Materials Recovery Facility Tool Kit

Through the 3R initiative, recycling will become part of local governments’ solid waste management. To some extent, it will formalize parts of waste processing, largely handled by informal sector waste pickers and recyclers. With this publication, the Asian Development Bank aims to support the 3R initiative and encourage developing member countries to initiate investments in materials recovery facilities, which are essential tools for waste recycling under the initiative. This tool kit will be useful in deciding the size and design of such facilities as it also provides an indication of the cost of such investments.

About the Asian Development Bank

ADB’s vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region’s many successes, it remains home to two-thirds of the world’s poor: 1.7 billion people who live on less than $2 a day, with 828 million struggling on less than $1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.
MATERIALS RECOVERY FACILITY TOOL KIT

Asian Development Bank
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Managing Asia’s Solid Waste: Materials Recovery Facilities and the 3R Initiative of ADB

Rapid development, rising personal consumption, and inefficient use of resources are producing unprecedented levels of waste in Asia, where cities will generate an estimated 1.8 million tons of garbage per day by 2025.

In 2007, the Asian Development Bank (ADB) had already warned that the increased waste in the region, from what was then 760,000 tons per day, would be beyond the capacity of governments to handle, requiring private involvement in waste management. According to ADB, both the quantity and nature of wastes have significantly changed due to new production and consumption patterns and that “rapidly expanding cities are being overwhelmed by the growing volume and toxicity of wastes disposed on land and into the air and waterways.”1 Further, the proper recovery, treatment, or disposal of waste “is increasingly beyond the financial resources or political will of many national and municipal governments.” Inefficient use of resources and the often hidden costs of waste management are already affecting the competitiveness of Asian companies.

ADB’s innovative 3R initiative for solid waste management to reduce, reuse, and recycle waste was launched in 2005 in Tokyo, based on an agreement by the Group of 8 industrialized nations to promote more efficient production and consumption and environmental conservation. ADB will support the 3R initiative by assisting local governments in providing storage facilities and markets for compost and recyclable materials and encouraging community-based initiatives. Through the construction of materials recovery facilities (MRFs), intended to become part of the municipal waste management, cities will be able to (i) generate value through recycling and (ii) reduce the volume of final disposal requirements at sanitary landfill sites.

Through the 3R initiative, recycling will become part of local government solid waste management. To some extent, it will formalize parts of the waste processing, which currently is largely handled by informal sector waste pickers and recyclers.

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1 Associated Press. 2007. Cities Will Generate an Estimated 1.8 Million Tons of Garbage Per Day by 2025. 15 February.
With this publication, the Southeast Asia Department and the Regional and Sustainable Development Department of ADB aim to support the 3R initiative and encourage developing member countries to initiate investments in MRFs, which are essential tools for waste recycling under the initiative.

This tool kit will be useful in deciding the size and design of such MRFs as it also provides an indication of the cost of such investments.

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Abbreviations

MRF – materials recovery facility
HDPE – high-density polyethylene
O&M – operation and maintenance
PET – polyethylene terephthalate
WACS – waste characterization study
SBMA – Subic Bay Metropolitan Authority

Currency Equivalents

(As of 17 October 2012)

Currency Unit – peso (P)
P1.00 = $0.0242
$1.00 = P41.278

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Definition of Key Terms

a) **Biodegradables** – organic materials which include food wastes and paper that can be broken down by microorganisms into simpler, more stable compounds such as carbon dioxide and water. This property allows these materials to be transformed into compost.

b) **End-of-pipe waste characterization** – process of determining waste composition at the end of waste collection, which is usually conducted at dumpsites or sanitary landfills. The results provide data on the amount and quality of recyclables that can be processed and recovered at materials recovery facilities (MRFs).

c) **Manual separation** – separation of recyclable or biodegradable components of waste by hand sorting.

d) **Mechanical separation** – separation of recyclable or biodegradable components of waste through the use of mechanical equipment such as trommels, screens, and separators.

e) **Materials recovery facility** – a facility where recyclable municipal solid waste is processed and separated using manual and/or mechanical methods. The recovered materials may include paper, glass, plastics, and metals, which are baled, temporarily stored, and eventually sold to recycling or manufacturing firms. The remaining residual wastes are then disposed of into a sanitary landfill. MRFs can process either source-separated recyclables or mixed wastes, in which case the biodegradable components can be processed into compost in another facility.

f) **Mass balance** – an application of the conservation of mass in solid waste management, where the quantity of inputs and outputs of an MRF are estimated to guide planning and operation.

g) **Municipal solid waste** – waste generated by residences, institutions, and commercial and business establishments. This includes paper, food items, yard waste, tin cans, bottles, plastics but not industrial and hazardous waste.

h) **Polyethylene terephthalate (PET)** – a plastic material commonly used to make bottles for food, beverages, pharmaceutical, and other liquid products. The standard plastic code for PET is #1.

i) **Polypropylene** – a plastic material that is used to manufacture chairs, dairy tubs, bags, ropes, carpets, and mats. The standard plastic code for polypropylene is #5.

j) **Recyclables** – materials that have served their original purpose but still have useful physical or chemical properties that can be reused or reprocessed as materials for new products. Typical examples include paper, glass, metals, cardboard, and plastic containers.
k) **Residuals** – waste materials with no commercial value that are left out after the segregation process in an MRF. These include broken glass, textile, rubber, ceramics, worn-out plastics, concrete fragments, and soil, among others.

l) **Source separation** – the segregation of biodegradable and recyclable materials from the waste stream at the point of generation before they are collected to facilitate reuse, recycling, and composting.

m) **Waste characterization study (WACS)** – a process whereby the composition by weight of municipal solid waste is determined in terms of the following components: plastic, paper, glass, metal, textile, discarded food materials, garden trimmings, and other materials. It also establishes the rate of waste generation of a particular community, town, or city in terms of kilograms per day per person.

n) **Waste diversion** – process of diverting waste from a sanitary landfill or disposal site through segregation and recovery of recyclable materials, composting, and treatment. The diverted amount is measured by weight, usually in tons or kilograms.
Introduction

Materials recovery facilities (MRFs) were established in different barangays (community or village) of the Philippines to recover recyclable materials from municipal solid waste. Required under the Ecological Solid Waste Management Act of 2001, these facilities were constructed out of local funds, grants, and loans but have attained only a limited degree of success. This condition is attributed to the lack of, or incomplete, understanding of the basic aspects of MRFs in terms of design, construction, and operations, as well as the parameters for a successful and sustained operation.

