



DESCRIPTIONS OF WASTE TECHNOLOGIES –  
**LANDFILL**

WA Waste Authority - Strategic Waste Infrastructure Planning



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# WA WASTE AUTHORITY

## STRATEGIC WASTE INFRASTRUCTURE PLANNING

### Concise Descriptions of Modern Waste Technologies

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#### Landfill FINAL REPORT

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## APPENDICES

Appendix A WA WASTE AUTHORITY MAP OF PERTH METRO LANDFILL SITES



# 1 SUMMARY

Hyder Consulting has been commissioned by the Western Australia Department of Environment Regulation (DER) on behalf of the Waste Authority to provide a concise description of best practice Landfill technologies as a means of modern waste treatment and resource recovery.

This report summarises a number of key parameters relating to this technology that have been requested by DER. It is one of a series of reports reviewing various waste treatment and disposal technologies that may be applied in the Perth Metro and Peel Region. The information is presented in a concise, standardised table format that, when merged with the information on other waste technologies will allow a comparison of key parameters across the technology types and inform the development of the Waste and Recycling Infrastructure Plan for the Perth Metropolitan and Peel Region.

The purpose of the project is to provide sufficient information on each technology type to allow a comparison with other waste technologies and help to assess the potential for each option to play a role in the future Perth and Peel waste infrastructure mix. The project is intended to inform Government planning and strategic decisions.

Landfill is a well-established and proven waste technology that can potentially make a significant contribution to the generation of renewable energy. It does not however contribute greatly to resource recovery being at the bottom of the established waste hierarchy. Landfill is, however an essential component of an integrated waste management system where waste materials that cannot be recovered or treated through other waste management facilities or processes can be disposed. Landfill is not a total waste solution in itself, however landfill should be considered as part of a broader integrated waste management system and it should complement other waste management systems.

A landfill facility is a controlled disposal method for solid waste, whereby waste is placed into the ground and buried to reclaim low lying ground or excavated pits. Engineered landfills are an established approach of waste management, which can generate renewable energy. Landfills do not, however, promote resource recovery; its viability will often depend heavily on the local or regional supporting integrated waste management facilities available.

Although there are different landfill technology variations and system configurations, for the current project, Hyder has focussed on three main categories of landfill processes for detailed analysis. A key differentiator is the type of waste that can be accepted at the landfill, as follows:

- 1 Standard Putrescible Landfill ('dry tomb' type)
- 2 Bio-reactor Landfill
- 3 Non-putrescible Landfill

The information presented in this report is a combination of details gained through consultation with the operators of the case study facilities and information arising from a review of relevant and available literature on the topic. Additional general information has been included based on Hyder's industry knowledge and experience.

On the basis of selection criteria agreed with DER, Hyder selected the following landfill facilities to use as case studies.

Type	Site	Location
Putrescible (dry tomb)	A	SA
Putrescible (bio-reactor)	B	VIC
Non-Putrescible	C	NSW

This report presents key details of each reference facility based on information provided by the operators. In some cases, information was not provided due to commercial concerns. The facility information has been summarised in a table as requested by DER to enable quick comparison with other waste management technologies. Section 8 contains a 'Study Synopsis' table for landfill which summarises the parameters across the different landfill variations.

## 2 INTRODUCTION

Following release of the *Western Australian Waste Strategy*, the Western Australian Waste Authority (WAWA) and Department of Environment and Conservation (DER) have established the Waste and Recycling Infrastructure Plan for the Perth Metropolitan and Peel Region. Working Group, with the aim of developing a plan for the future waste disposal and recycling infrastructure needs of the Perth metropolitan and Peel regions. The Working Group will guide the development of a *Waste and Recycling Infrastructure Plan for the Perth Metropolitan and Peel Region*.

The WA Waste Strategy sets out challenging recovery targets for each of the major waste streams: municipal solid waste (MSW), commercial and industrial waste (C&I) and construction and demolition waste (C&D), for both the Perth Metro and Peel regions. One of the key objectives of the Waste and Recycling Infrastructure Plan for the Perth Metropolitan and Peel Region is to identify the waste technology options and infrastructure mix that will help Western Australia to achieve those targets.

Hyder Consulting has been commissioned by DER on behalf of the Waste Authority to provide a concise description of best practice landfill technologies as a means of modern waste disposal. This report summarises a number of key parameters relating to this technology that have been requested by DER. It is one of a series of reports reviewing various waste treatment and disposal technologies that may be applied in the Perth Metro and Peel Region. The information is presented in a concise, standardised table format in Section 7 and Section 8 that, when merged with the information on other waste technologies will allow a comparison of key parameters across the technology types and inform the development of the Waste and Recycling Infrastructure Plan for the Perth Metropolitan and Peel Region.

In the current project, Hyder has focussed on three main types of landfill for detailed analysis:

- 1 Standard Putrescible Landfill ('dry tomb' type)
- 2 Bio-reactor Landfill
- 3 Non-putrescible Landfill

### 2.1 PURPOSE

The purpose of the project is to provide sufficient information on each technology type to allow a comparison with other waste technologies and help to assess the potential for each option to play a role in the future Perth and Peel waste infrastructure mix. The project is intended to inform Government planning and strategic decisions.

# 3 PROJECT METHODOLOGY

The information presented in this report is a combination of:

- (a) Details gained through case studies of representative reference facilities identified by Hyder in consultation with DER; and
- (b) Information arising from a review of relevant and available literature on the topic.

Additional general information has been included based on Hyder's industry knowledge and experience.

## 3.1 CASE STUDIES

Information was gathered for the case studies through direct interviews and consultations with the current operators of the selected existing facilities, and Hyder acknowledges their valuable contribution to the project.

To identify appropriate reference sites to use as case studies in the current project, Hyder has focussed on the criteria listed below. These generic criteria have been applied across all waste technologies described by Hyder, including the present study, and applied where appropriate:

- Use proven, mature and best practice technology;
- Have been operational for at least 12 months;
- Have been operating successfully to a high standard with no known major issues or fundamental failures;
- Are generally large capacity, on a scale that would be appropriate for the Perth Metro and Peel regions;
- Have established sustainable markets for any outputs and products from the process; and
- The operators have agreed to take part in the project and provide information.

As far as possible, Hyder has selected Australian facilities (where they exist), so that the costs, regulatory drivers and environmental standards are likely to be consistent with the Western Australian context.

To facilitate the provision of information by operators, DER wrote an introductory letter to each selected operator to introduce the project, explain Hyder's role and provide assurance as to the protection of commercially sensitive information.

## 3.2 LITERATURE REVIEW

To supplement the information obtained through the case studies and provide a broader view of typical facilities, Hyder has conducted a limited review of available literature on landfill technologies and representative reference facilities. Literature in this case includes:

- Technical publications;
- Published industry reports;
- Journal articles;
- Company websites; and
- Waste and recycling surveys and data reports.

Information obtained from published literature sources has been identified as such and references provided (see Section 9).

### 3.3 KEY PARAMETERS AND INFORMATION

The table below summarises the key parameters and information specified by DER. The same parameter list will be applied to each waste technology category in order to allow information to be presented in a standardised table format and therefore allow comparison across technologies.

Where relevant and representative information was obtained for the case study facilities, this is presented in the summary tables (see Sections 7 and 8). Where information was not available or there was a benefit in providing additional background, the table has been supplemented with information obtained through the literature review.

Ref	Information Parameter	Description
1	Process description	A high level description of the process (or technology type) for managing or treating waste including its purpose, conversion processes, stages of treatment and key inputs and outputs (including energy and waste residues)
2	Feedstocks	Types of suitable feedstocks, pre-treatment requirements, broad physical and chemical characteristics, key exclusions
3	Capacity	Processing or disposal capacity (in tonnes per annum) including typical values and ranges
4	Waste Hierarchy	How and where does the technology fit into the established waste hierarchy?
5	Landfill Diversion Potential	Potential to divert waste from landfill (for example, waste recycled/recovered and waste to landfill expressed as a percentage of total waste sent to facility)
6	Products and Residuals	Identify all products, outputs and residuals from the facility / process (including any potentially beneficial outputs and energy)
7	Capital Cost	Expressed as a total cost and \$ per tonne of annual capacity
8	Operational Cost	Expressed as \$ per tonne of waste processed / disposed
9	Gate fees	Typical gate fees charged to customers. Note gate fees do not necessarily correlate directly with running costs and may include a profit margin and be driven by market forces (i.e., prices of alternatives)
10	Set-up Timeframe	Typical timeframe to establish the technology including planning, approvals, procurement, design, construction and commissioning
11	Lifespan	Typical lifespan of the technology taking into account standard maintenance and replacement practices

Ref	Information Parameter	Description
12	Footprint	Typical land footprint for a facility including for the core technology and any surrounding ancillary requirements (access roads, waste and product storage, buffers, etc.)
13	Buffer zones	Extent of buffers required around the plant, including typical existing facilities and any requirements in regulation
14	Emissions Performance	Typical pollutants arising from the process (solid, liquid and gaseous) – key substances and approximate quantities / concentrations. Also high level estimates of carbon impact including direct carbon emissions and indirect emissions from electricity use
15	Environmental Performance	Compliance with regulations / permits, key environmental impacts including air, water, groundwater, noise, odour, dust, waste arisings
16	Social impacts / costs	Impacts on local community and neighbours, employment and local economy impacts
17	Compatibility with existing systems / technologies and supporting systems	To what extent is the technology compatible with the existing waste management system and facilities (sorting, collection, processing, disposal), what broad changes would be required and which other technologies are required to complement the technology
18	Risks	Identification of potential risks including technical, commercial, environmental, operational and market risks
19	Local Application	Most appropriate application of the technology to the local context (metro or non-metro, medium to high density)
20	Maturity of the technology	How long has the technology been in operation, is it considered proven and how many reference facilities exist in Australia and overseas
21	Availability	Typical annual maintenance shutdown requirements and plant availability as a proportion of the name-plate capacity
22	Penetration	Extent of existing penetration of the technology in the Perth Metro and Peel regions and within Australia (such as number / total capacities of existing facilities)
23	Benefits	Benefits of the technology (financial, environmental, social) compared with alternatives including landfill diversion performance, flexibility, future-proofing, etc.
24	Barriers / constraints	Barriers to implementation including markets for outputs, policy and regulatory constraints, availability of technology and support in Australia, etc.
25	Other relevant information	Any other relevant information which becomes apparent during investigations

## 4 BACKGROUND

Landfill facilities are an established and proven waste management technology for the long term disposal of solid waste residue and, in some cases, for the disposal of liquid waste. Landfills are necessary for the ultimate disposal of waste which cannot be managed using other waste treatment technologies due to economic, social and sustainability ( for example proximity principle,) factors.

