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The full cost of landfill disposal in Australia

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BDA Group

Economics and Environment

MELBOURNE
PO Box 6009
Hawthorn West, VIC 3122
Ph (03) 9852 8969
Fax (03) 9852 8969

CANBERRA
PO Box 4022
Manuka ACT 2603
Ph (02) 6282 1443
Fax (02) 6161 9310

Acknowledgement

The Department of the Environment, Water, Heritage and the Arts engaged BDA Group and Wright Corporate Strategy to undertake a desk-top assessment of the disposal of waste to landfill in Australia. The assessment is presented in two reports:

- Wright Corporate Strategy (2009), Landfill performance study; and
- BDA Group (2009), The full cost of landfill disposal in Australia (this report).

Despite every effort to verify data and clarify issues raised, any remaining errors or omissions are the responsibility of the authors. Accordingly, this report does not necessarily reflect the views of the Australian Government.

Contact Details

Drew Collins

Managing Director

BDA Group

PO Box 4022

Manuka ACT 2603

Ph: 02 – 6282 1443

Email: drewcollins@netspeed.com.au

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EXECUTIVE SUMMARY

The Department of the Environment, Water, Heritage and the Arts engaged BDA Group to undertake a study into the full cost of the disposal of waste to landfill in Australia.

The full cost of disposing waste to landfill includes both private costs incurred for landfill establishment, operation and end of life management, as well as impacts on the environment, human health or social amenity that are not captured in private costs and market transactions - ie: they are 'externalities'. Examples of externalities include the impact of releasing methane and greenhouse gases from the decomposition of organic wastes and the potential for impacts from the leaching of toxic metals and compounds into the surrounding soil structure.

In this report we review and compare estimates of both private and external costs of landfill disposal from recent studies in the Australian and international literature. We classify landfills according to factors influencing both the private and external costs of disposal such as physical characteristics, management practices and location. Our analysis focuses on landfills taking putrescible waste as they are the dominant type of landfill, making up around 90% of the number of non-hazardous landfills in Australia and around 65% of the waste disposed.

In the context of this study, the paramount considerations in developing estimates of external costs are cost and time, which prevent the direct application of most valuation methods. Therefore, as is common in environmental policy assessments, we rely on benefit transfer techniques which utilise values drawn from other sources.

We quantify the following key external costs of landfill in this study:

- Greenhouse emissions
- Other emissions to air
- Emissions to water (leachate)
- Disamenity

We discuss the significance of other potential impacts such as post-closure environmental effects; the opportunity costs of sterilisation / alienation of land; and increased future costs as sites for landfill become scarcer and more remote. While notable exceptions can be cited, these costs are increasingly being accounted for as part of the private costs of landfilling.

Also, similar to most studies in the literature, we do not value toxic pollutants as part of the assessment of non-market costs. Toxic pollutants are tightly regulated such that allowable emissions are not generally in a location, manner or concentration to cause health or environmental impacts.

Finally, the costs and benefits of alternatives to landfilling, such as the potential through recycling to reduce the use of virgin materials, energy and generation of pollution in industrial processes, are not considered.

The report provides indicative estimates of the full cost of disposing putrescible waste to various types of landfills, with these costs shown in Figures E1 and E2 for selected landfill types. It should be noted that the actual costs for specific landfills will be strongly influenced by site specific factors.

Figure E1: The full cost of disposing putrescible waste to landfills in urban areas

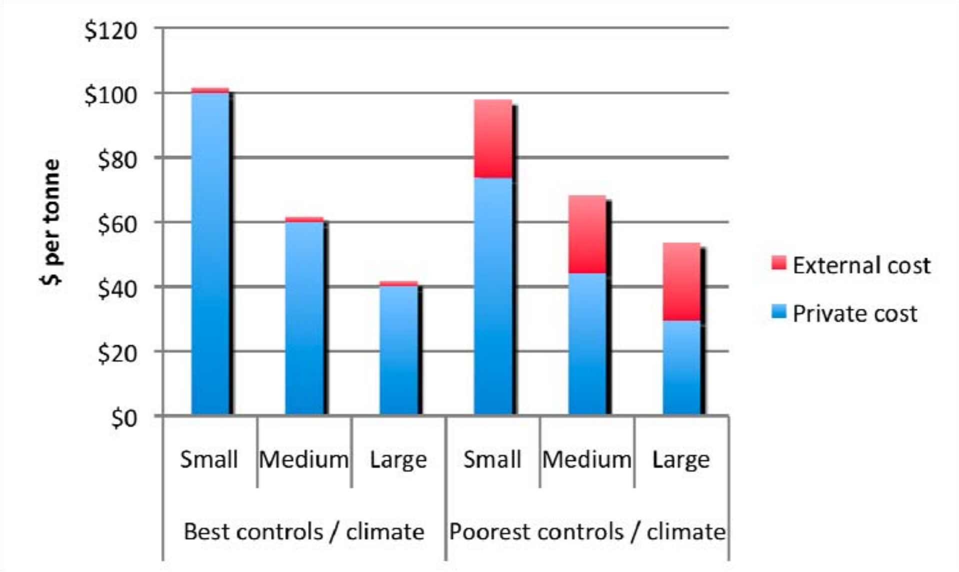
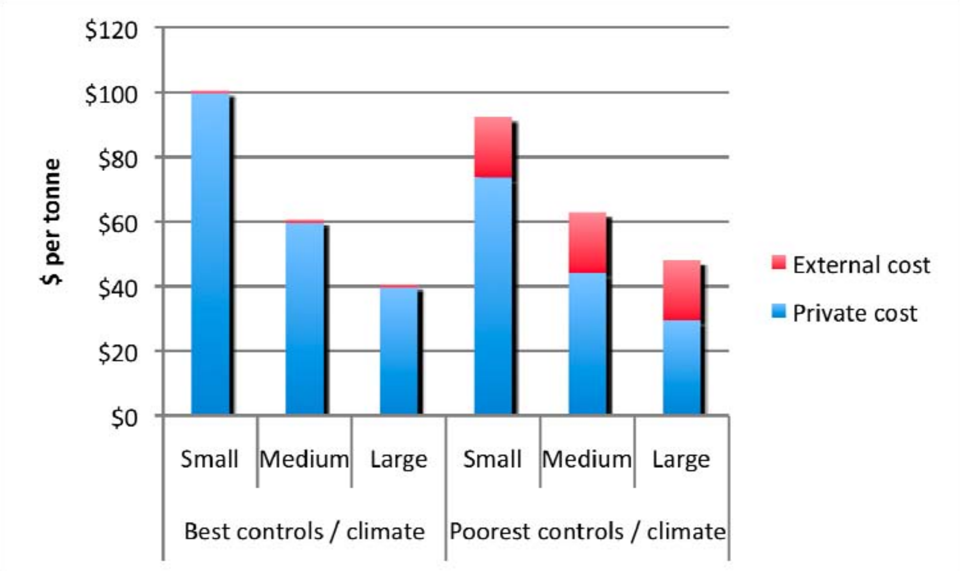


Figure E2: The full cost of disposing putrescible waste to landfills in rural areas



Total costs for urban and rural landfills are similar - ranging between $42 and $102 per tonne of waste in urban areas and between $41 and $101 per tonne in rural areas, depending on the level of management controls and prevailing climate.

External costs are significant for landfills with the poorest controls and in wet climates, making up 25%-45% of total costs for landfills in urban areas and 20%-40% of total costs for landfills in rural areas. The contribution of external costs to total costs is much lower for landfills with best practice controls at less than 4% in urban areas and less than 1% in rural areas.

The composition of external costs in urban and rural landfills is shown in Figures E3 and E4.

The greenhouse and amenity impacts dominate the external costs for landfills with poorer management. For landfills with liners, landfill gas collection, energy recovery and best practice amenity management the greatest impacts in urban areas are from disamenity and air pollutants other than greenhouse. For landfills with best practice controls in rural areas the impacts are dominated by disamenity.

Figure E3: Composition of external landfilling costs in urban areas

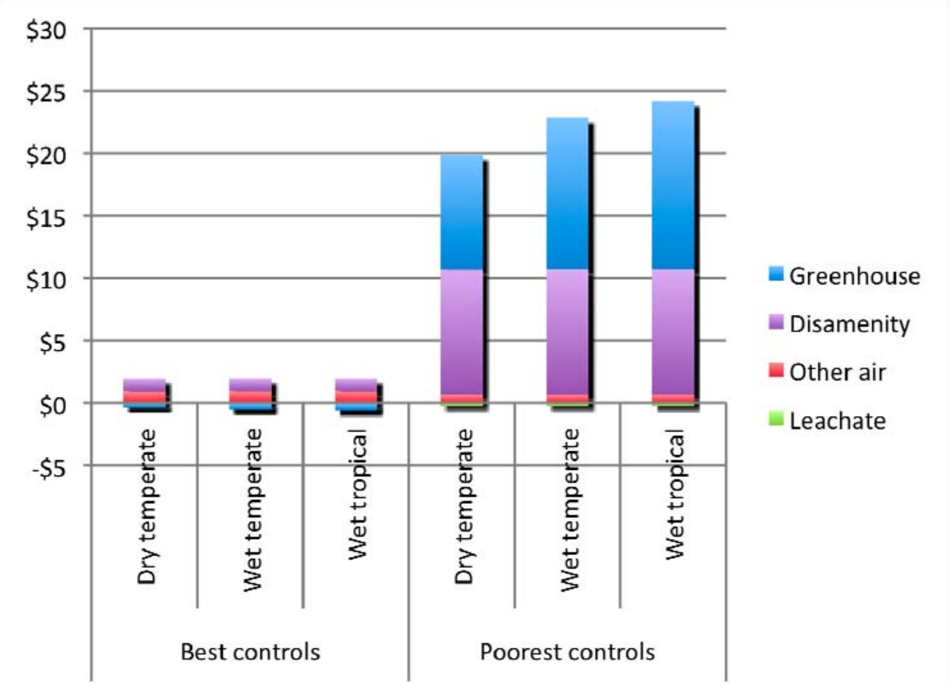
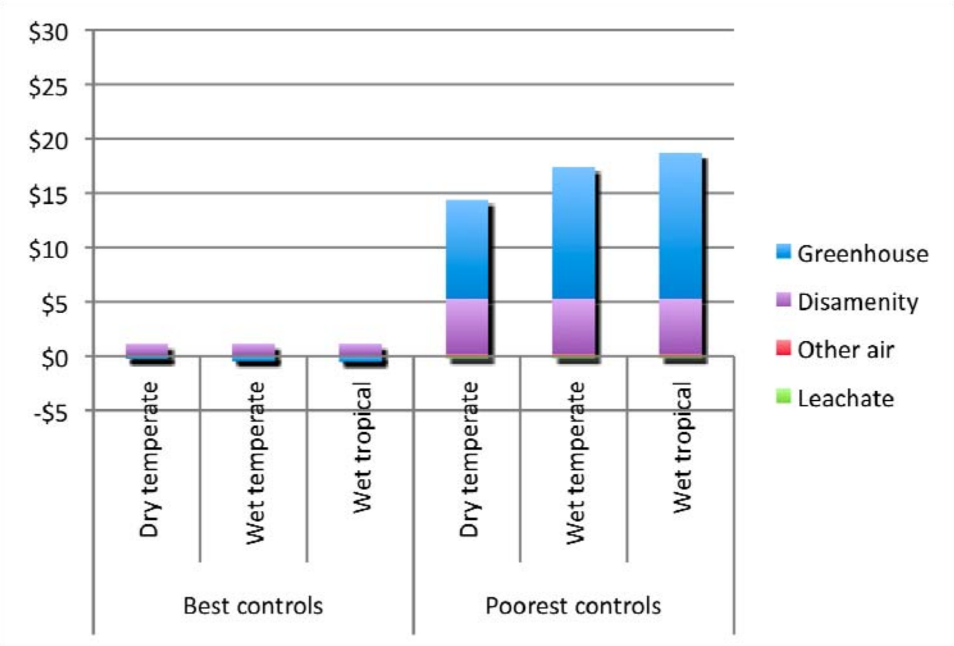
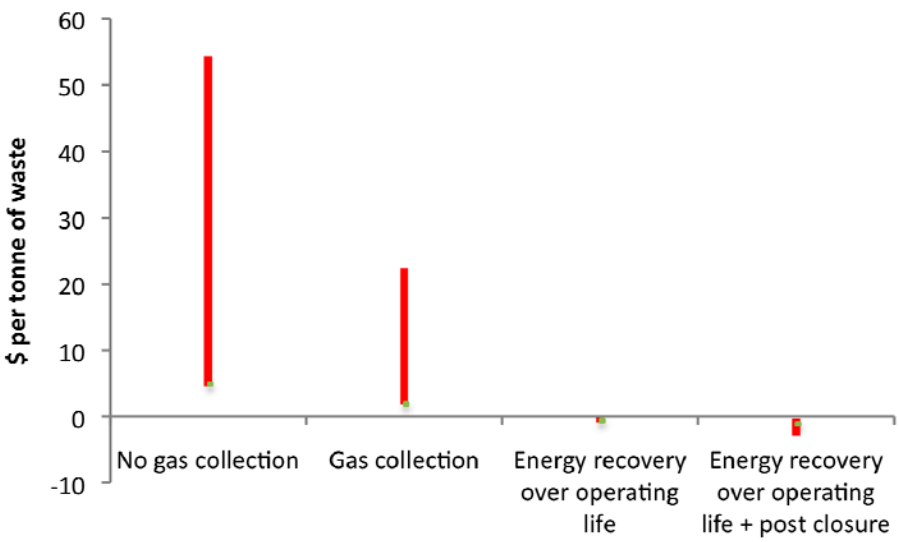


Figure E4: Composition of external landfilling costs in <u>rural</u> areas



The estimated cost of greenhouse emissions from landfills is sensitive to the discount rate chosen and the assumed damage cost per tonne of greenhouse gases. Figure E5 shows the range of values for the external costs of greenhouse emissions where the discount rate is varied between 2% and 7% and damage cost between $20 to $60 per tonne. The estimated cost of greenhouse emissions for landfills with poorer controls / climates are particularly sensitive.

Figure E5: Range in estimated cost of greenhouse emissions from landfills



1 INTRODUCTION

There are a number of different waste management practices available in Australia and their associated costs and environmental impacts vary widely. Table 1.1 highlights the key benefits and costs of the major alternatives. This report focuses on the costs and impacts of disposal to landfill.

