

# Guide to Municipal Solid Waste Management







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# Glossary of Abbreviations

ASP	Aerated Static Pile
BML	Beirut and Mount Lebanon
CDR	Council for Development and Reconstruction
CoM	Council of Ministers
IMFU	Independent Municipal Fund
ISWM	Integrated Solid Waste Management
MoE	Ministry of the Environment
MoIM	Ministry of Interior and Municipalities
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
OMSAR	Office of the Minister of State for Administrative Reform
WtE	Waste to Energy

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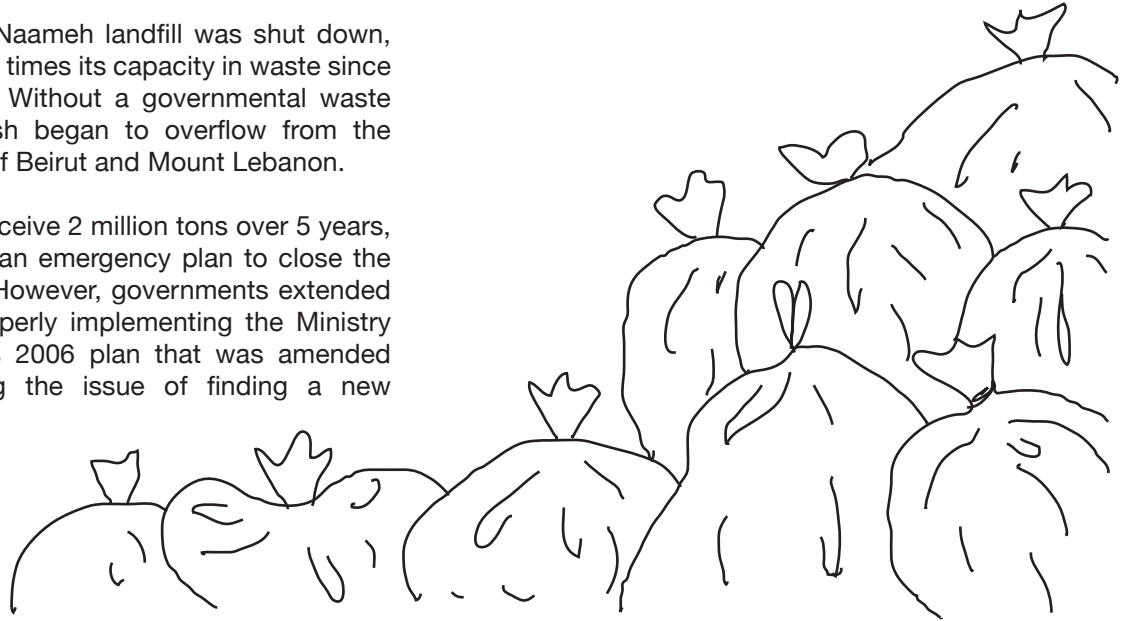
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# Preface

On July 17, 2015, the Naameh landfill was shut down, after accumulating eight times its capacity in waste since being opened in 1998. Without a governmental waste management plan, trash began to overflow from the streets and riverbanks of Beirut and Mount Lebanon.

Originally intended to receive 2 million tons over 5 years, the landfill was part of an emergency plan to close the Burj Hammoud dump. However, governments extended its lifespan without properly implementing the Ministry of Environment (MoE)'s 2006 plan that was amended in 2010 or addressing the issue of finding a new landfilling site.



In response, AUB faculty, students, and staff formed the AUB Solid Waste Management Task Force and tackled the behavioral, technical, health-related, and environmental aspects of the crisis through various activities:

- August 6, 2015: workshop targeting municipality representatives to evaluate their knowledge in regard to sustainable waste management. It revealed these municipalities to be lacking in resources and preparedness, and in need of further guidance.
- September 15, 2015: press release giving an overview of the Task Force's plan or "Roadmap" to efficient and sustainable waste management in rural areas.
- October 17, 2015: closed preliminary conference to share the Roadmap and document individual questions and concerns of attending municipality representatives.
- October 22, 2015: meeting between three Task Force members and Minister of Agriculture, Mr. Akram Chehayeb, to exchange plans and strategies. Both Parties agreed to collaborate on technically advising rural municipalities.
- October 29, 2015: workshop to officially launch the Solid Waste Management Roadmap that included recommendations addressing the issues raised on October 17.

The Task Force's strategy is based on continuously engaging individuals and raising awareness to reduce and sort at source, followed by recycling and composting, and only landfilling refuse that can no longer be treated. It also highly emphasizes the importance of monitoring the technical, environmental, and economic aspects of any waste management initiative.

One of the Task Force's final duties was to compile the content of the workshops into an accessible and detailed manual that will hopefully encourage municipalities to cooperate in order to facilitate the financial and logistic facets of the Roadmap. Its main objectives are to:

- Introduce, elucidate, and highlight the importance of integrated solid waste management.
- Give a brief overview of the current waste situation in Lebanon.
- Present the characteristics and requirements of the available waste management options.
- Introduce the suggested Roadmap, along with a few examples of its application.

It is important to note that although much of the information presented in this manual can be generalized, it mainly targets rural areas, rather than densely populated cities such as Beirut or Tripoli, which produce far more waste and may require different practices. Ultimately, the goal of the manual is to document the work of the AUB Solid Waste Management Task Force in order to allow all concerned parties to make informed decisions regarding their waste management strategies. It may also serve as an informational tool for those who need it.

# I. Introduction

Waste generation is steadily on the rise as a natural result of population increase and economic growth<sup>[1-3]</sup>. The type and quantity of produced waste is related to human activities, lifestyles, and level of environmental awareness<sup>[4]</sup>. Hence, waste management is considered a particularly challenging issue for most countries, especially developing ones, such as Lebanon.

## II. Integrated Solid Waste Management

### a. Definition

Integrated Solid Waste Management (ISWM) is the term applied to all the activities associated with the control of solid waste reduction, generation, sorting, storage, collection, transfer and transport, processing, and disposal, in accordance with the principles of public health, economics, engineering, and conservation, and taking public attitudes into consideration<sup>[5]</sup>.

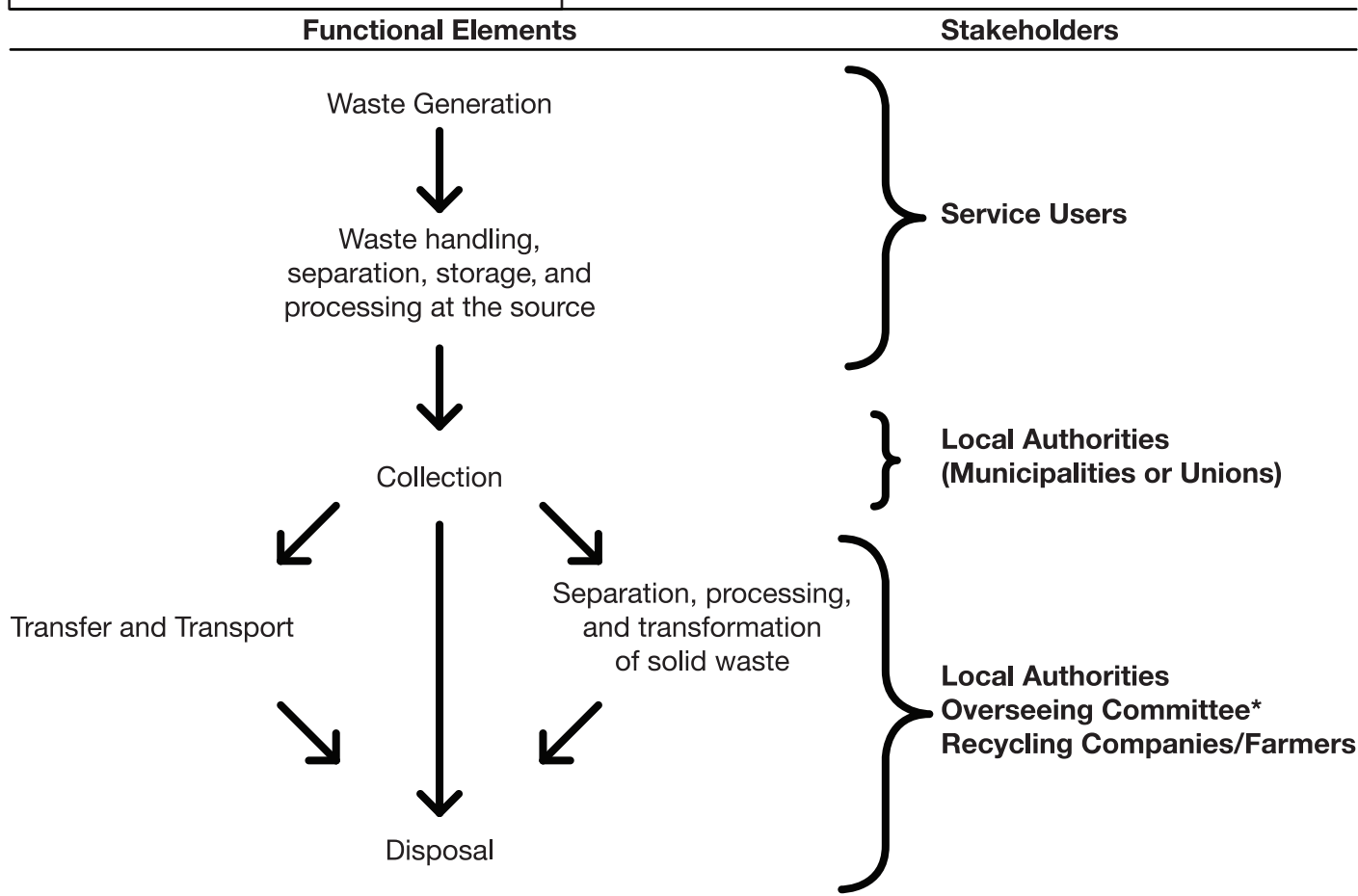
Some facts to consider when developing a solid waste management plan are that there is no single answer to the question of what to do with our waste. In addition, although all communities have the same alternatives, every community or region has its own unique profile in regard to solid waste generation and management.

### b. Components

There are three main components of any ISWM approach, each of which is of crucial importance and must be considered carefully during the planning process<sup>[6-8]</sup> (see fig 1):

- i. *Stakeholders* are the people, organizations, and entities that are, or should be, involved in solid waste management. In Lebanon, they may include government institutions, local authorities (e.g. municipalities or unions of municipalities), recycling companies, non-governmental organizations (NGOs), farmers, commercial institutions, and service users.
- ii. *Elements* are all the technical components of the waste management system. These include generation of waste, sorting, storage, collection, treatment, and disposal.
- iii. *Aspects* are all that needs to be taken into consideration to achieve a sustainable system. They encompass technical issues, environmental health, socio-economic factors, etc.

Fig 1. The Elements and Stakeholders of an ISWM plan



\*The Overseeing Committee should be made up of ministerial representatives, local community members, and waste management specialists.

## III. Waste Management in Lebanon

### a. The Legal Context

There are no legislative texts specifically addressing solid waste management, apart from some small fragments and general guidelines that directly deal with solid waste management in Lebanon<sup>[9]</sup>.

Five key legal instruments address the SWM sector:

- **Decree 8735/1974** on pollution from solid waste and wastewater, which designates SWM a municipal responsibility.
- **Decree 9093/2002**, which provides municipalities with a financial incentive to host a waste management facility by offering a five-fold increase in the budgeted Independent Municipal Fund (IMFU) allocation if the municipality establishes a sanitary landfill or a solid waste processing plant (incinerator/recycling/compost, etc.) within the municipal boundaries, and a 10-fold increase if at least 10 municipalities are allowed to dispose of their waste in the sanitary landfill or use the processing plant.
- **Law 216/1993**, which entrusts the MoE with assessing all sources of solid waste generation.
- **Law 444/2002**, which sets landfill standards and promotes recycling.
- A draft Law on Integrated Solid Waste Management, which was approved by the Council of Ministers (CoM) in 2012 and sent to the parliament for final approval under **Decree 8003**, dated 23/04/2012. It is currently still under discussion at the Parliament.