This tool kit provides a simple and practical document that serves as a basic reference for local government units and the private sector in establishing and operating an MRF. It also serves as an aid for financing institutions in evaluating loan or grant applications for the said solid waste management facility. Prepared using mostly Philippine data, the document can be applicable to developing countries with similar socioeconomic and waste management conditions.


This tool kit does not provide the details required in the planning, design, construction, and operation of an MRF. It will not include discussions on the processing of biodegradable materials into compost. The financial aspect was simplified to provide comparative indications of the profitability or non-viability of the proposed waste processing facility.
Materials Recovery Facilities and Solid Waste Management Systems

The basic solid waste management system is made up of five components: waste generation, storage, collection, processing and treatment, and disposal.

The waste generators include residences, institutions, markets, and business and commercial establishments. Additional waste is also contributed by street sweepings. The generation rate is proportional to the level of economic activity and development. Rural areas and developing countries generate less waste than urban areas and developed countries. The latter sites generate more potentially recyclable materials and are usually targeted in the operation of MRFs.

Waste storage is temporary and makes use of various containers of different capacities, such as plastic bags; cans; sacks; native baskets; and bins made from steel, concrete, and high-density polyethylene (HDPE).

Depending on the waste amount, collection is done by a single unit or a fleet of dump or compactor trucks at frequencies of once or several times per week. In general, mixed waste is collected by government-owned trucks in small towns and cities, and by contractors in large urban areas.

Composting plants, MRFs, and treatment facilities are found within the processing and treatment component.

Disposal in developing countries is done mainly in open dumps and in some sanitary landfills.

Realistically, actual management systems also include recovery of recyclables at source for reuse and sale to junk shops; burial, open dumping, burning, and littering of uncollected waste; unsanitary picking at waste bins, collection vehicles, and open dumps; and sale and resale of recovered recyclables at junk shops (Figure 1). This system is implemented in varying scales and efficiency in different towns, cities, and districts.

The extent of recyclable materials recovered at MRFs and sold to junk shops or trading centers is not known. Likewise, data on the amount of recyclables sold to and traded by junk shops are not available, although comparatively, these are bigger than those coming from MRFs.
Figure 1  Components of a Solid Waste Management System

1. Waste Generation
   - Households
   - Markets
   - Commercial establishments
   - Offices and institutions
   - Street sweepings

2. Temporary Storage
   - Unsanitary picking at bins and other waste containers

3. Mixed Waste Collection
   - Unsanitary picking at waste collection vehicles

4. MRF, Composting Plant, Treatment Facilities
   - Uncollected Waste
     - Litter, open dumping, burning, burial

5. Disposal to open dump/SLF
   - Unsanitary picking at open dump

MRF = materials recovery facility, SLF = sanitary landfill.
Types of Materials Recovery Facilities

MRFs can be classified in terms of inputs, capacity, and nature of waste processing (Table 1).

<table>
<thead>
<tr>
<th>Type</th>
<th>Inputs</th>
<th>Processing</th>
</tr>
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<tbody>
<tr>
<td>Clean</td>
<td>Clean or source separated</td>
<td>Manual/Mechanized</td>
</tr>
<tr>
<td>Dirty</td>
<td>Dirty or non-source separated</td>
<td>Manual/Mechanized</td>
</tr>
</tbody>
</table>


Clean MRFs are usually established in communities or cities where a high degree of segregation at source and separate collection of biodegradables and nonbiodegradables are implemented. The products of clean and dirty MRFs are essentially the same, although paper products recovered from the former are likely to be contaminated. Dirty MRFs are more common and could have a composting component to process the segregated biodegradable component. Issues of leachate generation and emission of foul odor are common in the operation of dirty MRFs.

MRF capacities may range from less than 1 ton per day (tpd) in small barangays to 200 tpd in big cities. In this tool kit, small MRFs refer to facilities that process 15 tons or less per day.1 Operational MRFs in the Philippines can generally process from 1 ton to 5 tons of mixed waste per day by manual separation, which can be aided by conveyors (semi-automated processing). Large-capacity facilities are mechanized and can process more than 15 tpd. The estimated rate for manual to semi-automated processing of source-segregated recyclables could vary from 0.3 tons per hour to 0.45 tons per hour per 2–3 sorters, while a fully automated system can process about 3 tons of mixed waste per hour per operational line (Dubanowitz 2000). Conservatively, processing time for mixed waste in an MRF will be twice that spent for source-segregated recyclables. The MRF subprojects for Cambodia, the Lao People’s Democratic Republic (Lao PDR), and Viet Nam estimated that a picker can segregate recyclables from 1 ton of dry, source-segregated, nonbiodegradable waste in 8 hours.

Manual operation is time-consuming and labor-intensive when applied to large amounts of waste materials, particularly of the mixed type. Most long-term financial analyses show that predominantly mechanized or automated waste processing is more cost-effective than manual sorting at large

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1 In the Philippines, facilities with capacities of less than or equal to 15 tpd are not required to secure an environmental permit.