Table 1.1: Key benefits and costs of alternative waste management practices

Waste management practice	Benefits	Costs
Recycling / reuse	Potential to reduce use of virgin materials, energy and generation of pollution in industrial processes	Recyclate collection, sorting and processing costs and associated environmental impacts
Composting	Potential to reduce use of virgin materials	Organic waste collection and processing costs and associated environmental impacts
Advanced waste technologies	Energy recovery Potential to reduce use of virgin materials, energy and generation of pollution in industrial processes	Processing costs and associated environmental impacts Environmental impacts with landfilling of residuals
Landfill	No further processing required Gas can be captured for conversion to electricity	Land consumption Environmental risks from gas emissions and leachate Long-term post-closure management
Incineration	No further processing required	Environmental risks from air pollution
Illegal disposal	-	Heightened environmental risks Amenity impacts

Detrimental impacts of landfill disposal include potential leachates from toxic wastes, release of methane from the decomposition of organic wastes, noise and odours impacting local amenity as well as air emissions and visual amenity impacts.

Our analysis focuses on landfills taking putrescible waste as they are the dominant type of landfill. They make up around 90% of the number of non-hazardous landfills in Australia and around 65% of the waste disposed. From an environmental point of view, landfills taking inert waste have few impacts. While landfills taking hazardous waste have both greater environmental impacts *and* management controls, and the costs associated with each landfill would require a detailed site-specific investigation of these controls and the composition of materials being deposited.

The Australian Government, in collaboration with the States and Territories, is leading the development of a comprehensive *State of Waste Report* and a new National Waste Policy, and a consultation paper seeking input from stakeholders on the priority issues to be considered and how these might be addressed has recently been released.

The Department of the Environment, Water, Heritage and the Arts engaged BDA Group to undertake a study into the full cost of the disposal of waste to landfill in Australia, which has been prepared in parallel with an analysis by Wright Corporate Strategy (WCS) of international and Australian landfill management practices.

This report - *The full cost of landfill in Australia* - provides a review and summary of Australian data and methods for estimating the full costs of the disposal of waste to landfill, a comparison with international data and methods, and estimates for the full cost of the disposal of putrescible waste to landfill in Australia. The report was prepared in parallel with WCS (2009), *Landfill Performance Study*, which provides a snapshot of the current operational performance of Australian landfills and reviews how Australian landfill management practices compare with world's best practice.

Section 2 of this report reviews the literature on the private costs of landfill disposal, compares the available estimates and provides the methodology used to estimate private costs in this report. Section 3 reviews the Australian and international literature on the non-market costs of landfill disposal and compares the valuation approaches used and estimates derived. We also explore valuation methods that could be used directly in future to support the estimation of the full costs of landfill disposal in Australia. Section 3 also provides the methodology used to estimate the non-market costs of landfill in this report.

Section 4 provides a classification of landfills and Section 5 provides estimates of private costs for Australian landfills. In Section 6 we derive estimates of the non-market costs of landfill disposal. The cost estimates are consolidated in Section 7 where estimates of the full cost of waste disposal at putrescible landfills with various characteristics are provided. Section 7 also provides the results of sensitivity analysis.

2 PRIVATE COSTS OF LANDFILL DISPOSAL

The private costs of landfill disposal include costs for landfill establishment, operation and end of life management. This section reviews and compares estimates of private costs available in the literature and outlines the approach used in this report.

2.1 Literature on private costs of landfill

The private costs of landfilling vary depending on the size of the landfill, type of waste taken, and management measures in place. Examples of the private costs of landfill include:

- Costs of land purchase;
- Cost of approvals process;
- Capital cost of equipment and buildings;
- Cost of lining landfill bases to prevent leaching;
- Cost of on-site gas recovery and flaring;
- Cost of fencing and other measure to prevent waste from being blown into adjoining properties;
- Operational costs including labour, fuel and materials;
- Cost of capping landfills and landscaping; and
- Cost of rehabilitation and aftercare.

In 2005, the Waste Management Association of Australia estimated the private cost of a large best practice landfill in an Australian capital city at around $25 per tonne[1]. Best-practice landfill was defined as one that is located to reduce the risk of harm to the environment and to reduce the impact on local amenity; is lined and has a leachate management system; incorporates gas collection with energy recovery; is capped after closure; and has provisions for aftercare for up to 30 years. Wright Corporate Strategy recently estimated the full private costs of a large best practice landfill for ACT NOWaste at around $50 per tonne.

Recent Australian studies estimating the costs of disposal at smaller landfill sites include:

- City of Mount Gambier – estimates of $25-$45 per tonne for the Caroline landfill depending on the amount of waste disposed[2]. This includes site establishment, cell construction, operations, cell closure and post-operations;
- Great Lakes Council – costs for four landfill sites range from around $40-$150 per tonne[3]. This covers establishment, operations, site closure and rehabilitation and post-closure costs; and

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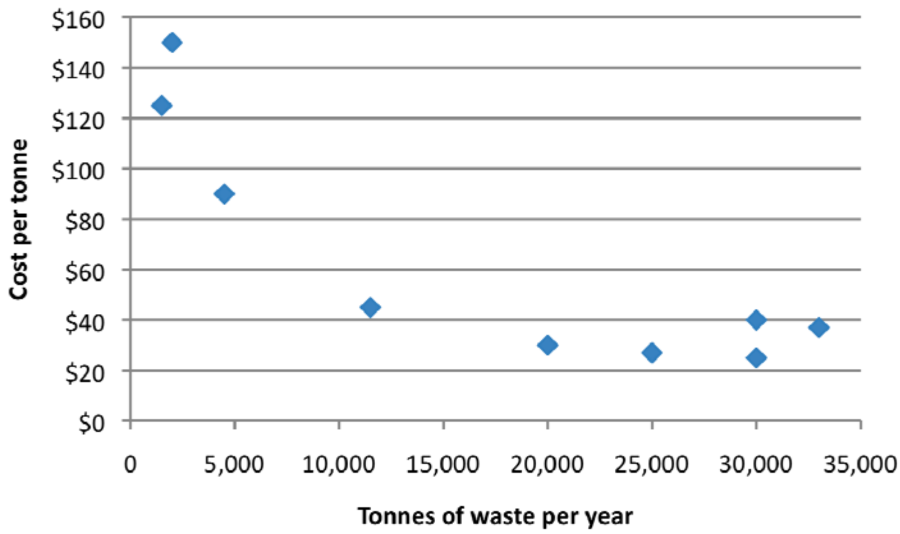
1 National Landfill Division Waste Management Association of Australia submission to the Productivity Commission's Inquiry into Waste Generation and Resource Efficiency in Australia

2 URS 2007

- Hastings Council – estimated costs of around $40 per tonne for the Cairncross landfill[4]. This covers establishment, operations, site closure and rehabilitation and post-closure costs.

These costs are summarised in Figure 2.1.

Figure 2.1: Examples of current private costs for small Australian landfills



A New Zealand report examined how the private costs of landfill disposal vary with landfill size and discount rate[5]. There are two curves shown in Figure 2.2, one at a discount rate of 5% and one at a discount rate of 10%.

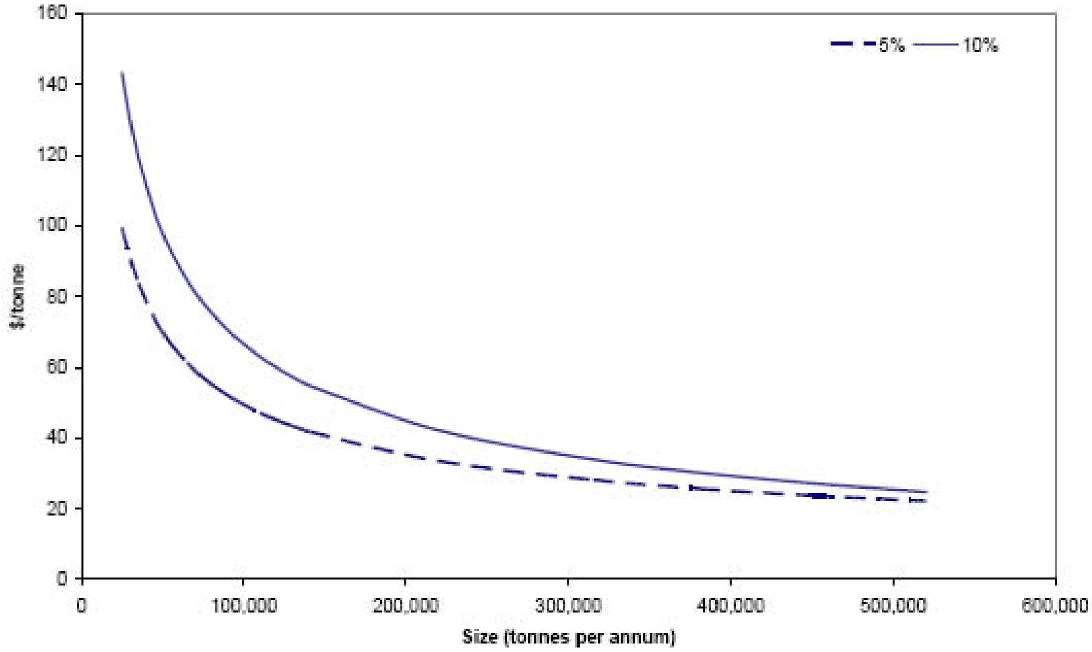
Both curves fall quite sharply from their initial costs before flattening out at about NZ$20-$50 per tonne (or A$16-$40) at the size of about 200,000 tonnes per annum.

3 Impact Environmental Consulting 2004

4 Impact Environmental Consulting 2004

5 Covec 2007

Figure 2.2: Costs of landfill disposal (NZ$)



By comparison, the operational costs of landfilling in the UK are estimated at £30-50 per tonne of waste or A$50-$100[6]. In the Netherlands[7] the private costs of best practice landfilling are estimated at 40 euro per tonne (or A$72) or 36 euro per tonne (A$65) after accounting for the cost savings from generating electricity. These estimates include measures to prevent leakage and energy recovery investments to generate 122 kWh of electricity per tonne of waste from landfill gas. It also includes costs for after closure care and insurance against after closure risks.

Two key methodologies have been developed for estimating the full private costs of landfilling:

- The United States Environmental Protection Agency's full cost accounting handbook for municipal solid waste management (1997);
- The New Zealand Ministry for the Environment's landfill full cost accounting guide for New Zealand (2002).

2.2 Comparison of estimates of private costs

There are significant differences in the estimates of the private cost per tonne of waste to landfill provided in the literature. Some of these differences are due to the size of the landfill, whether a landfill is new or already operating, the value of land, and the management practices employed at the site. Both the Australian and New Zealand cost estimates in section 2.1 show costs per tonne being higher for smaller landfills as a result of fixed cost components.

6 DEFRA 2003

7 Dijkgraaf, E. and H. Vollebergh 2004

The average cost estimates from European studies are relatively high compared to the Australian estimates. They would be expected to include much higher land values than in Australia and the level of management practice may also be more stringent.

For larger landfills two Australian estimates are available for comparison. The WMAA's estimated costs for a large best practice landfill and Wright Corporate Strategy's recent estimates of the costs of a landfill taking 200,000 tonnes per year for ACT NOWaste. The estimates for ACT NOWaste are double those from the WMAA. It should be noted that the WMAA estimates are an average for large best practice landfills and they do not include management costs. The WCS estimates were developed in the ACT context and include management costs.

Table 2.1 provides a comparison of the breakdown of costs. The greatest difference in per tonne estimates for large landfills is for the cost of operations and aftercare.

Table 2.1: Estimated costs for large best practice landfill in Australia

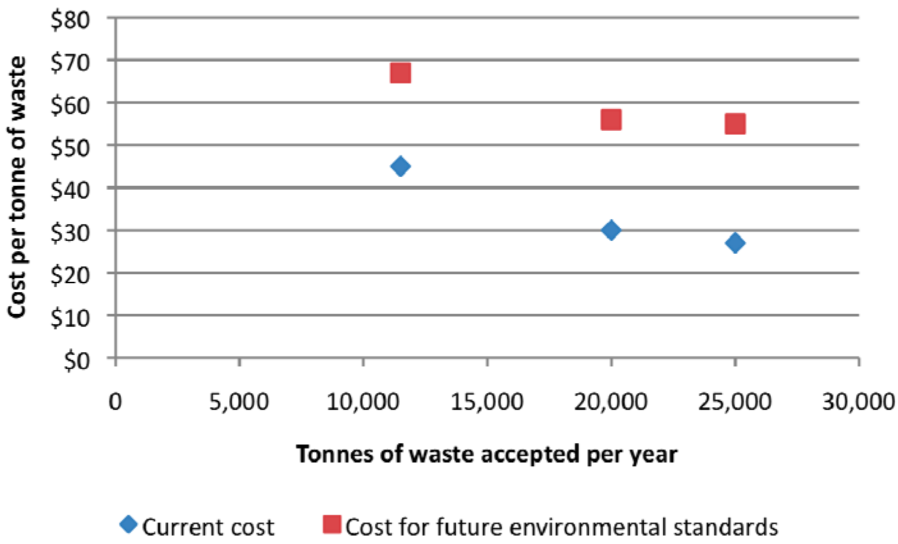
Type of cost	Cost per tonne of waste (WMAA)	Cost per tonne of waste (WCS)
Land purchase including airspace	$2	$2
Approvals / site development	$2	$6
Cell development	$6.5	$10
Operations	$10	$18
Capping and rehabilitation	$2.5	$5
Aftercare	$2	$8
Total	$25	$50

Source: WMAA National Landfill Division in PC 2006 and WCS unpublished

For smaller landfills some Australian and New Zealand estimates are available for comparison and were outlined in section 2.1. The New Zealand cost curve suggested much higher costs for small landfills than were estimated in recent cost studies of current landfill operations for Australian councils. The difference may be partly explained by the level of management practices included in the Australian estimates. One of the Australian studies included a comparison of the current costs of landfilling with that required to meet future environmental standards (in South Australia). Figure 2.3 shows the expected increase in costs.

The increase in the cost per tonne at Caroline landfill in South Australia varies from around 50% to 100% depending on the amount of waste accepted.

Figure 2.3 Increase in costs to meet environmental standards at Caroline landfill



2.3 Methodology used in this study to calculate the private costs of landfill

This section outlines our approach to estimating the private costs of waste disposal to landfill in Australia.

The private costs of waste disposal to landfill include:

- Costs of land purchase
- Cost of approvals process
- Capital cost of equipment & buildings
- Cost of lining landfill bases to prevent leaching
- Cost of on-site gas recovery & flaring
- Cost of fencing and other measures to prevent waste from being blown into adjoining properties
- Operational costs including labour, fuel & materials
- Cost of capping landfills & landscaping
- Cost of rehabilitation & aftercare

We draw on the available literature on the costs of landfilling in Australia and overseas to develop approximate cost estimates for Australian landfills. The level of information to break down the components of the estimates in the literature for private costs varies widely. We have primarily used the Australian estimates for overall costs and have drawn on some component breakdowns in the NZ full cost accounting model (eg. the proportions of cost spent on liners, leachate and gas management systems). The cost estimates are outlined in section 5.

