Appendix 6A

APPENDIX 6A
SUMMARY OF TECHNOLOGY OPTIONS

Overview of solid waste handling and treatment facilities:

TRANSPORTATION	RECYCLING	PHYSICAL TREATMENT	BIOLOGICAL TREATMENT	THERMAL TREATMENT	DISPOSAL	RESOURCE RECOVERY
Transfer Station	Source Segregation / Kerbside Recycling	Material Recovery Facilities (MRF)	Composting	Combustion	Sanitary Landfill	Energy-from Waste (EfW)
	Drop-Off Centre (Recyclables)	Shredding	Anaerobic Digestion	Gasification		Landfill Gas Recovery
	Buy-Back Centre (Recyclables)	Trommel Screens		Pyrolysis		
	Recyclables Processing Centre	Magnetic Ferrous Separation		Plasma		
		Baling				
		Refuse Derived Fuel (RDF)				

1. BIOLOGICAL TREATMENT

The quantity of organic material in Malaysian waste can be reduced with the use of biological technologies including **composting** and **anaerobic digestion.** Biological technologies are undertaken both in the presence and absence of oxygen. Neither process destroys the organic matter contained in biodegradable waste but they utilise micro-organisms to convert degradable organic matter into humus, known as compost. Effectively both processes mimic and accelerate the natural decomposition of biodegradable matter, but under controlled conditions.

All waste which can be broken down or digested by any form of biological or microbiological activity is termed "biodegradable".

In the compost process, carbon dioxide and water are also produced during the process. Under anaerobic conditions, methane gas is produced which can be used as a source of energy. Although kitchen waste can be converted into compost there may be sensitivity issues related to religious considerations, and also as to the poor "mix" of materials, and consequent risk of reduced quality. Therefore it is preferable to restrict to uncontaminated segregated green garden waste as this reduces the risk of end product contamination and minimises problems of odour generation and vermin. However the reduction in organic content from the waste mass will also reduce gas generation at landfill sites as a result of decomposition, and leachate generated will generally require less treatment before discharge.

1.1 Composting

The controlled biological decomposition and stabilisation of semi-dry organic waste (such as garden and vegetable wastes), under conditions that are predominantly aerobic. There is a development of thermophilic temperature as a result of biologically produced heat. The process can be likened to degradation of waste in landfill except that it is undertaken in the open air.

Most bacteria and fungi associated with waste products are aerobic. They are capable of metabolising[1] biodegradable material in the presence of oxygen. The product is humus-like material, which is nutrient rich and resistant to further decomposition. It can be used for agriculture, landscaping, and horticulture. For optimum quality it is necessary to remove contaminants such as plastic, glass, and metal fragments. It is necessary to control both feedstock and product, with physical, chemical and biological parameters. Problems include odours, although enclosed tunnels can address this issue. It can be used for all solid biodegradable waste, including cellulose-based material.