However, the distribution of roles and responsibilities in the implementation of these laws and decrees is unclear, and enforcement is practically non-existent. The main causes of this poor execution are staffing constraints, lack of training, low fines, and political interferences.

Hence, waste collection is clearly the responsibility of municipalities, under the tutelage of the Ministry of Interior and Municipalities (MoIM), while its treatment and disposal are somewhat vague. Municipal landfills and other treatment facilities have been thus heretofore operated on an *ad hoc* basis, while major landfills have been taken care of by the Council for Development and Reconstruction (CDR).

### b. Facts and Figures

#### i. Pre-Naameh Landfill Closure

In 2010, the waste generation rate varied from around 0.8 kilograms per person per day (kg/p/d) in rural areas to around 1.1 kg/p/d in urban areas, with a national weighted average estimated at about 1.0 kg/p/d and a total of 1.6 million tons of waste produced in Lebanon. This average increased to 1.05 kg/p/d in 2013, with an estimated total of 2 million tons of generated municipal solid waste (MSW), without accounting for the waste generated by Syrian refugees). Nearly 60% of this waste was generated in Beirut and Mount Lebanon (BML)<sup>[10]</sup>.

Almost all of the MSW generated in Lebanon was (and is) collected by public or private haulers. Its majority is organic, (varying between 50-55% in urban and rural areas respectively), while the rest mainly comprises recyclables like paper and cardboard (17-15%), plastics (13-10%), metals (6-5%), glass (4-3%), and others, such as textiles, wood, and miscellanea (12-10%). It is characterized by its high moisture content, often exceeding 60%<sup>[11]</sup>.

A relatively advanced solid waste management system was put in place in Beirut and parts of Mount Lebanon (excluding Jbeil) in 1997. It was based on manual and mechanical sorting, organic material separation, baling and wrapping (Karantina and Amrousieh), composting (Coral), and the landfilling of waste rejects and inerts (Naameh and Bsalim, respectively). However, many challenges hindered its proper operation, especially the limited capacity of available sites, compared with the large quantities of generated waste. As a result, over 85% of the waste was being disposed of at the Naameh sanitary landfill<sup>[12]</sup>.

Outside BML, full or partial waste management systems did exist, and included:

- A sorting plant and sanitary landfill (Zahle)
- A semi-controlled dump (Tripoli)
- A sorting facility and an anaerobic digester (AD) (Saida)
- Small and medium-sized sorting and composting plants, some of which are still being constructed by the Office of the Minister of State for Administrative Reform (OMSAR)
- Small community-based composting plants built in selected villages

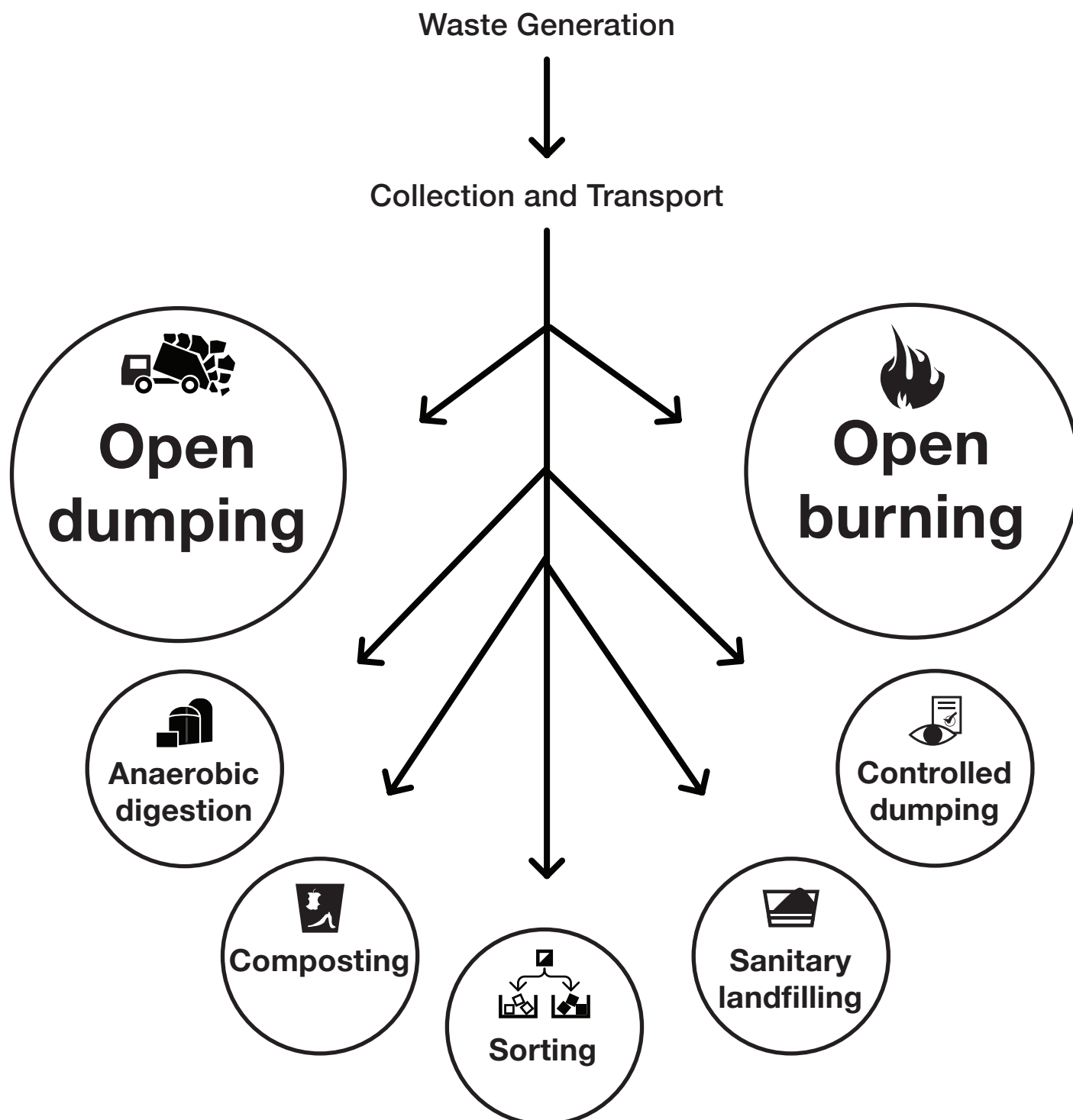
In the majority of other areas, primitive collect-and-dump practices were being employed.



## ii. Post-Naameh Landfill Closure Crisis

A few areas did not experience the consequences of the closure of the Naameh landfill, as they had previously built and were operating sorting plants, composting plants, anaerobic digestors, or other sanitary landfills, while others managed to adapt by introducing controlled dumps for their collected waste. However, the vast majority of municipalities saw their waste openly dumped on streets, under bridges, on riverbanks, in valleys, etc. In many cases, these open dumps were also being burned (see fig 2).

Fig 2. Post-Naameh landfill closure waste management practices



These uncontrolled practices of open dumping and burning carry a myriad of detrimental effects on both the environment and public health, some of which are listed below.

**Table 1. Health Effects of Open Dumping and Open Burning of Municipal Solid Waste**

### OPEN DUMPING

- Adsorption of toxins into soil.
- Production of foul odors and gases.
- Risk of contamination of ground and surface water from leachate generation.
- Release of greenhouse gases.
- Loss of resources that may be recycled or reused for energy recovery.
- Multiplication of rodent populations due to easily available food sources. Wild rodents also carry a variety of microbial and parasitic diseases, some of which are also infectious to human beings and/or pets, and many of which are asymptomatic<sup>[13,14]</sup>.
- Multiplication of other disease vectors, most of all insects, including mosquitoes, fleas, cockroaches, ringworm fungal species, and ticks<sup>[15,16]</sup>.
- Fire hazards and security risks related to direct contact and physical injuries that can lead to anything from allergic reactions and skin diseases, to different cancers<sup>[17,18]</sup>.
- Increase of microbial threats, including<sup>[19-21]</sup>:
  - bacteria (*salmonella*, *E. coli*, cholera, etc.), which spread through food, direct contact with animals, insects, rodents, and water sources. They may also become antibiotic-resistant.
  - fungi that spread through air and contaminated water, and engender respiratory complications like asthma exacerbations and allergic reactive airway diseases.
  - parasites, which spread through polluted water, food, insects, and dogs.
  - viruses (Hepatitis A and E and Rabies), which spread through insects, rats, chickens, bats, and dogs.

### OPEN BURNING

- Production of toxic residues and fumes that may cause respiratory complications.
- Risk of explosion or fire spreading.
- Release of harmful substances like greenhouse gases, asbestos, benzene, acid gases, metals, polycyclic aromatic hydrocarbons, and worst of all, dioxins, into the ambient air.
- Increased incremental risk of cancer in nearby communities, especially due to dioxins that are considered the most toxic substance to humans, as they are carcinogens and hormone disruptors that accumulate in our bodies and are passed on to our children. A study\* following the waste crisis has shown a massive increase in cancer risk in waste burning sites, as the incremental risk of cancer for toddlers in studied areas has increased from 1 toddler per million to 172.

Thus, open dumping and burning carry extremely high risks for contaminating natural resources with harmful and potentially toxic pollutants that increase the likelihood of nearby inhabitants contracting chronic, and potentially lethal, diseases and infections (see table 1). They also engender threats of infectious diseases, respiratory diseases, topical allergies, and physical injuries. Hence, open burning must be completely banned and open dumps must be closed and rehabilitated as soon as possible and monitored in order to avoid catastrophic health repercussions. It is also important for residents of compromised areas to practice rigorous hygiene, including wearing face masks, specifically particulate filtering face-piece respirators such as N95 respirators, which filter out at least 95% of airborne particles<sup>[22]</sup>. Finally, chemical pesticides must be avoided as they may accidentally harm humans or animals, as well as release toxic fumes and particles in case they are sprayed on open dumps that are later burned. If it is necessary to use a pesticide, it is best to use calcium carbonate, as it is the least toxic and carries the least harm to humans<sup>[23]</sup>, or sticky traps and other physical means to eliminate or at least reduce rodent populations.

Finally, it is important to state that the waste crisis is an opportunity to revisit the required reform, begin advocating for administrative decentralization, and promote environmental sustainability. To achieve this, it would be practical to assess the current status of waste management and the feasibility of decentralizing it (human, financial and technical resources) in order to provide municipalities with the necessary structures, partnerships, and funding<sup>[24,25]</sup>.

\*This study was conducted by the Air Quality Research Unit led by Dr. Najat Saliba, composed of AUB, USJ, and NDU labs, and initiated by the Lebanese National Council for Scientific Research (CNRS).