Our estimates of private costs include the costs of capping and remediation of the landfill at closure and the ongoing costs of maintenance. There are also longer term risks to human health and the environment associated with land that was formerly a landfill. In some cases these longer term costs are accounted for through financial assurances. However in many cases they remain externalities and we consider these further in section 3.

3 NON-MARKET COSTS OF LANDFILL DISPOSAL

The full cost of disposing waste to landfill includes both private costs incurred for landfill establishment, operation and end of life management as well as non-market costs or 'externalities'. Externalities, sometimes known as spillover effects or off-site impacts, impose costs or benefits on the community which are not priced into market exchanges.

Disposal of waste to landfill can result in externalities including the impact of releasing methane and greenhouse gases from the decomposition of organic wastes. There is also the potential for impacts from leaching of toxic metals and compounds into the surrounding soil structure. Other externalities include the impact of noise and odours on local amenity, and the impact of air emissions.

Different materials and products disposed to landfill will contribute differently to externality costs. For example, inert materials are likely to have few externality impacts, while biodegradable materials will present additional problems associated with greenhouse gas emissions and odours, while other materials may contain hazardous substances which pose potential risks to human health through air and water emissions.

This section summarises the international and Australian literature on non-market costs of waste disposal to landfill context. It provides an overview of cost estimates published in a range of studies, followed by a comparison of the individual components of the cost of waste disposal to landfill and the methods used to derive each component. The main categories of non-market costs covered in the literature include:

- Emissions of greenhouse gases – landfill gases include methane resulting from the anaerobic degradation of organic material.
- Emissions of other air pollutants – landfill gases include trace quantities of various other gases including hydrogen sulphide and volatile organic compounds.
- Leachate emissions – a range of pollutants are found in leachate that have the potential to be discharged to groundwater or sometimes surface water.
- Amenity impacts – includes impacts on local communities arising from the operation of the landfill and may cover noise, dust, litter, odour and pests. Sometimes referred to as disamenity.
- Transport impacts – including emissions from the collection and transfer of wastes.
- Pollution displacement - some studies estimate ‘gross’ externalities referring to impacts measured at landfill. Others are ‘net’ externalities that take into account the displacement of pollution elsewhere. For example, although landfill gas has a negative impact at the landfill, it can also have a positive impact if the gas is used to produce energy. This is because it reduces the need for energy generation from other sources such as coal fired power stations.

This section also explores alternative valuation methodologies that could be used directly in future to develop estimates of the non-market costs of landfill for use in Australia. Finally, the section outlines the approach used in this study to estimate non-market costs for Australian landfills.

The glossary at the end of this report provides simple explanations for the range of 'valuation methods' used in the literature and discussed in this section.

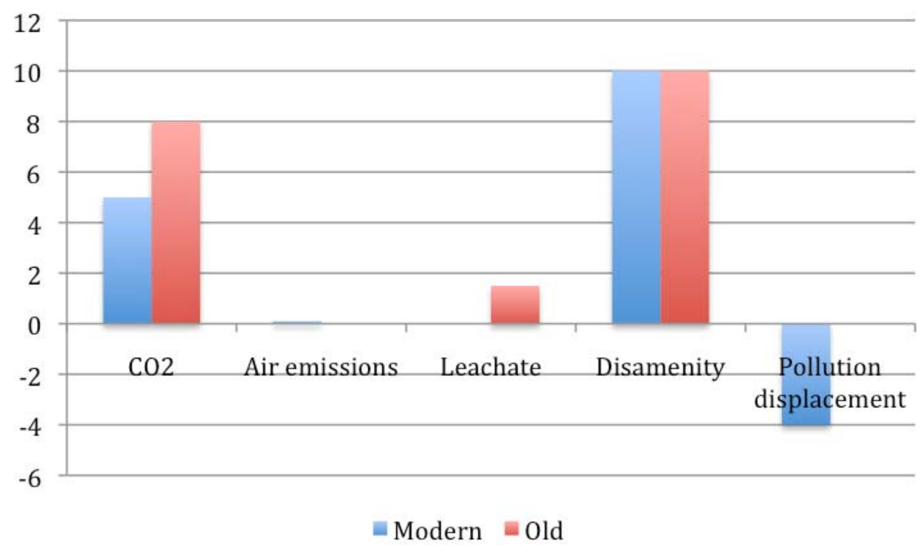
3.1 International literature on non-market costs

A comprehensive international investigation of landfill impacts was undertaken by the European Commission[8] in 2000. The study was largely based on municipal waste generation and management practices in Europe, but drawing on environmental impact values estimated in the US context. They estimated environmental impacts based on both a modern landfill with modern leachate collection and treatment and with landfill gas collected to generate electricity and heat. Old landfills were assumed not to have a liner and leachate collection or gas collection.

Estimated non-market impacts are shown in Figure 3.1.

The total external impact of landfills in Europe is estimated to range between 11 and 20 euros per tonne of waste delivered to modern and old landfills respectively. Because of the larger populations and closer settlement in Europe, a greater number of households could be expected to be directly impacted by each landfill, and this is borne out in the large environmental cost attributed to disamenity impacts on local communities arising from noise, dust, litter, odour and vermin.

Figure 3.1: European Landfill externalities (euro/tonne waste)



Greenhouse gases were found to represent a significant impact while impacts from air and water emissions were small. The overall impact identified for modern landfills in Europe has also been

8 European Commission 2000

reduced by estimated reductions in (largely air) pollutants associated with coal-fired electricity and heat generation displaced by the energy capture at landfills.

Across the OECD more broadly, De Tilly[9] argues that environmental impacts of waste management have diminished considerably, particularly due to more stringent landfill regulations and technologies employed.

Porter 2002 estimated the external costs of landfilling in the US at between $US3 and $US15 per ton[10]. This estimate covers methane emissions, leachate and amenity impacts and draws on earlier work[11]. It ignores land costs and assumes no landfill gas is recovered.

In 2003 the UK Department for Environment Food and Rural Affairs commissioned Cambridge Econometrics to identify and estimate the disamenity costs of landfill in Great Britain. Disamenity costs were defined as those local nuisance costs experienced by households living close to a landfill such as odour, dust, litter, noise, vermin, and visual intrusion. The study used hedonic pricing[12] to estimate disamenity costs. The disamenity cost in the UK was estimated at between £1.5 and £2.2 per tonne of waste disposed to landfill.

In 2004 the external costs of landfilling in the UK were explored as part of a study on a landfill tax for the UK. Davies and Doble 2004[13] estimated external costs at around £4.6 - £6 per tonne of waste landfilled. The estimates cover global pollutants such as greenhouse gases, local (urban) air pollution, transport impacts[14], leachate, disamenity and pollution displacement. The disamenity values were derived by transferring results from US studies of property pricing to the UK context.

A 2004 study from the Netherlands[15] estimated a total environmental cost of around 26 euros per tonne for landfilling waste. Around 65% of the cost relates to the opportunity cost of land. They also calculated environmental savings of around 4 euros per tonne from electricity generation. The values for the external costs reflect marginal abatement costs to meet target emission levels for 2010 in the Netherlands and are assumed to reflect minimum willingness to pay for emission reductions. For the land use value the average price of residential building land in the Netherlands was used.

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9 De Tilly 2003

10 Porter 2002

11 Miranda and Hale 1997

12 Hedonic pricing is an economic valuation method based on assessing the indirect impact on a market price – in this case housing prices – when an externality occurs. Landfill sites were categorised, and variation in the level of prices of adjacent houses that are solely attributable to disamenity impacts were identified.

13 Davies and Doble 2004

14 The estimates shown in this section include many components of the costs of disposal (and these are specified). In later sections of the report our assessment of external costs ignores collection and transport impacts as these will be similar whether sent to landfill or for recycling.

15 Dijkgraaf, E. and H. Vollebergh 2004

Fullerton 2005[16] derives estimates of the external costs of landfill disposal for each State in the US. The estimates cover global and local pollutants and draw on estimates from another source[17] which uses a range of techniques to quantify impacts including direct estimates of human and environmental health impacts, cost-benefit analysis, abatement costs for specific pollutants and contingent valuation of changes in human and environmental health. The external costs are estimated to range from US$5.8 -$14.2 per tonne of waste landfilled.

Another 2005 US study on residential recycling estimated the total external costs of waste transportation and disposal at between $US5.38 and $US8.76 per ton[18]. The estimate includes disamenity impacts, greenhouse gases and transportation of waste to landfill and draw on DEFRA 2003 and Davies and Doble 2004.

Pearce 2005 examines the external costs of landfill disposal in the UK as part of an assessment of European Union waste policy. The cost are estimated at around £6- £7 per ton of waste[19].

In 2007 the New Zealand Ministry for the Environment commissioned a cost-benefit analysis of recycling[20]. The study by Covec estimates the external costs of landfilling at around NZ$10-$60 per tonne of waste landfilled. The estimates cover avoided disamenity impacts, greenhouse gases and leachate and are drawn from key estimates in the literature including DEFRA 2003 (discussed above), the Productivity Commission 2006, BDA Group & Econsearch 2004 and Nolan ITU 2004 (all discussed further in section 3.2).

3.2 Australian literature on non-market costs

An early estimate of landfill externalities in Australia was undertaken by the NSW EPA in 1996 to support increasing the State's landfill levy. The levy increase was introduced to reduce market distortion in waste disposal. The levy rate was based on estimates of the external environmental and social costs of waste disposal including greenhouse, local amenity, transport corridor and intergenerational impacts[21]. The external costs were estimated to range between $A13.10 and $A33.20 per tonne depending on the location.

BDA Group reviewed and updated these estimates in 2003[22]. The combination of stringent environmental regulation plus collection of landfill gas and its use for generation displacing fossil fuels has meant that, over time, the externalities of landfilling are reducing and may even be positive rather than negative for the community as a whole as landfills become low-cost biofuel generators. However, the location of emissions and externalities is also important, with different

[16] Fullerton 2005

[17] Miranda and Hale 1997

[18] Kinnaman 2006

[19] Draws on EC 2000 and DEFRA 2003

[20] Covec 2007

[21] NSW EPA 1996

[22] BDA/MMA 2003

valuations possible at different sites. In 2003 the total external cost of landfilling was estimated by BDA Group to be in the range of $0 to $15 within the Sydney Metropolitan Area.

The ACT Government also commissioned a study[23] into waste disposal costs when preparing its 2002 Waste strategy. The estimated downstream environmental costs associated with landfilling comprised greenhouse gases (estimated at $11.10 per tonne of organic waste or $6 / tonne mixed waste) and amenity impacts associated with dust, odour, noise, etc (estimated at $3.80 / tonne).

The greenhouse estimate was based on a value of CO2 emissions of $5/t, while the amenity impact was based on the cost of buffer zones to avoid these impacts, and nominally costed at 5% of the economic costs of landfilling. Air and leachate management costs to prevent associated impacts were included operational rather than environmental costs.

In 2006 the Productivity Commission examined the external costs of landfill as part of its Inquiry into Waste Generation and Resource Efficiency in Australia. The Productivity Commission examined a range of estimates including the value of avoided air and water emission benefits at landfills inferred using ‘eco-dollars’. ‘Eco-dollars’ is a proprietary tool for the monetary valuation of environmental impacts associated with changes in waste management. The initial estimates were developed by Nolan-ITU as part of an *Independent Assessment of Kerbside Recycling in Australia* (Nolan-ITU/SKM) in 2001.

The Productivity Commission reviewed the basis of the Nolan-ITU eco-dollar values and concluded they were ‘implausibly high’[24]. This was attributed to

- the inclusion of estimates based on the *potential* impacts of pollution without any risk adjustment for the *expected* impact; and
- valuing all pollution as if it occurred in a large metropolitan area where human health costs of pollution are relatively high.

The Productivity Commission identified the value of avoided air and water emission benefits at landfills inferred using the ‘eco-dollar’ approach was between $89 and $182 per tonne. When correcting for the factors identified above, the Productivity Commission estimated that the environmental benefits were more likely in the order of $0 to $5 per tonne.

Table 3.1 shows the external costs of landfill estimated by the Productivity Commission in 2006.

23 RPM Pty Ltd, Kenney Lin & Associates and Energy Strategies Pty Ltd, 2001

24 Productivity Commission 2006, page 425

Table 3.1: **Estimated external costs of 'best practice' landfills** ($/t waste to landfill)

	Municipal	*Commercial & industrial*	*Construction & demolition*
'Best practice' landfill			
Leachate	<$1	<$1	<$1
Greenhouse gas emissions	$4 - $15	$5 - $21	$1 - $4
Other gas emissions	<$1	<$1	<$1
Amenity	<$1	<$1	<$1
Total	**$4 - $18**	**$5 - $24**	**$1 - $7**
'Best practice' landfill with methane capture & electricity generation			
Leachate	<$1	<$1	<$1
Greenhouse gas emissions	$0 - $1	$0 - $2	$0 - $1
Other gas emissions	<$1	<$1	<$1
Amenity	<$1	<$1	<$1
Total	**$0 - $4**	**$0 - $5**	**$0 - $4**

Source: Productivity Commission 2006

BDA Group recently estimated the environmental costs associated with landfilling in South Australia based on emission rates developed from the National Pollutant Inventory and Greenhouse Gas Inventory estimation methods[25]. The emission values were developed using the fee relativities proposed for the SA pollution fee scheme and an 'anchor value'[26] of the damage cost of fine particulate pollution from the UK[27].

Table 3.2 provides value estimates for metropolitan and rural landfills in South Australia. The estimates are regarded as minimum values, because not all pollutants and impacts have been able to be valued.

25 BDA Group & MMA 2006

26 An anchor value is a value for the damage costs of one pollutant which is used to estimate damage costs for a range of pollutants.

27 Enviros Consulting 2004

Table 3.2: Estimated environmental costs of landfilling waste in SA ($/t waste sent to landfill)

	Metro landfills in SA	Rural landfills in SA
Greenhouse gas emissions	*$6*	*$10*
Other gas emissions	*$0.3*	*$0.4*
Leachate	*$0.0004*	*$0.002*
Total	*≈ $6*	*≈ $10*

Source: BDA Group & Econsearch 2006

The higher values for rural landfills reflects the higher level of emissions likely with less stringent environmental management.

3.3 Comparison of non-market cost estimates

There are two stages involved in arriving at a cost estimate for non-market costs of disposal to landfill. Firstly, the physical impact must be identified. Secondly, a dollar value must be placed on the changes in physical impacts incorporating broader economic and social values.

The physical impacts can rarely be directly measured and therefore 'emission factors' are generally applied to waste disposal volumes to derive estimates. Emission factors are typically differentiated for different types of waste and landfill management practices employed.