i. Windrow Composting and Aerated Static Piles

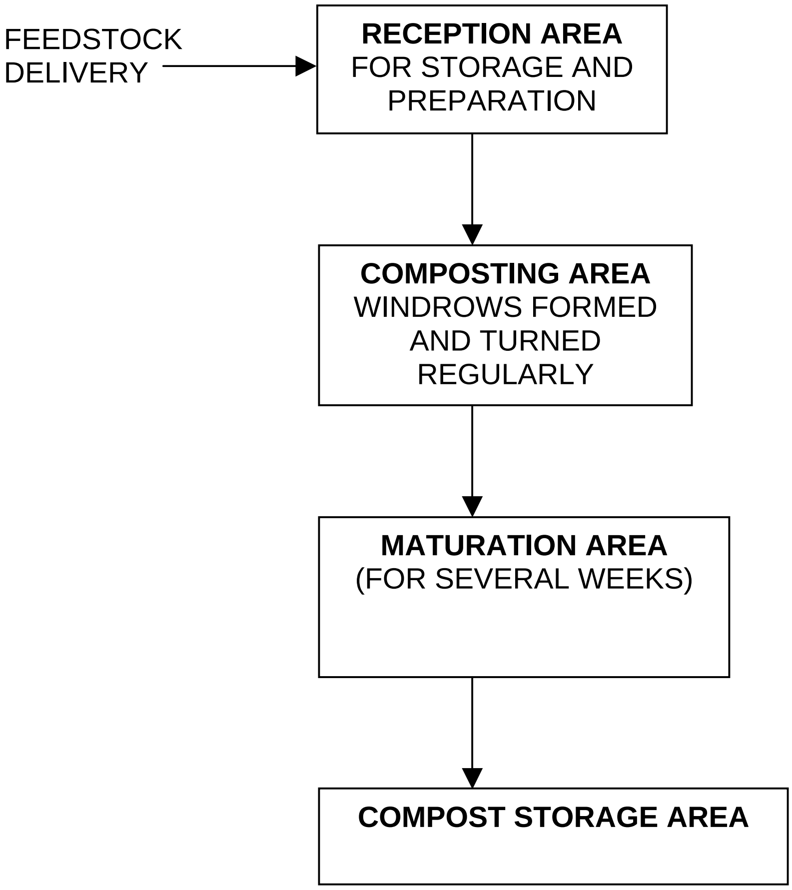
"Windrows" are simply heaps of material, triangular in section, which are frequently turned (manually or mechanically) to maintain the correct temperature and aeration. This is the most commonly used process for green waste composting and is low cost, but needs a large area of land. Most central composting systems employ the open windrow method of composting which involves shredding the waste and placing it into long rows where it is turned regularly for up to 20 weeks (typically 8 – 12 weeks) until such time as the compost is ready. Regular turning of the waste is essential to

[1] Metabolism – the conversion of energy derived from sunlight and fuels into energy utilised by a cell to undertake chemical, osmotic and mechanical functions.

ensure adequate aeration, the production of a consistent end product and to prevent excessive odour generation. Typically, the windrows can be up to 3 metres in height and 4 metres in width.

"Aerated static piles" achieve aeration by pumping air through the static pile and thus turning of the waste is unnecessary. The air may be forced through the pile from below, or drawn through the pile from above. There is a greater need for site engineering compared to windrows, but mature compost may be produced more quickly because of the better control. Aerated static pile composting requires less land, but has higher capital costs.

Figure 1 : Flow of Materials in Windrow Composting



ii. In-Vessel Composting

"In-vessel systems" may be drums, tunnels or boxes (e.g. roll on/off containers), and offer better process and emission control of the composting process. The vessels usually include biofilters for odour control, automated aeration and moisture regimes within the vessel, and movement of the material (e.g. using moving floors). The investment costs are higher for this more complex technology, and there is normally some need for further maturation of the processed compost from such systems, but the land requirements may be lower. These systems are often easier to accommodate in terms of planning requirements, due to reduced vermin and odour problems. Systems have been used primarily for sewage sludge composting, but many suppliers are now encouraging the merits of this technology for the composting of MSW. In vessel, composting facilities are not currently used in Malaysia, but this is expected to increase if composting plays an increasing role in an integrated waste management strategy.

iii. Vermicomposting

Vermicomposting is the process of using selected species of earthworms to help compact biodegradable wastes. Both vermicomposting and traditional composting both involve aerobic decomposition of biodegradable matter, but in vermicomposting the earthworms break down, mix and aerobic the waste. In this case, temperature control is very important, because at temperature above 35ºC earthworms will be killed. (In traditional composting, temperature of composting piles may exceed 70ºC.)

iv. Home Composting

Home composting is a long established practice in many countries involving the use of special compost bins and, more recently wormeries (a container which houses a colony of worms), to break down the organic elements of the household waste stream, including kitchen waste, into nutrient rich compost. It relies on households to manage their own biodegradable waste. This method would generally account for only a small proportion of the total volume of material diverted from landfill, due to the small number of households that undertake composting and the low throughput of material. The adoption of pilot schemes is an option whereby households are provided with the necessary facilities. However, a major barrier to its increased use is that many householders, especially those who live in flats or are without open areas outside, do not have the space required to allow home composting. Increased public awareness and education are also required. The development of such schemes however does invoke an involvement in waste reduction initiatives among the public, and consequently can play a useful part in promoting community involvement.