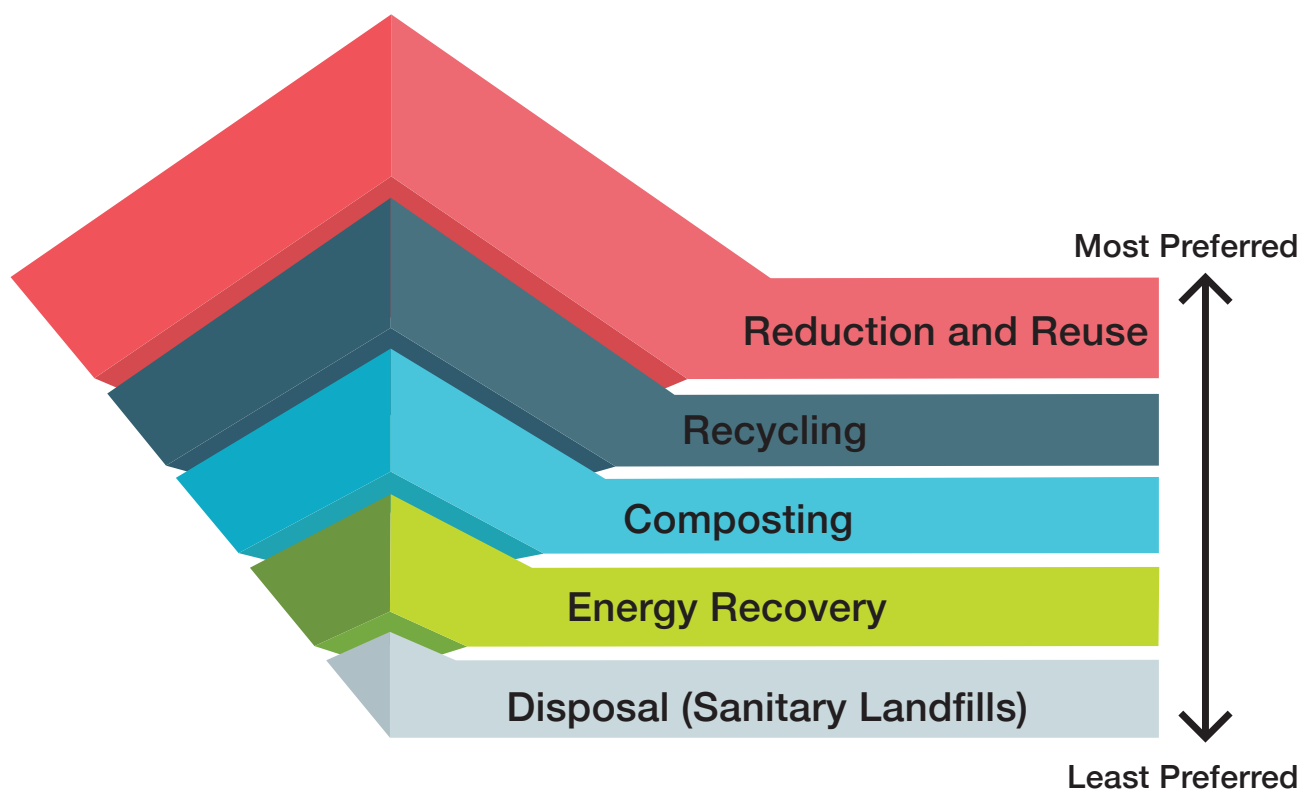
## IV. Overview of Waste Management Components

The health-related and environmental risks of open dumping and burning are clearly unsettling. It is therefore extremely important to begin implementing a sound integrated solid waste management plan to prevent or mediate these risks and achieve a more sustainable waste management strategy. There are currently several alternatives to open dumping that are in practice and that may be integrated into such a plan<sup>[8, 26-28]</sup>. The essential components of this plan are:

- Reduction and Reuse
- Waste Collection
- Recycling
- Composting
- Energy recovery
- Disposal (Sanitary Landfills)

Many concerned authorities have chosen to employ a waste management hierarchy as an operational guideline. This hierarchy promotes source reduction, reuse, recycling, and composting, and relegates the simple disposal of waste<sup>[29, 30]</sup>. However, it only reflects the environmental aspects of ISWM, and does not take other perspectives into consideration, especially the financial/economic one, which is frequently an extremely important limiting factor.

Fig 3. Waste Management Hierarchy



### a. Reduction and Reuse



Waste reduction can be achieved by decreasing consumption, increasing the durability of products and materials, reusing them, and reducing the resources employed to develop and market them, most of all packaging.

The various strategies for waste reduction can be categorized under Education (e.g. raising awareness), Recognition and Voluntary Programs (e.g. community initiatives), Economic Incentives and Disincentives (e.g. monetary rewards for proper sorting at source), and Administrative and Regulatory Actions (e.g. execution of legislations by municipal authorities).

Before deciding which waste reduction strategies and opportunities are most suitable, a comprehensive analysis of their respective environmental impacts and economic feasibilities must be conducted.



### b. Waste Collection

Once the quantity of generated waste is minimized, the next step requires its collection. There are many possibilities for this, the most common of which are summarized below<sup>[31]</sup>:

**Table 2. The Different Waste Collection Options**

Curb Collection	The homeowner is responsible for placing waste bags at a defined curb and at a specified time and day. This would be a feasible option for rural areas, as they are not too highly populated.
Alley Service	The homeowner drops off their waste bags at alley storage containers, which should be a basic part of the layout of their city or residential area.
Setout-Setback Service	Homeowners' waste containers are set out from their property and set back after being emptied of waste (bagged or not) by additional workers in conjunction with the collection crew that loads the collection vehicle.
Setout Service	Essentially the same as the setout-setback service, except that the homeowner is responsible for returning the containers to their storage location.

The choice of collection strategy will depend on what is acceptable by the community and how much residents are willing to pay for such a service. The last two services might not be feasible as a starting point for Lebanon, as they are usually employed abroad for individual houses rather than residential buildings and will be both more costly and difficult to manage.

It is also important to consider the most economic route for collection, in order to reduce unnecessary expenses. This can be achieved through an optimization study or by trial and error. Another thing to consider is the frequency of collection, which can be reduced for rural areas, where the population density is lower and less challenging.

Once collected, the waste is shipped to concerned parties for treatment or disposal.



### c. Recycling

Recycling is being strongly encouraged in most developed countries. From an environmental perspective, it is an extremely favorable option for Municipal Solid Waste<sup>[32, 33]</sup>, mainly due to its relatively low negative environmental impact, its role in preserving raw materials by reusing discarded ones, as well as the energy it saves by reducing extraction processes. It must, nonetheless, be noted that not all waste components can be recycled.

Recycling involves four steps, namely:

- Sorting recyclables from other wastes.
- Collecting recyclables into centralized locations for shipment.
- Storing and transferring recyclables to processors or remanufacturers.
- Processing recyclable wastes to make them easier to ship or prepare them for remanufacturing.

The efficiency of recycling is significantly affected by sorting, whether at source or at a specialized facility.

### i. Sorting

Waste may be sorted at the source or at a Material Recovery Facility (MRF). Sorting at source requires waste generators (individuals, business owners, etc.) to set aside storage space and one or more containers to hold the discarded recyclables. Some communities mandate that recyclables be separated according to type (e.g. glass from paper) or certain characteristics (e.g. clear glass from colored), while others accept recyclables that are commingled in the same container, as long as they are dry, clean, and separated from non-recyclable wastes. Commingled waste can also be sorted at Material Recovery Facilities, which are intended to handle large volumes of material and engineered to receive, process, ship and/or store recyclables. An MRF may be labor-intensive or highly mechanized. Naturally, the latter requires greater funds and technical expertise, but is more efficient<sup>[34]</sup>.

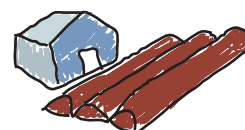
One of the main setbacks that a material recovery facility can face is the lack of market for some of its products. Planning ahead and conducting proper market analysis are therefore critical steps to ensure the facility's success.

### ii. Storage/Transfer

Most recycling programs will have to account for the storage of recyclables for periods of a few days up to one month, with respect to the average waste production rate of the area in question. This depends on market demand for recyclables and the capacity of the facility.

### iii. Processing

Processing yields clean, homogeneous material that can be further processed through baling or shredding to reduce volume and facilitate transport. Many communities choose to also use MRFs, which are cost-effective in the case of large-scale cooperative programs. They are organized to serve large municipalities, unions of municipalities, or governorates for example. Waste can then be used in the production of new materials or products. For example, collected plastic bottles can be reused and made into garbage bins.



### d. Composting

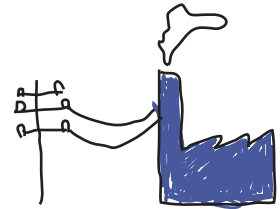
Composting is the transformation of organic material into a stable end-product by microbial organisms<sup>[35, 36]</sup>. It is an environmentally friendly and economically viable technique for treating municipal solid wastes<sup>[37, 38]</sup>. The three main types of composting are windrow composting, aerated static piles (ASPs), and in-vessel composting<sup>[39]</sup>. Factors to be considered before choosing the optimum composting option include, but are not limited to:

- Available space
- Carbon to Nitrogen (C:N) ratio
- Projected use of the compost/end product
- Speed of composting
- Odor, dust, and leachate generation
- Investment and operational costs

Composting is also subject to market dynamics and the price of the produced compost directly affects the feasibility of the project<sup>[40]</sup>. It is consequently essential to take all necessary measures to produce competitive-quality compost. Factors that affect compost quality include the choice of method and machinery, proper planning and engineering, and of course constant supervision and monitoring, as well as the presence of workers knowledgeable about the composting process (especially waste composition and variability).

In addition, the produced odors and leachate must be carefully treated to avoid significant threats to the environment and to neighboring communities. The municipal waste stream also contains quantities of glass, plastics, metals and hazardous materials, which can contaminate the finished compost. Thus, separating contaminants from the raw material at the compost site alone is insufficient, as they would have probably already become too commingled and costly to sort. Source sorting of organic and food waste before collection is hence an environmentally and technically better way to improve the quality of the final compost.

## e. Energy Recovery



Waste to Energy (WtE) is about turning waste into a useable form of energy, usually in the form of electricity. The waste management hierarchy prioritizes the recovery of energy from waste over disposing of it to landfills<sup>[29, 30]</sup>. In addition, more and more plants are looking to also make use of the generated heat. This is known as combined heat and power<sup>[41]</sup>. As such, Waste to Energy infrastructures can reap benefits for the community through the generation of energy from its waste stream.

Some of the main types of WtE processes are incineration with heat and energy recovery, Gasification, Pyrolysis, and Anaerobic Digestion. These processes differ in type (thermal vs. non-thermal), operating temperature, products and byproducts, etc. It is important to note that WtE facilities are mainly used for large quantities of Municipal Solid Waste. All WtE plants comprise the same basic steps<sup>[42]</sup>:

- Reception of the waste in a designated area and preparation for treatment.
- Thermal/biological treatment, which essentially releases the energy from the waste.
- Conversion to a transportable form of energy (e.g. electricity, heat, fuels).
- Clean-up of emissions and residues, which ensures that waste gases and residues are safely treated or disposed of.

Although WtE plants are gaining ground, especially in European countries, they are not without their limitations, for instance in regard to waste type and composition. WtE facilities are also more costly than other options in terms of investment and operation<sup>[41, 43]</sup>. Their overall environmental benefits depend not only on the thermal treatment but the energy conversion technology with which it is coupled, not to mention the efficiency of any energy required to run the process.

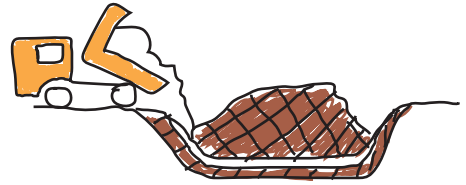
For WtE to be possible, the following criteria must be fulfilled:

- A well-functioning waste management system that has been in place for a number of years.
- A stable supply of combustible waste.
- A proper pollution control system, which includes the treatment and disposal of toxic ashes and incineration residues at controlled and properly operated landfills.
- An environmental permit.
- Constant monitoring and supervision.
- The recruitment and maintenance of skilled staff.
- A willingness of the community to absorb the increased treatment cost through management charges, tipping fees, and tax-based subsidies.
- A community stable enough to allow a planning horizon of 15 years or more.

Incineration is the most well-known WtE process. It is an efficient way to reduce waste volume and hence required landfill space. Other benefits of incineration include a fast processing speed, destruction of biological threats, and the production of heat and energy in the case of energy recovery.