Landfills do not contribute to zero waste agendas, and are situated at the bottom of the globally accepted waste management hierarchy. Notwithstanding this, landfills do have a place in an integrated waste management system, however, use of landfills must support other available waste management systems such as source separation.

A landfill facility is essentially an engineered pit or area of land that is lined with a non-permeable matrix to prevent contamination to the surrounding environment and groundwater. Systems to manage the leachate (liquid generated from the landfill) and landfill gas are used throughout the operating life and for a number of decades following the closure of the landfill to monitor emissions to the air and land. Waste is deposited in staged intervals, known as cells, and stored indefinitely. Once the void space of the landfill is full, it is capped (covered with soils and clay, similar to the liner) and restoration is undertaken to rehabilitate the area of land. The rehabilitated land is generally used as park land, and rarely constructed upon due to the potential for settlement.

### 4.1 TERMINOLOGY

Landfill is a term used to describe a facility where waste is to be disposed on land, usually within the upper layer of the earth's mantle. There is no official specification for a landfill. It can be an excavated trench or pit, a canyon or depression or an area of land. Landfills can be engineered (constructed with robust lining system) or unlined. They can be installed with or without leachate or gas systems. Landfills can be classified to take differentiated waste types, such as municipal solid waste, which decomposes, inert waste which does not decompose, and even hazardous waste.

For the purpose of this document, the concept of landfill will be based around an engineered and fully lined landfill which accepts either inert or municipal solid waste (including commercial and industrial waste).

### 4.2 PURPOSE OF LANDFILL

Historically, landfill has been the popular method of waste management around the world. Prior to alternative waste management methods which conserve resources, landfills were established to manage both solid and liquid waste. Landfilling is a well-established and proven system, which is still required in integrated waste management systems to deal with residue waste following maximum resource recovery.

### 4.3 BRIEF PROCESS OVERVIEW

Landfill is a controlled disposal method for solid waste, whereby waste is placed into the ground and buried to reclaim low lying ground or excavated pits. A landfill can also involve the deposition of waste above the ground, forming a mound. Landfills are raised above ground when there is a risk to contamination in wet areas or terrains where excavation cannot take place or pits are not available.

The generic process of landfill involves:

- 1** Excavation of cell (cover material stockpiled);
- 2** Design and preparation of liner (clay, membrane, composite or geo-synthetic), gas recovery system and leachate management system;
- 3** Surface water management;
- 4** Waste delivery to site:
  - a** Waste is deposited into a cell;
  - b** Compaction of the waste;
  - c** Daily cover of soil over the deposited waste;
  - d** When a cell is full, the next cell is excavated and steps 1 and 2 are followed repeatedly until all available space for landfilling is used;
- 5** Gas conversion to power, or gas flaring;
- 6** Leachate treatment;
- 7** Environmental monitoring;
- 8** Final cap and cover;
- 9** Landfill closure and maintenance.

As waste deposited into landfill degrades, it undergoes a number of simultaneous and interrelated chemical, biological and physical processes<sup>1</sup>. An overview of the processes that occur is as follows:

**a** Biological Reactions

Organic material decomposes to produce landfill gases and a liquid discharge. Initially, until the oxygen is depleted in the cell, aerobic bacteria bring about decomposition. When available oxygen is depleted, anaerobic bacteria are able to dominate. Carbon dioxide (CO<sub>2</sub>) is produced in the aerobic stage, whereas CO<sub>2</sub>, Methane (CH<sub>4</sub>) and trace amounts of ammonia (NH<sub>3</sub>) and hydrogen sulphide (H<sub>2</sub>S) are generated in the anaerobic stage.

**b** Chemical Reactions

Numerous chemical reactions are initiated in a landfill together with the biological reactions that take place. A key chemical reaction is hydrolysis and dissolution of organic matter into the liquid percolating through the deposited waste, this liquid will eventually form leachate. Other chemical reactions can have an impact on the clay liner whereby organic compounds can interact with structure and permeability of the liner. The many interrelated chemical reactions which take place in landfill are not fully understood and are the subject of on-going research.

**c** Physical Reactions

The physical reactions are the diffusion of gases within the landfill and emissions of gases to the surrounding environment, movement of leachate within the landfill and underlying soils and settlement caused by waste decomposition.

Landfills have many controls in place to manage these processes during operation as well as post-closure. These include:

- Environmental monitoring;
- Landfill operational plans;

- Landfill closure and reclamation plans;
- Control of gas movement through gas recovery / flaring;
- Surface water drainage;
- Control of leachate through well systems;
- Settlement management; and
- Landfill closure and remediation plans.

Landfills have an operational life, throughout which waste is deposited until all void space is filled. The landfill is then capped and begins a post-closure care period where monitoring of air emissions and leachate takes place for an extended period - generally between 30 and 50 years.

## 5 CASE STUDY DETAILS

On the basis of the selection criteria set out in Section 3.1, Hyder selected the landfill sites outlined in Table 5-1 to use as case studies.

**Table 5-1 Landfill Case Studies**

Type	Site	Location
Putrescible (dry tomb)	A	SA
Putrescible (bio-reactor)	B	VIC
Non-Putrescible	C	NSW

This section provides a brief description of each facility, including the key features that make them representative case studies of best practice landfill technologies, and how they satisfy the criteria set out in Section 3.1.

### Case Study 1 – Landfill A, SA

This landfill facility is located close to the edge of a metropolitan area in South Australia; it began operating in 2005 and has an operating life of forty years. The facility is a putrescible landfill that will be undertaking gas recovery collection within the next six months. The landfill accepts the following materials:

- Domestic waste;
- Commercial and Industrial waste;
- Municipal waste;
- Green waste;
- Kerbside collected green waste;
- Construction and Demolition waste;
- Clean fill;
- Intermediate landfill cover;
- Non-friable asbestos;
- Quarantine waste;
- CCA treated timber;
- Low level contaminated soils;

- Liquid treatment plant residues; and
- Shredded tyres.

The landfill began construction in 2002 after a 5 year planning and approvals process. The facility started operations and began to accept waste in 2005. The facility has a development approval and licence to accept an unlimited volume of waste per annum. In 2012, 300,000 tonnes of waste was accepted and landfilled at the site. The buffer zone that surrounds the facility is a minimum of 500m in accordance with SA regulatory requirements.

The landfill site has a 15m layer of clay below it. Groundwater flow is exceptionally slow and therefore will mitigate the escape of leachate and its impacts to the surrounding environment, during operation and post- closure of the site.

The putrescible landfill is engineered to a standard design and operates on standard landfill operating methods consisting of placement of waste, compaction and cover. Leachate systems are operated on site to collect and treat leachate.

The landfill is in the process of being fitted with gas recovery system which will become operational within the next six months.

The landfill is expected to operate a total of forty years until 2045. The aftercare monitoring period is expected to be a minimum of thirty years until 2075.

## Case Study 2 – Landfill B, VIC

This landfill is situated at the edge of a metropolitan area in Victoria. The site includes a landfill facility and a recycling transfer station. The landfill is a bioreactor landfill and generates renewable energy through recovery of the methane produced at the site. The landfill has an operating life of over one hundred years based on a 350,000 tonnes per annum intake of waste (as stipulated by the development approval). The site has an EPA Licence to accept the following waste types:

- Putrescible waste – waste from homes, councils, commercial and industrial premises, except prescribed industrial waste.
- Solid inert waste – all types;
- Asbestos – all types;
- Contaminated soil – Category C soils that are contaminated by industrial processes and that are classified as "low level"; and
- Small vehicles carrying household and garden waste are also accepted at the transfer station.

The on-site transfer station conducts recycling for a range of materials including:

- Engine oil in domestic quantities (maximum of twenty litres per person);
- Car batteries;
- Truck and car tyres (charges apply, as tyres must be removed from site);
- Cardboard;
- Plastic bottles and cans; and
- All metals.

The site commenced operations in 2000, following a ten year establishment process of planning approvals and construction. There is a buffer zone surrounding the site at a minimum of 500m,

although some parts of the site have a greater buffer zone distance up to 1.5km. The site is on the fringe of the metropolitan area, away from residential settlement.

The bioreactor technology recirculates the majority of the leachate back into the landfill to accelerate the decomposition and stabilisation of biodegradable waste. This results in enhanced landfill gas generation and recovery, reduced leachate treatment requirements, and reduced future post-closure care requirements.

The facility generates 5.5 MW of renewable energy which is exported to the electricity grid.

The landfill operates a transfer station on-site which accepts recyclable materials. Metals are further recovered from the landfill using magnets fixed to the tip face of excavators.

### Case Study 3 – Landfill C, NSW

This landfill is a non-putrescible landfill located at the edge of the metropolitan area in NSW and is well served by major road networks. The site is a clay extraction void which has had historical brick quarrying works. It has development approval to accept a maximum of 430,000 tonnes per annum.

The landfill accepts low level contaminated soils (can include asbestos) and non-putrescible general solid waste. The waste materials are generally commercial and industrial process residues. Timber, green waste (garden) and C&D waste is also accepted at the landfill facility, however this is recycled off-site.