Advantages of Composting

- Contributes to climate change abatement. Little methane is produced compared to landfill.
- Volume reduction 30-40% (dependant on waste components).
- It is recycling – nutrients can be returned to the soil.
- Well established.
- Relatively inexpensive.
- Handles variable waste streams more easily than anaerobic digestion.
- May be a source of fuel when dried.
- Capital investment costs are lower than other technologies.
- Simple (comparatively) low technology option.

Disadvantages of Composting

- The microbial activity is exothermic, thus there is heat generated and there must be close control of aeration, temperature and moisture content (This is most effectively achieved by using in-vessel composting followed by windrowing).
- High land use (when compared to anaerobic digestion), typically one square metre of land for each tonne of compost being created.
- Prior sorting is required to ensure the process is effective, to reduce contamination, and to produce a high quality compost.
- Odours at plant or in transit.
- Quality of end product is critically dependant on feedstock, and contamination can be a significant problem. Heavy metal content is

generally high compared with naturally occurring soils, thus further processing may be required.

1.2 Anaerobic digestion

In anaerobic digestion (AD) organic waste matter is reduced into a material similar to compost, known as digestate, which can have similar applications. The main difference between the two processes is that AD is an anaerobic (oxygen free) process, whereas composting requires aerobic conditions.

AD is, however, also referred to as an Energy from Waste (EfW) process because one of the by-products is biogas, which can be utilised as a fuel either on-site or converted to electricity and transferred to the national grid. AD is more suited to wet organic wastes such as sewage and foodstuffs from the household waste stream. Garden waste can also be processed but the degree of degradation varies according to the type of input, e.g. grass cuttings will degrade quicker than wood. Segregation of wastes, whether by the householder or at a material recycling facility (MRF), can significantly benefit the AD process by excluding those elements of the waste stream not suited to the process e.g. plastics, glass and textiles.

The natural biological process is artificially accelerated in a closed vessel, where bacteria are used, in an oxygen-starved atmosphere, to decompose complex organic materials. The gases, which are produced by the decomposing matter, mostly methane and carbon dioxide, are drawn off and converted into energy or used to generate steam. The purity of feed material determines the quality of end product, and the end products are (can be) products for horticultural use or gas collection.

Ideal feedstock for AD plant is organic-vegetable origin, but waste paper, which is too contaminated to be recycled or has no market value, can also be digested. Most AD plants incorporate a number of stages including shredding, pre-digestion, post-digestion, aerobic curing and screening.

Water is required for biological treatment but AD plants can accommodate up to 45% solids. For a typical wet biowaste containing 55% water, the total feedstock converted to methane (biogas), compost, and residual matter is 15%, 55% and 8% respectively.

Advantages of Anaerobic Digestion

- Disposal volume of waste reduced by up to 60% (dependant on characteristics of feedstock) and the residue for disposal to landfill is small.
- The process is a form of recycling, and has additional benefits over the alternative of open composting because it is fully enclosed, obviating nuisance caused by odours.
- It has relatively (comparatively) low land use.
- May be integrated into sewage treatment infrastructure - thus deriving benefits in terms of proximity principle.
- Greater control of gas and leachate.
- Biogas produced represents about 25% of the energy content of the waste, so can be used as an on-site fuel, or to generate electricity for export off-site.

Disadvantages of Anaerobic Digestion

- Requires an engineered vessel to ensure anaerobic conditions.
- More expensive than composting.
- Can handle only limited waste streams, thus prior separation of input waste is essential.
- If the feedstock is variable then it may cause operational problems.
- Plastics and cellulose products (such as wood and wood fibre) are not digestible.