2 The assumed waste density is 300 kilograms/cubic meter (kg/m³). Accordingly, 0.3 tons and 0.45 tons translate to 1 m³ and 1.5 m³, respectively, of mixed waste.
scales of operation because of high labor cost, notwithstanding the high initial cost of equipment. Such analyses though are made in MRFs established in developed countries where dry, source-segregated, nonbiodegradable waste materials (which have not been picked at bins and collection trucks) are processed.
Materials Recovery Facility
Siting Criteria

Accessibility, land use, and geology need to be considered when siting MRFs.

a) MRFs need to be located close to existing roads, but traffic resulting from the movement of waste collection trucks should be considered. These facilities must be near or within urban areas that generate the inputs to be processed for recyclables.

b) A minimum buffer zone of 100 meters is used for sensitive receptors such as schools, hospitals, parks, and residential areas. If the area is zoned, MRFs are preferably located in an industrial zone or close to a sanitary landfill to facilitate efficient movement of waste from various generators and disposal of residual or biodegradable materials.

c) MRFs should be sited in flat or gently sloping, stable areas to reduce excavation cost and avoid problems of slope stability.\(^3\) Flood-prone areas should be avoided.

\(^3\) Slope stability is considered when MRFs are within the compound of sanitary landfills that are sited in sloping to hilly terrain.
Parameters Considered in Planning, Design, and Operation of Materials Recovery Facilities

Nature of Waste Generators

The nature of waste generators should be considered when planning MRFs. Residential areas discard newspaper, mixed paper, plastics, clothing, food packaging, cans and bottles, food scraps, and yard trimmings. Commercial and institutional establishments dispose of cardboard, office paper and mixed paper, newspaper, packaging materials, and food waste. Schools and offices produce predominantly paper waste. Industrial facilities produce more packaging materials than most waste generators. Hotel and restaurants generate a large amount of plastic bottles and tin cans.

Urban areas tend to generate more paper and plastic materials than rural areas. Low- to medium-income residential areas segregate more recyclable materials than high-income residences.

Waste Composition

Local government units submit results of waste characterization studies (WACS) to the National Solid Waste Management Commission. The data are usually presented as tables and pie diagrams similar to Figure 2, which show relative percentages of different waste components. Recyclable...
materials determined from WACS conducted at source range from 40% to 50% of the generated waste. It is, however, misleading to think that this is similar to the amount of salable recyclables gained in MRFs, considering that materials segregated may be contaminated or not seggregable (i.e., too small for hand sorting and/or not identifiable by the mechanical sorting equipment). Therefore, an end-of-pipe WACS must be conducted prior to acquiring equipment to process the recyclables. Where possible, the WACS should determine the amount or proportion of recyclables that is segregated at the collection trucks. A mass balance of the waste must be prepared to determine the amount of each material the facility must process and store, as well as the quantity of residuals that must be disposed of or subjected to further processing at the expected year or period of the start of MRF operations.

Waste Generation

Waste generation rates indicate how much waste can be generated by a given city or municipality, which can potentially serve as the source of recyclables for MRFs. In the Philippines, the estimated per capita waste generation rates observed in rural and urban areas are 0.3 kilograms per day (kg/day) and 0.7 kg/day, respectively. Table 2 shows the waste generation rates of key Asian cities, which could serve as a guide for the potential waste that can be generated by the city which intends to build and operate an MRF. The MRF proponent should take note that generation rates increase with economic activity and should be updated by conducting WACS for a more updated and realistic estimate of potential recyclable waste.

<table>
<thead>
<tr>
<th>City</th>
<th>Per Capita Waste Generation</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phnom Penh, Cambodia</td>
<td>0.740</td>
<td>2005a</td>
</tr>
<tr>
<td>Vientiane, Lao PDR</td>
<td>0.686</td>
<td>2011b</td>
</tr>
<tr>
<td>Dhaka, Bangladesh</td>
<td>0.340</td>
<td>2004c</td>
</tr>
<tr>
<td>Ho Chi Minh City, Viet Nam</td>
<td>0.81</td>
<td>2009d</td>
</tr>
<tr>
<td>Kolkata, India</td>
<td>0.605</td>
<td>2011e</td>
</tr>
<tr>
<td>Jakarta, Indonesia</td>
<td>0.713</td>
<td>2008f</td>
</tr>
<tr>
<td>Beijing, People’s Republic of China</td>
<td>0.85</td>
<td>2006g</td>
</tr>
<tr>
<td>Kuala Lumpur</td>
<td>1.72</td>
<td>2011h</td>
</tr>
<tr>
<td>Bangkok, Thailand</td>
<td>0.98</td>
<td>2008i</td>
</tr>
<tr>
<td>Singapore</td>
<td>3.65</td>
<td>2011j</td>
</tr>
</tbody>
</table>

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Waste Collection

Collection is usually presented as a percentage of total waste generation. It immediately gives an indication of the amount of waste that can be processed in an MRF. Waste collection rates and frequencies are higher in cities than in rural areas. Waste collection coverage in the Philippines varies from about 30% in rural areas to as much as 70% in highly urbanized cities.

Segregated waste collection is implemented only in selected areas where solid waste management has attained a high level of compliance. The nature of collected waste can affect the design and operation of an MRF. Collected mixed waste is fed into dirty MRFs, while segregated recyclable materials are sent to clean processing facilities.

Waste Diversion

Solid waste diversion in developing countries takes place at households, commercial establishments, waste bins, and in collection trucks. Most of the materials eventually end up in local junk shops, while some are reused. By the time the collection trucks reach the disposal site or waste processing facility, the municipal solid waste has already undergone at least two levels of segregation: (i) directly at the household level and (ii) from receptacles and/or during waste collection. These activities greatly affect the quantity and quality of recyclable wastes left at the end of the collection system to be processed at MRFs. The amount and type of recyclables left should be determined through a WACS as the data will influence the viability of an MRF.

Market Requirements

Recyclable materials recovered through an MRF must satisfy basic market specifications to facilitate sale at optimum prices (Table 3). These requirements highlight the advantage of processing source-segregated recyclables over mixed waste and the need to provide the basic utilities (water and power) and equipment, such as balers, to help attain them. Recyclables that do not satisfy these requirements command lower prices.