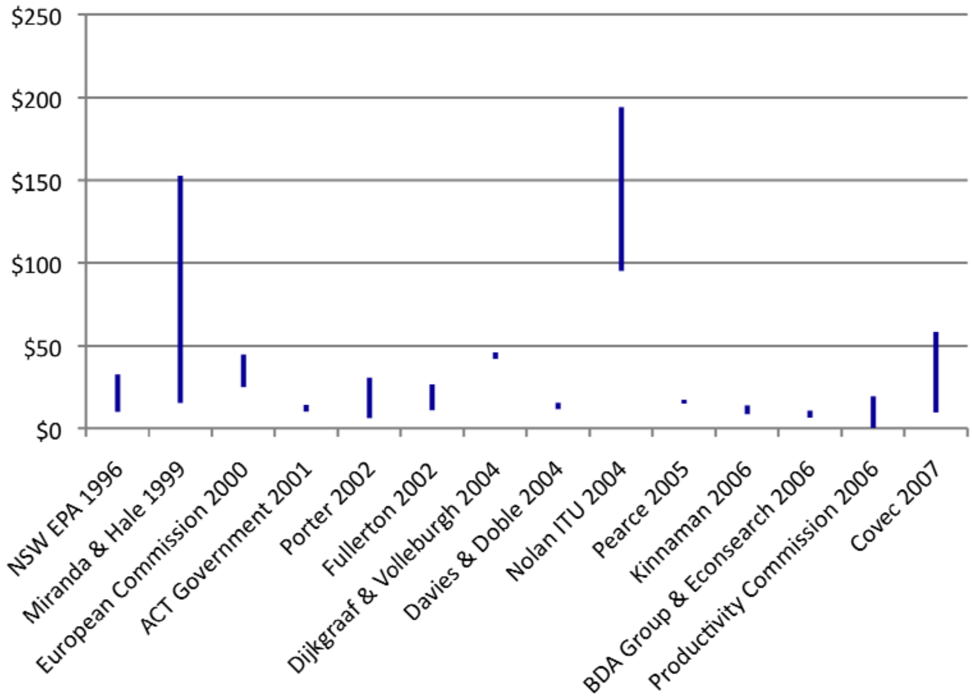
A range of valuation techniques have been developed to estimate the *value* of environmental impacts, from techniques that variously seek to directly measure damage costs (or the community willingness to pay to avoid impacts) or other surrogate measures such as preventative expenditures. The range of techniques are described in Attachment A.

There are a range of estimates of the external costs of landfill disposal in the literature across a number of different countries. Figure 3.3 compares the estimates from 14 recent studies.

The values have been converted to 2008 Australian dollars to allow a comparison, however, it should be noted that the studies have been developed for different purposes in different places and their assumptions about the characteristics of landfills and surrounding conditions vary widely.

Figure 3.3: Estimates of external costs of landfilling

(A$ 2008 per tonne of waste sent to landfill)



Most studies estimate the external costs of landfill disposal at less than $50 per tonne of waste. Some studies have generated higher estimates as well as larger ranges. Sections 3.3.1 – 3.3.4 discuss and compare the estimates of specific components of the external costs and the methodologies used where a breakdown of components is available. We cover the key components of interest in the Australian context - greenhouse emissions, other air emissions, leachate and disamenity impacts. Section 3.3.5 provides a comparison of the relative importance of different components.

3.3.1 Greenhouse gas emissions

The impact of greenhouse gas emissions from landfills is generally derived by estimating methane emission generation potential given the waste composition and landfill controls in place and then applying a monetary value to reflect the impact of greenhouse gas emissions. The same value for damage costs can be used for any location as the climate change impact of greenhouse gas emissions is not dependent on the location of emissions, unlike for other air and water emissions.

Estimates of climate change impacts use a range of methods that calculate the environmental damage, production impacts and infrastructure damage costs predicted with increasing concentrations of greenhouse gas emissions. Given the global nature of the issue, uncertainty in climate modelling, mix of methods used to estimate damage costs (including some inappropriate ones) there is considerable uncertainty in these damage cost estimates.

Table 3.3 summarises the results of valuations of greenhouse emissions from landfill from recent studies. Most estimates are under $20 per tonne of waste landfilled. The two key determinants of the value are the practices assumed at landfills and the value used for the damage costs of greenhouse gas emissions. These assumptions are also shown in the table.

Table 3.3: Valuation of impact of greenhouse emissions from landfills (2008 $AUD)

Study	Location	Value of CO2-e externality per tonne of waste	Landfill assumptions	Assumed damage cost per tonne of CO2-e
Miranda & Hale 1999	US	$6 - $125	Range with / without methane flaring	$7 - $20
European Commission 2000	EU	$11 - $18	Range of best estimates for new / old	$9
ACT Government 2001	AUS	$7	Assumes no gas capture	$5
Davies & Doble 2004	UK	$2 - $17	Range for existing / new, urban / rural, with methane capture / without	$5 - $37
Dijkgraaf & Volleburgh 2004	NED	$11	Best practice (Dutch standards stringent by world standards)	$65
BDA Group & Econsearch 2006	AUS	$6 - $11	Range for urban / rural	$16
Productivity Commission 2006	AUS	$0 - $16	Range for best practice with / without electricity generation	$5 - $20
Covec 2007	NZ	$8 - $13	70% of NZ landfills have gas capture with 44% efficiency	$15 - $25

Notes: Dijkgraaf & Volleburgh 2004 is for total air emissions – no breakdown available.

Most estimates for greenhouse externalities are similar in magnitude even though there are differences in the assumptions about the characteristics of landfills and values for the marginal damage cost of greenhouse emissions. Miranda and Hale 1999 has a much higher upper bound than all other studies. This upper bound estimate relates to landfills with no gas flaring and assumes the worst landfill gas composition and conditions for methane generation. When these figures were used by Fullerton 2002 to estimate the external costs of landfill disposal for each state in the United States the highest *total* external cost was only $27 per tonne ($A 2008).

A number of other studies also provide information on the damage costs of greenhouse gas emissions (although they do not provide externality values per tonne of waste). Tol 2005[28] reviewed a range of studies on the marginal damage costs of greenhouse gas emissions. The values varied from A$3 per tonne of CO2-e to A$740 per tonne and the study concluded that the marginal damage cost is unlikely to exceed A$22 per tonne. DEFRA 2004[29] in a comprehensive review of scientific evidence of the physical health and environmental effects of options to manage wastes in the UK developed monetary values for the physical impacts. The study recommends an environmental value of A$25 - A$100 per tonne of carbon dioxide.

As noted above, estimating the marginal damage costs of greenhouse gas emissions is a complex and uncertain exercise. Therefore estimates of the cost of abatement are often used as a proxy for damage costs. One source of information on the costs of greenhouse gas abatement in the Australian context is the NSW Greenhouse Gas Reduction Scheme. The scheme has operated since 2003 to reduce greenhouse gas emissions associated with the production and use of electricity and to encourage activities that offset emissions. The 2007 year end spot price was $7 per tonne of CO2-e emissions[30].

McKinsey 2008[31] develops an abatement curve for reducing greenhouse gases in the Australian context. The study found that there are significant “negative cost” abatement opportunities available in the short term and that the longer term marginal cost of abatement is likely to be around $60-$70 per tonne.

The Australian government has proposed a Carbon Pollution Reduction Scheme (CPRS) to meet targets for reducing Australia’s greenhouse gas emissions. The proposal includes a cap on the price of carbon permits of $40 per tonne. If the scheme is introduced abatement costs in Australia will generally not exceed $40 per tonne of CO2-e (although mandatory targets for renewable energy will result in some abatement costs exceeding the CPRS cap value).

Hyder 2008[32] recently examined the impact of including landfill facilities in the proposed CPRS, with a focus on the impact of legacy emissions from historical waste. They developed a number of scenarios for different landfills in WA, VIC and NSW and found that landfills continuing to take waste after the scheme is introduced would face costs of $2 - $14 per tonne of waste in order to cover the future cost of purchasing permits under the scheme. These results are based on average gas capture of 60%-75%, a carbon permit price of $20 per tonne and a 10% discount rate.

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28 Tol 2005

29 DEFRA 2004

30 IPART 2008

31 McKinsey & Company 2008

32 Hyder 2008

The valuation of the impact of greenhouse gas emissions is discussed further in section 3.5 (where we develop the damage values to be used to estimate the external costs of landfilling in Australia).

3.3.2 Other air emissions

The impact of air emissions is generally valued by estimating the physical quantities of emissions likely to be generated from landfills given the waste composition and landfill controls in place, and then applying dollar values drawn from the literature which represent the marginal damage costs of different pollutants (a technique called 'benefit transfer' which is discussed in Attachment A). Damage costs are typically developed using estimates of the health costs of illnesses associated with air pollution.

The true value of air pollution impacts in any particular situation will depend on the type of air pollutant, concentrations of emissions, ambient concentrations, the population likely to be impacted, the concentration threshold at which people are impacted and how the pollutant effects the population (eg: through increased incidence of health impacts, decaying of infrastructure etc). The location of the landfill is very important as the impact of air emissions in an urban area may be much greater than in a less populated areas.

Table 3.4 summarises the results of valuations of non-greenhouse air emissions from landfill from recent studies. Most values are below $1 per tonne of waste landfilled. The key determinants of the value are the practices assumed at landfills, the location of the landfills and the value used for the damage costs of non-greenhouse air pollutants.

Table 3.4: Valuation of impact of non-greenhouse air emissions from landfills

Study	Location	Range of values ($A 2008 / tonne of waste)	Landfill assumptions
Miranda & Hale 1999	US	$10 - $25	Range of different compositions of gas and conditions
European Commission 2000	EU	$0 - $0.2	Range for new and old landfills
BDA Group & Econsearch 2006	AUS	$0.3 - $0.4	Range for urban and rural locations
Productivity Commission 2006	AUS	$0 - $1	Best practice landfills with and without electricity generation

The US study looks at the variety of possible outcomes at landfills and uses estimates of marginal damage costs of pollutants from the literature. It provides much higher estimates than the other studies. The European study develops estimates of emissions from a typical new and old landfill in the European Union and applies values for damage per tonne of five non-greenhouse air pollutants transferred from the literature. The BDA Group study develops estimates of air emissions for a typical urban and rural landfill in South Australia and also applies values for damage per tonne for five pollutants. This study used an “anchor” value for the health costs of fine particulates from a UK study (DEFRA 2004) and the relativities proposed for the South Australian licence fee scheme to develop values for environmental costs for each pollutant. The Productivity Commission estimates were developed for best practice landfills only directly from a review of external costs per tonne of waste in relevant literature.

There are also related studies that are useful for examining the health costs of individual air pollutants. These studies provide values for the damage costs of air pollutants but not per tonne of waste disposed to landfill.

DEFRA’s 2004 review of the physical health and environmental effects of options to manage wastes in the UK estimated damages costs for individual air pollutants. DEC 2005[33] also undertook a detailed study on the health effects of air pollutants in the Sydney, Hunter and Illawarra regions. This study uses PM10 as an indicator of the presence of air pollutants and health effects more broadly and estimates the impact cost per tonne of PM10 emissions. Table 3.5 compares the results of these studies with those used to generate damage costs per tonne of waste in Table 3.4.

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33 DEC 2005

Table 3.5: Damage costs for air pollutants ($A2008/tonne of pollutant)

Pollutant	DEFRA 2004	DEC 2005	Miranda & Hale 1999	EC 2000	BDA 2006	DV 2004
Particulates	$400 - $2,700	$30,200 – $153,400	$1,300 - $11,900	$54,000	$2,700 - $10,400	-
SOx	$1,700 - $7,700	-	$4,500 - $12,100	$20,200	$300 - $600	$8,900
NOx	$400 - $2,600	-	$4,900 - $20,900	$35,900	$300 - $600	$6,300
VOC	$700 - $1,700	-	$31,500 - $36,000	-	$2,700 - $5,500	-
Lead	-	-	$1.9m - $2.4m	-	$27,400 - $819,000	-
CO	-	-	$2,500 - $2,600	$11	-	-
Dioxins	-	-	$3.7b - $4.5b	$22b	-	-

The DEFRA 2004, DEC 2005 and BDA 2006 studies provide values for 'fine' particulates (ie: PM10). The European Commission study and Miranda & Hale 1999 refers to all particulates. The EC 2000 values are higher than the other studies for all pollutants – other than the upper bound DEC 2005 value for particulates which relates to fine particulate emissions in Sydney. While some of the differences between these estimates will relate to methodological assumptions, as discussed further in section 3.5, some reflect differences in ambient air quality, meteorology and population health and demographics.

3.3.3 Leachate

The impact of leachate is generally valued by estimating the physical quantities of emissions to water and soil likely to be generated from landfills given the waste composition and landfill controls in place and then applying monetary values representing the marginal damage costs of different pollutants from the literature. The location of the landfill is important for this. Damage costs are typically developed using estimates of the abatement costs or clean up costs associated with water pollution.

Table 3.6 summarises the results of valuations of leachate emissions from landfill from recent studies. Most values range between $0 and $5 per tonne of waste landfilled. The exception is the New Zealand study (discussed further below). The key determinants of the value are the practices assumed at landfills, the location of the landfills and the value used for the damage costs of emissions.

Table 3.6: Valuation of impact of leachate emissions from landfills

Study	Location	Range of values ($A 2008 / tonne of waste)	Landfill assumptions
Miranda & Hale 1999	US	$0 - $2	US landfills
European Commission 2000	EU	$0 - $3	Range for new / old
Dijkgraaf & Volleburgh 2004	NED	$0 - $5	Best practice (Dutch standards stringent by world standards)
Davies & Doble 2004	UK	$0 - $2	Range for existing / new, urban / rural, with methane capture / without
BDA Group & Econsearch 2006	AUS	$0.0004 - $0.002	Range for urban / rural locations
Productivity Commission 2006	AUS	$0 - $1	Best practice landfills with / without electricity generation
Covec 2007	NZ	$1 - $36	Range for NZ landfills

Notes: Dijkgraaf & Volleburgh 2004 value is for chemical waste

Most of these studies use benefit transfer to impute values per tonne of waste derived from other studies that use cleanup costs, abatement costs or marginal damage costs. The only study that provides explicit values per tonne of water pollutant is BDA 2006 and these values are shown in Table 3.7.

The upper bound value for the NZ study is much higher than all other studies. This study draws on the estimates that the Productivity Commission "inferred" from Nolan ITU 2004 which assumes all leachate generated from a landfill would escape and cause environmental damage and the cost of the damage would not be influenced by the geological or other characteristics of the surrounding area. The NZ study uses the mid-point Nolan ITU estimate scaled down 50% as an upper end value to reflect the fact that a proportion of landfills in NZ do not adhere to best practice.