2.0 ENERGY FROM WASTE

Energy from Waste (EfW) refers to waste management technologies whereby energy is captured as a by-product of the process and converted into electricity. It is usually used in the context of waste incineration (but can also be applied to anaerobic digestion and recovery of landfill gas from waste disposal sites) where, in addition to providing a supply of electricity to the national grid, the process can also be utilised to supply district heating to neighbourhoods or other buildings in the vicinity, or to provide power to run the plant.

Incineration with energy recovery provides a means of reducing the volume of waste to a relatively inert ash and recovering the energy content of the organic waste. Different combustion processes can be used, including refuse derived fuel and combined heat and power.

Refuse derived fuel (RDF) – in this process the mainly organic fraction of the MSW (with non combustible material removed) is used as a fuel. The fuel source may be either loose (coarse RDF) or compressed into pellets (densified RDF), which typically have calorific values of 30% - 50% of coal. Pelletised fuel must be burnt in dedicated facilities, because it normally has a high chloride content, which can cause erosion in incineration plants.

Combined heat and power (CHP) – This is a thermal process involving the use of waste as a combustion fuel for power generation and steam that is used locally for heating.

Advantages of EfW (thermal)

- The process maximises the use of available heat derived from the fuel.
- Can accept a wide range of wastes.
- Waste is a renewable energy resource, with consequent benefits through international non-fossil fuel obligations, and a positive response to the implications of the Kyoto Agreement as determined at the Framework Convention on Climate Change.

Disadvantages of EfW (thermal)

- Capital and operational costs are high.
- Pollution control equipment is expensive.
- Ash produced (approximately 10% of input mass dependant upon constituents), may require to be disposed of in a hazardous waste landfill due to heavy metal content.
- Requires a sustained market for the energy generated.
- Thermal treatment produces several waste streams (solid wastes as fly ash and bottom ash, gaseous emissions and discharges to water), each

of which may contain pollutants that can adversely affect the health of exposed individuals.[2,3]

3.0 GASIFICATION AND PYROLYSIS

Both gasification and pyrolysis, like incineration, are options for recovering value by thermal treatment. They both involve the conversion of waste into energy-rich fuels by heating it under controlled conditions. However, whereas incineration fully converts the input waste into energy and ash, these processes limit conversion so that combustion does not take place directly. The waste is instead converted into intermediate products, which can be further processed for material recycling or energy recovery.

Previously these processes were considered as "novel technologies", but now are considered to be at the forefront of emerging technologies for waste treatment. It is being recognised that gasification and pyrolysis techniques can play an important role in implementing both modern waste management and renewable energy policies in the developed and developing world.[4]

3.1 Gasification

Gasification is the conversion of solid waste into its gaseous components (principally hydrogen and carbon monoxide). The process involves the reaction of hot carboniferous material (the waste) with air, steam or oxygen to produce a gaseous fuel, "syngas" which is then used for electricity production in gas turbines, or in combination with heat exchangers and steam turbines. The temperatures involved are high and vary between 800ºC and 1100ºC in the case of air gasification, and between 1,000ºC and 1,400ºC in the case of oxygen gasification. The environmental burden, often associated with "conventional" thermal treatment, is generally low, due to the contained nature of the process.

Advantages of Gasification

- Energy efficiency is high - small scale facilities using gas turbines have typical efficiencies of 30%, larger scale combined facilities can have efficiencies up to 45%.
- Volume of waste reduced by 80% - 90%.
- Emissions of NO_x, SO_x, dioxins and furans are reduced.
- Inert residual material.
- It is an energy-reducing process.
- It is capable of having a wide range of wastes as feedstock, including plastics, tyres, clinical waste and hazardous waste.

[2] Various conclusions from Institute of European Environmental Policy reproduced from extensive study undertaken by the National Society for Clean Air UK, (2001). Conclusions include: emissions of toxic and carcinogenic pollutants such as dioxins and heavy metals from MSW incineration have fallen significantly in the last ten years. Health impacts from dioxins, metals etc. from modern incinerators are very low, particularly those plants with efficient gas cleaning and ash treatment processes. Some uncertainties remain, e.g. in relation to pollutant mixtures and for potentially susceptible groups.