In general, incineration is adopted in densely populated areas or countries where land is limited. It generates three main types of solid residues, namely bottom ash, fly ash, and air-pollution control residues<sup>[44]</sup>, which can all be managed through recycling and landfilling. Worryingly, these residues include particulate matter, which can be toxic to living organisms. In addition, the produced fly ash is toxic due to the presence of dioxins, heavy metals, chlorides, and sulfates. Moreover, pollutants found in flue gases include Carbon Monoxide (CO), Carbon Dioxide (CO<sub>2</sub>), Nitrates (NO<sub>x</sub>), Sulfates (SO<sub>x</sub>), Volatile Organic Compounds (VOCs), Dioxins, and Furans<sup>[45]</sup>. These pollutants can, nonetheless, be filtered, treated, and neutralized before being recycled or landfilled, making them less of a threat. However, this would require expensive equipment and complex processes

MSW incineration plants tend to be among the most expensive options, particularly when considering the emission control measures, which require highly skilled personnel and careful maintenance. Another key factor in incineration is the composition of the waste, as the efficiency of the process decreases significantly if the calorific value of the waste is low<sup>[44]</sup>. A thorough study of the nature and quantity of the waste to be incinerated is thus essential in the planning and design phases of installing an incinerator.



## f. Disposal (Sanitary Landfills)

Any sustainable solid waste management system for Lebanon will require a sanitary landfill to ensure an environmentally sound disposal of waste. All definitions of a sanitary landfill call for the isolation of the landfilled wastes from the environment until they are rendered harmless through the processes of nature. A landfill is hence necessary to dispose of waste, recycling and composting rejects, as well as residues of processes such as combustion. It can also be used if alternative facilities break down.

In order to be designated a sanitary landfill, a disposal site must meet certain control measures, namely the presence of:

- **A bottom Liner system:** seals off the bottom of the landfill to isolate it from the underlying environment or water source.
- **A leachate collection system:** collects any generated leachate that percolates downward and which contains a high amount of toxic compounds.
- **A leachate treatment system:** treats collected leachate before discharging it.
- **A gas collection system:** collects any gases that are produced and that may escape into the atmosphere, especially methane. These gases must be managed through reuse, burning, or treatment.
- **Covering or Capping:** seals off the top of the landfill to avoid odors or the spreading of diseases and other public health concerns.
- **Constant Monitoring:** uses probes and sampling methods to keep an eye on nearby surface and groundwater as well as air quality.

Some planning and environmental issues to be considered are that:

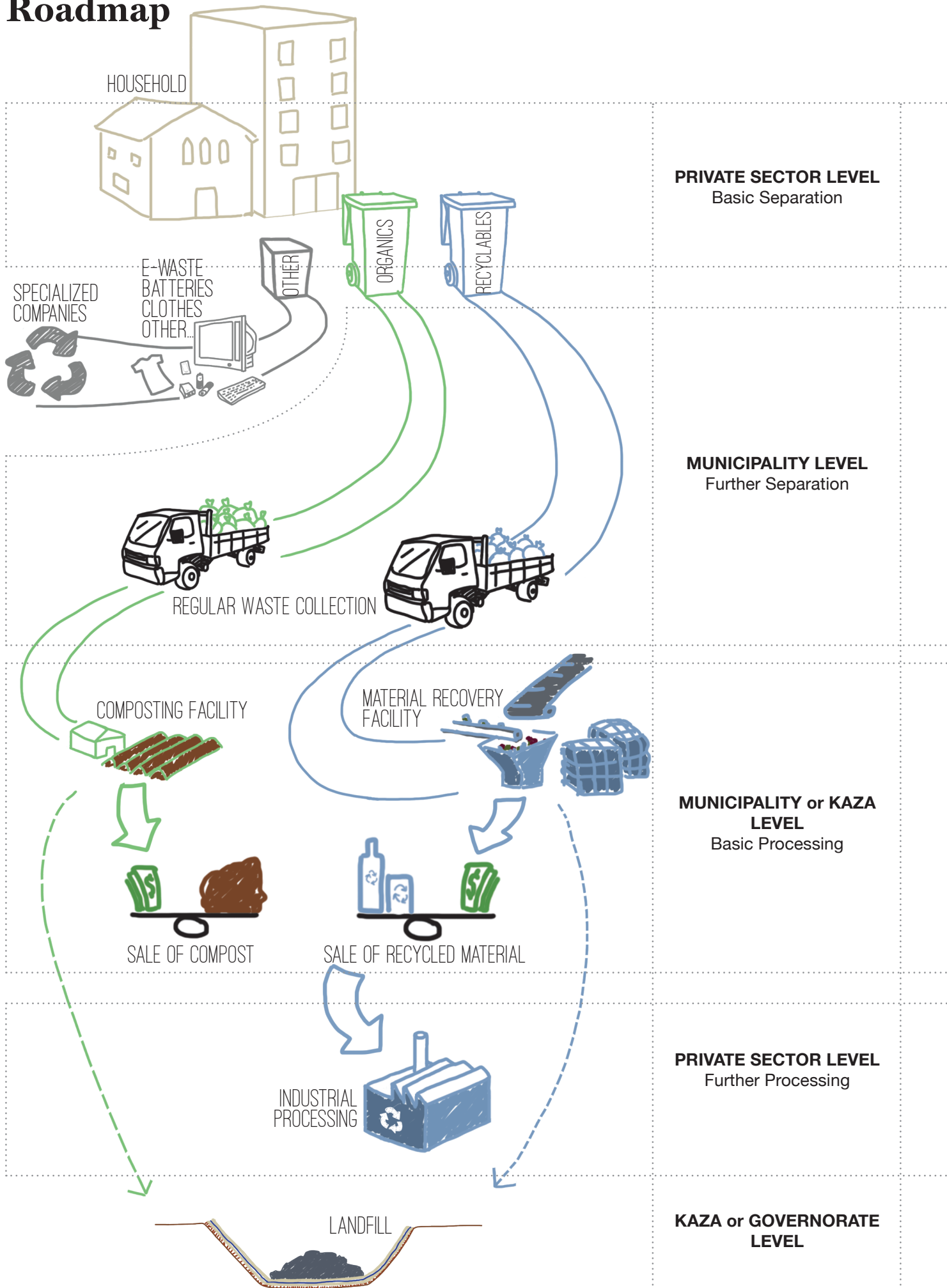
- Landfills must meet local zoning and land use criteria, including road weight limits and other restrictions, in order not to affect external environmentally sensitive areas.
- Landfills must be easily accessible by waste transport vehicles in all weather conditions.
- Surface and groundwater qualities must be protected.
- Landfill gas emissions and leachate must be controlled.
- There should be access to earth cover material that can be easily handled and compacted.
- Landfills should comprise enough land and internal capacity to provide a buffer zone from neighboring properties and have room for expansion.
- Siting must account for the increased cost of hauling waste for long distances.

## V. The Municipal Solid Waste Management Roadmap

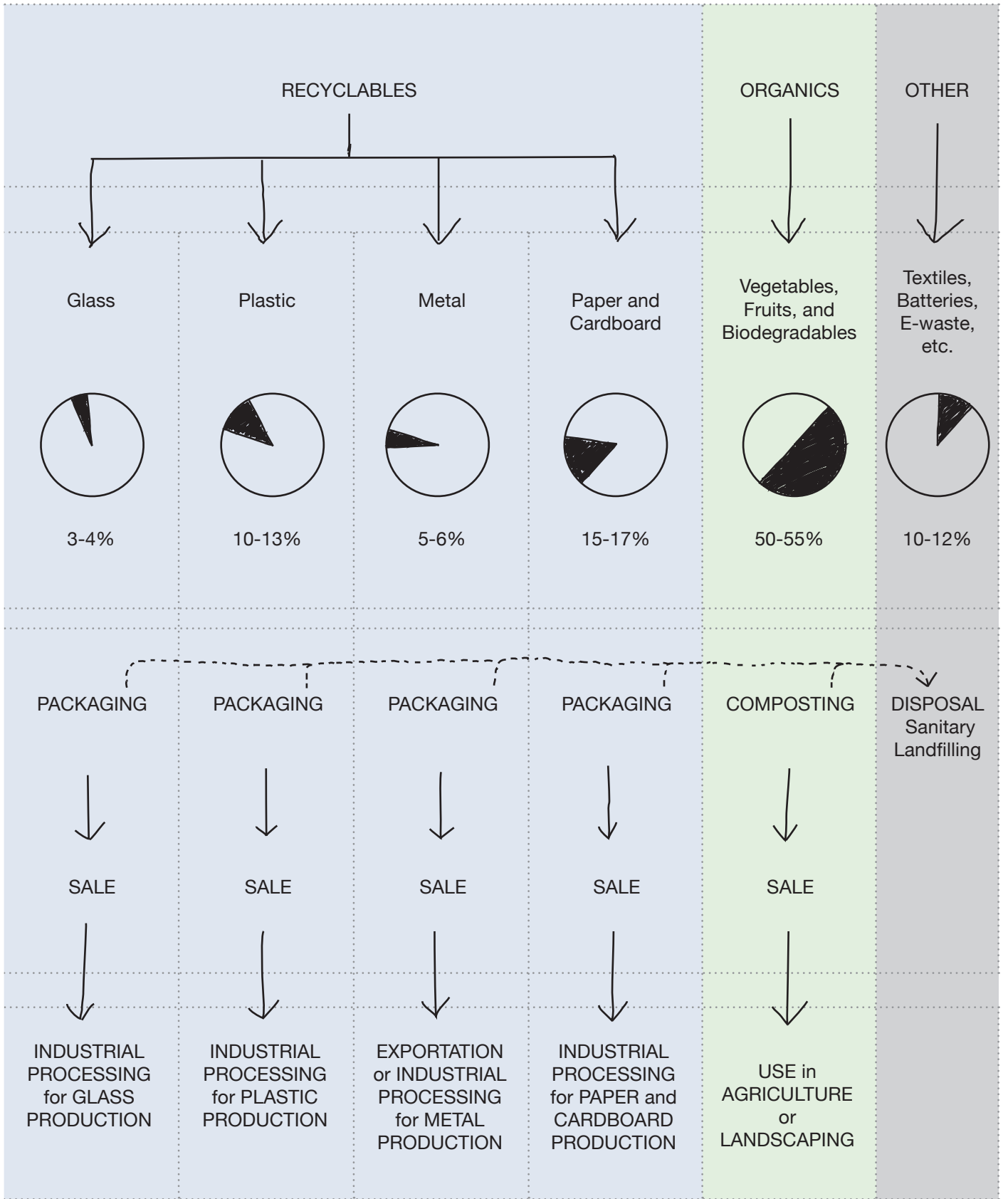
The next few pages will elucidate the Roadmap that the American University of Beirut Solid Waste Management Task Force has compiled by considering the different options mentioned above, comparing their environmental impacts, and respective feasibilities in Lebanon. It takes into consideration the public opinion and might be subject to changes in the case of future developments in the field of waste management. It can be modified to better suit the needs of each individual municipality or union of municipalities. However, large densely-populated cities, such as Beirut or Tripoli, might find the plan less suitable than other alternatives, such as WtE practices, after conducting their own Environmental Impact Assessments and other necessary evaluations.