Table 3.7: Damage costs for water pollutants in SA ($A2008/tonne)

Pollutant	BDA 2006
Nitrogen	$2,700 - $8,200
Phosphorus	$2,700 - $5,500
Suspended solids	$2,700 - $5,500
Organic matter	$2,700
Temperature	$270
Zinc	$2,700 - $5,500
Copper	$27,400 - $54,700

Source: BDA Group & EconSearch 2006

3.3.4 Disamenity

Estimates of disamenity impacts have generally been developed from hedonic pricing studies, either directly or by transferring the relationships between proximity to landfills and house prices established for one or more different housing markets.

For example, DEFRA 2003[34] reviewed 13 hedonic pricing studies and found that a home located within one mile of a landfill is valued at 5-10% less than a comparable home away from a landfill. Table 3.8 summarises the values used for the disamenity costs of landfills in recent studies.

The European Commission study has the highest value per tonne of waste at $22, the UK and NZ studies have the next highest and the Australian studies have the lowest values. The estimate for the EU is likely to reflect larger populations and closer settlement meaning a greater number of households could be expected to be directly impacted by each landfill.

34 DEFRA 2003

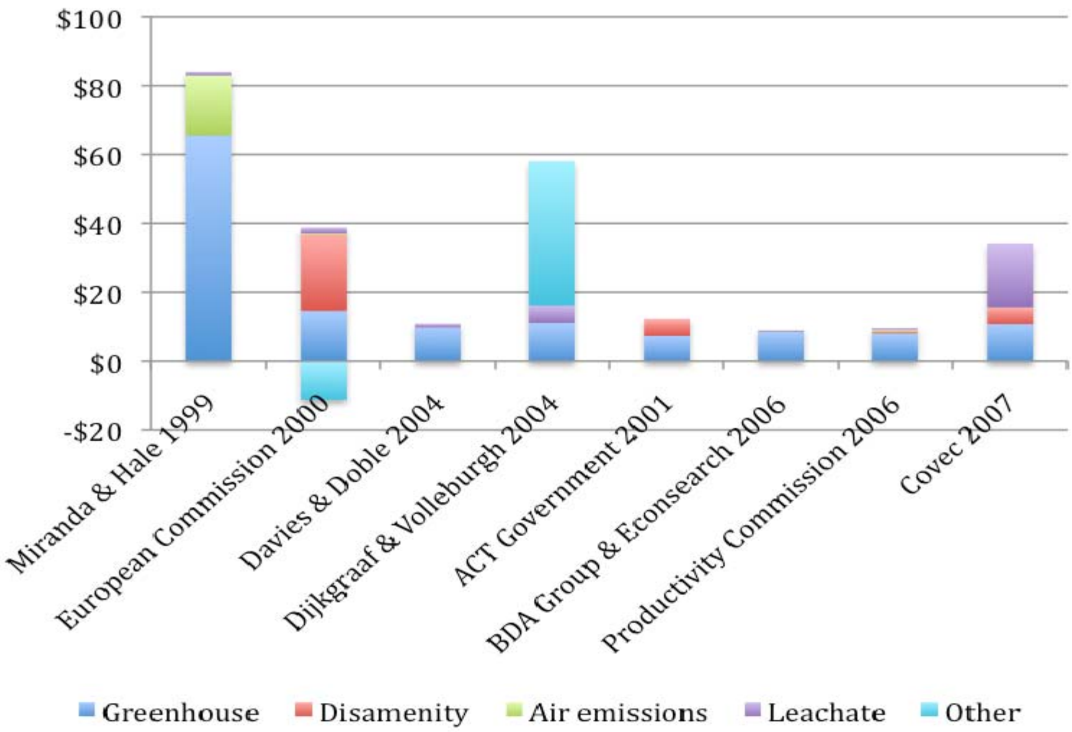
Table 3.8: Valuation of impact of disamenity from landfills

Study	Location	Range of values ($A 2008 per tonne of waste)	Landfill assumptions	Derivation
European Commission 2000	EU	$22	Range for new / old	Transferred hedonic price function from Brisson & Pearce 1998
ACT Government 2001	AUS	$5	ACT landfills	Examined replacement costs valued at 5% of cost of managing waste
DEFRA 2004	UK	$7 - $9	UK landfills	Transferred hedonic price values from DEFRA 2003
Productivity Commission 2006	AUS	$0 - $1	Best practice landfills with / without electricity generation	Review of international & Australian literature
Covec 2007	NZ	$1 - $9	Range for NZ landfills	PC 2006 for low end DEFRA 2003 high end

3.3.5 Relative importance of components of external costs

The studies examined in this section cover a combination of impacts from greenhouse emissions, other emissions to air, leachate, disamenity, and the opportunity cost of land. Figure 3.4 compares the make-up of the total value of external costs for studies that provide a breakdown of components.

Figure 3.4 Comparison of components of external cost estimates



The external cost of greenhouse gas emissions is a significant component of all estimates. The European Commission's estimate includes a relatively large component for disamenity as the larger populations and closer settlement in Europe means a greater number of households could be expected to be directly impacted by each landfill. The estimate for the Netherlands includes the opportunity cost of land under "other" (65% of the total external cost), which would be much higher than in larger countries. The New Zealand estimate has a relatively high proportion of costs for leachate compared to other studies.

The most significant components of the external cost estimates are generally greenhouse emissions and disamenity.

3.4 Alternative approaches to estimate non-market costs

This section provides information on alternative methodologies that could be used in future to improve the estimation of the external costs of landfilling in the Australian context.

3.4.1 Greenhouse gases

The most common approach to valuing the impact of greenhouse gases has been the preventative expenditure method, where the cost of abating greenhouse gases as reflected in the price of purchasing greenhouse credits is used as an indicator of the value of carbon emissions While this pragmatic approach enables a value for carbon to be readily used, the relationship of this price to actual consumer or producer values is unclear.

An alternative more conceptually correct method is to ask people their willingness to pay to avoid certain impacts associated with greenhouse gases, through the use of 'stated preference' valuation techniques such as contingent valuation or choice modelling. However, even this is problematic as both methods would require dose-response data on what climate change impacts would be avoided if greenhouse gas emissions were reduced by various amounts. To our knowledge no willingness to pay study has been undertaken in Australia in relation to greenhouse gases.

3.4.2 Air pollution

The appropriate method for valuing air pollution impacts will depend on the type of air pollutant, concentrations of emissions, ambient concentrations, the population likely to be impacted, the concentration threshold at which people are impacted and how the pollutant effects the population (eg: through increased incidence of health impacts, decaying of infrastructure, etc).

DEC 2005[35] estimates the health costs of air pollution in the Sydney, Hunter and Illawarra regions, using the presence of fine particulates as an indicator pollutant. If air emissions from landfills had a similar composition to that more broadly present in these air sheds, and the emissions impacted similar populations, then this value or values from similar studies across Australia could be used. However these conditions are unlikely to hold.

Air emissions may represent a significant impact value on a case by case basis and targeted health studies may be appropriate in these instances. However given the relatively small impact values identified across a broad range of studies, primary evaluations to support state-wide or national impact assessments are probably not warranted.

3.4.3 Leachate

The approach to the valuation of environmental impacts from landfill leachate depends on what is physically impacted and how consumers or producer values (or utility) are ultimately impacted. If leachate were impacting water quality that ultimately impacted oyster growers or commercial fishers, then the value of changes in the levels of leachate could be estimated directly from how the producer surplus (profit) associated with these commercial activities would be impacted (eg: increased revenues, reduced costs or increased production levels).

If leachate were to affect some recreation activity in a stream or river, then these values could potentially be estimated using the travel cost method in a similar way to that described below for aesthetic impacts on a recreation site. However, if leachate were affecting biodiversity as well as recreation, then a 'stated preference' valuation technique would be required. Again however, it would first be necessary to identify environmental attributes potentially impacted by the leachate (eg: is the impact likely to be on primary contact activities in the waterway, riparian vegetation, or presence and abundance of fish species, etc).

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35 DEC 2005

Similar to the situation for air pollutants, primary evaluations to support state-wide or national impact assessments are probably not warranted given the relatively small impact values identified across a broad range of studies.

3.4.4 Amenity impacts

To value aesthetic impacts associated with a landfill operation, the hedonic pricing method (specifically the property valuation method) is often used. The hedonic pricing method is founded on the concept that an individual's value for a good or service is based on the attributes that the good or service possesses. Hence, for houses the value is based on the attributes of that property, including environmental attributes such as views, exposure to odours and noise etc. The difference in property prices "with" and "without" a landfill in the area or "with" or "without" a landfill operating with different levels of noise, odour etc gives an indication of the economic impact. This property value impact can be estimated based on advice a property valuer or real estate agent.

A hedonic pricing study could be undertaken in the Australian context to provide better information on the impact of Australian landfills on amenity. Alternatively, use of a 'stated preference' valuation technique such as choice modelling is likely to generate a richer dataset in relation to the various types of amenity impacts and also provide more robust valuations for use via benefit transfer.

3.4.5 Priorities for further work

The most significant components of the external costs of landfilling in the Australian context are greenhouse gas impacts and disamenity. Australian Governments are investing significantly in assessing likely impacts from climate change and estimating the likely costs of greenhouse gas mitigation and adaptation, and therefore further research in this area from a narrow waste context would not appear a priority.

The priority for further research to help assist the assessment of external costs of landfilling in the Australian context therefore appears to be studies to better assess amenity impacts, including differentiating likely values in an urban versus rural setting, and the contribution various management practices may make to reducing these impacts.

3.5 Methodology used in this study to calculate the non-market costs of landfill

The studies summarised in the literature review include a range of different types of non-market costs and use various different approaches to valuation. They have been developed to be suitable for specific locations and applicable for different policy and demographic contexts. Some were developed as part of a cost-benefit analysis or regulatory impact analysis to support a particular proposal, whereas others were developed to inform broader policy processes. In this section we set out the types of non-market costs to be considered and the methodology proposed to estimate non-market costs relevant for the Australian context.

3.5.1 Scope of non-market costs considered

We quantify the following key non-market costs of landfill in this study:

- Greenhouse emissions
- Other emissions to air
- Emissions to water (leachate)
- Disamenity

The next section provides the methodology used for estimating these four key non-market costs.

The significance of other potential impacts are also considered in section 3.5.3. These include post-closure environmental effects; the opportunity costs of sterilisation / alienation of land; increased future costs as sites for landfill become scarcer and more remote; and the opportunity costs of not recovering resources in waste (often referred to as the 'upstream' benefits of recycling).

We do not extend the analysis of externalities to consider the environmental impacts of the collection and transport of waste to landfills. We focus on the environmental impacts directly from landfills. Transport externalities have been discussed in other studies and will be very context specific.

We do not value toxic pollutants as part of the assessment of non-market costs. This is similar to most studies in the literature. Toxic pollutants are tightly regulated such that allowable emissions are not generally in a location, manner or concentration to cause health or environmental impacts. For example, South Australia and Western Australia are not licensing new landfills in the metropolitan area where groundwater is drawn on for potable supplies of water. While there may be some exceptions due to poor knowledge, compliance or enforcement, toxic pollutants are not routinely emitted from landfills.

3.5.2 Methodology for estimating externalities

In the context of this study, the paramount considerations in developing estimates of external costs are cost and time, which prevent the direct application of most valuation methods. Therefore, as is common in most environmental policy assessments, benefit transfer techniques which use values from other sources are relied upon.

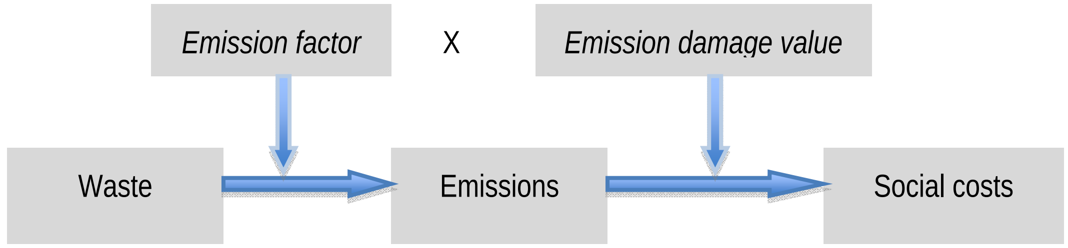
Our proposed approach for the landfill externality costs includes a number of steps:

- Identification of landfill type, operating characteristics and locational context for current Australian landfills;
- Identification of the likely physical loadings from landfills;
- Determination of the 'receptors' of the loadings and the resulting physical impacts given the context; and
- Valuation of the physical impacts in monetary terms.

The approach is similar to that used in the study by the European Commission (EC 2000) following an "impact pathway methodology". The methodology follows the passage of pollutants from the place where they are emitted to the final impact on the receptors affected.

Figure 3.5 is taken from EC 2000 and shows the links in the pathway from waste disposal to cost. When a landfill takes waste, emissions are created which affect the quality of air, soil or water. The physical emission loadings have differing impacts depending on the context. For example, some impacts are likely to be site specific (eg: loss of amenity), affect local populations (eg: leachate from rural landfills which generally have lower controls), regional populations (eg: associated with some air and water pollutants) or national or even global populations (eg: greenhouse gas emissions). Depending on the type of emission and location of the landfill, a group of receptors (humans, buildings, animals etc) is exposed to the emissions in a certain dose. This dose has a negative effect in terms of health or environmental impacts and finally, the impacts give rise to costs to society.

Figure 3.5: Overview of externality impact valuation methodology



The two key figures that are essential for quantifying the externalities are the:

- Emission factors to estimate physical loadings from landfills (which for pollutants are typically measured in kilograms per tonne of waste); and
- Emission damage values (measured in $ per kilogram of emissions).

A number of emission factors to estimate physical loadings from landfills have been developed in the Australian context. Emission damage values are not as readily available and need to take into account the exposure, dose and effect of emissions given the Australian context.