<table>
<thead>
<tr>
<th>Material</th>
<th>Specifications</th>
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<tr>
<td>Tin can</td>
<td>Flattened, baled, dry, clean</td>
</tr>
<tr>
<td>Metal</td>
<td>Flattened, without label, clean</td>
</tr>
<tr>
<td>Plastic</td>
<td>Baled, separated by color or type, with or without caps</td>
</tr>
<tr>
<td>Paper</td>
<td>Separated by grade or type, dry, baled, clean</td>
</tr>
<tr>
<td>Glass</td>
<td>Separated by color, dry</td>
</tr>
</tbody>
</table>

Price of Recyclables

The prices of key recyclable materials, such as plastics, metal, paper, and glass, are affected by the global economy and demand from the manufacturing sector. The prices cited in Table 4 reflect those that prevail at the Materials Recovery Facility of the Central Office of the Environmental Management Bureau, Philippines. Copper wire, stainless steel, and aluminum cans commanded the highest prices. Common recyclables generated at households, commercial establishments, and institutions (e.g., polyethylene terephthalate [PET] bottles, white paper, and newspaper) also sell at good prices.

<table>
<thead>
<tr>
<th>Recyclable Items</th>
<th>Junk Shop Price</th>
<th>Factory Price (estimated)</th>
</tr>
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<tbody>
<tr>
<td>White paper (used)</td>
<td>8,000</td>
<td>9,000</td>
</tr>
<tr>
<td>Cartons (corrugated, brown)</td>
<td>2,500</td>
<td>3,000</td>
</tr>
<tr>
<td>Newspaper</td>
<td>4,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Assorted papers/Mixed waste paper</td>
<td>1,500</td>
<td>2,000</td>
</tr>
<tr>
<td>PET bottles – clean without caps and labels</td>
<td>16,000</td>
<td>20,000</td>
</tr>
<tr>
<td>PET bottles – unclean without caps and labels</td>
<td>12,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Aluminum cans</td>
<td>50,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Plastic (HDPE)</td>
<td>10,000</td>
<td>13,000</td>
</tr>
<tr>
<td>Copper wire – class A (red color)</td>
<td>300,000</td>
<td>350,000</td>
</tr>
<tr>
<td>Copper wire – class B (reddish yellow color)</td>
<td>250,000</td>
<td>300,000</td>
</tr>
<tr>
<td>Copper wire – class C (yellow in thin strands)</td>
<td>150,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Steel – iron alloys</td>
<td>9,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Steel – stainless</td>
<td>60,000</td>
<td>70,000</td>
</tr>
<tr>
<td>Steel – galvanized steel sheet</td>
<td>7,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Tin can</td>
<td>3,000</td>
<td>5,000</td>
</tr>
</tbody>
</table>


Materials Recovery Facility Development and Operation and Maintenance Costs

The establishment of an MRF will entail cost in the following items:

1) Feasibility study
2) Environmental permitting
3) Lot acquisition
4) Site development
5) Facility construction
6) Equipment acquisition
7) Training of operations personnel

The cost of each item, as well as permit requirements, varies in different countries. In the Philippines,
facilities with inputs exceeding 15 tpd are required to apply for an Environmental Clearance Certificate. MRFs with less waste inputs need only to secure a Certificate of Non-Coverage.

The price of the lot varies, depending on the location and desired size of the facility. In most cases, the lot for the MRF has already been acquired at the time the proposal for a loan is submitted.

An amount equivalent to 2%–3% of the estimated project cost is usually allotted for the conduct of feasibility studies and 5%–6% for site investigation and design.

Site development costs also vary and will depend on particular features such as terrain, land use, vegetation, and accessibility. Low areas will need backfilling, while rolling terrain would require leveling and earthmoving to attain the desired flat level. If the site is occupied by other structures such as buildings or houses, then additional costs would be incurred for their removal. The removal of vegetation and trees will entail cost and so is the acquisition of permits from local or national agencies.

As a general rule, MRF building construction in the Philippines may vary from P12,000 to P25,000 per square meter, depending on the design of the facility and the type of materials to be used.

Cost for the construction of fencing may vary, depending on the type of materials to be used and extent of the area to be enclosed. MRFs with processing capacities greater than 10 tpd are usually fenced.

The installation of basic utilities, such as power, water, and communications, should be included in the cost estimate for the MRF. Likewise, a budget should be provided for the training of personnel who will manage the facility and operate and maintain the equipment.

In the Philippines, manual MRFs that process less than 2 tons of mixed waste per day currently cost anywhere from P0.5 million to P1.5 million. Semi-automated facilities that can process 10–15 tons of source-segregated waste per day would require an investment of P20 million–P25 million exclusive of the acquisition of the lot for the facility (ADB 2010). Results of the feasibility studies of seven MRFs in Cambodia, the Lao PDR, and Viet Nam indicated direct costs* ranging from $0.4 million to $0.5 million (from P17 million to P20 million) for fully manual MRFs, which are planned to process 8–12 tons of dry, source-segregated, nonbiodegradable waste. Mechanized facilities with two sorting lines that can handle 80–100 tons of recyclable waste can indicatively cost from P120 million to P140 million (Table 5).

The cost for operation and maintenance (O&M) is key to the viability of MRFs. As a rule, O&M costs should not exceed the revenue from the sale of recyclables.

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* Based on 2012 prices.
The major O&M cost components include the following:

1) Salaries for operation, maintenance, administration, and security
2) Electricity and water bills
3) Fuel and oil consumption
4) Equipment and facility maintenance
5) Supplies
6) Residual/biodegradable waste disposal
7) Facility depreciation

Manually operated MRFs usually entail the deployment of a supervisor and a team of utility workers whose number depends on the amount of waste input. Aside from sorting, these workers are tasked with weighing and storing recyclables and assisting in the loading of the residuals and biodegradables into collection vehicles for disposal or delivery to composting plants. Waste sorters or pickers in Cambodia and the Lao PDR are paid based on the amount of recyclables recovered (ADB 2010).