Small quantities of landfill gas are generated at the site and currently flared. Leachate generation is very minimal at the site as there is no putrescible waste accepted at the facility and therefore leachate that is generated is recirculated back into the landfill.

The buffer is stipulated at 250m by the development approval and this distance is based on the regulatory framework.

# 6 LITERATURE REVIEW

## 6.1 PROCESS DESCRIPTION

Landfilling is the method of waste disposal used most commonly for municipal solid waste. It involves the controlled deposition of waste into the upper layer of the earth's surface for treatment and long term storage. Organic wastes decompose over time, causing many chemical and biological reactions between the waste materials and surface water entering the landfill. These reactions lead to the creation and dispersion of landfill gas within the landfill and surrounding environment, and the generation of leachate. Landfill gas and leachate in modern landfills are managed to prevent pollution of the surrounding environment. Systems are installed to collect gas for recovery and subsequent electricity generation, or for flaring, and systems are installed to collect and treat leachate.<sup>i</sup>

The landfill method for waste disposal has been used since early civilisation. Suitably engineered landfill systems are very effective in managing waste which cannot be physically or financially managed in an alternative manner.

### 6.1.1 OPERATIONAL METHODS

There are many operational methods for landfilling that have been developed through historical field experience. A plan of operation for the placement of the waste material is required to utilise the available area at a landfill. There are three principal methods and are classified as area, trench and depression<sup>ii</sup>.

#### 1 Area

When the terrain is unsuitable for excavation of trenches in which to deposit the waste, the area method is applied. An embankment or platform is built, on which waste is deposited in thin layers and compacted until the height of the compacted waste reaches a specific value. At this height and at the end of each day's operations, a 150mm-300mm layer of cover material ('daily cover') is placed over the deposited waste. Daily cover is applied as a means of controlling litter and vermin.

In most cases of landfill operation, the cover material is taken from adjacent land or borrow pits (where material has been dug for use at another location) in the surrounding area. It is generally hauled in by truck or earth moving equipment.

Successive deposition of waste, compaction operation and deposition of daily cover is undertaken on a daily basis until the final height specified in the development plan is reached. A final layer of cover material (a 'cap') is used when the fill of waste reaches the final landfill design height.

The next landfill cell is created and the same operations commence. Landfills are made up of a series of cells; each 'cell' being a completed section including the cover material.<sup>ii</sup>

#### 2 Trench

The trench method can be applied to areas where the water table is well below the surface, and where there are adequate depths of cover material available. The process is begun by excavating a portion of the trench using a bulldozer and stockpiling the soil to form an embankment behind the first trench. In larger landfills, a dragline and a series of scrapers are used to form a deep pit.

Waste is then deposited in the trench in thin layers and compacted, with cover material placed upon the waste deposition on a daily basis. Cover material is sourced by either

continued excavation of the trench or excavating an adjacent trench. The operation continues until the desired landfill height is reached.<sup>ii</sup>

### **3 Depression**

Areas where natural or man-made depressions exist can be developed as landfills. Canyons, ravines, dry borrow pits and quarries are examples of the depression landfilling method. The operations to deposit waste in depressions will vary and depend on the dimensions, the hydrology and geology of the site, and characteristics of the cover material.

If leachate or gas has the potential to contaminate the local environment, the bottom of the landfill is lined with clay as a seal to prevent leachate escape and encapsulate the waste (this is called a clay liner). Wet areas tend not to be used for siting landfills because of the impacts associated with contamination of groundwater, structural stability and generation of odours. If wet areas are used, then distinctive provisions must be made to contain or eliminate the escape of leachate which includes draining the site and using clay liners or other appropriate sealants.<sup>ii</sup>

## **6.1.2 LANDFILL TYPES**

There are a number of types of landfills and are classified differently between jurisdictions and around the world. In general the landfill types are: putrescible, non-putrescible, inert and hazardous. The study is focused on the following landfill types:

### **1 Putrescible Landfill**

Landfills which accept putrescible waste, for the purpose of this study, are described as a putrescible landfill. Classification of landfills differ in each state and around the world. The general process as described in Section 4.3 is used for the operation of a putrescible landfill.

### **2 Bioreactor Landfill**

The bioreactor landfill is one which accepts putrescible waste and uses an enhanced process to increase the microbial activities in the landfill under anaerobic or aerobic conditions. In an anaerobic bioreactor landfill, this is done through the reinjection and recirculation of the leachate generated by the landfill and /or water. This process accelerates the decomposition of waste and therefore rapidly stabilises the waste whilst generating landfill gas at a quicker rate.

In an aerobic bioreactor landfill, leachate is re-circulated into the landfill in a controlled manner whilst air is injected into the waste mass, using vertical or horizontal wells, to promote aerobic activity and accelerate waste stabilisation.

Waste within a bioreactor landfill must be kept extremely moist in order to achieve the accelerated decomposition rate. This causes increased leachate to be generated and increased landfill gas. This increased rate of landfill gas must be managed properly in order to mitigate any effects on air quality and to control greenhouse emissions.

The end result is that the landfill gas is produced faster and hence the post-closure maintenance period is reduced. It is estimated that landfill gas recovery is limited to 10-15 years after landfill closure<sup>iii</sup>, a significant reduction in the post-closure period which normally consists of decades of monitoring. In addition, the speed of recovery results in a reduced operational requirement. These long term recovery and monitoring requirements can place financial liability on landfill owners and therefore increasing disposal costs to fund post-closure activities.

Another benefit is that the stabilisation of waste in a bioreactor landfill occurs at a quicker rate, and results in greater airspace recovery within the landfill. This allows more waste to be deposited and hence more revenue to be generated from the same landfill void capacity. In turn this can alleviate any negative settlement impacts, allowing quicker redevelopment of the site.

As leachate is recirculated into the bioreactor landfill, the treatment of leachate is not required or is relatively minimal in the event of excess quantities. It follows that the costs for leachate treatment, if it is required, is relatively small compared to a normal putrescible landfill.

### **3 Inert Landfill**

Man-made depressions such as redundant quarry pits often require filling to allow for redevelopment<sup>iv</sup>. Filling pits with inert material by establishing the pits as inert landfills is a practical method to complete this task.

Inert waste materials are defined or classified by the regulatory framework within the jurisdiction in which the landfill is situated. Inert materials are generally a stable, non-hazardous material which are not practical or economic to re-use or recycle. Infilling using inert material results in a stable, compacted and rehabilitated parcel of land that can be redeveloped with little cause for concern to the environment and biodiversity.

## **6.2 LANDFILL FEATURES**

### **6.2.1 CAPACITY AND FOOTPRINT**

The footprint and capacity of the landfill is limited by the available land space and the development licence held. Landfills can be as large or as small as required. The operating capacity is dependent on the active landfill or landfill cell that is currently in use for the depositing of waste, and the operational staff and equipment used.

For example, consultation with Australian landfill facilities provided information on their footprints and capacities. One facility was 350ha, which included the buffer zones and all ancillary systems such as the gas collection system, leachate collection system, weighbridge, access roads and the on-site transfer station. The annual capacity varied between the three sites from 250,000 tonnes to 430,000 tonnes. These are vastly different but are typical of landfills.

### **6.2.2 FEEDSTOCK**

There is no particular specification for the types of feedstock suitable for landfill. It is physically possible to accept any waste but the licence places restrictions as a waste acceptance criterion. The jurisdiction specifies the types of waste which can be accepted at a landfill through the development approval.

No pre-treatment is required although, normally, it is preferable that waste materials are solid, however liquid wastes can sometimes be accepted depending on the licence.

Landfills are commonly classified to take particular categories of waste and this classification system varies between jurisdictions. As a general rule, landfills are divided into those which accept hazardous waste and those which only accept non-hazardous waste (which include municipal solid waste, putrescible waste) and inert landfills (which can accept stable materials which undergo very little or no decomposition).

## 6.2.3 PRODUCTS AND RESIDUALS

### 1 Landfill gas

There are a number of gases that occur in landfill due to the decomposition of organic waste. The principal gases generated include:

- Ammonia;
- Carbon dioxide (CO<sub>2</sub>);
- Carbon monoxide;
- Hydrogen;
- Hydrogen sulphide; and
- Methane (CH<sub>4</sub>).

Most of the gas produced from the decomposition of organic waste in the landfill is CH<sub>4</sub> and CO<sub>2</sub>. Landfills should be designed to release landfill gas to the atmosphere through vents, or flared at the point of release, or collected for the production of energy.<sup>i</sup>

If landfill gas is not being collected or flared, and is vented to the atmosphere in an uncontrolled manner, methane can accumulate in nearby enclosed areas posing a risk of explosion.

The density of CO<sub>2</sub> is higher than air and CH<sub>4</sub>, resulting in movement towards the lower area of the landfill and even into the groundwater. As CO<sub>2</sub> is soluble in water, it will result in lowering the pH, causing the mineral content and hardness of the water to increase.<sup>i</sup>

There are various mechanisms that can be used to control landfill gas. The construction of vents or barriers controls movement of gas in the landfill. The other mechanism is by the installation of gas recovery systems.

Gas recovery systems involve the construction of gas recovery wells into deposited waste. Where gas is to be recovered, clay liners are used to prevent the gas from escaping from the landfill. In theory, there should be no gas generated at an inert landfill.

### 2 Leachate

Leachate is usually observed at the bottom of landfills, however has the potential (where there is a problem with the clay liner or in an unlined landfill) to escape or move through the underlying strata. It can also move laterally depending on the characteristics of the surrounding material.<sup>ii</sup>

Allowing the leachate to percolate through the underlying strata can filter the chemical and biological constituents contained within it by the adsorptive characteristics of the strata (this is dependent, however, on the characteristics of the strata and its clay content). However, because of the potential risk to groundwater, best practice landfill operation requires the collection and treatment of leachate to eliminate this risk.