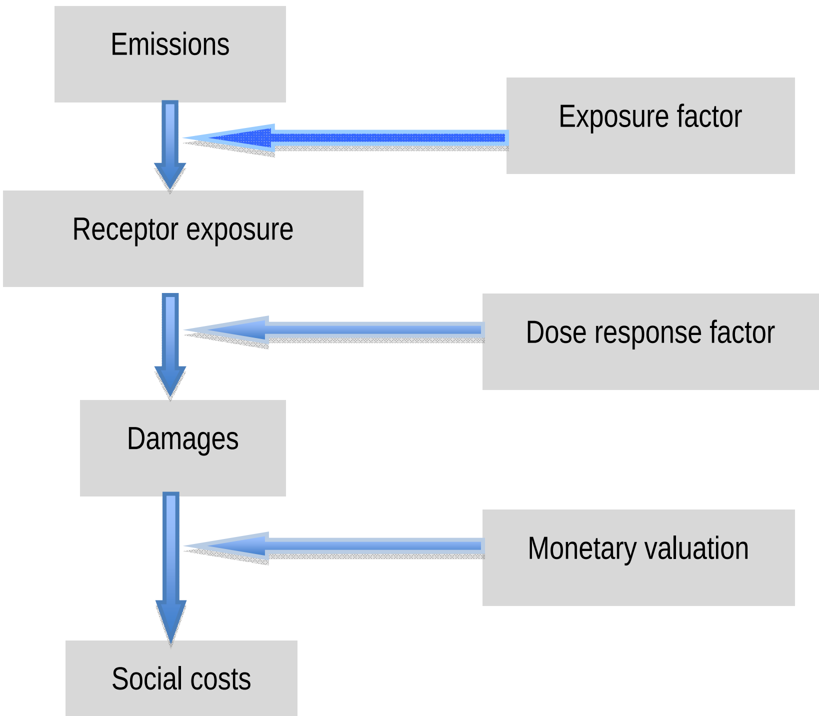
Figure 3.6 explores the components that need to be taken into account in emission damage value estimation. The figure is adapted from EC 2000.

The emission damage values need to take into account the 'receptors' affected by the emissions and the level of exposure (eg: receptors from pollution may be the health of nearby human communities with exposure being the risk of a cancer(s)). The 'dose-response' factor links the exposure and the physical damages (eg: how do changes in exposure affect cancer risks in the identified population). The final step is the monetary valuation of the subsequent damages.

The remainder of this section describes the methodologies to be used to estimate physical emissions for the key emissions from landfills of greenhouse gases, other air emissions and leachate. We also assess the appropriateness and reliability of different emission damage values from the literature. Pollutant damage values (or ranges of values) are selected for the valuation of each impact. We also discuss our approach to valuing disamenity impacts, an externality that is largely fixed rather than varying with the amount of waste disposed at a landfill.

Our approach is to recommend a "range of values" likely to be appropriate for each externality for various landfill classifications. This approach is intended to explicitly overcome criticisms by the Productivity Commission 2006 and others that impact valuations should be context specific rather than generic.

Figure 3.6: Composition of per unit emission damage values



Greenhouses gas emissions

For the estimation of greenhouse emissions from landfilling of wastes we have used the National Greenhouse Accounts (NGA) Factors published by the Department of Climate Change in November 2008. We take into account the typical mix of wastes being landfilled in the States and Territories and estimate typical greenhouse emissions per tonne of waste for landfills without gas collection or with controls. We then examine the likely level of methane recovery across Australia drawing on Hyder 2007[36] which incorporates the issue of legacy emissions.

[36] Hyder 2007

Section 3.3.1 reviewed the emission damage values used for greenhouse emissions in various waste studies and other related studies, and indicated a range from $5 - $65 per tonne of CO2-e. An approach commonly used for estimating damage values for greenhouse emissions is the preventative expenditure method, where the price of purchasing greenhouse credits is used as an indicator of the value of carbon emissions. We propose to use the price cap proposed for the Australian government's Carbon Pollution Reduction Scheme of $40 per tonne of CO2-e. This value is also in the middle of the range of values used in other recent waste studies for the damage cost of greenhouse emissions.

Due to the uncertainties surrounding the damage values for greenhouse emissions we carry out an analysis of the sensitivity of the results to these values in section 7.3.

Other air emissions

Landfills that meet certain emission thresholds are required to report on a range of substances to the National Pollutant Inventory. The National Pollutant Inventory Emission Estimation Technique Manual for Municipal Solid Waste Landfills published by the Department of Environment and Heritage in May 2005 provides guidance for landfills. For emissions other than greenhouse gases we use the NPI emissions estimation technique manual to estimate physical loadings for different types of landfills with different characteristics (a bottom up approach). We also use the data reported to the NPI to estimate aggregate physical loadings for Australian landfills to provide a comparison (a top down approach).

The emissions estimates are developed taking into account the characteristics of landfills in different classification groupings including capacity, annual waste acceptance, rainfall and emission controls.

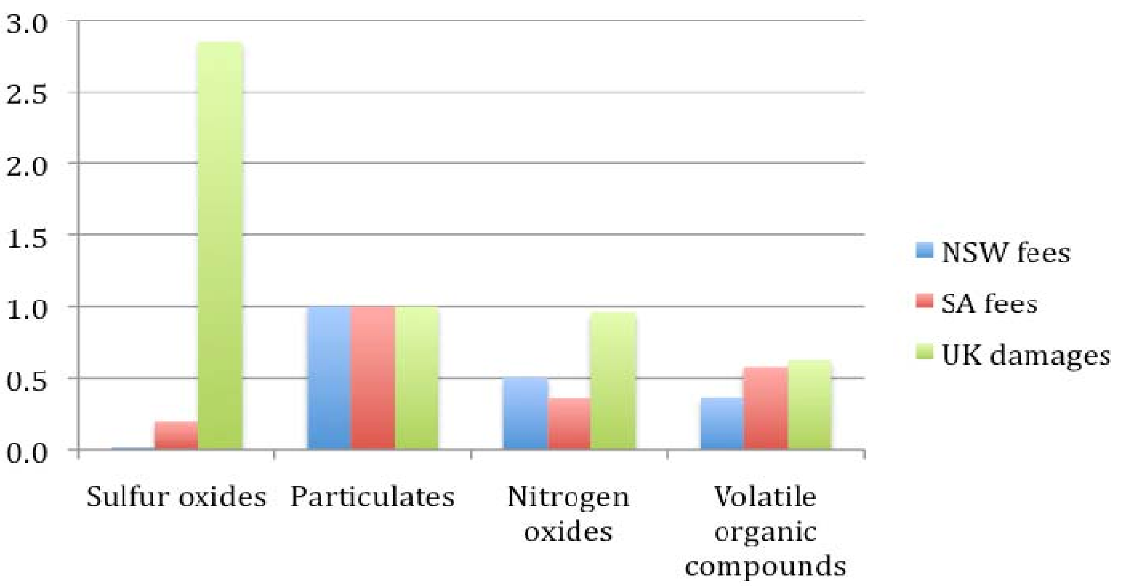
The per unit emission damage values for air emissions were then estimated assuming that the key impact of air emissions is human health impacts. These impacts will vary between pollutants and between locations according to likely population exposure. Our approach was to firstly develop alternative damage values for urban and rural landfills to reflect, albeit in very broad terms, the differences in likely population exposure.

Secondly, we sought to differentiate health impacts by pollutant. One approach is to adopt the impact relativities expressed in government pollution fees, and to use an estimated damage valuation for one pollutant as the basis to derive valuations for other pollutants. As PM10 has often been used as an indicator pollutant, using a damage valuation for PM10 appears a reasonable selection. Most Australian states have pollution fee schemes for industry to provide an incentive to reduce emissions and some fees vary according to location. In particular, the New South Wales and South Australian fee systems have been developed explicitly taking into account priorities for reducing pollution across their States.

To examine the robustness of using PM10 as an 'anchor' value to derive impact values for other pollutants, a comparison of the pollution value relativities between the NSW and SA pollution fees and UK pollution damage costs as estimated by DEFRA 2004 was undertaken and is reported in Figure 3.7.[37] PM_{10} has been given an index value of 1 and other pollutant values are shown as an index relative to the PM_{10} value.

Both NOx and VOC are precursors to ozone formation and their relative importance will depend upon the level of aggregate emissions of each and on particular airshed factors. VOC emissions are considered a greater problem in managing ozone pollution in SA than are NOx emissions, whereas the reverse is the case for NSW and for the UK as shown by the damage cost estimates.

Figure 3.7: Comparison of pollution value relativities (PM_{10} index value =1)



While the relativities for NOx and VOC are comparable between these jurisdictions, differences for SO2 are more significant. SO2 emissions are a relatively low priority in NSW and SA while they represent a high damage cost pollutant in the UK. This is to be expected as high ambient concentrations of SO2 in Europe has led to acid rain and associated environmental problems. Due largely to the low sulphur content of coal in Australia used to produce electricity, SO2 has not posed a similar problem.

The selection of a damage valuation for PM10 for use as an anchor emission damage value is more problematic. For this we drawn on DEFRA's 2004 review of the physical health and environmental effects of options to manage wastes in the UK. While the DEC 2005[38] study on the health effects of air pollutants in the Greater Metropolitan Region in NSW provides local

[37] The NSW and SA pollution fees are those applicable in their 'critical zones', while the UK damage costs are based on the 'high mortality valuation' derived by DEFRA.

[38] DEC 2005

information it uses PM10 as an indicator for all air pollutants, and so is not appropriate to use as an 'anchor' value.

The DEFRA study provides low and high mortality estimates for the damage costs of particulates and assumes that emissions are in rural areas. We have selected the high mortality estimate to use as the anchor value for emissions of PM10 in rural areas of Australia as shown in Table 3.9.

Table 3.9: Proposed anchor value for particulates ($A2008/tonne)

Location	Anchor value
Rural	$2,700

This anchor value must then be applied to a schedule that indicates the relative impacts of different pollutants in different locations in Australia. The NSW pollution fee system has been developed explicitly taking into account the priorities for reducing pollution across the State and is used to develop the relative estimates of damage costs. The fee system includes critical zone weights setting higher fees for nitrogen oxides and volatile organic compounds in metropolitan areas. The NSW DECC has recently reviewed and revised the urban air pollution critical zone weights upwards.

We use the "anchor" value for the health costs of fine particulates shown in Table 3.8 and the relativities of the NSW pollution fee scheme to develop values for environmental costs for each pollutant in an urban and rural setting. Table 3.10 shows the resulting per tonne pollution emission damage values.

Table 3.10: Emission damage costs for air pollutants ($A2008/tonne of pollutant)

Emissions to air	Urban	Rural
Benzene	$16,000	$16,000
Coarse particulates	$400	$400
Fine particulates	$2,700	$2,700
Hydrogen sulphide	$7,000	$7,000
Mercury	$2,400,000	$2,400,000
Nitrogen oxides	$1,400	$200
Sulfur oxides	$50	$50
Volatile organic compounds	$1,000	$140

Notes: includes all air pollutants in NSW licence fee scheme that are emitted by landfills.

Water emissions (leachate)

Emissions to soil and water from leachate have been estimated using NPI emission estimation techniques and taking into account the characteristics of landfills in different classification groupings. We use the same approach to developing damage cost estimates for water pollution as above – with the "anchor" value for the health costs of fine particulates shown in Table 3.9 and the relativities of the NSW pollution fee scheme.

The only regional differences in fees for water emissions in the NSW scheme are for catchments where salinity and nutrients are at critical levels and these pollutants are generally not present in leachate from landfills. There are no penalties for toxics discharged in an urban setting because the fee system is aimed at emissions directly to surface waters and in urban areas the toxics are largely discharged through tradewaste treatment systems and ocean outfall (with minimum impact). However, leachate would impact on groundwater with potentially greater impacts.

In the absence of any information to differentiate between urban and rural impacts, Table 3.11 shows the damage values used for water pollutants.

Table 3.11: Emission damage costs for water pollutants ($A2008/tonne of pollutant)

Emissions to water	Urban & Rural
Arsenic	$54,000
Cadmium	$1,447,000
Chromium	$91,000
Copper	$37,000
Lead	$138,000
Mercury	$3,888,000
Total PAHs	$82,000
Total phenolics	$106,000
Zinc	$150

Notes: includes all water pollutants in NSW licence fee scheme that are present in leachate from landfills.

Amenity impacts

Section 3.3.4 reviewed the literature valuing the external costs of impacts of landfills on amenity. The only Australian estimate is the Productivity Commission assessment which relates to best practice landfills. We use the Productivity Commission's estimate of around $1 per tonne of waste for disamenity associated with a best practice landfill.

For landfills that are not at best practice it is important to differentiate between urban and rural areas given that in rural areas there would be lower population exposure, possibly more remote siting (ie: a greater distance from the closest houses) and lower land / house valuations.

We use an estimate of around $10 per tonne for Australian urban areas which is at the upper end of the values reported in DEFRA 2004 for the UK and Covec 2007 for NZ. We use an estimate of $5 per tonne for rural areas to reflect the impact setting, but stress that there are currently no local studies to support this assumption.

Table 3.12 summarises the disamenity values to be used to estimate external costs.

Table 3.12: Proposed disamenity values ($A2008/tonne)

Management controls	Urban	Rural
Best practice	$1	$1
Not at best practice	$10	$5

3.5.3 Other potential non-market impacts

Other costs are sometimes considered as external costs of landfilling. These may include:

- post-closure environmental effects;
- opportunity costs of sterilisation / alienation of land;
- increased future costs as sites for landfill become scarcer and more remote; and
- opportunity cost of not recovering resources in waste.

As awareness of the full costs of landfill management has increased the costs of closure and post closure maintenance are increasingly accounted for as part of the private costs of landfilling. In addition, financial assurances are commonly required to cover the costs of managing the land to minimise risks after closure.

However, there remain longer term risks to human health and the environment associated with land that was formerly a landfill. This is sometimes referred to as the long term opportunity cost of sterilisation or alienation of land. An example of this arose recently with problems with methane gas identified at the former Stevensons Road (Cranbourne) landfill. As well as requiring improved management at this site, the Victorian EPA undertook a review of methane management at 260 operating and former landfills in Victoria[39]. The review found that 97 per cent of those assessed were unlikely to have any methane effects on adjacent communities.

A small number of landfills had methane from landfill gas above investigation trigger levels detected at the landfill boundary. Although methane from these landfills was thought unlikely to have any effect on adjacent communities, the landfill operators/managers are now adopting improved methane management controls. The review indicates that methane gas movement is primarily a legacy of landfilling practices over many decades, typically in larger metropolitan landfills and particularly where siting and design standards predate EPA's current best practice guidelines.

39 VIC EPA 2009

Regarding the impact of landfill sites becoming scarce and more remote, this appears the case for example in WA and SA where groundwater protection priorities place restrictions on landfill siting. However in other instances former mine and quarry sites have offered beneficial reuse of 'orphaned' sites such as the Woodlawn landfill in NSW. There are also increasingly innovative future uses available for end-of-life landfill sites, increasing otherwise low residual land values. However, there is considerable local community opposition to the siting of some new landfills.

The pertinent question is the extent to which these costs are external to prices faced in land markets and other transactions made by landfill operators. If landfill services are supplied in a competitive market, increasing landfill scarcity over time will be reflected in increased disposal charges and serve to increase the relative cost-competitiveness of alternative waste management options. In these circumstances, continued landfill development will be a reflection of the returns available in that land use and accord with an efficient use of (land) resources – there are not additional external costs. Similarly, many of the other perceived externality costs associated with future scarcity are borne directly by landfill operators. These include:

- the cost of future environmental damage (for example via post-closure guarantees);
- costs of finding sites that are acceptable to local communities (including environmental impact statements and legal costs); and
- cost of sterilisation of land (this is reflected in the lands progressive loss of value over the life of the landfill).