Semi-automated and fully mechanized sorting facilities entail lower cost for labor but require higher skills for O&M of equipment, facility, and utilities.

Separate personnel are assigned for O&M of equipment used for sorting, weighing, and recording, and for security and facility management.

As a general rule, the cost of O&M is placed at 5%–10% of the investment for an MRF.

---

### Table 5  Indicative Estimates of Investment and Operation and Maintenance Cost of Materials Recovery Facilities (P Million)\(^a\)

<table>
<thead>
<tr>
<th>MRF Capacity Range (tpd)</th>
<th>Type</th>
<th>Investment</th>
<th>Civil Works(^b)</th>
<th>Equipment</th>
<th>Indirect Cost(^c)</th>
<th>O&amp;M</th>
<th>Basic Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤2</td>
<td>Manual</td>
<td>1.13</td>
<td>1</td>
<td>0.03</td>
<td>0.1</td>
<td>0.1</td>
<td>Sorting table, weighing scale</td>
</tr>
<tr>
<td>10–15</td>
<td>Semi-automated</td>
<td>24.8(^d)</td>
<td>20.5</td>
<td>2.5</td>
<td>1.8</td>
<td>2.5</td>
<td>Single-line conveyor, sorting table, small payloader, small baler, weighing scales (2)</td>
</tr>
<tr>
<td>40–50</td>
<td>Automated</td>
<td>68.5(^e)</td>
<td>33</td>
<td>24</td>
<td>11.7</td>
<td>7</td>
<td>1 sorting line with conveyor system, hopper, trommel, magnetic separator; 2 payloaders, 2 forklifts, 2 balers, and 2 weighing scales</td>
</tr>
<tr>
<td>80–100</td>
<td>Automated</td>
<td>121.8(^f)</td>
<td>52.3</td>
<td>57</td>
<td>12.5</td>
<td>12</td>
<td>2 sorting lines with conveyor system, 2 hoppers, 2 trommels, 2 magnetic separators, 2 payloaders, 2 forklifts, 1 bottle perforator, 4 balers, 1 weigh bridge, and 4 weighing scales</td>
</tr>
</tbody>
</table>

MRF = materials recovery facility, O&M = operations and maintenance, tpd = tons per day.

\(^a\) Indicated cost does not include lot acquisition as this varies depending on the location, accessibility, and nearby land use.

\(^b\) Includes site development, access road, fence and building construction, and utilities.

\(^c\) Includes permitting, design, site investigation, training of personnel, and contingencies.

\(^d\) 2010 cost at a consumer price index of 127.97.

\(^e\) 2005 cost at a consumer price index of 100.

\(^f\) 2006 cost at a consumer price index of 106.24.
Design of a Materials Recovery Facility

A typical MRF is sited within a warehouse-type building with concrete flooring and enclosed by a perimeter fence for security. It should have the following components: (i) receiving or tipping area, (ii) sorting/processing area, (iii) storage area for recyclables, (iv) residuals storage area, (v) equipment area, (vi) space for an office, and (vii) loading area for residuals and processed recyclables. It should also be provided with the basic connections for water and electricity and adequate space for the entry and exit of waste trucks. Provisions for washing and a septic tank must be included. The warehouse design will minimize the placement of columns that could interfere with the efficient movement of materials and equipment, and facilitate the installation of higher ceilings. Receiving areas should have the capacity to receive at least 2 days’ worth of the MRF’s processing capacity (Kessler Consulting 2009) in anticipation of equipment breakdown and to provide materials for the second-shift operation where required.

Diagrams of a manual MRF and a fully mechanized facility are shown in Figures 3 and 4, respectively.

Manually operated MRFs with capacities of less than 2 tpd usually have roofed floor areas of at least 50 square meters (m²), which contain only the receiving, processing, and storage areas. Semi-automated to fully mechanized facilities would require areas ranging from 150 m² to 1,500 m², excluding parking and buffer zones. The Material Recovery Facility Handbook of the Recycling Marketing Cooperative of Tennessee (2003) suggests a building area not exceeding 1,400 m² for MRFs that process less than 10 tons of recyclable waste per day and about 1,800 m² of floor area for facilities that will handle waste not exceeding 100 tpd.

The basic equipment, even for a manual operation, would include sorting tables, weighing scales, a baler, and payloader. Semi-automated MRFs make use of a conveyor system that could be aided by a loader to facilitate sorting (Table 6). Automated facilities utilize the combination of screens, magnetic separators, air classifiers, and conveyor systems with options for more than one processing line. The choice of equipment will depend on the target capacity and the nature and composition of incoming waste.
Figure 3  Diagram of a Manual Material Recovery Facility