Leachate can be controlled by containment (using best practice clay liners) and elimination through collection and treatment. Membrane / geo-membrane liners are a less permeable but more expensive alternative, and are susceptible to damage from filling operations.<sup>v</sup>

Surface water infiltration is another factor that requires control in order to manage leachate, as surface water contributes to the total volume of leachate. Surface water can

be controlled effectively through the use of an impermeable clay layer, appropriate surface slope of the pit and adequate drainage.<sup>v</sup>

Bioreactor landfill systems involve the collection of leachate, pumping it to the top of the landfill and injecting it through perforated lines located in drainage trenches. Typically this recirculation of leachate results in a greater production of gas. Alternatively, if leachate is not recirculated, water can also be added in a similar manner.<sup>iii</sup> In theory, no leachate should be generated at an inert landfill.

### 3 Settlement

Landfills settle over time as waste decomposes. The rate of settlement is dependent on the following:

- The initial compaction;
- Characteristics of the waste;
- Degree of decomposition;
- Effects of material consolidation following the production of gas and leachate; and
- Height of the completed landfill.

Inert landfills are considered more stable and normally would not be subject to settlement problems due to the inert nature of the waste, providing waste has been placed within the landfill and compacted accordingly.<sup>v</sup>

## 6.2.4 RESOURCE RECOVERY POTENTIAL

Although landfill as a waste management technology is positioned at the bottom of the established waste hierarchy (being a form of disposal), the operation has the potential for on-site recovery and recycling, either by the provision of a drop off facility, a transfer station or a materials recovery facility (MRF). Therefore an element of recycling is possible at a disposal site.

At an inert landfill, a construction and demolition waste recycling facility with crushing facilities would enable masonry to be crushed and resold as aggregate or fill material. Other materials could also potentially be recovered such as timber and metals.

Putrescible and bioreactor landfills have an element of recovery through the power generation potential of the methane produced as landfill gas. If there is gas recovery and on-site recovery of materials at a landfill, these landfills cannot be categorised as strict disposal because these activities provide additional diversion of waste from final disposal.

At the Victorian landfill in Case Study 2, some excavators are retrofitted with a magnet to draw out any ferrous metals deposited within the waste, allowing further recycling of metals. There is also a transfer station on-site which recovers waste that is destined for disposal.

The examples provided demonstrate that landfill can support, and is compatible with, on-site recovery technologies: from simple magnets to recover materials for recycling, to a recycling facility with crushers to generate re-usable products.

## 6.3 COSTS AND INCOMES

### 6.3.1 CAPITAL COST

The capital cost is based on the cost of purchasing the land before waste can be deposited, as well as construction and preparation of the cells throughout the landfill's operational life. In addition infrastructure such as roads, fencing, and fire fighting systems etc should be considered. The cost will vary depending on the type of landfill and its dimensions.

Bioreactor landfills are more expensive to construct and operate than dry tomb landfills, but can reduce the post-closure period and post-closure care required, which will save costs in the long term.

A putrescible landfill will require a robust lining system, leachate treatment system and gas management system, whereas an inert landfill only requires a minimal lining system.

The capital cost is relative to the site area (including the buffer zone). The cost of equipment is part of the capital cost. Equipment requirements depend on the size of the landfill operation, local site conditions and the method of operation. Typical equipment used at landfills include:

- Crawlers;
- Rubber-tyred tractors;
- Scrapers;
- Compactors;
- Draglines;
- Motor graders; and
- Excavators.

### 6.3.2 OPERATIONAL COSTS

The operational costs include labour, maintenance of equipment, cover material, leachate treatment, fuel use and on-site utilities.

### 6.3.3 INCOME

Income is generated at landfills from gate fees, the export of power from landfill gas and the sale of recovered materials.

The amount of void space to accept waste determines the potential for income and therefore the larger the landfill, the more potential for income.

## 6.4 RISKS

As with any waste management technology, there are risks associated with landfill. The most prominent risks are the environmental risks from pollution to groundwater by leachate and to air from landfill gas. Other notable risks include the catastrophic failure of the structure of the landfill during the landfill's operational life or after closure, and the potential for methane build up and therefore risk of explosion and /or fire.

Technical, commercial and operating risks are not as significant as shown by the number of sites operating satisfactorily around the world. Technically, landfill is a proven and established

method for long term storage and treatment of waste. According to the 2007 Waste Management Association of Australia National Landfill Survey<sup>vi</sup> there are 458 landfills operating in Australia.

Commercially, there will always be a requirement for cost effective disposal of waste material that cannot be readily treated in an alternative safe manner. Aside from the operating hours, landfills do not have shutdown periods and will remain open until all the void space is filled.

As landfill levies increase, and the carbon pricing mechanism impacts operating costs, other waste management technologies will become more economical to treat waste. This increases the commercial risk for landfills.

Operationally, running a landfill is relatively inexpensive. It has no shutdown or maintenance periods that affect the management of waste and unless the price of power for the leachate and landfill gas systems or the price of diesel becomes unexpectedly high, the operational cost will be relatively low.

There are no market risks to consider for landfill technologies. The management of by-products (leachate and landfill gas) is part of the technology and is well proven. Providing the risks for the landfill are carefully managed, the technology is an operationally, economically and environmentally sound method of managing residual waste.

It should be recognised that litter, traffic, noise and odour issues associated with landfills can result in community opposition to the operation, however with adequate buffer zones and well managed operations, the associated risks are manageable.

## 6.5 ENVIRONMENTAL CONSIDERATIONS

Landfills require a licence to operate which is granted by the state regulatory authorities. The licences have conditions which stipulate how the landfill must operate, and the landfill must have a management plan which addresses an environmental monitoring program for the facility. The operations must comply with the regulatory framework and have control measures in place to manage the environmental receptors that can potentially be impacted from landfill operations.

The common environmental receptors that are susceptible to impacts from landfill include water (groundwater, surface water and stormwater) and air. Nuisance from odour, birds, rodents and pests, windblown litter, traffic movements and dust also impact neighbours and local communities.

There are a number of control measures that are usually implemented to protect the environment from the impacts associated with the construction, operation and decommissioning of landfills. These include buffer zones, daily cover, correct drainage and environmental monitoring.<sup>1</sup>

Buffer zones are a regulatory requirement around landfill facilities, with the extent of the buffer specified by the jurisdiction and considered on a case by case basis during the planning approvals stage. Buffer zones are used to control odour and visual amenity issues to local communities, and to provide protection to environmental features such as watercourses. Generally, buffer distances pertain to the distance from the landfill to features such as: significant environmental or conservation value sites, residential areas and watercourses.

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<sup>1</sup> WA DER has a draft document on Siting, Design, Operation and Rehabilitation of Landfills, published in 2005. The International Solid Waste Association has published Landfill Operational Guidelines.

Landfills also cannot be situated within a drinking water supply catchment or overlying a drinking water aquifer.

A non-putrescible landfill consulted for this study sited in NSW has a 250m buffer specified and is 40m from a watercourse.

Daily cover is a layer of material which is placed over the daily deposit of waste at the end of each day. Daily cover with soil or other inert materials usually effectively manage the issues associated with windblown litter, odour, scavenging birds, vermin and pests and mitigate the risk of fire and visual impacts.

Litter screens or fences around the landfill site are often used to control and reduce issues with litter. A wheel wash system will reduce the transfer of mud and dust onto the roads.

The risk of fire is significant at landfills and measures need to be in place to prevent fires and to manage any incidents should they occur. A fire prevention and control plan should be implemented, which includes such measures as internal temperature and gas composition monitoring.

Stormwater drainage at landfills must be designed to manage flood risks and avoid adverse effects from sediment, landfill leachate and contamination from site run-off. Drainage must also be considered during the final capping of the landfill.

Environmental monitoring for leakage of leachate and movement of landfill gas around the site is necessary. Sampling of groundwater and leachate discharge monitoring should be implemented across the site and surrounding areas to assess any pollution potential to the water quality from the landfill.

CO<sub>2</sub> and CH<sub>4</sub> gas emissions from landfill are unavoidable due to the decomposition of biodegradable waste, however gas collection systems can aid in recovering as much gas as possible. Monitoring of gas emissions help in identifying where large volumes are being emitted. A long term gas monitoring program should be in operation across the site and allow for control measures to be applied such as flaring where required.

Although landfill causes emissions to the air, it can also generate renewable energy through recovering methane for power use.

There are numerous social impacts that come with any waste treatment facility including landfills. The *not in my backyard* (NIMBY) attitude is prevalent for all waste infrastructure, however the careful planning and siting of facility and the use of buffer zones can substantially mitigate this problem.

Local communities are aware that waste treatment is an essential component to urban community living. It is essential to provide the community with confidence that the controls to manage the impacts on the local community will be in place. Information must be provided on the positive benefits that the facility will bring, such as the provision of employment opportunities directly at the facility as well as the generation of power.

## 6.6 APPLICATION OF LANDFILL

Notwithstanding the fact that landfill technology is well proven, the typical set-up time for a landfill can vary significantly. For instance, a putrescible landfill can take between six and ten years from planning approval to commissioning.

It is not uncommon to find landfills at the fringes of the metropolitan area, away from urban settlements, but close enough to serve the metropolitan area.

The lifespan of the landfill is typically between a minimum of fifteen years up to one hundred years, depending on the available void space and the rate of filling. General maintenance activities with gas management and leachate systems will not affect the filling operations and therefore a landfill facility generally does not experience shutdowns.

## 6.6.1 DESIGN AND OPERATION OF LANDFILLS

In the design and operation of landfills, there are a number of considerations including:

- Land requirements;
- Types of wastes that must be handled;
- Evaluation of potential emissions (for gas and leachate);
- Design of drainage and seepage control facilities;
- Development of an operational plan;
- Design of a solid waste filling plan; and
- Equipment requirements.