[3] "Bottom ash, whether at the incinerators themselves or at sites where the ash is either stored, recovered or disposed of, does not contribute significantly to the publics exposure to dioxins" UK Environmental Agency Report - Solid Residues from Municipal Waste Incinerators in England and Wales 2002.

[4] Pyrolysis and Gasification of Waste - A Worldwide Technology and Business Review, Juniper Consultancy Services Ltd. March 2000.

Disadvantages of Gasification

- Technically complex.
- Generally more expensive than EfW plant, if ash melting is included to meet higher environmental standards.
- Feedstock has to be pre-treated (homogenising/sizing)

3.2 Pyrolysis

Pyrolysis is the thermal degradation of waste in the absence of oxygen in a sealed vessel. Organic matter is heated in a closed retort in the absence of air and subsequent volatilisation produces combustible gases, a low calorific combustible char, a mixture of oils and a liquid effluent. Temperatures are in the range of 700ºC to 1,000ºC.

Advantages of Pyrolysis

- Designed to maximise the recovery of various products and residues.
- Up to 90% reduction in volume of waste.
- Potential for energy production.
- Can accept wide range of wastes.
- Pyrolysis and gasification liberate a higher amount of energy per tonne of MSW feedstock as compared to conventional incineration processes.

Disadvantages of Pyrolysis

- May have a high-energy demand for processing, thus reducing the net amount of energy for export.
- (When compared to gasification) there is a range of by-products formed, which can be difficult to handle and may not be easily marketable. (For example the char, which may still account for more than 30% by weight of feedstock, contains non-volatile fixed carbon and heavy metals. It will require further processing unless it can be used, for example, in a coke or RDF fired boiler).
- More complex design than mass burn EfW plants.
- Generally more expensive than EfW plants, dependant upon process controls and equipment to meet higher environmental standards.

3.3 Plasma

Plasma is the fourth state of matter, i.e. a highly ionised gas which can be produced as a result of electric discharges. Plasma energy is produced when the ionised gas resists the flow of electric current through the gas, thus creating radiant heat that generates temperatures higher than 10,000^{0}C (Lightning strike is an example of naturally-occurring plasma energy.) The intense heat of plasma energy is normally used in combination with pyrolysis for treatment of solid waste, the heat source being a plasma arc torch.

Heat is transferred to the waste via convection, where temperatures of up to 2,000^{0}C are established in the waste melt. Volatile organic materials break down and reform to hydrogen-rich, simple gases such as carbon dioxide. Inorganics form a glass-like melt as they stabilise.

Advantages of Plasma

- Very high destruction efficiency for organic materials.
- Up to 90% reduction in volume of waste.
- Potential for energy production.

- Non-leachable (vitrified) slag is recyclable.
- The plasma arc torch has no moving parts, thus operating costs may be lower than conventional incineration.

Disadvantages of Plasma

- High-energy demand (electricity) for processing, thus reducing the net amount of energy for export. The power demand of the plasma arc torch is about 3,000 kW.
- More complex design than mass burn EfW plants.
- Generally more expensive than EfW plants (but modular build basis may provide greater flexibility).
- Currently worldwide there are limited full-scale applications of plasma arc technology for solid waste treatment.

4.0 TRANSFER STATIONS AND MATERIAL RECOVERY FACILITIES (MRFs)

The main function of a transfer station is to transfer waste from relatively small vehicles, designed for waste collection, into larger vehicles designed for bulk haul over long distances. Transfer stations will range from simple, low technology, container-type transfer stations to large compaction type transfer stations in which waste is discharged onto a tipping floor, and pushed into a "hopper" or pit, then compacted into large vehicles prior to being loaded onto road transfer trailers or rail bogies.