Figure 4  Diagram of an Automated Material Recovery Facility

Source: Authors.
### Table 6  List of Materials Recovery Facility Equipment

<table>
<thead>
<tr>
<th>MRF Equipment</th>
<th>Intended Use</th>
<th>Estimated Unit Cost (₱ in million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighing scale</td>
<td>Weighing of incoming waste and sorted recyclables</td>
<td>0.001–0.005</td>
</tr>
<tr>
<td>Weighbridge</td>
<td>Weighing of large quantities of incoming waste</td>
<td>1.5–3.0</td>
</tr>
<tr>
<td>Sorting table</td>
<td>Manual sorting and segregation of recyclables</td>
<td>0.004–0.015</td>
</tr>
<tr>
<td>Payloader</td>
<td>Loading of incoming waste into conveyor system, sorting tables; loading of baled recyclables into outgoing vehicles; moving of residual or biodegradable waste out of the facility into the adjacent disposal site</td>
<td>1–3</td>
</tr>
<tr>
<td>Conveyor with hopper</td>
<td>Receipt of waste from payloader and movement of waste for segregation</td>
<td>1.0–2.0</td>
</tr>
<tr>
<td>Conveyor system</td>
<td>Mechanized and regulated movement of waste for segregation</td>
<td>1.0–2.5</td>
</tr>
<tr>
<td>Trommel</td>
<td>Segregation of mixed waste or recyclables based on particle size</td>
<td>0.5–5.0</td>
</tr>
<tr>
<td>Magnet separator</td>
<td>Separation of iron-bearing materials</td>
<td>5–7</td>
</tr>
<tr>
<td>Air classifier</td>
<td>Separation of materials such as paper and plastic based on size, shape, and density</td>
<td>5–10</td>
</tr>
<tr>
<td>Bottle perforator</td>
<td>Perforation of plastic bottles prior to compaction to optimize baling</td>
<td>3–5</td>
</tr>
<tr>
<td>Baler</td>
<td>Compaction and binding of recyclables</td>
<td>0.5–2.0</td>
</tr>
<tr>
<td>Forklift</td>
<td>Movement of baled waste within MRF</td>
<td>0.4–1.0</td>
</tr>
</tbody>
</table>

MRF = materials recovery facility.

Materials Recovery Facility Operations

MRF operations start with the registration, inspection, and placement of mixed or segregated waste into the receiving area. Bulky or unusual materials are removed for disposal or sale to recycling facilities, while the rest of the waste is placed on a conveyor for semi-automated or fully automated sorting or on sorting tables for manual sorting.

For mixed waste, biodegradable materials are separated from recyclables and collected for processing into compost in another facility or loaded into trucks for disposal in a sanitary landfill. The separated biodegradables must not be stored within the roofed section of the MRF and must be transferred to a composting plant or disposal facility, preferably within the day. Otherwise, these components can be temporarily placed in a paved section within the MRF compound where they can be easily loaded into waste collection trucks.

For source-segregated waste, valuable recyclables, such as paper and carton, tin cans, metals, plastics (polyethylene terephthalate and polypropylene), and glass, are separated either manually or mechanically.

The recovered recyclables are weighed and temporarily stored in designated bins. When sufficient quantities have been accumulated, tin cans are compacted and baled; plastic bottles are pierced, flattened, and baled; paper is stacked; and glass is broken, then bulked up.

The residual materials are temporarily stored and then disposed of in a sanitary landfill or used as refuse-derived fuel for waste-to-energy plants, where practicable.

Records of the amount of incoming and outgoing waste must be kept for monitoring purposes and for regular validation of the facility mass balance.

Typical MRFs operate 8 hours a day Mondays through Saturdays.

Figure 5 illustrates the general flow in an MRF that accepts either mixed or source-segregated waste.
Figure 5  Materials Recovery Facility Flow Chart

GENERAL MRF FLOW CHART

Incoming Waste (mixed/segregated)
  ↓
Registration
  ↓
Receiving Area
  ↓
Inspection
  ↓
Separation of Biodegradables from Recyclables
  ↓
Manual/Mechanized Sorting
  ▶ Glass
  ▶ Metals
  ▶ Plastics
  ▶ Papers/Cardboards
  ▶ Sale
  ▶ Storage/Baling

Unusual and bulky items (for direct sale or disposal to a landfill)
  ▶ Biodegradables
  ▶ Recyclables

Composting in a separate facility
  or
Disposal to a landfill

MRF = materials recovery facility.
Recommendations and Considerations for Feasible Facilities

The key parameter to be considered for the feasible operation of an MRF is the amount of recyclables that can be recovered from either the source-segregated or mixed waste. This is controlled by the extent of waste segregation and diversion that take place at the source, waste bins, and collection trucks. Table 7 shows the basic data requirements and the corresponding assessment to be considered in setting up an MRF. The following should be accomplished for a reasonable estimate of the extent of waste diversion:

1) Conduct an assessment of the solid waste management condition at the target project area. Low-income residential areas have a high degree of segregation of recyclable materials. Medium- to high-income groups have a comparatively lower level of waste diversion. Indicators of the high degree of waste diversion include the large number and size of junk shops and the presence of waste pickers near bins.

2) Undertake an end-of-pipe waste characterization for target sectors such as residential areas and commercial and institutional establishments. The results will provide indications of the potential recyclable materials that can be realistically recovered from the collected waste and those segregated by the waste collection crew.

3) Prepare a mass balance based on the results of the WACS and assessment of the prevailing waste management condition. Figures 6 and 7, respectively, show typical waste diversion estimates and mass balance of waste from an economic zone in the Philippines. In addition to the indicated figures, the percentages of the recyclables should be presented, e.g., 3.1% plastic bottles, 6.2% paper and carton, 2.1% aluminum cans, and 5.3% metal.
Figure 6  Waste Diversion Estimate

1st level segregation at locators, offices, housing units

11.62%  
(4.72 tpd)

2nd level segregation at waste bins

2nd level segregation at waste bins

3rd level segregation at waste collection trucks

Food waste diversion at big hotels and restaurants

Collection of scrap by private haulers

16.70%  
(6.78 tpd)

32.18%  
(13.06 tpd)

15.48%  
(6.78 tpd)

4.21%  
(1.71 tpd)

tpd = tons per day.