In summary, most of the costs discussed above are unlikely to be external to the commercial operation of landfills. To the extent that some environmental risks do remain external to the private costs faced by landfill owners, there is little information on the extent of such risks let alone sufficient information to quantify associated costs.

Finally, the costs and benefits of alternatives to landfilling, such as the potential through recycling to reduce the use of virgin materials, energy and generation of pollution in industrial processes, have not been considered. Such costs and benefits will be unique to the alternative chosen which could vary significantly between say illegal disposal, incineration and recycling. Further, the costs of the policy mechanism and any changes in waste handling, including collection, sorting and transport would need to be identified as well as the extent and composition of any residuals that may still be landfilled. These costs and benefits will be unique to specific policy proposals and are outside the scope of this report.

4 CLASSIFICATION OF AUSTRALIAN LANDFILLS

This section proposes a classification for Australian landfills to guide and report on the costs of waste disposal to landfill. We have classified landfills according to factors influencing both the private and external costs of waste disposal. Figure 4.1 sets out the major factors including physical characteristics, management practices and location.

Figure 4.1 Classification of landfills

PHYSICAL CHARACTERISTICS

Type of waste:
- Inert
- Putrescible

Size:
- Small
- Medium
- Large

Climate:
- Wet temperate
- Dry temperate
- Moist & wet tropical

MANAGEMENT PRACTICES

Landfill gas management:
- No gas collection
- Gas flaring

Leachate management:
- No liner
- Liner

Amenity management:
- Not best practice
- Best practice

IMPACT SETTING

Location / population:
- Urban
- Regional / rural

The physical characteristics influence the cost and potential environmental impacts of a landfill. The size is particularly important in determining private costs and the type of waste taken and climate are important determinants of the potential for environmental impacts. The management practices in place to control landfill gas, leachate and amenity impact all influence private costs. The management practices in place and the location / nearby population determine the resulting environmental impacts over time.

A number of general assumptions have been made about the typical characteristics of landfills in different classifications in order to generate estimates of the costs of disposal. The basic assumptions about waste acceptance are:

- Inert landfills are taking inert wastes and do not have significant air emissions or leachate impacts.
- Putrescible landfills are taking the bulk of Australia's municipal solid waste and commercial and industrial waste with average waste compositions shown in the 2008 Department of Climate Change Guidelines[40] and resulting in a combined degradable organic carbon content of around 25%.

Landfills have been categorised as small, medium and large and the assumed annual waste acceptance is shown in Table 4.1 below. The representative categories and annual waste acceptance estimates are consistent with those in the Landfill Performance Study undertaken in parallel with this analysis (WCS 2009).

Table 4.1: Classification of landfills by size

	Category (tonnes / yr)	Assumed annual disposal (tonnes / yr)
Small	< 10,000	5,000
Medium	10,000 – 100,000	35,000
Large	> 100,000	230,000

Another important factor for emissions estimation is climate. The IPCC guidelines for National Greenhouse Inventories has four climate classifications used as one input to determining methane generation rates. These methane generation constants are adopted in the Department of Climate Change technical guidelines with the Australian states categorised according to climate.

Table 4.2 shows the classification groupings of Australian States and Territories as well as the assumptions we have made where specific estimates of temperature and rainfall have been required.

40 Department of Climate Change 2008

Table 4.2: Climate characteristics

Class	States	Assumed average temperature (°C)	Assumed average rainfall (mm)
Wet temperate	NSW	22	500
Dry temperate	VIC, WA, SA, TAS, ACT	25	300
Wet tropical	QLD, NT	28	700

Notes: The mid-point estimates of average temperature and rainfall are from the National Pollutant Inventory Landfill Emissions Assistant

5 ESTIMATED PRIVATE COSTS FOR AUSTRALIAN LANDFILLS

Our estimates of the private costs of landfilling, derived from the available Australian data and NZ full cost accounting guide presented in section 2, are shown in Table 5.1. The table provides estimates for small, medium and large landfills (as defined in Table 4.1) and a breakdown of the major components of the private costs of landfilling.

Table 5.1: Estimates of the private costs of landfilling ($ per tonne)

Type of cost	Small	Medium	Large
Land	$5	$3	$2
Approvals / site development	$10	$6	$4
Best practice liner	$13	$8	$5
Leachate collection	$6	$4	$3
Gas recovery	$6	$4	$3
Amenity management	$1	$1	$1
Operations	$34	$20	$14
Capping & remediation	$10	$6	$4
Post-closure maintenance	$15	$9	$6
Total	*$100*	*$60*	*$40*

Source: BDA estimates

There is limited information available to differentiate costs between urban and rural areas. In rural areas land would be cheaper, however the cost of land is a small component of the overall costs of landfill disposal, and so would not have a significant impact on the cost structure. The greatest driver for costs is likely to be economies of scale (as shown in the Table 5.1) which are also not likely to be significantly impacted by urban versus rural location.

6 ESTIMATED NON-MARKET COSTS FOR AUSTRALIAN LANDFILLS

This section provides estimates of the environmental and social costs of landfill disposal for landfills of different characteristics, management practices and locations. It provides a costing of the externalities per tonne of waste disposed for landfills taking putrescible waste.

Estimation of the landfill externality costs requires firstly identification of the likely physical loadings from landfills; then a determination of the receptors of the loadings and the resulting physical impacts given the context; and finally valuation of the physical impacts in monetary terms.

Indicative estimates of non-market costs are provided for various types of putrescible landfills. We estimate these costs over the life of a landfill (beginning from now) and beyond. It should be noted that estimation of the non-market costs for any individual landfill will need to take into account site specific factors and identify a specific time profile of emissions.

6.1 Physical environmental loadings from landfills

There are two main types of emissions from landfills: landfill gases formed when materials with degradable organic carbon dissimilate; and leachate which is liquid that has passed through a landfill and may have become contaminated and enter groundwater, or sometimes surface waters. Emissions result mainly from the decomposition of organic waste and the types, quantities and timeframes of landfill emissions are difficult to estimate. This section provides an indicative assessment of the physical loadings of pollutants for landfills taking putrescible waste.

6.1.1 Greenhouse gas emissions

The greenhouse gas emissions have been estimated using the Tier 1 first order decay method for estimating methane emissions from solid waste landfills[41]. The quantity of methane generated from solid waste disposal is estimated using a carbon mass balance approach that involves estimating the degradable organic carbon (DOC) content of the solid waste (ie: the organic carbon that is accessible to biochemical decomposition) and using this estimate to calculate the amount of methane that can be generated by the waste. Methane is generated by the decay of the degradable organic carbon stock in the landfill site and reflects waste disposal activity over time. The assumptions relating to the characteristics of the landfills were outlined in section 4.1 above.

The key assumptions we have used to derive the estimates of greenhouse gas emissions are:

- the life of each landfill is 30 years and we assess greenhouse emissions from the opening time to 50 years after closure.

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[41] We have used the IPCC spreadsheet supporting the 2006 IPCC Guidelines for National Greenhouse Inventories.

- the landfills receive an average waste composition derived from adding the total waste disposed in each of the MSW and C&I waste streams for 2006/07[42] and the compositions in the DCC guidelines[43].
- the hundred year global warming potential for methane is 21 (as assumed in the current DCC guidelines).
- a typical gas collection system recovers 60% of landfill gases (the default value used for the estimation of emissions from landfills to the National Pollutant Inventory[44]).This is supported by a recent analysis by Hyder Consulting[45] that argues that while capture efficiencies of up to 95% have been reported and best practice is accepted as 75%, a more realistic typical value over an extended period of operation would be closer to 60%.
- gas collection systems are assumed to be in place over the 30 year life of the landfill as well as during a 30 year post closure period. Although we assess emissions for up to 50 years after closure, we assume gas collection ceases after 30 years as ongoing recovery of small quantities of methane becomes unviable – see figure 6.2 for the assumed profile of methane recovery over time
- all the landfills are "managed" according to the IPCC definition. The amount of methane produced depends in part upon the available oxygen and the level of compaction of the waste. In general, waste in managed sites potentially generates more methane than waste in unmanaged sites.

Landfill emissions of methane are particularly important because they have a much greater climate change impact than greenhouse gases from other sources (for example 21 times the impacts of carbon dioxide emissions from electricity generation).

The greenhouse emissions from landfills are estimated to range from 0.65 – 1.53 tonnes of carbon dioxide equivalent (CO2-e) per tonne of waste landfilled depending on the climate and whether there is a gas collection system in place. Table 6.1 summarises the physical loads of greenhouse emissions estimated from the example landfills. The estimated emissions per tonne of waste do not vary with the size of the landfill.

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42 From Hyder 2008

43 Department of Climate Change 2008

44 The unpublished Landfill Emissions Assistant spreadsheet was provided to the project team in June 2009 by the National Pollutant Inventory and is based on the latest information from the USEPA AP42.

45 Hyder Consulting 2008

Table 6.1: Greenhouse emissions from landfills (tonnes CO2-e / t waste)

Gas management	Dry temperate	Wet temperate	Wet tropical
No gas collection	1.41	1.51	1.53
Gas collection	0.66	0.66	0.65

Notes: The figures represent total CO2-e over the 30 year life of the landfill and 50 years after closure divided by the total tonnes of waste disposed to landfill over the 30 year period. Gas collection recovers 60% of landfill gases over the landfill life and post-closure period.

In Table 6.1 the greenhouse emission rates do not appear to vary significantly across the climatic conditions. This is because we have summed the physical emissions over a long period of time. However, the rate of decomposition does differ - with carbon available for methane generation much earlier in the wet tropical climate. Figure 6.1 shows an example of the emissions profile at a small landfill without gas collection in different climates. Emissions increase with cumulative disposal volumes to the landfill, then fall away with closure of the landfill.

Figure 6.1: Greenhouse emissions profile from small landfill without gas collection

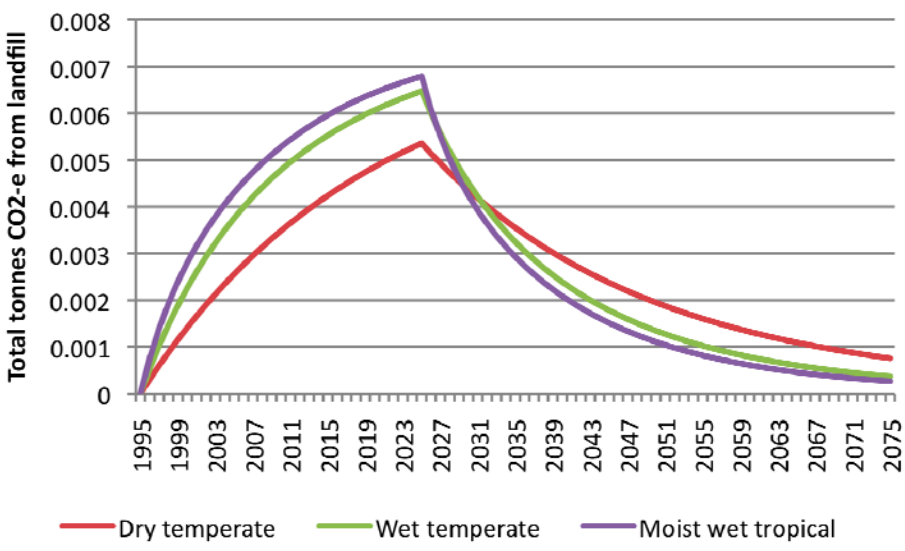
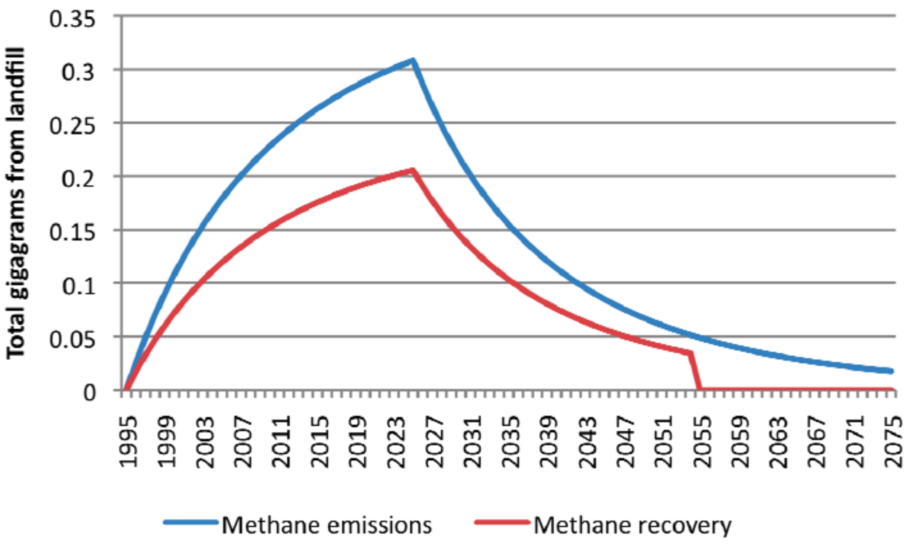


Figure 6.2 shows an example of the profile of methane generation and recovery at a landfill with gas collection. Methane recovery is reduced to zero at the end of the post closure period.

Figure 6.2: Methane recovery profile from small wet temperate landfill



Where landfill gas is captured and used to generate electricity this avoids greenhouse emissions from the combustion of fossil fuels.

We have assessed the greenhouse gas emissions likely to be displaced through the use of landfill gas for energy recovery. We have used the approach and key assumptions outlined in Hyder 2008 which assessed the level of methane capture that would be required to fully offset the instantaneous greenhouse emissions from a large landfill[46]. We have assessed the displaced emissions over the life of the gas recovery system. The following assumptions have been applied:

- Energy content of methane 55.52 MJ/kg;
- Conversion factor of 3.6 MJ/KWh;
- Efficiency of conversion of the methane to electricity of 30%; and
- Emissions for purchased electricity of 1.06 kg CO2-e/KWh.

The net emissions from landfills with energy recovery are estimated to be between 0.42 and 0.55 tonnes CO2-e per tonne of waste depending on the climate and period of time over which landfill gas is used for energy recovery. Figure 6.2 summarises the results.

46 Hyder Consulting 2008

Table 6.2: Net greenhouse emissions with energy recovery (tonnes CO2-e / t waste)

Energy recovery	Dry temperate	Wet temperate	Wet tropical
Over operating life of landfill	0.52	0.55	0.50
Over operating life of landfill and post-closure period	0.44	0.46	0.42

Notes: The figures show gross emissions less displaced emissions.