Waste transfer stations vary in design and complexity. The structure and equipment should be assigned based on the following parameters:

- waste composition
- proximity to and requirements of recycling
- quantity of solid waste collected
- haul distance from the proposed transfer station to the landfill
- waste throughput
- site location, and characteristics
- haulage distances, routes and times to disposal facilities
- peak times at which waste is received
- operating hour
- transfer trailer loading and discharging times
- cost efficiency

Transfer stations can be used for material separation and recycling, either as "drop-off centres" (civic amenity facilities for the public) or as an integrated facility for processing waste in a single fully enclosed plant, a material recovery facility (MRF). The MRF achieves separation of the components of waste and recovers useful material from mixed solid waste (dirty MRFs) or from source separated materials (clean MRFs). Better environmental performance is achieved with clean MRFs (due to "clean" input material) compared to dirty MRFs.

It is possible to recover a range of materials, such as paper, plastics, glass, metals, organic materials for composting, or materials for use in refuse derived fuel plants. A mixture of manual and mechanical processing (e.g. shredding, magnetic belts, eddy current separators, trommel screens) can be employed dependant on the quality and types of end products required.

Material recovery facilities can be consolidated within **ecological-industrial parks** (eco-park) to work in synergy with a network of manufacturers by reducing waste, sharing resources to seek to develop business and environmental excellence. Such eco-parks would adopt pollution prevention strategies and resource recovery facilities for energy, waste and materials, to achieve enhanced environmental and economic performance. **Figure 2** shows the typical function of an MRF in household waste management.

Advantages of MRFs

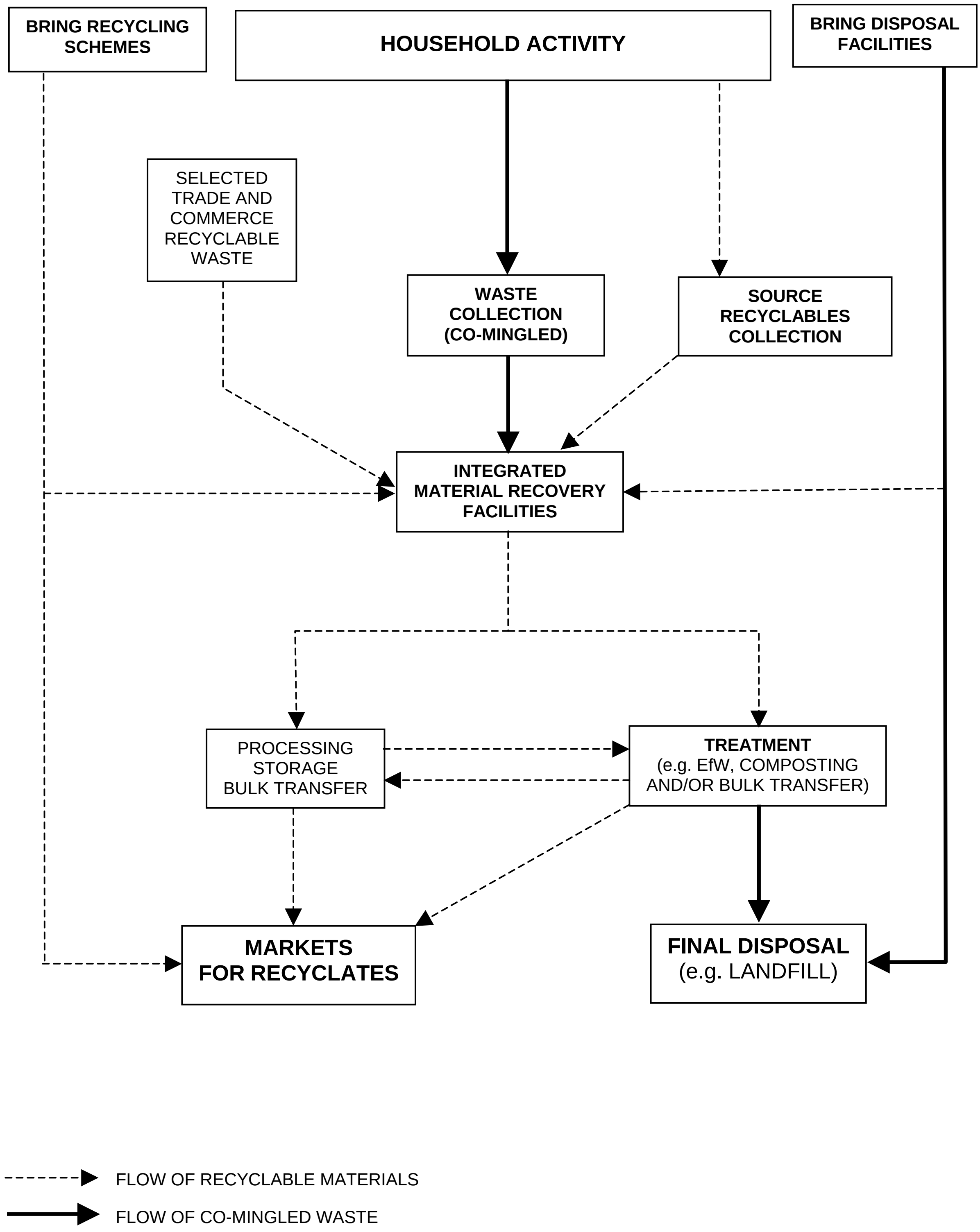
- Economies of scale of operation.
- Source of secondary material production.
- Potential for significant quantities of waste to be recovered.
- Capital and operating costs cheaper than thermal treatment options.