# Roadmap










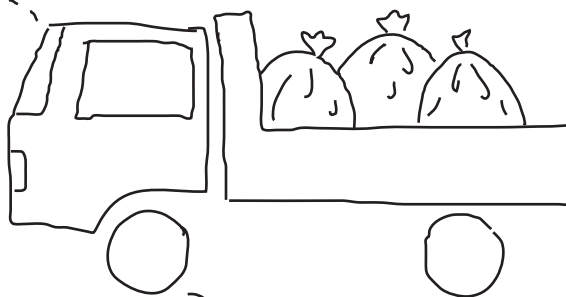
# Tips for Sorting at Source

**Table 3. Tips for sorting at source**

Types of Waste			
Include	Bottles, cans, cups, boxes, pots, tools, car and bicycle parts, paper and cardboard, newspapers, magazines, etc.	Kitchen waste (fruits, vegetables, bread, meat with small bones, coffee grounds, tea bags, tissues, greaseproof paper, etc.) and garden waste (cut flowers, etc.).	Clothes, batteries, fluorescent lights, hazardous materials (paints, thinners, etc.), electronic waste (E-waste), etc.
Do NOT Include	Windowpanes, lightbulbs, mirrors, ovenproof dishes, tissues, composite packaging (milk or juice cartons), photographic film, cling film, disposable food and drink containers, etc.	Sweepings, vacuum cleaner bags, cigarette butts, nappies and sanitary towels, cotton, packaging, large bones or knuckles, cooking oil, etc.	
Conditions	Must be dry and unsoiled.	Must be removed from packaging and allowed to drain.	Electronics and toys must be checked for hidden batteries before being thrown away.
Sent to	Material Recovery Facilities.	Composting plants.	Clothes can be donated to the less fortunate or landfilled. Meanwhile, other hazardous materials should be handed over to specialized companies.

## Collection

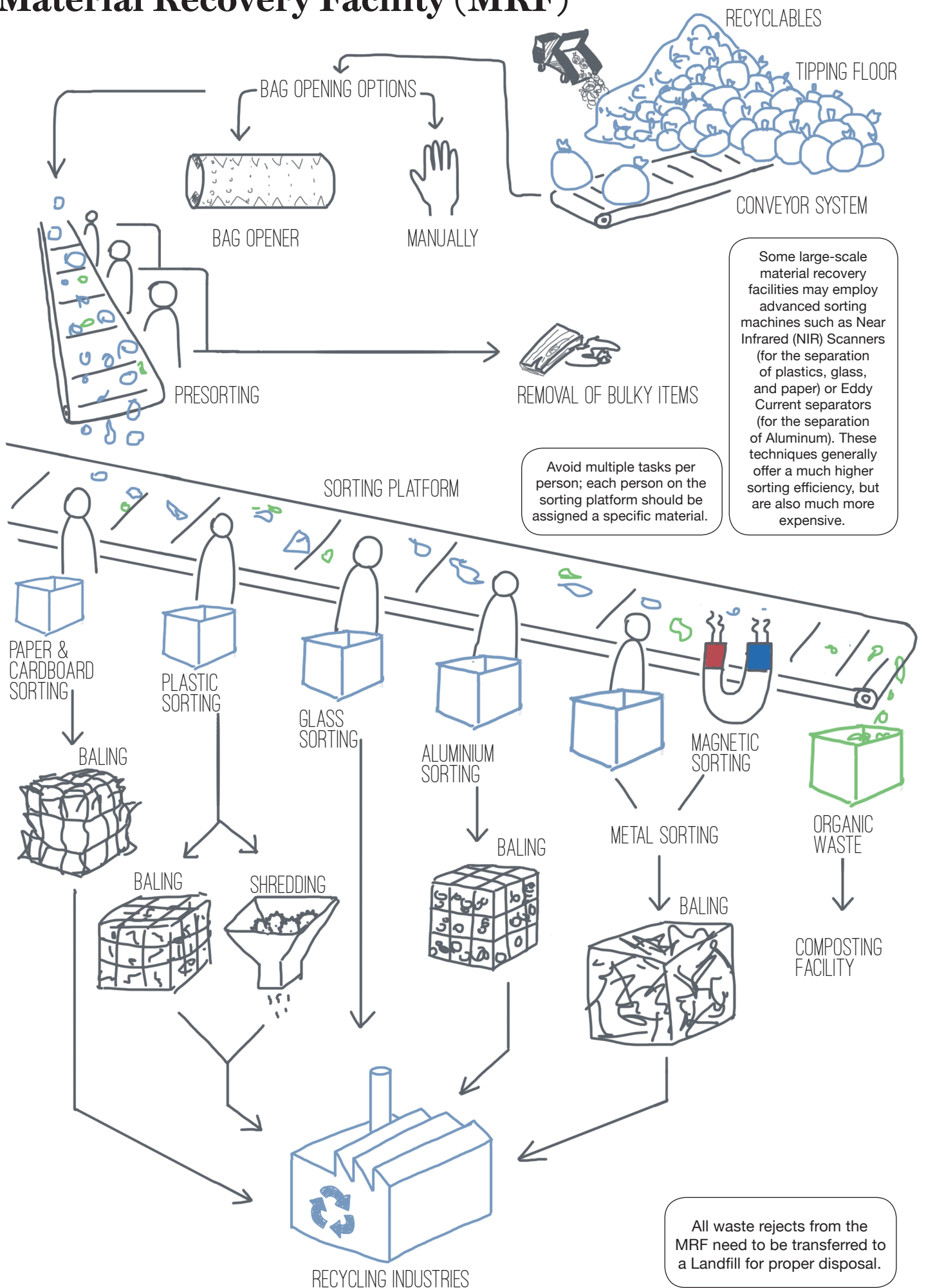
Waste collection frequency varies between areas and at different times of the year. In rural areas, during cold weather, and for areas with a limited budget, it might be better to collect waste less frequently, whereas a higher frequency is more suited to urban areas and/or temperate seasons.



Trucks used to transport MSW from the collection area to the treatment facility must not be compacting. The compaction of waste makes it much more difficult to sort later, and decreases the efficiency of MRFs.

Truck routes must be optimized in order to reduce fuel consumption, overall costs, and air pollution.

# Material Recovery Facility (MRF)



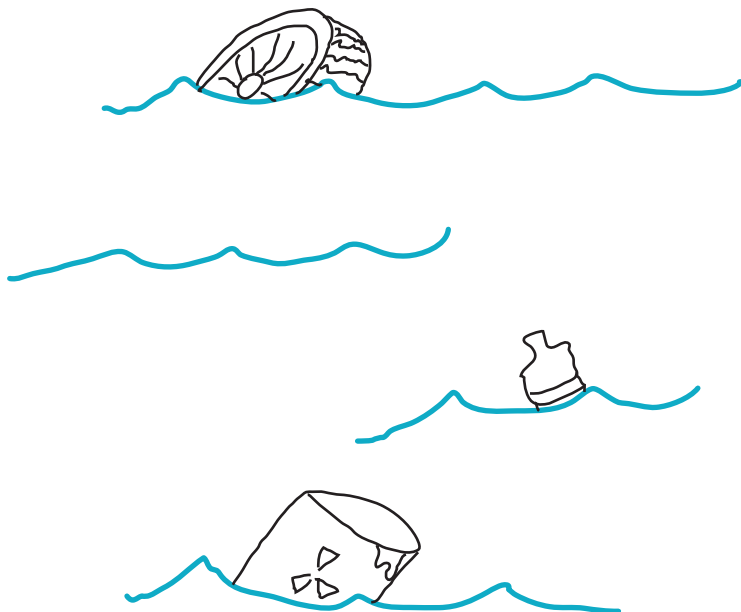
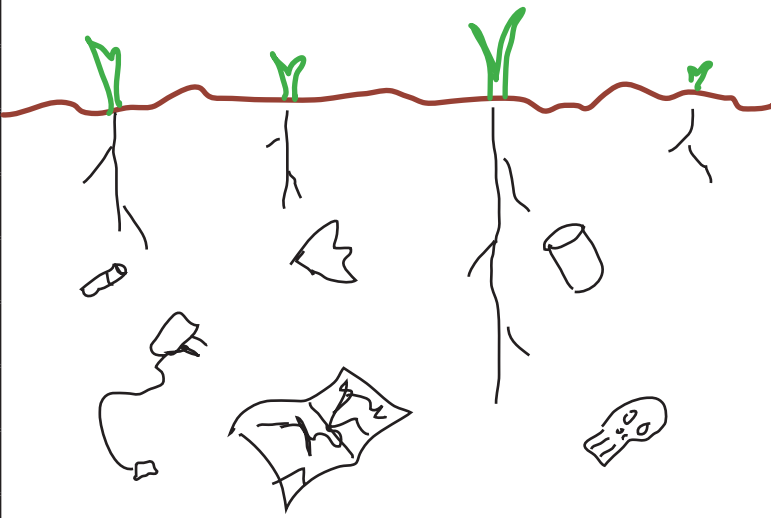
# Time Flies, Waste Stays



The average time needed for different substances to decompose varies substantially from one material to the next (see table 4). it is hence important to keep in mind that although landfilling is highly adopted, landfilled objects still require a certain amount of time to be degraded, which can sometimes be extremely long. The same applies to dumping waste in the ocean, where it will likely accumulate faster than it will decompose.

**Table 4. Average Natural Degradation Times for Different Materials**

Material	Time until degradation in soil
Tires	1000 years - indefinite
Plastic bottles	100 - 1000 years
Aluminium cans	10 - 100 years
Glass	400 - 4000 years
Nylon	400 years
Tissue paper	3 months
Cigarette butts	1 - 12 years
Matchsticks	6 months
Gum	5 years
Diapers	400 years
Magazines	6 months - 10 years



Material	Time until degradation in the sea
Tires	indefinite
Plastic bottles	1000 years
Aluminium cans	500 years
Glass	1000 years
Nylon	500 years
Tissue paper	3 months
Cigarette butts	2 - 12 years
Matchsticks	6 months
Gum	5 years
Diapers	200 years
Magazines	2 months

## List of Some Recycling Companies:




Recycling Company	Phone Number	What does it recycle?					
		Paper	Plastic	Metals	Glass	Electronics	Tires
Al Zoujaj al Yadawi	03/906091				X		
Aluxal	05/480406			X			
Arcenciel	01/495561	X	X	X			
Beeatouna	01/249653					X	
Charmtal	01/823675			X			
ETS. Carlo pour le commerce et l'industrie	01/497100			X			
Kamaplast	07/222200		X				
Lebanese Company for Raw Materials	03/281434			X			
Lebanese Recycling Works	01/809383		X				
L'Ecoute	70/391908	X	X	X		X	
LEFICO	08/921222		X				
Mazar Plast	08/500683		X				
MIMOSA	06/401876	X					
OLA 3R	03/977041						X
Oreibi	08/510194			X			
Panda Plast	01/650888		X				
Plastic Chim	03/337788		X				
PlastWood	01/491152		X				
Publitex	03/607678		X				
Roky Plast	09/795666		X				
Sharmetal	01/823675			X			
SICOMO	08/500550	X					
SIPCO	05/433553	X					
TERRE Liban	05/923060	X	X	X	X		
Unipack	09/478911	X					
United Glass products	06/389107				X		
Waste-MAWARA	01/258369						X
Zero Waste Act	01/381381	X	X	X			

Common sources of waste materials:


**Steel**

- Railway
- Main home appliances
- Cars
- Screws and nails
- Washing machines and refrigerators
- Pipes
- Heavy equipment
- Office furniture
- Industrial tools




**Plastic**

- Soft drink bottles
- Bags
- Pipes
- Fuel tanks
- Refillable bottles
- Detergent bottles
- Computer parts (e.g. hard disks)
- Sewage pipes
- Thin films used for food packaging
- Water and juice bottles
- Chairs and tables
- Trash bags
- Milk jugs
- Electric insulators
- Pressurized bottles
- Yogurt bottles
- Door mats and outdoor carpets
- Winter clothing
- Disposable cups and plates
- Sound amplifiers



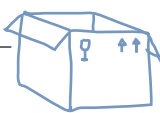
**Bronze**

- Electric pliers and fasteners
- Engines and pumps
- Electric wires
- Hammer
- Bells




**Cardboard**

- Cardboard boxes
- Corrugated cardboard
- Egg trays



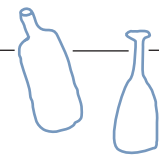
**Aluminium**

- Soft drink cans
- Metal chips
- Car parts
- Kitchen tools
- Construction material
- Electric transmission lines



