the management system implemented is up to good standards and that dumping is not taking place.

[12] According information to the authors there is a belief that burning baby diapers will result in your child getting fever. Thus many diapers are thrown into the river.

Additional actions could be to collect good initiatives from industry to showcase good and resource efficient procedures. Meetings at the wood board factory and fish processing industry show examples of good practices. Industrial production may also result in hazardous wastes which should not end up at the landfill. This latter will be even more important if incineration is implemented as it may cause toxic substances forming in flue gases etc.

# 6 Conclusion

Probolinggo needs to take action to ensure that i) landfill capacity in the short- and long-time perspective is secured, and ii) reducing the un-collected waste that ends up in open-air burning, littering the streets and backyards of Probolinggo or just flows out to the ocean. This report has showed a possible strategic plan that provides actions in short, medium and long-term to achieve a modern resource efficient waste management system. In addition to providing a technical solution it would also provide opportunities for people today involved in informal waste picking in formal work and improved working conditions.

The strategy is considered realistic, but will require long-term commitments and also strategic planning. One of the main challenges will be to source the funding required to finance the investments. Here the political leadership in Probolinggo, together with city officials need to come to a joint understanding of the actions needed and to work along this approach. Ensuring that plans are formalised, supported and stuck to are important aspects. One of the reasons for this need for long-term planning is that funding for these investments would most likely come from Government sources. This means providing motivation and details of these actions in good time before they are planned to happen.

The actions suggested in the report will create substantial revenues from capture of landfill gas as well as electricity production. These revenues will support the city budget. The generated revenues in themselves will however not provide enough capital for financing investments as pay back times will be still be too long. Opting for a route where investments are based on raising gate fees and waste collection fees is not considered realistic at this point due to the low willingness to pay for these services and subsequent risk of further increasing un-collected waste volumes. Still, by the actions suggested here citizens and visitors to Probolinggo will see that the solutions for handling waste are good and the environment is clean. The feeling that you get something, a clean and tidy city, for what you pay for, the waste collection, will support opportunities to collect fees. Another aspect is that un-controlled dumping or open air burning will not be socially acceptable to the inhabitants in Probolinggo and thus a certain pressure to do right will emerge. The different actions presented in this report will go hand in hand and support each other.

One of the big uncertainties, and also one of the major problems, is the large volume of un-collected waste. These waste streams should be reduced – which needs to be an integrated part of this plan to improve the waste management. Only looking at managing the existing waste to the landfill is not enough – the aim should be to ensure that as much as possible of the waste generated in Probolinggo is handled properly.

The strategic plan suggested here would, if implemented, make a showcase that a medium sized city in Indonesia can establish waste management system with high international standard. The technical solutions are resource efficient and with high level of environmental concern. The strategic plan also includes actions to ensure that existing waste pickers on the landfill can have new income opportunities as they are no longer allowed on the sanitary landfill. These actions would support further development of making Probolinggo a green city.

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# Annex I: Data on waste generation put on landfill, and sources

*Table 12: Total mass of waste put on the landfill 2015, by source and month (Bappeda 2016).*