Figure 7  Typical Mass Balance

Waste Generation 40.6 tpd

- Waste Diversion 13.06 tpd

= Waste Disposal 27.54 tpd

SBMA Trimmings ~ 15 tpd

Recyclables; Scrap

Food Waste

Junk Shops

Piggeries

SBMA Dumpsite

Residuals; Biodegradables; Other Inorganic Waste; Hazardous Waste

Olongapo Dumpsite

SBMA = Subic Bay Metropolitan Authority, tpd = tons per day.
Table 7  General Materials Recovery Facility Evaluation Guide

<table>
<thead>
<tr>
<th>Basic Data Requirements</th>
<th>Typical Assessment and Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste generators/sources</td>
<td>More recyclables than biodegradables in urban areas  \nMore biodegradables than recyclables in rural areas  \nAt least two levels of segregation in low-income areas; less recyclables for MRF  \nCommercial and industrial sectors and high-income areas likely to have lower level of waste diversion and more recyclables for MRFs  \nProliferation of junk shops and roaming waste pickers not favorable for establishment of MRFs; buyback schemes need to be employed to acquire recyclables from informal sector.</td>
</tr>
<tr>
<td>Current population</td>
<td>Multiply with per capita waste generation to get daily waste generation; larger population translates to more waste.</td>
</tr>
<tr>
<td>Per capita waste generation (kg/day)</td>
<td>Updated rate preferred; assume 2% annual increase; multiply with current population to get daily waste generation.</td>
</tr>
<tr>
<td>Waste generation (tpd)</td>
<td>Indicates gross potential MRF input</td>
</tr>
<tr>
<td>Waste collection (tpd)</td>
<td>Serves as more realistic estimate of MRF waste input than waste generation; multiply waste collection percentage with waste generation to get potential MRF input; mixed waste collection could lead to development of dirty MRFs.</td>
</tr>
<tr>
<td>Results of WACS</td>
<td>Confirm if WACS is current and was done at source or at disposal site; end-of-pipe WACS gives more realistic estimate of potential recyclables; multiply percentage of different recyclables with daily waste collection to get estimate of recoverable materials for MRF; deduct amount of recyclables from waste input to get an estimate of the residual materials.</td>
</tr>
<tr>
<td>Price of recyclables</td>
<td>Multiply unit price with estimate of daily recyclables to get indicative MRF revenues; if recyclables will be acquired using buyback scheme, deduct the buying price from the selling price to get the margin; multiply this margin by the amount of purchased recyclables to get the indicative revenue from the buyback scheme.</td>
</tr>
<tr>
<td>MRF operation and maintenance cost</td>
<td>Compare O&amp;M cost with estimated revenues to get indication of MRF viability; O&amp;M cost would vary by locality but should include labor, materials, utilities (power, water, communication), and oil and fuel (for moving equipment, facility cleaning, and maintenance); this comparison will determine if the MRF can support itself and make a profit, or if a subsidy will be needed.</td>
</tr>
<tr>
<td>Recovery of investment cost</td>
<td>If MRF revenues exceed O&amp;M cost, compare profit with amount of loan and amortization rate at the prevailing interest rate to establish if investment can be recovered within the period required by the creditor.</td>
</tr>
</tbody>
</table>

kg/day = kilograms per day, MRF = materials recovery facility, O&M = operation and maintenance, tpd = tons per day, WACS = waste characterization study.

Source: Authors.
MRF operators should also enter into collection contracts with industrial and commercial establishments to gain additional sources of recyclables to complement those gathered from typical municipal solid waste, which have undergone at least two levels of segregation. They can also adopt buyback schemes in coordination with the collection contractor where the segregated recyclables at households are purchased during the collection of waste schedule and brought to the MRF for further segregation instead of being sold to junk shops.

At the feasibility level and during operation, MRF investors or operators should compare potential or actual revenues with projected and actual O&M cost and capital investments. This can be done using a simplified financial spreadsheet (as shown in Table 8). The analysis assumed constant prices and input to facilitate conservative calculations. In actual practice, a progressive increase in generation, collection, and anticipated variation in diversion should be indicated in the feasibility studies and used in the analysis.

### Table 8  Sample Financial Analysis of a Materials Recovery Facility

<table>
<thead>
<tr>
<th>Population</th>
<th>100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kg/capita</td>
<td>0.6</td>
</tr>
<tr>
<td>Waste generated</td>
<td>60 tons</td>
</tr>
<tr>
<td>Collection efficiency</td>
<td>70% fraction of waste collected</td>
</tr>
<tr>
<td>Waste collected</td>
<td>42 tons Recovery 50% Fraction</td>
</tr>
<tr>
<td>Waste Components</td>
<td>tons Recycled Price P/Ton Revenue P</td>
</tr>
<tr>
<td>Paper and carton</td>
<td>6.2% 2.604 1.302 3,000 3,906</td>
</tr>
<tr>
<td>Aluminum can</td>
<td>2.1% 0.882 0.441 60,000 26,460</td>
</tr>
<tr>
<td>Metals</td>
<td>5.3% 2.226 1.113 5,000 5,565</td>
</tr>
<tr>
<td>Plastic bottle</td>
<td>3.1% 1.302 0.651 20,000 13,020 P Million P Million</td>
</tr>
<tr>
<td>Food waste</td>
<td>32.7% 13.734 48,951 17.867 7 10.867</td>
</tr>
<tr>
<td>Other organics</td>
<td>21.4% 8.988 Total/day Sale/year O&amp;M Net revenue</td>
</tr>
<tr>
<td>Other inorganics</td>
<td>28.9% 12.138</td>
</tr>
<tr>
<td>Special waste</td>
<td>0.3% 0.126</td>
</tr>
<tr>
<td>Total</td>
<td>100.0% 42</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Investment</th>
<th>Equity</th>
<th>Debt</th>
<th>Interest</th>
<th>Income</th>
<th>Dividend</th>
<th>Repayment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 0</td>
<td>68.5</td>
<td>30%</td>
<td>70%</td>
<td>8%</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>Year 1</td>
<td>64.551</td>
<td>20.550</td>
<td>47.950</td>
<td>3.836</td>
<td>7.031</td>
<td>3.083</td>
</tr>
<tr>
<td>Year 2</td>
<td>60.287</td>
<td>20.550</td>
<td>44.001</td>
<td>3.520</td>
<td>7.347</td>
<td>3.083</td>
</tr>
<tr>
<td>Year 4</td>
<td>50.707</td>
<td>20.550</td>
<td>35.131</td>
<td>2.810</td>
<td>8.057</td>
<td>3.083</td>
</tr>
<tr>
<td>Year 5</td>
<td>45.335</td>
<td>20.550</td>
<td>30.157</td>
<td>2.413</td>
<td>8.455</td>
<td>3.083</td>
</tr>
<tr>
<td>Year 6</td>
<td>39.533</td>
<td>20.550</td>
<td>24.785</td>
<td>1.983</td>
<td>8.884</td>
<td>3.083</td>
</tr>
<tr>
<td>Year 7</td>
<td>33.267</td>
<td>20.550</td>
<td>18.983</td>
<td>1.519</td>
<td>9.348</td>
<td>3.083</td>
</tr>
<tr>
<td>Year 9</td>
<td>19.191</td>
<td>20.550</td>
<td>5.950</td>
<td>0.476</td>
<td>10.391</td>
<td>3.083</td>
</tr>
</tbody>
</table>