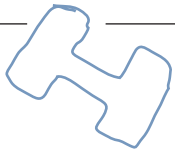
**Glass**

- Transparent glass
- Brown glass
- Green glass




**Lead**

- Bullets
- Car batteries
- Construction materials
- Weights




**Copper**

- Electronics
- Electric wires
- Adapters
- Magnetrons
- Electrical switches
- Water faucets
- Locks
- Ammunition
- Generators
- Construction
- Door knob
- Water heaters



**Paper**

- Printing paper
- Newspapers

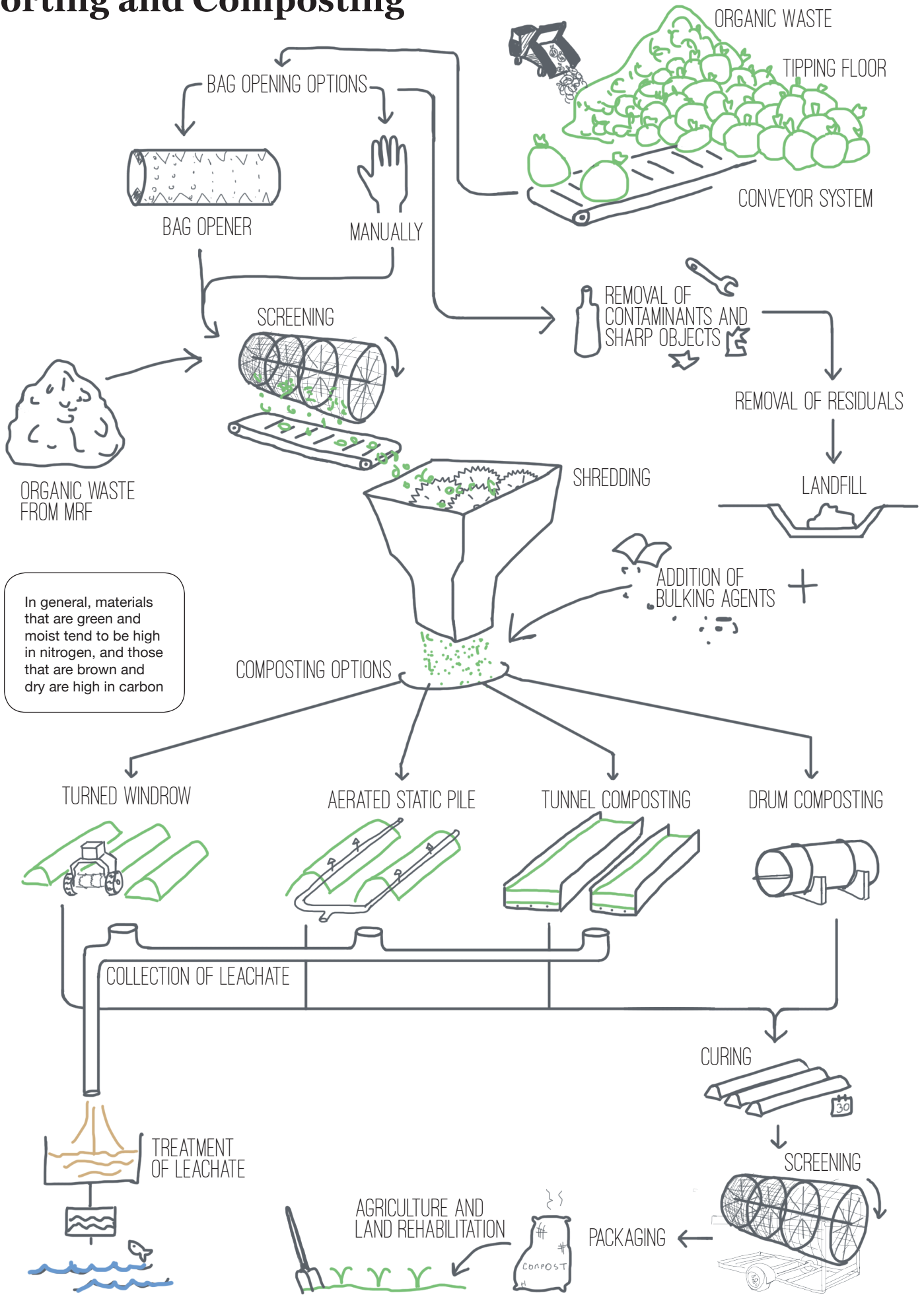


**Textiles**

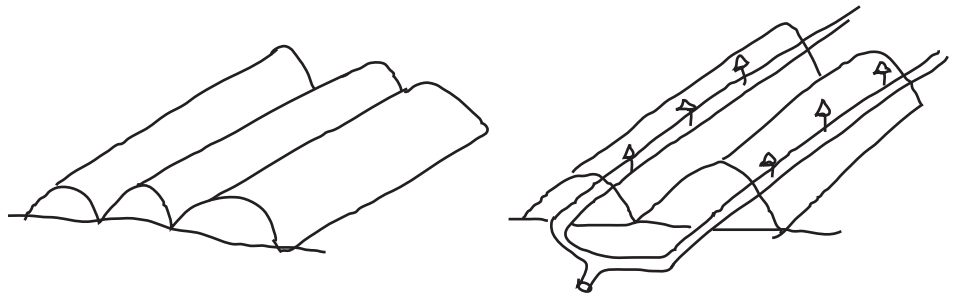
- Worn-out clothes



# Sorting and Composting



## Requirements and Comparison of different composting methods:



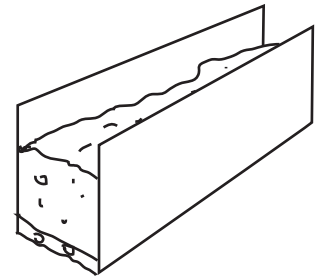
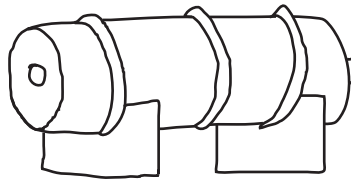
	<b>Windrow</b>	<b>Aerated Static Pile</b>
Capacity for which it is adapted	2 to 300 tons per day	More than 30 tons per day
Active Composting Time	8 to 24 weeks	2 to 10 weeks
Curing Time	3 to 6 weeks	3 to 6 weeks
Odor Production	High	Medium to Low
Electric Consumption	Low	Medium
Leachate Production	High	Medium
Land Requirements*	2X	X+
Labor Requirements**	Site Manager	Site Manager
	Machinery drivers	Machinery drivers
	Laborers	Laborers
	Maintenance Personnel	Maintenance Personnel
	Specialized Operator	Specialized Operator
Investment Costs	Low to Medium	Medium
Operation and Maintenance Costs	Low	Low to Medium
Machinery and Required Material	Shredder	Shredder
	Windrow Turner	Aeration system (Blowers, piping...)
	Screen	Screen
	Electric Generator	Electric Generator
	Biofilter	Biofilter
	Leachate Treatment System	Leachate Treatment System
	Skid-steer/Front End Loader	Skid-steer/Front End Loader

\*Estimation of the area (X) for the scenario of a 30-tons-per-day facility

\*\*The number of workers varies according to type of composting and capacity of the facility



## In-vessel

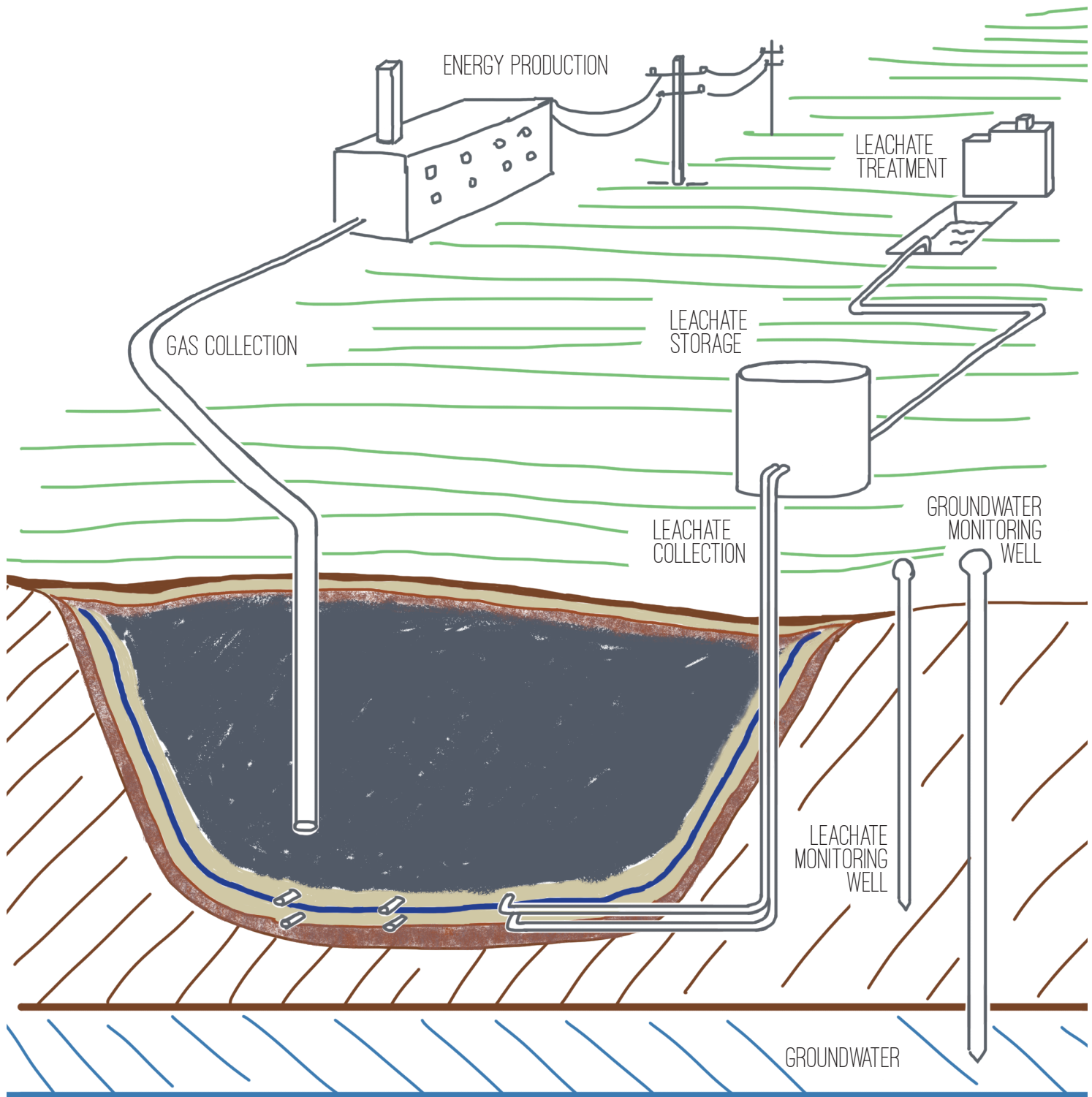


	<b>Drum</b>	<b>Tunnel</b>
Capacity for which it is adapted	2 to 30 tons per day	30-100 tons per day
Active Composting Time	Up to 1 week	3-4 weeks
Curing Time	3 to 6 weeks	3 to 6 weeks
Odor Production	Low	Medium
Electric Consumption	High	Medium
Leachate Production	Low	Medium
Land Requirements*	X	X
Labor Requirements**	Site Manager	Site Manager
	Machinery drivers	Machinery drivers
	Laborers	Laborers
	Maintenance Personnel	Maintenance Personnel
	Specialized Operator	Specialized Operator
Investment Costs	High	Medium to High
Operation and Maintenance Costs	Medium to High	Medium to High
Machinery and Required Material	Shredder	Shredder
	Drum(s)	Aeration system (Blowers, piping...)
	Screen	Screen
	Electric Generator	Electric Generator
	Not needed	Biofilter
		Leachate Treatment System
	Skid-steer/Front End Loader	Skid-steer/Front End Loader

\*Estimation of the area (X) for the scenario of a 30-tons-per-day facility

\*\*The number of workers varies according to type of composting and capacity of the facility

# Landfills



## Landfill Layers:



## Characteristics of the landfill used as an example:

Landfill Area	20,000 m <sup>2</sup>
Inert material from 100 tons per day	30 tons per day
Volume of inert material after compression and cover	50 m <sup>3</sup> per day
Volume of waste per year	18,250 m <sup>3</sup>
Height of material in landfill	around 14 meters
Average age of landfill	15 years

# Scenarios for Waste Management

The Roadmap is hence composed of a number of components, each of which is important to its integrative and sustainable qualities. In order to give a better idea about the different tools, manpower, machinery, land, and construction work needed to put these components to work, below are four examples, or scenarios, of areas with different rates of daily waste production.