| Month | Mass of waste (kg) to the landfill (TPA) and origin | | | | | | | | | | | | Average per day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | House-holds | Market | Road and collected | Garden | Collected rivers | Bus, train station | Hospital | Hotel | Restau-rants | Industry | Sewage* | **Total** | |
| Jan | 1,064,320 | 258,060 | 79,905 | 14,810 | 17,980 | 24,370 | 11,980 | 1,690 | 1,290 | 18,730 | 80,540 | **1,493,135** | 48,166 |
| Feb | 976,260 | 235,310 | 74,870 | 16,390 | 12,480 | 17,330 | 9,510 | 1,240 | | 30,300 | 70,850 | **1,373,690** | 49,060 |
| Mar | 1,082,300 | 263,690 | 84,510 | 35,160 | 54,510 | 26,480 | 10,770 | 2,110 | 950 | 20,430 | 58,660 | **1,580,910** | 50,997 |
| Apr | 999,540 | 251,200 | 80,990 | 9,760 | 14,090 | 21,160 | 10,600 | 2,120 | 460 | 19,410 | 72,170 | **1,409,330** | 46,978 |
| May | 979,340 | 241,380 | 73,600 | 13,160 | 60,620 | 22,620 | 9,790 | 1,240 | 1,050 | 25,020 | 54,150 | **1,427,820** | 46,059 |
| Jun | 900,220 | 233,170 | 70,740 | 8,940 | 13,330 | 19,180 | 8,740 | 2,500 | 580 | 44,500 | 61,010 | **1,301,900** | 43,397 |
| Jul | 870,320 | 235,550 | 71,120 | 7,640 | 16,000 | 21,100 | 8,080 | 870 | 680 | 57,630 | 44,830 | **1,288,990** | 41,580 |
| Aug | 928,870 | 215,820 | 82,830 | 15,070 | 20,150 | 26,370 | 8,100 | 1,070 | 190 | 38,220 | 53,230 | **1,336,690** | 43,119 |
| Sep | 866,740 | 221,380 | 79,080 | 5,270 | 38,990 | 18,780 | 10,020 | 1,300 | 1,530 | 40,510 | 61,210 | **1,283,600** | 42,787 |
| Oct | 917,030 | 224,560 | 83,190 | 3,090 | 11,480 | 21,630 | 10,880 | 1,170 | 3,380 | 46,220 | 50,970 | **1,322,630** | 42,665 |
| Nov | 949,070 | 232,060 | 84,980 | 6,960 | 12,590 | 22,440 | 9,400 | 1,190 | 730 | 50,910 | 70,650 | **1,370,330** | 45,678 |
| Dec | 1,060,180 | 265,940 | 90,140 | 16,480 | 22,570 | 24,320 | 10,010 | 1,060 | 2,230 | 51,280 | 45,350 | **1,544,210** | 49,813 |
| **Total** | **11,594,190** | **2,878,120** | **955,955** | **152,730** | **294,790** | **265,780** | **117,880** | **17,560** | **13,070** | **443,160** | **723,620** | **16,733,235** | **45,844** |
| **Per day** | **31,765** | **7,885** | **2,619** | **418** | **808** | **728** | **323** | **48** | **36** | **1,214** | **1,983** | **45,844** | |
| **Percentage of total (%)** | **69.3** | **17.2** | **5.7** | **0.9** | **1.8** | **1.6** | **0.7** | **0.1** | **0.1** | **2.6** | **4.3** | **100** | |

*The sewage is not part of the total as this is fed into the leachate treatment plant

*Table 13: Volume of waste put on the landfill 2015, by source and month (Bappeda 2016)*

| **Month** | **Volume of waste (m3) to the landfill (TPA) and origin** | | | | | | | | | | | | **Average per day** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | House-holds | Market | Road and collected | Garden | Collected rivers | Bus, train station | Hospital | Hotel | Restau-rants | Industry | Sewage* | **Total** | |
| Jan | 4,155 | 1,297 | 249 | 94 | 208 | 120 | 85 | 36 | 4 | 93 | 80 | **6,341** | 204.56 |
| Feb | 3,835 | 1,185 | 248 | 115 | 199 | 88 | 78 | 22 | | 143 | 72 | **5,913** | 211.18 |
| Mar | 4,017 | 1,312 | 262 | 228 | 254 | 136 | 82 | 38 | 4 | 89 | 72 | **6,422** | 207.18 |
| Apr | 3,802 | 1,276 | 242 | 65 | 185 | 105 | 81 | 104 | 2 | 84 | 84 | **5,946** | 198.20 |
| May | 4,153 | 1,314 | 276 | 105 | 224 | 120 | 78 | 34 | 6 | 114 | 52 | **6,424** | 207.23 |
| Jun | 4,080 | 1,312 | 257 | 62 | 171 | 120 | 78 | 42 | 6 | 351 | 96 | **6,478** | 215.93 |
| Jul | 3,944 | 1,364 | 265 | 42 | 188 | 120 | 75 | 34 | 6 | 567 | 96 | **6,605** | 213.06 |
| Aug | 4,023 | 1,289 | 278 | 67 | 207 | 144 | 76 | 28 | 4 | 434 | 116 | **6,550** | 211.29 |
| Sep | 3,862 | 1,325 | 256 | 52 | 232 | 112 | 85 | 35 | 15 | 481 | 116 | **6,455** | 215.18 |
| Oct | 3,836 | 1,354 | 280 | 34 | 162 | 128 | 79 | 35 | 26 | 545 | 116 | **6,479** | 209.00 |
| Nov | 3,774 | 1,286 | 258 | 70 | 171 | 120 | 74 | 40 | 11 | 258 | 132 | **6,062** | 202.07 |
| Dec | 4,020 | 1,371 | 254 | 70 | 217 | 128 | 80 | 34 | 24 | 454 | 112 | **6,652** | 214.58 |
| **Total** | **47,501** | **15,685** | **3,125** | **1,004** | **2,418** | **1,441** | **951** | **482** | **108** | **3,613** | **1,144** | **76,328** | **209.12** |
| **Per day** | **130.14** | **42.97** | **8.56** | **2.75** | **6.62** | **3.95** | **2.61** | **1.32** | **0.30** | **9.90** | **3.13** | **209.12** | |
| **Percentage of total (%)** | **62.23** | **20.55** | **4.09** | **1.32** | **3.17** | **1.89** | **1.25** | **0.63** | **0.14** | **4.73** | **1.50** | **100** | |