Important factors that must be considered within the operational plan, solid waste filling plan and equipment requirements are<sup>1</sup>:

- Access;
- Cell design and construction;
- Cover material;
- Drainage;
- Equipment requirements;
- Fire prevention;
- Groundwater protection;
- Land area;
- Landfilling method;
- Litter control;
- Spreading and compaction;
- Unloading area;
- Communications;
- Days and hours of operation;
- Employee facilities;
- Equipment maintenance;
- Operational records;
- Salvage and recovery; and
- Weighbridge facilities.

## 6.6.2 LANDFILL OPERATION PLAN

A landfill operation plan considers the layout of the site and a practical operating schedule. In planning the layout of the site, the following features must be determined:

- Access roads;
- Equipment storage;
- Weighbridge;
- Storage for special waste/quarantine;
- Topsoil stockpile areas;
- Resource recovery stockpiles;
- Green waste management;
- Landfill area; and
- Planting/restoration/seeding.

## 6.6.3 SOLID WASTE FILLING PLAN

This plan will be in a pictorial format and its development is dependent upon the characteristics of the site. A detailed drawing is generally completed which shows the proposed layout of individual landfill cells and features for the control of gas and leachate.

## 6.7 BENEFITS AND BARRIERS OF TECHNOLOGY

The landfill as a waste treatment facility is an established, cost effective and bankable technology. The landfill has the potential to recover recyclables on-site prior to disposal using simple mechanisms such as magnets to recover metals, or use of a transfer facility or drop-off facility on-site.

Landfills can operate for a short period or very long periods, and do require rehabilitation and close monitoring for many years following closure. The bioreactor technology is a proven method to speed up and stabilise the landfill and hence allow for faster redevelopment of the land.

Landfill technology is relatively cheap to design and implement, it requires no maintenance and is available most of the time (unless closed due to extreme bad weather). It has a very large capacity and throughput, waste requires no pre-treatment (apart from optional resource recovery activities) and is limited only to the classification of the landfill as to which waste types can be accepted.

Even though leachate and gas emissions from landfills pose a risk to the surrounding environment, there are recognised control methods and systems to mitigate the associated risks and impacts.

There are no major market constraints to consider since the renewable energy market is well established, and technology and systems for managing the environmental risks are available.

However, there are some disadvantages and constraints to the use of landfills. The set-up time period for a landfill is considerably long due to the process of obtaining approval to construct and operate the landfill. This incorporates achieving a design which satisfies both the community and regulatory authorities, ensuring environmental impacts and social impacts are appropriately addressed.

Because of the length of time involved, landfilling of waste streams without having undergone any form of resource recovery to retrieve resources and minimise disposal volumes is not only a lost opportunity for recycling, but also could be considered to be a misuse of landfill void space.

## 6.8 EXISTING FACILITIES

According to the WMAA National Landfill Survey<sup>vi</sup>, there are 458 landfills operating in Australia. The breakdown in the number of sites, by their annual capacities in each state, can be obtained from WMAA. It should be noted that capacity data for NT and ACT, and information on the classification of the landfills in each state, is not available in the current database.

# 7 SUMMARY OF WASTE TECHNOLOGY FEATURES

In the project brief, DER identified a number of key features and parameters to be identified for each technology type and case study. This information has been collated in the following summary table. By collating information in this standardised and summary format, a comparison of different waste technologies should be simplified.

**Table 7-2 Summary Features – Landfill Technology**

Technology	1	2	3	4	5	6
	Process	Feedstock (type and tonnes)	Annual processing capacity (t/yr)	Place in waste hierarchy	Landfill diversion potential (%)	Products and residuals
Literature Review	Process differs depending on landfill type. See Sections 4.3 and 6.1.	Feedstock differs depending on landfill type. See Section 6.2.	Annual processing capacities differ depending on size of landfill and operating plan of the landfill. See Section 6.2.	Place in hierarchy is typically centred on 'disposal', however recovery of materials for recycling can also be undertaken at the facility. See Section 6.2.	Apart from recovery of materials for recycling undertaken at the facility and, there is no diversion. Gas capture and use for power generation could be classed as diversion.	Products and residuals at putrescible and bioreactor landfills are landfill gas and leachate. See Section 6.2.

Technology	1	2	3	4	5	6
	Process	Feedstock (type and tonnes)	Annual processing capacity (t/yr)	Place in waste hierarchy	Landfill diversion potential (%)	Products and residuals
Landfill A, SA	<p>Putrescible landfill (dry tomb).</p> <p>Process consists of:</p> <ul style="list-style-type: none"> <li>▪ Waste delivered to landfill from a transfer station;</li> <li>▪ Waste is weighed;</li> <li>▪ Waste is deposited and disposed into landfill;</li> <li>▪ Waste is compacted;</li> <li>▪ Waste is covered; and</li> <li>▪ Large netting structures placed over the covered waste to prevent birds from entering the site.</li> </ul>	<p>250,000-300,000 t/yr.</p> <p>Feedstock is mixed: putrescible municipal solid waste (MSW), mixed waste from transfer station, low level contaminated waste, asbestos and solids residues from liquid treatment plants.</p> <p>High level contaminated waste, liquid waste, and wastes not approved by SA EPA Environmental Protection Policy are not accepted.</p>	<p>Unlimited processing capacity as specified by the Development Approval (DA).</p> <p>Could potentially be 1 million t/yr. There are no operational constraints to achieving this.</p>	Disposal with properly installed recovery of landfill gas.	<p>N/A.</p> <p>A transfer station off-site does undertake recovery operations prior to waste being delivered to the landfill facility.</p> <p>An excavator with attachment pulls out metals, timber and concrete for recovery.</p>	<p>Leachate collected.</p> <p>Landfill gas generated.</p>

Technology	1	2	3	4	5	6
	Process	Feedstock (type and tonnes)	Annual processing capacity (t/yr)	Place in waste hierarchy	Landfill diversion potential (%)	Products and residuals
Landfill B , VIC	<p>Bioreactor landfill.</p> <p>The landfill accepts organic and non-organic wastes and safely encapsulates the waste using best practice techniques.</p> <p>The facility recirculates leachate to produce methane gas which is used to generate electricity.</p> <p>There is a transfer station at the site.</p>	<p>210,000 t/yr (60%) of Municipal Solid Waste from Councils.</p> <p>87,500 t/yr (25%) of Commercial and Industrial waste.</p> <p>52,500 t/yr (15%) of Construction and Demolition waste including asbestos, contaminated waste (Category C), and garden waste from cars/trailers.</p> <p>All materials handled in the same way except for asbestos, which is handled separately.</p> <p>Wastes not accepted: liquid wastes, industrial waste, Category A, B, high level contaminated waste (VIC classification) and radioactive waste.</p>	<p>350,000 tonne/yr.</p> <p>The total capacity of the landfill is 50 million tonnes (70 million m<sup>3</sup>).</p> <p>Currently 3.5 million tonnes has been filled.</p>	<p>Disposal with an element of recovery.</p> <p>Disposal, long term storage of waste.</p> <p>Recovery of landfill gas (renewable energy) for generation of power.</p> <p>Recovery and recycling of materials from transfer station.</p>	<p>A magnet fixed to an excavator is used to attract and pull out ferrous metals (steel, and small metal materials), which is transferred to a recycling facility.</p> <p>Further diversion of materials are undertaken on site at the transfer station including oil, car engine batteries, tyres, oil containers, e-waste and cardboard.</p> <p>The total amount of waste diverted for recycling is 15,000 t/yr. This volume is in addition to the 350,000t of processing capacity at the landfill (4% diversion from landfill).</p>	<p>The product generated is methane which is converted to electricity.</p> <p>The facility generates 5.5MW which is exported (equates to 3.2MkWh per month or 38.4MkWh per annum).</p>

Technology	1	2	3	4	5	6
	Process	Feedstock (type and tonnes)	Annual processing capacity (t/yr)	Place in waste hierarchy	Landfill diversion potential (%)	Products and residuals
Landfill C, NSW	<p>Non-putrescible landfill (dry tomb). Defined as a Class 2 landfill in NSW.</p> <p>Reclamation of clay extraction void from brick quarrying works through filling with non-putrescible waste.</p> <p>Non-putrescible waste comprises of low level contaminated soils and non-putrescible general solid waste.</p> <p>General solid waste is compacted and soils are disposed in a separate area (not compacted).</p>	<p>50% low level contaminated soils (can include asbestos).</p> <p>50% non-putrescible general solid waste (process residues) generated by commercial and industrial processes.</p> <p>Green waste, timber and construction and demolition (C&amp;D) waste also accepted on site but recovered for recycling.</p> <p>No food, liquid and hazardous waste accepted.</p>	<p>Annual processing capacity is 430,000 t/yr. This figure is set by the DA.</p> <p>The operating capacity is set by the development approval. There are no operational constraints to increasing the capacity.</p>	<p>Disposal as a final solution for residual waste.</p> <p>The facility recovers and recycles some waste materials including: green waste, timber and C&amp;D waste.</p>	N/A	<p>Landfill gas.</p> <p>The volume of leachate is very little as the site is a very dry facility and leachate is recirculated back into the landfill.</p>