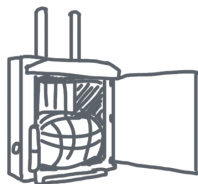
## Scenario 1: Mini Scale (around 1 ton per day)

### Machinery and tools needed:

BINS



BALERS



SHREDDER



SKID-STEER LOADER/ SHOVEL



<b>Labor needed</b>
4

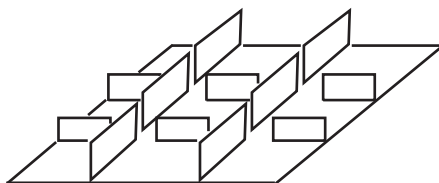
### Required Construction Work:



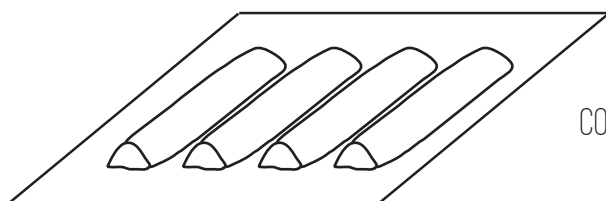
RECEPTION AREA



SORTING AREA



STORAGE AREA

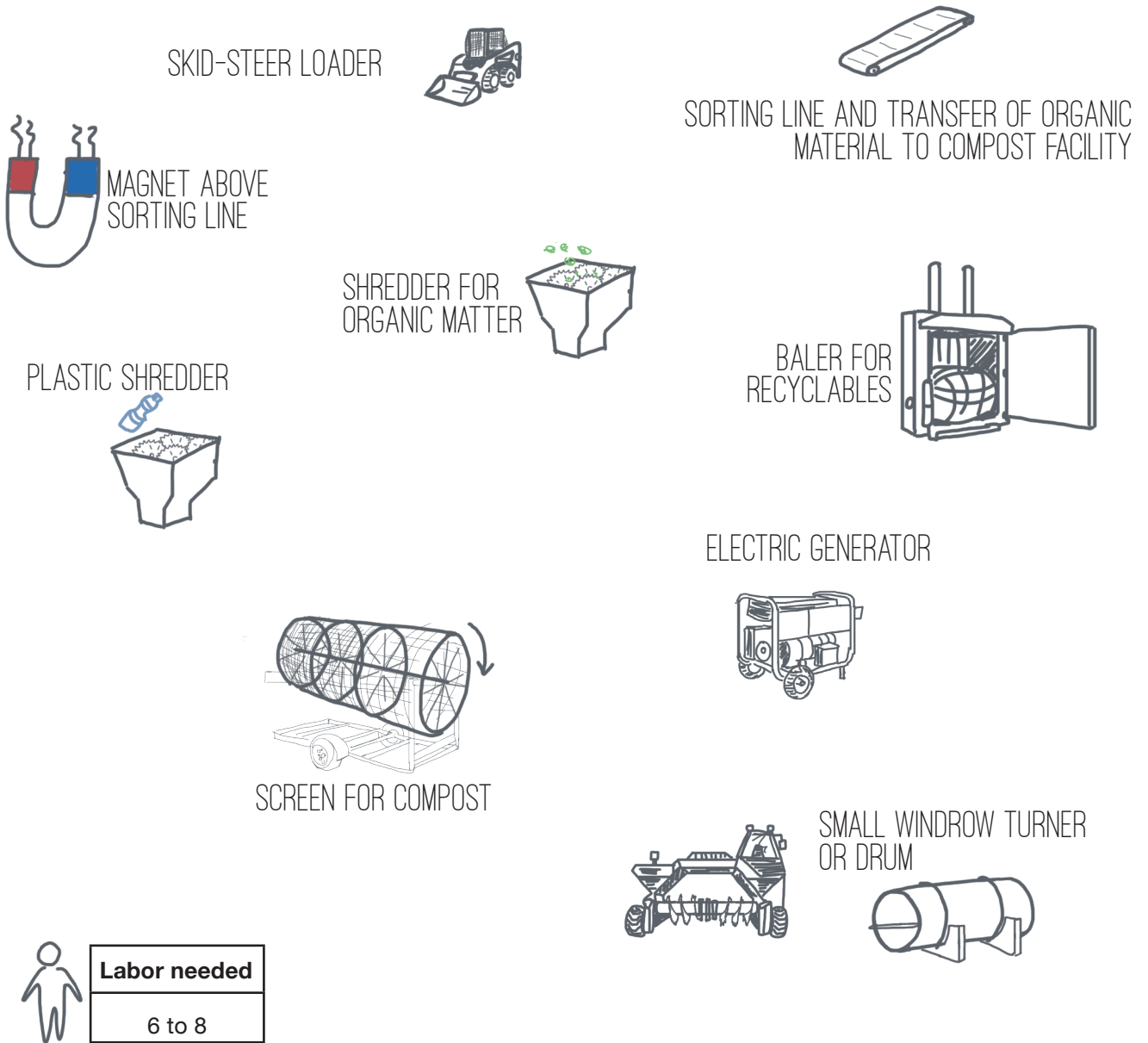


COMPOSTING AND CURING AREA

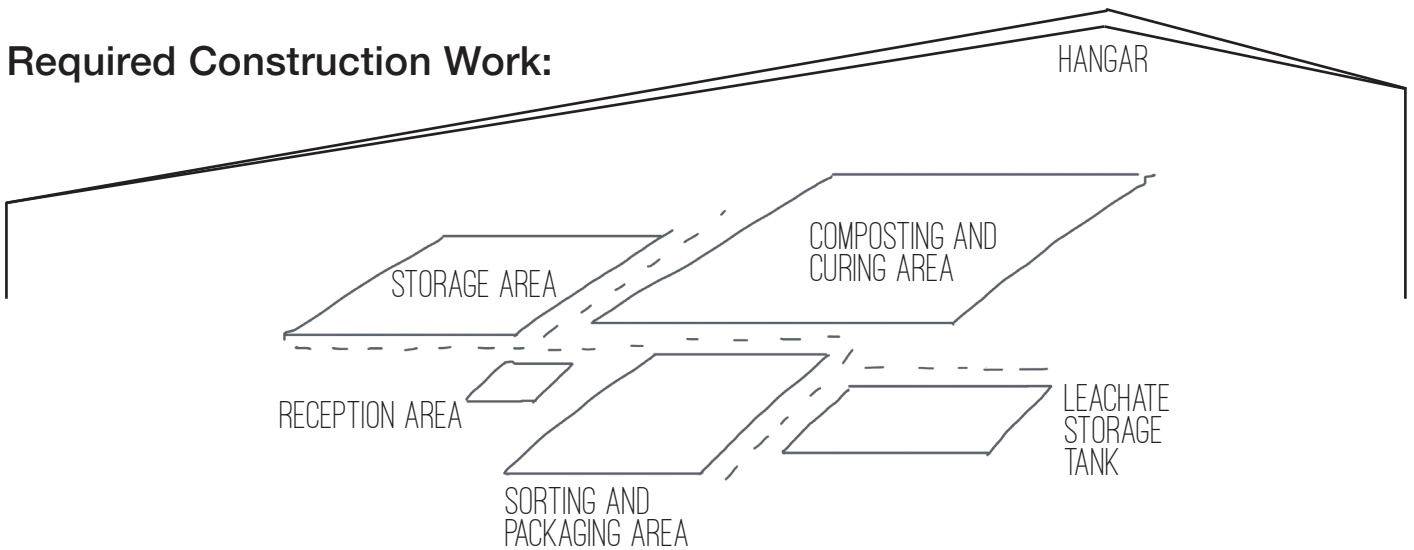
Total space: 500 to 1,000 m<sup>2</sup>

### Scenario 2: Small Scale (around 10 tons per day)

#### Machinery and tools needed:



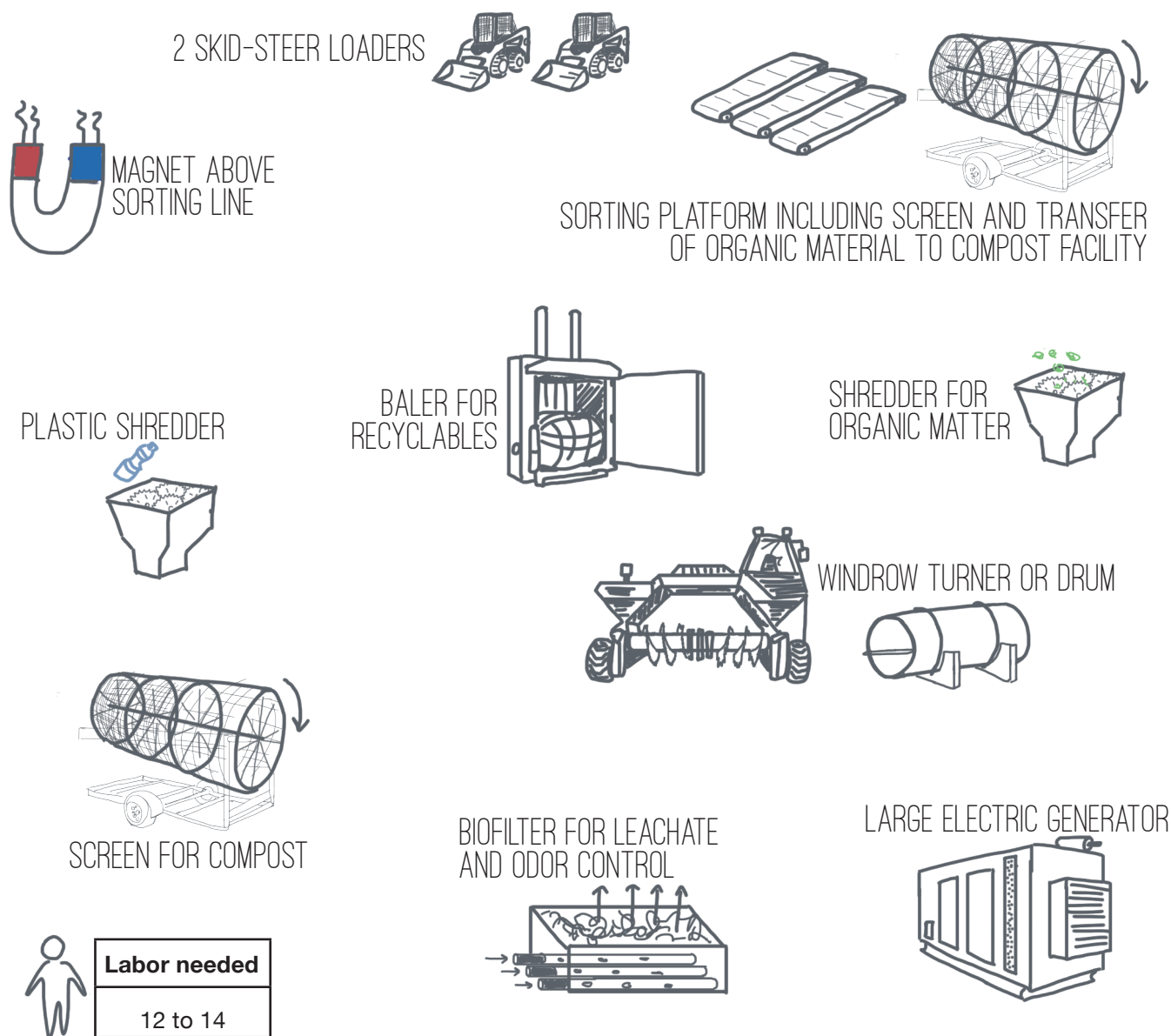
#### Required Construction Work:



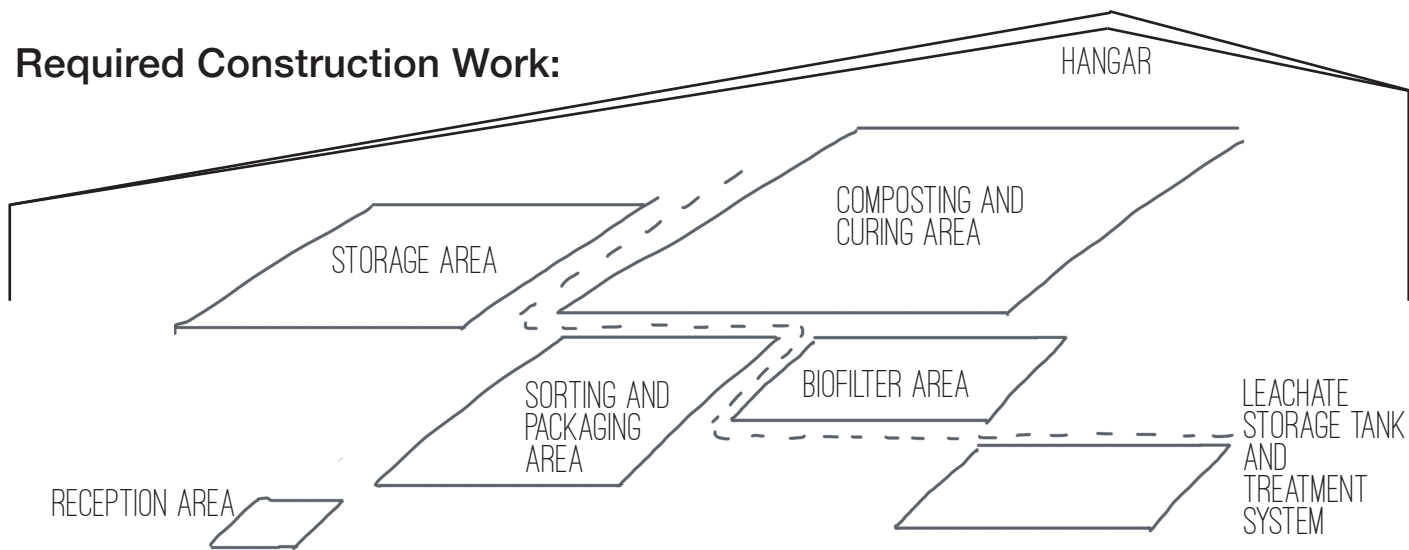
Total space: 1,500 to 2,000 m<sup>2</sup>

### Scenario 3: Medium Scale (around 30 tons per day)

**Machinery and tools needed:**



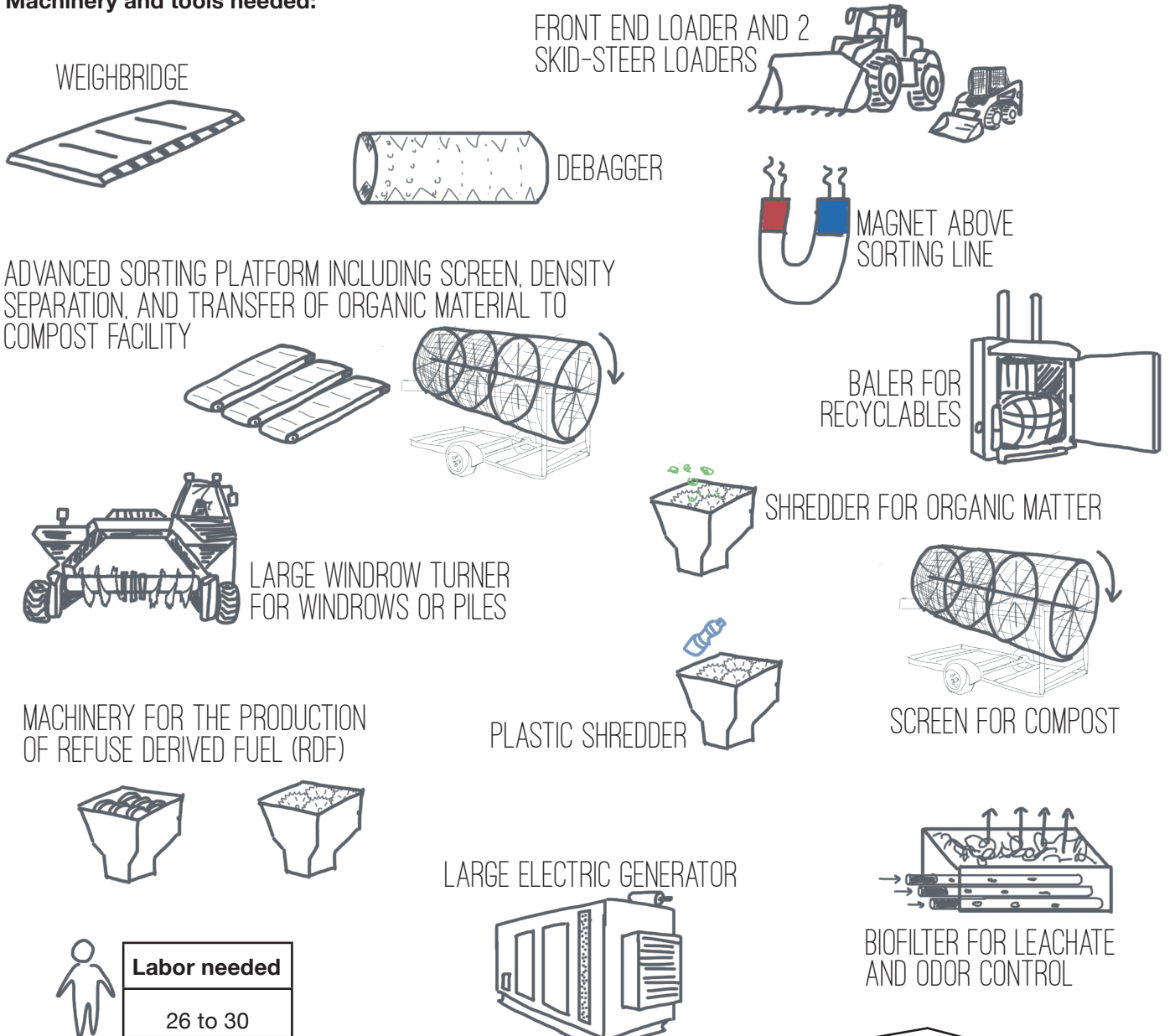
**Required Construction Work:**



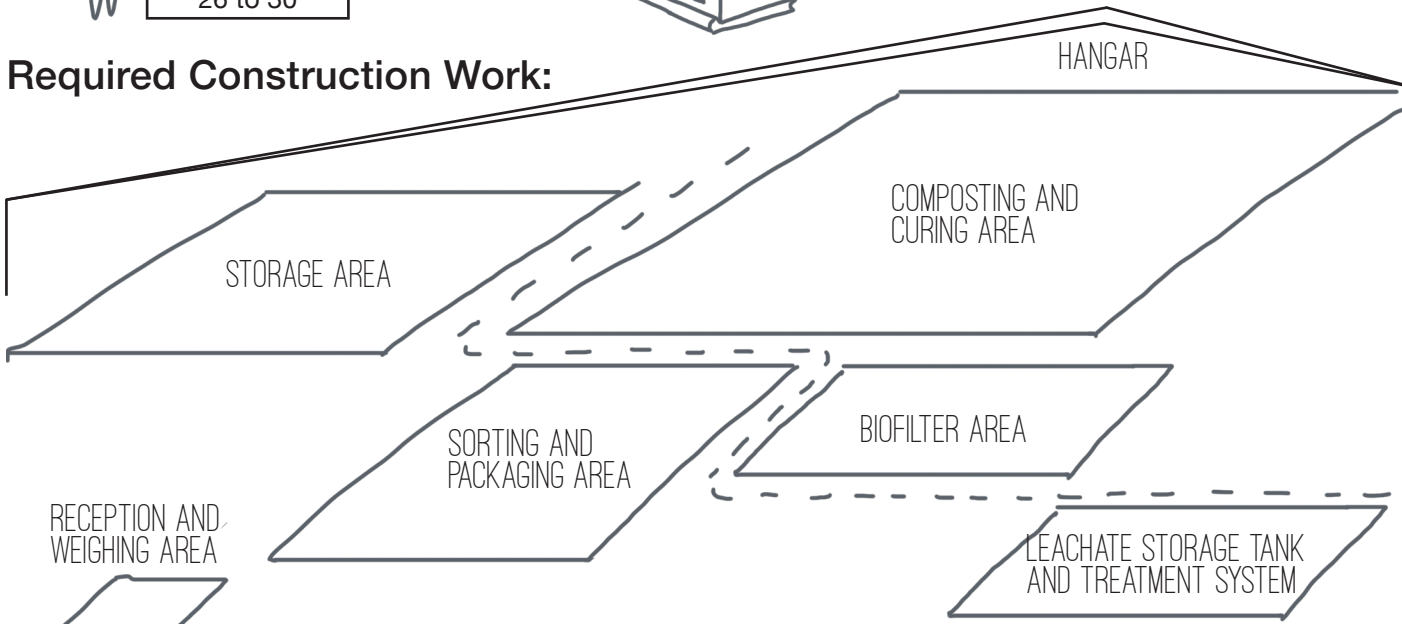
Total space: 2,500 to 4,000 m<sup>2</sup>

Scenario 4: Large Scale (around 100 tons per day)

**Machinery and tools needed:**



**Required Construction Work:**



Total space: 7,500 to 10,000 m<sup>2</sup>

# Final Recommendations

This manual having elucidated the different options for solid waste management, and described the American University of Beirut Solid Waste Management Task Force's Roadmap for a sustainable employment of some of these options, it is now the responsibility of stakeholders, mainly individual citizens and concerned municipal authorities to take the steps necessary for its application.

It is crucial for municipalities to build partnerships with each other, in order to lighten the burden of financing and managing such a fully fledged solid waste management plan. These collaborations would incorporate economics of scale into the process of waste management, and hence facilitate the implementation of sustainable waste management in the municipalities or kazas in question.

In addition, it is even more crucial for individuals, whether home or business owners, to actively take part in the transition that is inevitable for Lebanon to become sustainable at all. Citizens and residents of different municipalities and kazas must accept the added responsibilities and duties of sustainable living and begin integrating elements of the Roadmap into their day-to-day lives, most important of which is sorting at source.

Finally, the Roadmap should be taken as a guideline. It is essential, as per Decree 8633/2012, for concerned parties to conduct an Environmental Impact Assessment (EIA) before implementing any solid waste management facility. This type of assessment will act as a planning tool to assist decision-makers in bringing all the economic, social and environmental factors that could directly or indirectly affect the project and society into focus. The EIA process can modify and improve the design of a proposal, ensure that resources are used efficiently, enhance the social aspects of the proposal, identify measures to monitor and manage impacts, and facilitate informed decision-making in order to mitigate predicted negative environmental consequences and enhance those which are beneficial<sup>[46, 47]</sup>. This said, it becomes clear that sustainable solid waste management will require an effort from all stakeholders, but also that it is not a complex or impossible undertaking. The American University of Beirut Solid Waste Management Task Force sincerely hopes that this manual will serve as a tool in the efforts of different parties to sustainably manage their waste.

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