*The sewage is not part of the total as this is fed into the leachate treatment plant

# Annex II: Map showing neighbouring city and regencies landfill locations

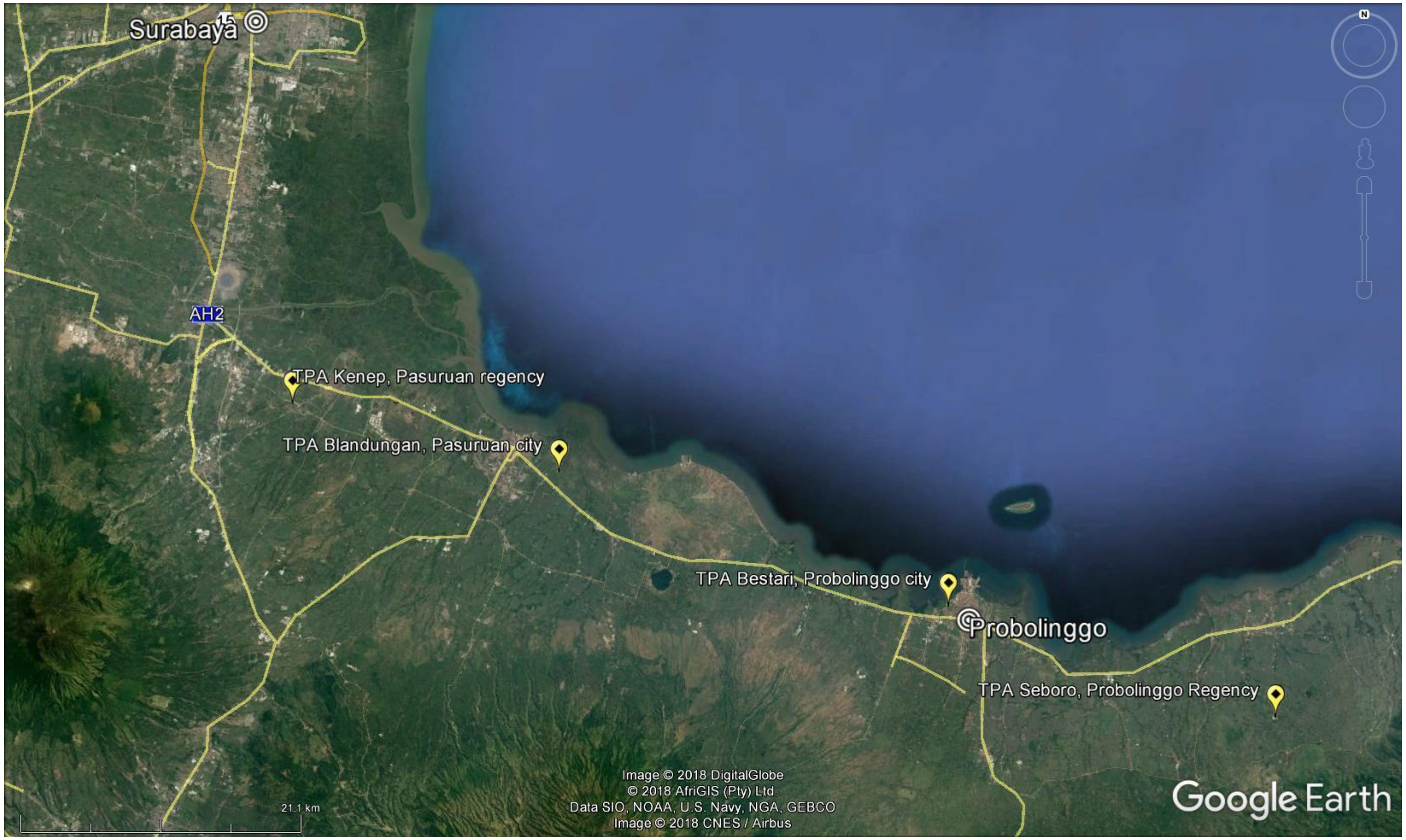


*Figure 29: Map showing neighbouring city (Pasuruan) and regencies (Probolinggo regency and Pasuruan regency) landfill locations.*

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