kg = kilogram, O&M = operation and maintenance.
Calculations at constant prices and constant input.
Source: Authors.
MRFs should be part of an integrated solid waste management system and should not be established as a stand-alone facility (see Figure 1). Feasibility of an MRF can be enhanced if the local government and environmental authorities can progressively enforce waste segregation at source and segregated waste collection. These conditions will contribute to the increase in the quantity and quality of recyclable materials that can be processed in an MRF.
APPENDIX 1
Mass Balance for a Proposed Materials Recovery Facility

<table>
<thead>
<tr>
<th>Step</th>
<th>Proposed MRF</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total amount of generated waste</td>
<td>Per capita waste generation x population</td>
</tr>
<tr>
<td>2</td>
<td>Total amount of collected waste</td>
<td>% collection x generated waste</td>
</tr>
<tr>
<td>3</td>
<td>Waste composition</td>
<td>WACS at source</td>
</tr>
<tr>
<td>4</td>
<td>Waste diversion</td>
<td>Updated WACS (end-of-the-pipe)</td>
</tr>
<tr>
<td></td>
<td>Segregation at source</td>
<td>Subtract 4 from 2</td>
</tr>
<tr>
<td></td>
<td>Segregation from waste bins</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Segregation during collection</td>
<td></td>
</tr>
</tbody>
</table>

Input/MRF Capacity

<table>
<thead>
<tr>
<th>Mixed Recyclables</th>
<th>Mixed Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper/cardboard</td>
<td>Paper/cardboard</td>
</tr>
<tr>
<td>Metal</td>
<td>Metal</td>
</tr>
<tr>
<td>Plastic</td>
<td>Plastic</td>
</tr>
<tr>
<td>Glass</td>
<td>Glass</td>
</tr>
<tr>
<td>Residuals</td>
<td>Residuals</td>
</tr>
<tr>
<td>Biodegradables</td>
<td>Biodegradables</td>
</tr>
</tbody>
</table>

Output

<table>
<thead>
<tr>
<th>Recyclables</th>
<th>Residuals</th>
<th>Biodegradables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total of 5, 6, 7, 8</td>
<td>Based on 9</td>
<td>Based on 10</td>
</tr>
</tbody>
</table>

MRF = materials recovery facility, WACS = waste characterization study, Wt = weight.
Source: Materials Recovery Facility Tool Kit.
### APPENDIX 2

**Computation Guide for a Materials Recovery Facility**

**Waste Source Urban**

<table>
<thead>
<tr>
<th>Calculation Instructions</th>
<th>Results</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b x c) /1000</td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

Usually given, calculations made just to check if cited collection figures are realistic.

<table>
<thead>
<tr>
<th>Calculation Instructions</th>
<th>Results</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(d x e) /100</td>
<td>42</td>
<td>Sum of results is 7.01, which represents the potential amount of recyclables; actual recovery will be lower.</td>
</tr>
</tbody>
</table>

Sum of results will be considered in budgeting for disposal or delivery to a composting facility.

<table>
<thead>
<tr>
<th>Potential Recyclables</th>
<th>Wt. in tons</th>
<th>Assumed % Recovery of Saleable Materials</th>
<th>Saleable Materials</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and carton</td>
<td>2.60</td>
<td>50</td>
<td></td>
<td>Assumed recovery may differ based on actual conditions; wet paper not included in recovery; plastic to include only PET, HDPE, and polypropylene.</td>
</tr>
<tr>
<td>Aluminum can</td>
<td>0.882</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metals</td>
<td>2.226</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic bottle</td>
<td>1.302</td>
<td>50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HDPE = high-density polyethylene, kg = kilogram, PET = polyethylene terephthalate, tpd = tons per day.

Source: Materials Recovery Facility Tool Kit.
APPENDIX 3
Photos of Materials Recovery Facilities

Baled tin cans from a manual MRF
Manual MRF in an urban area

Semi-automated MRF in operation
Semi-automated MRF

MRF = materials recovery facility.
Note: Photos taken by authors from various solid waste management projects.
APPENDIX 4
Photos of Materials Recovery Facilities Equipment

Trommel Screen

Hopper, Screen, Conveyor

Baler

Conveyor

Note: Photos taken by authors from various solid waste management projects.
References


Associated Press. 2007. Cities Will Generate an Estimated 1.8 Million Tons of Garbage per Day by 2025. 15 February.


Materials Recovery Facility Tool Kit

Through the 3R initiative, recycling will become part of local governments’ solid waste management. To some extent, it will formalize parts of waste processing, largely handled by informal sector waste pickers and recyclers. With this publication, the Asian Development Bank aims to support the 3R initiative and encourage developing member countries to initiate investments in materials recovery facilities, which are essential tools for waste recycling under the initiative. This tool kit will be useful in deciding the size and design of such facilities as it also provides an indication of the cost of such investments.

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ADB’s vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region’s many successes, it remains home to two-thirds of the world’s poor: 1.7 billion people who live on less than $2 a day, with 828 million struggling on less than $1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

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