Technology	7	8	9	10	11	12	13
	Capital cost	Operational cost	Gate fees	Set-up timeframe	Lifespan	Technology/ facility footprint	Buffer
Literature Review	<p>No information available.</p> <p>Capital cost dependent on landfill ownership size, void space capacity and landfill process.</p> <p>See Section 6.3.</p>	<p>No information available.</p> <p>Operational Cost dependent on void space, landfill type process, infrastructure and systems on-site and operation plan.</p> <p>See Section 6.3.</p>	<p>Gate fees will vary between jurisdictions and applicable landfill levies and carbon tax.</p> <p>See Section 6.3.</p>	<p>The set-up time for a landfill will vary. A putrescible landfill will take between 6 and 10 years from planning approval to commissioning.</p> <p>See Section 6.6.</p>	<p>The lifespan of a landfill will vary and is dependent on the available void space. It will typically be between 15 years and 100 years.</p> <p>See Section 6.6.</p>	<p>The footprint of the landfill is limited by the available land space and the development licence held. Landfills can be as large or as small as required.</p> <p>See Section 6.2.</p>	<p>Buffer zones are a regulatory requirement around landfill facilities; the extent of the buffer is specified by the jurisdiction.</p> <p>See Section 6.5.</p>
Landfill A, SA	<p>The capital cost for the facility is approximately \$7 per tonne for the expected annual intake.</p> <p>This would include costs for liner construction and final cap.</p>	<p>The operational cost is approximately \$10 per tonne.</p>	<p>The gate fee is approximately \$50 per tonne (exclusive of the landfill levy and carbon tax).</p>	<p>The timeframe for the set-up of the facility was 8 years. The planning process began in 1997 and approval was granted in 2002. The facility became operational in 2005.</p>	<p>The lifespan of the facility is 40 years (based on 40 years' worth of void space filling operations).</p> <p>Post closure works would take approximately 30 years.</p>	<p>The footprint of the site is approximately 100 ha.<sup>2</sup></p>	<p>The buffer at the facility is 500m based on the minimum required (in accordance with the SA regulations). This buffer is exceeded in most areas at the facility.</p>

<sup>2</sup> Estimated using Google Earth

Technology	7	8	9	10	11	12	13
	Capital cost	Operational cost	Gate fees	Set-up timeframe	Lifespan	Technology/ facility footprint	Buffer
Landfill B, VIC	The capital cost is \$11 per tonne of waste for the expected annual intake.	Operational costs are approximately \$7-8 per tonne.	<p>The typical gate fee is \$112/t +GST for commercial waste.</p> <p>The fees charged to councils are slightly less (by \$10 per tonne).due to the longer term contracts</p> <p>50% of the gate fee is carbon tax/landfill levy.</p>	<p>The facility took 10 years in total for set-up. Planning began in 1990. The approval was granted in 1996 and the facility became operational in 2000. Acceptance of the conditions took longer on this project due its unique nature.</p> <p>A realistic set up timeframe would be 6 years.</p>	The lifespan of this facility is over 100 years.	<p>The total site footprint is 350ha.</p> <p>The active landfill, cells which are in operation at any time is 3.5ha (1% of site).</p>	The minimum buffer is 500m (in accordance with regulations, however some parts of the site have a buffer of up to 1.5km, exceeding the regulatory minimum requirements).

Technology	7	8	9	10	11	12	13
	Capital cost	Operational cost	Gate fees	Set-up timeframe	Lifespan	Technology/ facility footprint	Buffer
Landfill C, NSW	<p>The capital cost is dependent on the procurement of the site, and taken in to account is the purchase of the site, or payment of royalties to the landowner. The typical capital costs include: civil cell construction, excavation of the void, engineering works (lining of the cell), aftercare and restoration (final capping).</p> <p>The approximate capital cost element of the facility is \$15 per tonne for the expected annual intake.</p>	<p>The operating cost is dependent on the tonnage throughput and is typically \$10-15 per tonne.</p> <p>The operational cost includes: labour, equipment, plant and maintenance (making up 50% of the cost). The remaining cost is made up from gas field infrastructure, leachate treatment systems, civil works and other ancillary costs.</p>	<p>The gate fees vary significantly and are \$140-250 per tonne. This includes the landfill levy which is currently \$95.20 per tonne.</p>	<p>The planning/ development approval stage can vary and can take between 2 and &gt;5 years. Following site approval, the design, excavation and construction of the first cell can take less than one year.</p> <p>Rehabilitation can vary and depends whether it is done continuously or at the end, and can take over three years. Post-closure care will take between 10 and 30 years as it is a non-putrescible landfill.</p>	<p>This site began operating in 2002. It will operate for 15 years based on the annual capacity until 2018.</p>	<p>30.71ha (does not include existing shared access road with neighbouring business).</p>	<p>The buffer is 250m (as specified by the development approval).</p> <p>There is a 40m buffer distance from a watercourse.</p> <p>Vegetated bunds are utilised to visually screen the site from view of passing motorists.</p>

Technology	14	15	16	17	18
	Emissions	Environmental impacts	Social impacts	Supporting technology required	Risks
Literature Review	Putrescible facilities have the potential to disperse landfill gas into the surrounding environment. The control of emissions can be undertaken by flaring or recovery of the gas See Section 6.2.	There are a number of environmental factors that require consideration. These are normally controlled by the development approval and licence. See Section 6.5	The <i>not in my backyard</i> (NIMBY) attitude is prevalent for all waste infrastructure, however the careful planning and siting of the facility and the use of buffer zones can substantially mitigate this problem. See Section 6.5.	Landfill facilities are able to complement any other waste treatment facility. They will accept the residual component which cannot be treated, recycled or recovered.  No changes would be required to the landfill technology system (new facilities or facilities already operational) to continue supporting an integrated waste management system.	There are many environmental risks associated with landfill facilities. Significant risks include catastrophic failure, fire, and methane dispersion. See Section 6.4.

Technology	14	15	16	17	18
	Emissions	Environmental impacts	Social impacts	Supporting technology required	Risks
Landfill A, SA	The facility is currently undergoing construction to install landfill gas capture systems and will begin landfill gas collection within the next six months.	<p>The licence for the operation of the landfill requires:</p> <ul style="list-style-type: none"> <li>▪ Leachate monitoring every six months;</li> <li>▪ Groundwater monitoring every six months;</li> <li>▪ Quarterly landfill gas monitoring;</li> <li>▪ Noise monitoring as required;</li> <li>▪ Constant monitoring of odour; and</li> <li>▪ Clearing of litter daily.</li> </ul> <p>The landfill has 15m layer of clay below the void space as backup to control any escape of leachate.</p>	<p>Initially, local communities were against the siting of the landfill, however, approval was granted.</p> <p>The community is engaged regularly and issues that are discussed include odour and litter.</p> <p>Local workers are employed where possible.</p>	Landfill gas capture.	<p>The risk to the pollution of the environment and groundwater is addressed through the design of a safe leachate treatment system.</p> <p>The site is located where groundwater flow is slow. Therefore if an incident involving escape of leachate or waste was to occur, pollutants would take a very long time (~10,000 years) to make an impact.</p>

Technology	14	15	16	17	18
	Emissions	Environmental impacts	Social impacts	Supporting technology required	Risks
Landfill B, VIC	<p>Landfill gas comprised of methane, CO<sub>2</sub>, and odour.</p> <p>The facility collects 75-80% of the landfill gas, equating to 1 million m<sup>3</sup> methane per month (12 million m<sup>3</sup>/year). This gas is converted to renewable energy as electricity at a rate of 70-100kW per tonne.</p> <p>The majority of the leachate generated is collected and recirculated. A volume is sent off-site for treatment (20% was sent off site last year).</p> <p>Quantifying the volume of leachate is difficult as the residence time of the leachate is unknown.</p> <p>It is estimated that the facility currently has 60 megalitres recirculating. During an abnormally wet weather period, the leachate volume was estimated to be 100 megalitres.</p>	<p>The facility has the potential to cause impacts to:</p> <ul style="list-style-type: none"> <li>▪ Air (gas emissions, odour, dust);</li> <li>▪ Water (surface water, groundwater); and</li> <li>▪ Amenity (noise, litter, odour).</li> </ul> <p>Monitoring is undertaken over the whole site to identify and mitigate issues.</p> <p>The facility is certified to ISO 14001 and holds a VIC EPA landfill licence.</p> <p>All activities are undertaken in line with VIC EPA Best Practice Environmental Management Guidelines: Siting, Design, Operation and Rehabilitation of Landfills.</p> <p>An annual performance statement has to be submitted to the VIC EPA covering all susceptible receptors.</p>	<p>The main issue that the facility has been faced with is odour. Complaints have been made from neighbouring residents/community. This was rectified through improving the efficiency of the gas collection and through the use of odour control spray carts to control the odour.</p> <p>Windblown litter could be a potential issue, however the facility has litter nets, and a crew that collects litter regularly.</p> <p>An annual open day is held for the local community. The community are aware that the site serves as a dual purpose, in managing waste and generating power.</p>	<p>Current transfer station supports the facility by recovering materials.</p> <p>The landfill is an appropriate method to treat organic and other waste that cannot be recycled. The facility uses relatively little energy (2 litres of diesel per tonne disposed).</p>	<p>The main risk is the mismanagement of landfill gas which can emit odour and gas emissions to air. Proactive management must be undertaken, to avoid nuisance of odour. The facility has historically had issues, and managed them appropriately.</p> <p>Leachate management is another risk with a bioreactor landfill. A sophisticated logging and tracking exercise is undertaken to proactively manage the recirculation at the facility.</p> <p>Risk of pollution to groundwater is managed through engineered lining systems and frequent monitoring.</p> <p>For this facility, there are risks to endangered species, which is regulated by the <i>Environment Protection and Biodiversity Conservation Act 1999</i>.</p>