Disadvantages of MRFs

- Potential for odour nuisance, dependant upon whether clean or dirty MRF.
- Airborne contaminants.

Appendix 6A

Figure 2 : Typical Function of an MRF in Household Waste Management



Source: Derived from Material Recovery Facilities, Publication of Institute of Wastes Management U.K.

5.0 LANDFILL

Landfill involves the controlled deposit of waste onto or into land, often created by former mineral extraction activities. It is usually undertaken as a means of restoring the land to its former levels to facilitate appropriate after uses such as agriculture, forestry or recreational purposes.

In Malaysia the siting of landfill sites is determined by Local Authorities in co-operation with State Authorities, and generally there is no restriction on the types of waste they may accept (except for hazardous waste which must be consigned to the purpose-built facility in Negeri Sembilan).

Except for sites for the deposit of inert waste, new landfill sites should be lined to ensure that leachate and other potential pollutants do not escape from the site and enter underground water sources etc. Sites are usually divided into "cells" where waste is tipped and compacted to pre-defined contours. Litter and pest control is undertaken through the covering of active cells on a daily basis. On completion, the site is capped with an additional membrane (usually high-density polyethylene - HDPE), soil and vegetation.

5.1 Landraising

Landraising involves raising the levels of a given piece of land by depositing waste and altering the natural topography of the land. Landraising provides an alternative to landfilling as the number of mineral void spaces suitable for waste tipping decrease. While greenfield sites are often used, this practice is also often used as a way of restoring previously used or contaminated land to a beneficial after use.

Advantages of Landfill

- Economic way to dispose of waste.
- The only practicable means of ultimate disposal of some wastes.
- Suitable for a wide range of wastes.
- Landfill gas is a clean source of fuel for heat and power generation.

Disadvantages of Landfill

- Large land area required.
- Risk of ground and groundwater contamination from operational and closed landfill sites.
- Energy recovery is less efficient than other technology options e.g. incineration.
- Release of methane (a "greenhouse" gas) to atmosphere[5].
- After landfilling, the land may retain contamination for an extensive period of time preventing its use for development[6].
- Noise, odour and visual intrusion may cause a nuisance.

[5] "Even in the most sanitary landfills they only capture up to 70% of methane" (Composting Association of UK, 1998).

[6] Persistent soil contamination in previous, poorly-managed landfill sites has made them difficult to develop after closure (U.K. House of Commons Select Committee on the Environment Sixth Report 1998).