Technology	14	15	16	17	18
	Emissions	Environmental impacts	Social impacts	Supporting technology required	Risks
Landfill C, NSW	<p>This landfill has similar management responsibilities to other landfills including: landfill gas, leachate, dust, noise and stormwater etc.</p> <p>The gas collection system is generally extracting between 750–850 m<sup>3</sup> per hour of landfill gas from non-operational landfill cells.</p> <p><u>Landfill emissions</u></p> <p>67,788 tCO<sub>2</sub>-e (emissions figure for 2012/2013 from NGERS solid waste calculator) based on zero capture.</p> <p>Indirect emissions from electricity 82tCO<sub>2</sub>-e per annum (based on 2012 figures).</p>	<p>The licence stipulates environmental controls in relation to the capacity of 430,000 tonnes as set by the development approval.</p> <p>The Landfill Environmental Plan contains controls on: engineering requirements, surface water management, operational control for dust and odour amongst other issues to prevent environmental harm.</p> <p>The landfill has been engineered with a clay liner, leachate drainage and collection infrastructure, landfill gas extraction and flaring infrastructure, ponds, drains and bunds to control surface water runoff, and wheel wash facility for vehicles exiting the site.</p>	<p>The facility has not had any negative social impacts due to its location being close to an industrial area and another landfill facility.</p>	<p>Landfill is still a core component of modern waste management as a final disposal site for residual material from waste treatment technologies.</p>	<p>Minimal technical risks. Technology is well proven for landfilling and good engineering standards are in place. Commercial risks are high due to the application of the landfill levy on all wastes whether recyclable or not.</p> <p>Environmental risks are also minimal as the technology is well proven and leachate production is limited as it is a non-putrescible landfill and the facility is an engineered (clay liner) landfill.</p>

Technology	19	20	21	22	23	24	25
	Applicability to local context	Technology maturity	Availability rate	Regional penetration	Benefits	Barriers	Other
Literature Review	It is not uncommon to find most landfills at the fringes of the metropolitan area, away from urban settlements, but close enough to serve the metropolitan area. See Section 6.6.	Landfill facilities are an established and proven waste management technology for the long term disposal of solid waste residue. See Sections 4 and 6.	General maintenance work at landfills will not affect the filling operations and therefore a landfill facility generally does not experience shutdowns. See Sections 6.4 and 6.6.	The WA Waste Authority Map of Perth Metro Landfill Sites, published in 2006, shows 17 landfills were operating in the Perth metropolitan area. See Appendix A	Established, cost effective and bankable technology.  No maintenance and therefore is 100% available.  Have very large capacities. No pre-treatment required.  Is limited only to which waste types can be accepted. See Section 6.7.	Major constraints to gaining approval to construct and operate a landfill relate to convincing of the regulatory authorities any concerns related to environmental impacts and social impacts are appropriately addressed.  See Section 6.7.	
Landfill A, SA	A non-metropolitan area connected to a major highway and/or main road is an ideal site for a landfill facility.	Landfill technology is proven to standard designs.  Clay liners are also a standard technology.	The facility operates daily with no restrictions. It would be very rare for vehicles to build up. On occasion the weather (high winds >50km/h) may cause the facility to close (no tipping takes place).	The WMAA National Landfill Survey shows that SA has 71 landfill facilities, however the variation of landfill type is unknown.	The landfill takes the residual component of all other waste technologies that cannot be treated.  As a waste technology/facility, landfill is financially sustainable for the foreseeable future.	Major barriers include: Planning approval, <i>NIMBY</i> , meeting the EPA Landfill Design guidelines and operating within the EPA licence and DA conditions.	

Technology	19	20	21	22	23	24	25
	Applicability to local context	Technology maturity	Availability rate	Regional penetration	Benefits	Barriers	Other
Landfill B, VIC	<p>The facility is on the northern edge of the metropolitan area at a quarry site and away from residential developments.</p> <p>Landfill facilities are suited to a similar location: inland, at the fringes of a metropolitan area and protected from close residential settlement. It would be preferable if the site is a quarry with a buffer zone.</p>	<p>Bioreactor technology was established in the 1980s in the US and Europe.</p> <p>Landfill B began operating in 2000.</p> <p>The technology can be classed as proven. The facility survived an abnormally wet period (high rainfall) and coped well.</p> <p>A bioreactor landfill would not be suitable for a tropical climate.</p>	<p>The facility is available 24/7.</p> <p>There is the possibility of shutdown at the power station (however this would not have a big impact, the landfill gas would just be flared). This would not impact the landfilling operations.</p>	<p>There are four bioreactor landfill facilities currently operating in Australia, serving, Sydney, Melbourne, Perth and Brisbane.</p>	<p>The bioreactor landfill stabilises waste rapidly.</p> <p>It has an energy output generating 100kWh electricity per tonne of waste deposited. This energy output increases as the facility ages.</p> <p>The facility has a low energy use and it is a low cost operation in comparison to other waste management technologies.</p>	<p>For the bioreactor landfill, the main barrier would be regulatory constraints (provision of information to justify the facility).</p> <p>Other barriers are convincing the regulator that water/leachate recirculation will be controlled diligently and assuring that careful management of the gas collection will be undertaken with strict odour control.</p>	<p>There is a lot of support in Australia to operate a bioreactor landfill, however the location and climate are key areas that need to be taken in to consideration for them to work.</p> <p>This bioreactor landfill generates 38.4MKWh electricity, and therefore generates far more energy than used.</p>

Technology	19	20	21	22	23	24	25
	Applicability to local context	Technology maturity	Availability rate	Regional penetration	Benefits	Barriers	Other
Landfill C, NSW	<p>The facility is on the outskirts of the metropolitan area. There was no motorway close by to the site when the landfill was first constructed, however it now has significant encroachment surrounding it.</p> <p>A good site location is at the edge of a metropolitan area with good transportation access (rail or road), and can service waste generating areas.</p>	<p>Landfill technology is very well proven, and has been operating for a very long time.</p> <p>Landfilling is highly regulated in Australia and there are many reference sites around the world.</p>	<p>Very occasionally, the weather (heavy rain/high winds) may cause the landfill to be closed, however this is rare.</p> <p>There are entry and exit weighbridges and in the event of failure a single system is utilised. Back up machinery is available onsite and hiring of machinery is a second option.</p> <p>In the event of power failure the weighbridge will still operate and manual dockets can be issued.</p> <p>The landfill has closed only once since it began operations in 2002.</p>	<p>The WMAA National Landfill Survey shows that NSW has 85 landfill facilities, however the variation of landfill type is unknown.</p>	<p>Landfill is not only a much needed solution for managing residual waste, it is also a solution for land reclamation and remediation.</p> <p>Clay sites with impenetrable bedrock are ideal and can be filled to reclaim land.</p> <p>The real cost of landfill is small in comparison to other waste management technologies. The landfill levy cost is substantial in the overall cost.</p> <p>Engineered landfills can also harness a resource (landfill gas) that can be utilised as a renewable energy source.</p>	<p>Regulatory consent and development approval are large constraints to establishing a landfill.</p> <p>Finding sites with available space and sufficient buffer zones is another constraint.</p>	<p>The introduction of the high landfill levy is a real constraint to any new landfills, and will be a barrier to new sites becoming established and to landfills already operating.</p>

## 8 STUDY SYNOPSIS

Technology	1	2	3
	Process	Feedstock (type and tonnes)	Annual processing capacity (t/yr.)
Landfill Study Synopsis	<p>The landfill process differs slightly depending on the waste the landfill can accept. The basic operational process of landfilling is:</p> <ul style="list-style-type: none"> <li>Waste is delivered to landfill for ultimate disposal;</li> <li>Waste is weighed;</li> <li>Waste is tipped into landfill;</li> <li>Waste is compacted; and</li> <li>Cover material placed on waste.</li> </ul> <p>A treatment system is operated for leachate, and if gas is recovered, the gas can be flared or used for electricity generation.</p> <p>In a bioreactor landfill the leachate is recirculated into the landfill to accelerate the landfill gas production.</p> <p>In non-putrescible or inert landfills, limited leachate is generated and gas recovery is dependent on the gas generation potential of the waste. Inert landfills are unlikely to generate gas.</p>	<p>The feedstock is determined by the facility's approvals and licence within its jurisdiction and therefore the landfill is classified as a 'type' or 'class' ranging from putrescible, non-putrescible, inert, hazardous and other sub-types of these.</p> <p>Dependent on the facility's approval, licence and regulatory framework within its jurisdiction, a putrescible landfill would normally accept putrescible municipal solid waste (MSW), low level contaminated waste, construction and demolition waste, asbestos, solid residues from liquid treatment plants, industrial process residues and garden waste.</p> <p>Wastes not usually accepted at putrescible landfills are: hazardous waste, high level contaminated waste, liquid waste, industrial waste, radioactive waste and other wastes not approved by the licence, approval and regulatory framework within the jurisdiction.</p>	<p>Annual processing capacity is determined by the facility's development approval within its jurisdiction. Physically, the processing capacity differs depending on the size of landfill (available void space) and the operating plan as there are no operational constraints to achieving a maximum processing capacity.</p> <p>The annual processing capacities at the Australian landfills that were consulted were between 250,000 and 430,000 tonnes per annum.</p>

Technology	4	5	6
	Place in waste hierarchy	Landfill diversion potential (%)	Products and residuals
Landfill Study Synopsis	<p>The place of landfill in the waste hierarchy is centred at the bottom at 'disposal'. The landfill as a waste management facility is typically the end solution of ultimate disposal. This does not, however, reflect the component of recovery and recycling that is undertaken at some landfill sites. The recovery of landfill gas and its conversion to renewable energy is commonly implemented at putrescible landfills.</p> <p>Some sites also undertake recovery of materials such as timber, garden waste and construction and demolition waste at transfer stations and drop-off facilities on-site.</p>	<p>Diversion from landfill does not apply to landfill facilities.</p> <p>There are opportunities to divert recyclables that have been destined for landfill using mechanisms such as on-site transfer stations, drop-off facilities and equipment to draw out recyclable materials. A magnet fixed to an excavator is commonly used to extract ferrous metals, which are then transferred to a recycling facility.</p>	<p>Products and residuals at putrescible and bioreactor landfills are landfill gas and leachate. Leachate is either recirculated back into the landfill (for a bioreactor, or where very little leachate is generated) or collected and treated on-site or off-site.</p> <p>Landfill gas generated is either flared to avoid dispersion into the air or recovered using gas collection systems and converted to electricity.</p>
Technology	7	8	9
	Capital cost	Operational cost	Gate fees
Landfill Study Synopsis	<p>The capital cost is dependent on a number of factors including the procurement of the site (purchasing of the site or payment of royalties to the landowner), the cell construction, excavation of the void space, engineering works (including lining of the cell), final capping, and the aftercare and restoration of the landfill.</p> <p>The capital cost at the Australian landfills that were consulted was between \$7 per tonne and \$15 per tonne for the expected annual intake.</p>	<p>The operational cost is reflective of the landfill type, the void space available, the waste types accepted, the landfilling process and the operational plan.</p> <p>The operational costs comprise: labour, equipment, plant and maintenance, gas field infrastructure, leachate treatment systems, civil works and other ancillary costs.</p> <p>The operational cost at the Australian landfills that were consulted was between \$7 per tonne and \$15 per tonne.</p>	<p>The gate fee varies and usually incorporates any jurisdictional landfill levies and carbon tax. The tax and levies make up approximately 50% of the gate fee cost.</p> <p>The gate fees charged at the Australian landfills that were consulted were between \$112 per tonne and \$250 (exclusive of GST) per tonne.</p> <p>Customers that use the landfill regularly, normally have a negotiated contract price that would be less than the commercial advertised rates.</p>

Technology	10	11	12
	Set-up timeframe	Lifespan	Technology Footprint
Landfill Study Synopsis	<p>The set-up timeframe for a landfill is between 2 and 6 years for development approval and can take between less than one year and 4 years for the site to be constructed (design, construction and excavation) and become operational.</p> <p>The set-up timeframes for the Australian landfills that were consulted were between 8 and 10 years.</p>	<p>The lifespan of the landfill is determined by the available void space.</p> <p>Post-closure works are also part of the operations at landfills. Rehabilitation can vary and depends on whether it is done continuously or when infilling operations cease. Rehabilitation can take over three years. Post-closure work can take between 10 and 30 years depending on the landfill type.</p> <p>The lifespan for the Australian landfills that were consulted were between 15 and 100+ years.</p>	<p>Footprints of landfill facilities vary. Landfills can be as small or large as required depending on the available land space to site the facility.</p> <p>Not all of the Australian landfills that were consulted provided a footprint, however one facility had a footprint of 350ha and the other 30.7ha.</p>

Technology	13	14	15
	Buffer	Emissions	Environmental impacts
Landfill Study Synopsis	<p>Buffer zones for landfills are considered on a case by case basis during the planning and approvals stage. They are a regulatory requirement and the extent of the buffer is specified by the jurisdiction.</p> <p>SA and VIC regulations require a minimum buffer of 500m, whereas in NSW, the buffer distance is 250m. These distances are specified by the development approval of each facility. Sometimes there are different buffer distances and conditions for areas of the site situated closer to watercourses, or near drinking water catchment areas and aquifers.</p>	<p>Putrescible facilities have the potential to disperse landfill gas (comprised of methane and CO<sub>2</sub>) and odour into the surrounding environment. The control of emissions can be undertaken by flaring or recovery of the gas</p> <p>Landfill facilities either flare the gas, or collect as much of it as possible from the non-operational cells of the landfill. The gas is a form of renewable energy that can be exported to the power grid and generate income. Although gas can be captured, not all of it can be contained and some is still dispersed to the atmosphere.</p> <p>The emissions at each facility vary due to the decomposition rate of the waste, and its unique characteristics (waste types deposited and the age of the facility, dry tomb or bioreactor etc.).</p>	<p>There are a number of environmental factors that require consideration. These are normally controlled by the development approval and licence.</p> <p>Landfills have the potential to cause impacts to:</p> <ul style="list-style-type: none"> <li>▪ Air (gas emissions, odour, dust);</li> <li>▪ Water (surface water, groundwater); and</li> <li>▪ Amenity (noise, litter, odour).</li> </ul> <p>Monitoring is undertaken over landfill facility sites to identify and mitigate issues.</p> <p>A Landfill Environmental Plan contains controls on: engineering requirements, surface water management, operational control for dust and odour, amongst other issues to prevent environmental harm.</p>

Technology	16	17	18
	Social impacts	Supporting technology required	Risks
Landfill Study Synopsis	<p>The <i>not in my backyard</i> (NIMBY) attitude is prevalent for all waste infrastructure, however the careful planning and siting of facilities and the use of buffer zones can substantially mitigate this problem.</p> <p>Community engagement can be beneficial. Regular engagement to discuss issues and concerns proactively can foster goodwill and support.</p> <p>The common complaints at landfill are generally in response to odour and litter.</p> <p>Positive social impacts can be achieved through promoting local economic benefits to the area such as power generation, introduction of other businesses to the vicinity, promoting growth and employing local workers.</p>	<p>Landfill is still a core component of modern waste management as a final disposal site for residual material that cannot be managed by other waste treatment technologies and residual waste from waste treatment facilities themselves.</p> <p>No changes would be required to the landfill technology system (new facilities or facilities already operational) to continue supporting an integrated waste management system.</p> <p>Some landfill facilities have on-site transfer stations or are served by transfer stations where recovery of materials has been undertaken.</p> <p>Material recovery facilities can complement landfills through providing a recovery operations, with the remaining residue then disposed at landfill.</p>	<p>There are many risks associated with landfill facilities. Environmental risks include catastrophic failure, fire, methane dispersion (excess emissions to air). Regular monitoring is essential to mitigate these risks.</p> <p>The risk of pollution to the environment and groundwater from the escape of leachate is addressed through the design of a safe treatment system, with logging, tracking and monitoring to proactively manage leachate at the facility.</p> <p>Standard construction and engineering of landfill including the design of landfill liners, gas recovery and leachate treatment systems are important to the safe functioning of the landfill.</p> <p>Commercial risks are also a factor, such as the application of the landfill levy on all wastes (recyclable/non-recyclable) in some jurisdictions. The carbon pricing mechanism will promote competition with alternative treatment solutions (energy from waste, on site remediation of soils).</p>

Technology	19	20	21
	Applicability to local context	Technology maturity	Availability rate
Landfill Study Synopsis	<p>It is not uncommon to find most landfills at the fringes of the metropolitan area, away from urban settlements, but close enough to serve the metropolitan area. The ideal location for a landfill facility should be:</p> <ul style="list-style-type: none"> <li>▪ At the edge of a metropolitan area or a non-metropolitan area;</li> <li>▪ Near enough to serve waste generating areas;</li> <li>▪ Connected to a major highway or main road or have good transportation access (rail, road, boat);</li> <li>▪ Away from residential developments;</li> <li>▪ A site with adequate buffers; and</li> <li>▪ An excavation pit or quarry void site.</li> </ul>	<p>Landfill facilities are an established and proven waste management technology for the long term disposal of solid waste residue.</p> <p>Landfilling technology and engineering is proven to standard designs.</p> <p>Landfills have been operating worldwide for a very long time. It is highly regulated in Australia and there are many reference sites around the world.</p>	<p>General maintenance work at landfills will not affect the filling operations and therefore a landfill facility generally does not experience shutdowns.</p> <p>Many landfills have entry and exit weighbridges and in the event of failure, a single system can be utilised. Back up machinery is normally available at landfills and hiring of machinery is a secondary option.</p> <p>In the event of power failure, weighbridges can still operate and manual dockets can be issued.</p> <p>For landfills exporting power, a shutdown in the power station would not impact operations because the gas would be flared.</p> <p>On rare occasions, the weather may cause the facility to close to prevent tipping (normally in extreme wind).</p>

Technology	22	23	24
	Regional penetration	Benefits	Barriers
Landfill Study Synopsis	<p>The WA Waste Authority Map of Perth Metro Landfill Sites<sup>3</sup>, published in 2006, shows 17 landfills were operating in the Perth metropolitan area.</p> <p>Sahel Road, Tamala Park, South Cardup are a few of the many landfills operating in the Perth metropolitan area.</p>	<p>Landfill has a number of benefits, including:</p> <ul style="list-style-type: none"> <li>▪ It is an established, cost effective and bankable technology;</li> <li>▪ It rarely has shutdowns and therefore is 100% available;</li> <li>▪ They can have very large capacities and tonnage throughputs, and are limited only to which waste types can be accepted and the throughput specified by the development approval;</li> <li>▪ No pre-treatment of waste is required;</li> <li>▪ Some systems (bioreactor) stabilise waste rapidly and can have a positive energy output;</li> <li>▪ It has very low energy use and is a low cost operation in comparison to other waste management technologies;</li> <li>▪ It is a solution for land reclamation and remediation of excavated voids;</li> <li>▪ Engineered landfills can also harness a landfill gas, which can be utilised as a renewable energy source; and</li> <li>▪ Landfills are the only economic option for material designated for final disposal (asbestos-contaminated soils etc.) and residual material from recycling and treatment facilities.</li> </ul>	<p>There are a number of constraints to gaining approval to construct and operate a landfill including:</p> <ul style="list-style-type: none"> <li>▪ Finding a site with available space and with sufficient buffer areas;</li> <li>▪ Convincing of the regulatory authorities that concerns related to environmental impacts and social impacts are appropriately addressed; and</li> <li>▪ Gaining development approval with NIMBY communities being against the development.</li> </ul>

<sup>3</sup> See Appendix A

Technology	25		
	Other		
Landfill Study Synopsis	<p>The need for landfills will always exist while materials (such as asbestos) are designated for final disposal at a landfill.</p> <p>Bioreactor landfills are gaining much more support due to the benefits of quicker stabilisation and recovery of gas for renewable energy export. Siting the bioreactor has to take into account the climate in addition to other siting criteria.</p>		

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## APPENDIX A

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# WA WASTE AUTHORITY MAP OF PERTH METRO LANDFILL SITES

Government of Western Australia Department of Environment and Conservation , 17 Dec 2009,  
Landfill Waste Classification and Waste Definitions 1996 (as amended December 2009)