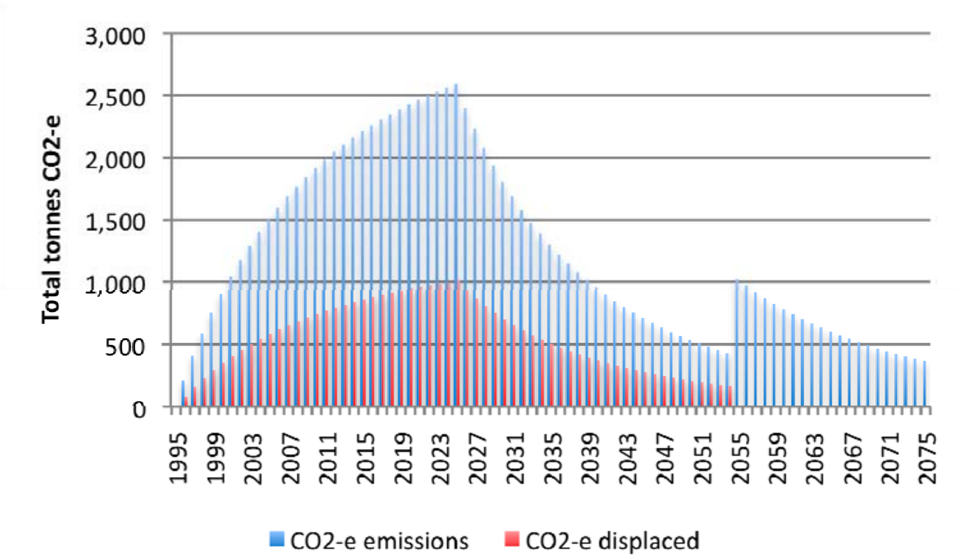
Gross emissions = total CO2-e over the 30 year life of the landfill and 50 years after closure divided by the total tonnes of waste disposed to landfill over the 30 year period

Displaced emissions = total CO2-e displaced over the 30 year life of the landfill and 30 year post closure period if relevant divided by the total tonnes of waste disposed to landfill over the 30 year period

Our assessment indicates that gas collection (with 60% efficiency) and energy recovery over the operating life and post closure period has the potential to reduce the overall greenhouse impact of landfilling by around 70% compared to landfills with no gas collection.

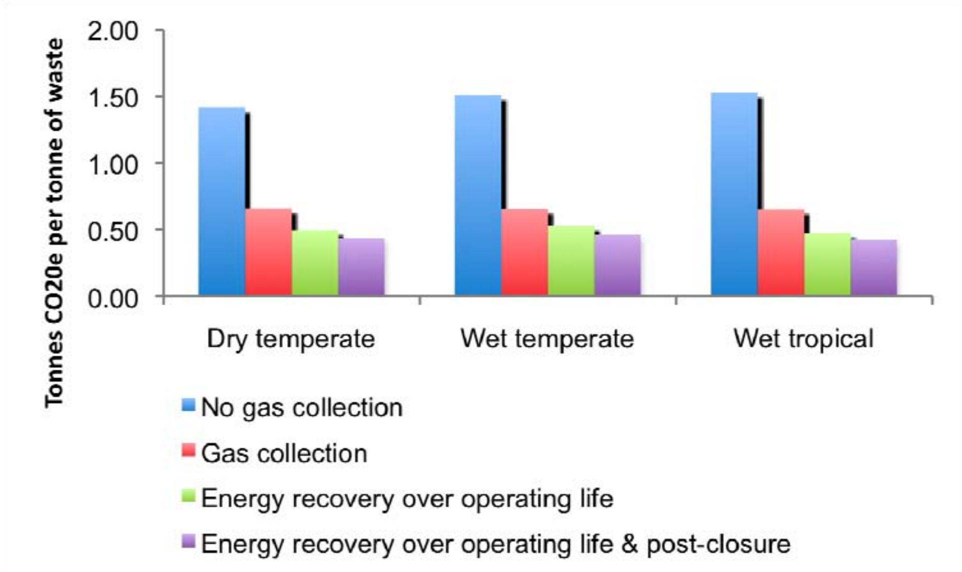
Figure 6.3 shows an example of the profile of emissions estimated to be emitted and displaced over time for a small landfill in wet temperate conditions. The jump in the CO2-e emissions indicates where gas collection stops at the end of the 30 year post-closure period.

Figure 6.3: CO2-e emitted and displaced from small wet temperate landfill



The results for the net greenhouse gas emissions from landfills with different gas management systems in different climates are summarised in Figure 6.4.

Figure 6.4: Net greenhouse gas emissions from landfills



6.1.2 Other air emissions

Other air emissions from landfills have been estimated using the National Pollutant Inventory emissions estimation techniques for solid waste landfills[47].

The key assumptions we have used to derive the estimates of other air emissions are:

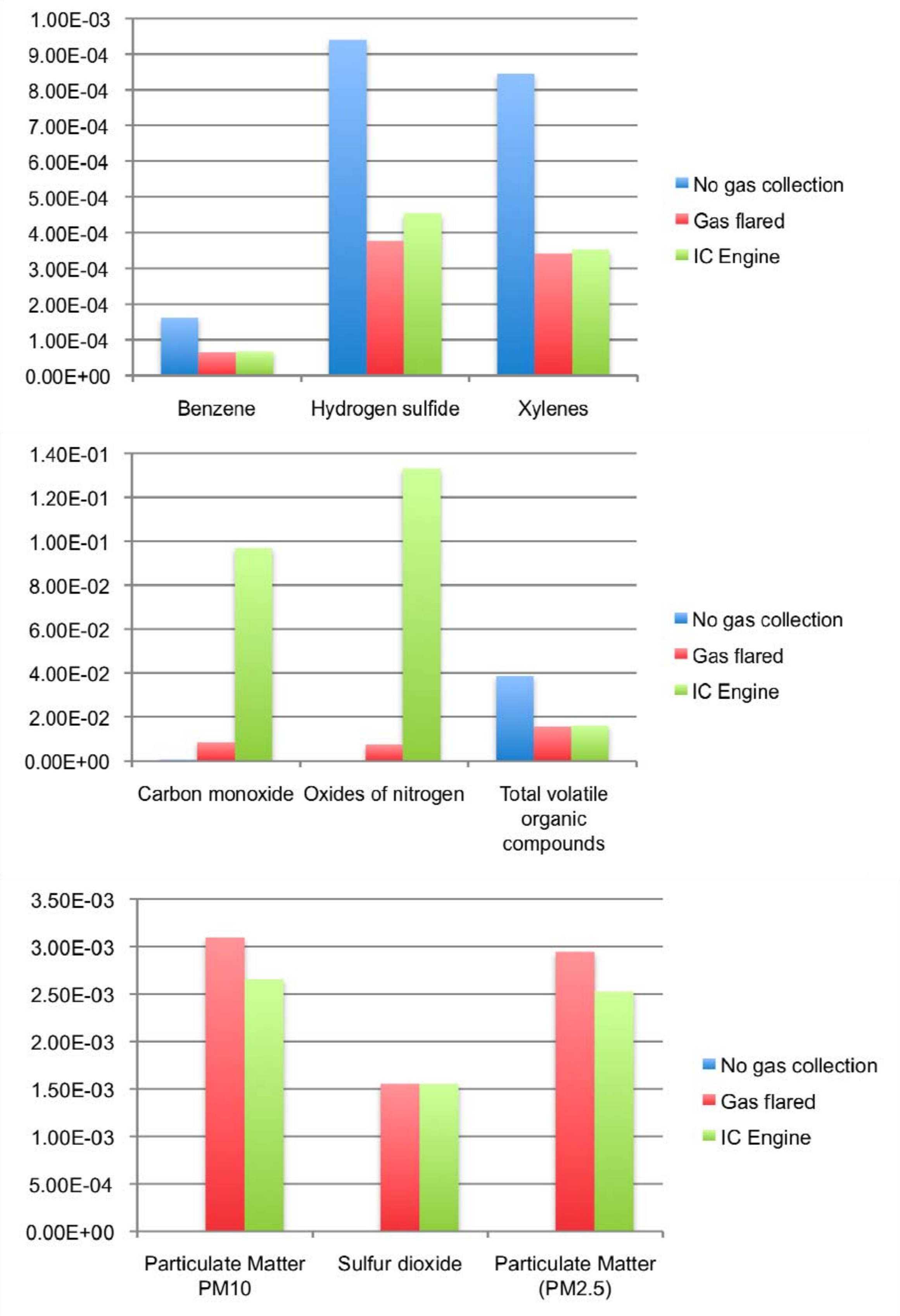
- the NPI emissions estimation spreadsheet model is set up to report on emissions in any one year. We have assumed an average age of 15 years and therefore estimated emissions in the 15th year of operation;
- our estimate of the efficiency of gas collection systems is the default value used for the estimation of emissions from landfills to the National Pollutant Inventory - 60% efficiency;
- we assess the three gas management outcomes: no gas collection; gas collection and flaring; and gas recovered for use in an internal combustion engine.

The outcomes of the spreadsheet model for the 34 NPI substances emitted by wet temperate landfills is shown in Attachment B (as an example). The landfill gas management systems significantly reduce emissions of many of the trace constituents of landfill gas including hydrogen sulphide, volatile organic compounds and benzene. However, they also increase or add some other air pollutants such as nitrogen oxides, carbon monoxide, sulphur dioxide and particulate matter.

Figure 6.5 provides some of the outcomes for key pollutants for landfills in wet temperate conditions – the pollutants are grouped according to the scale / quantity of pollutants for presentation purposes only.

47 The unpublished Landfill Emissions Assistant spreadsheet was provided to the project team in June 2009 by the National Pollutant Inventory and is based on the latest information from the USEPA AP42.

Figure 6.5: Range of air emissions from wet temperate landfills (kg / t of waste)

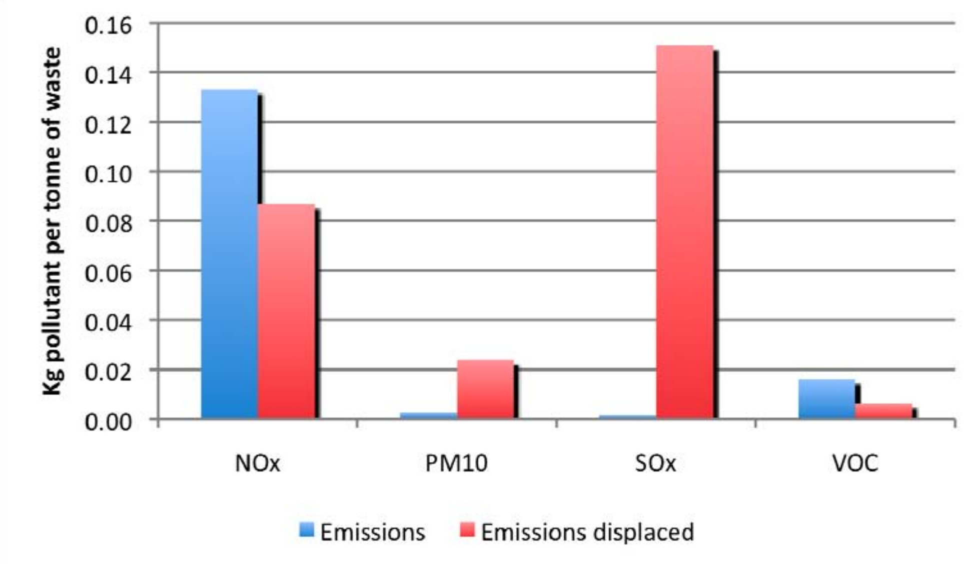


Where landfill gas is captured and used to generate electricity this avoids release of pollutants from the combustion of fossil fuels. We provide an indicative assessment of some key pollutants likely to be displaced based on the estimates of methane generation from the NPI model and assuming:

- Energy content of methane 55.52 MJ/kg;
- Emission factors for pollutants from the life cycle data inventory in RMIT 1998[48] for Australian high voltage electricity derived from coal.

The results are summarised in Figure 6.6. The analysis indicates that emissions of nitrogen oxides and volatile organic compounds are partly offset through energy recovery. For particulate matter and sulphur oxides the analysis suggests a greater level of emissions are displaced than generated with energy recovery at a landfill.

Figure 6.6: **Indicative estimates of key pollutants displaced w energy recovery** (kg / t of waste)



6.1.3 Water emissions (leachate)

Water emissions (leachate) from landfills have also been estimated using the National Pollutant Inventory emissions estimation techniques for solid waste landfills[49].

The key assumptions we have used to derive the estimates of leachate emissions are:

- the NPI emissions estimation spreadsheet model is set up to report on emissions in any one year. We have assumed an average age of 15 years and therefore estimated emissions in the 15th year of operation.

48 RMIT & NSW Cooperative Research Centre for Waste Management and Pollution Control 1998

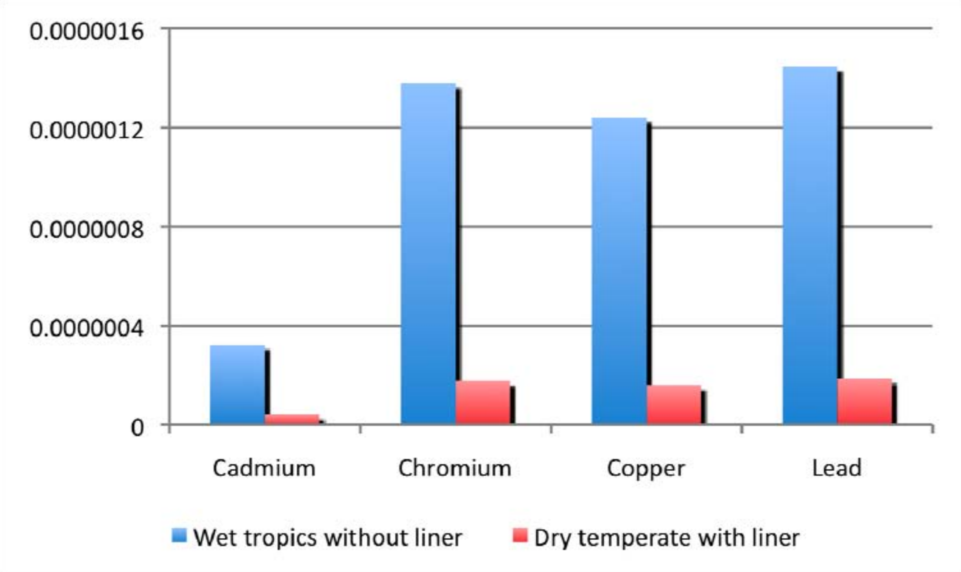
49 The unpublished Landfill Emissions Assistant spreadsheet was provided to the project team in June 2009 by the National Pollutant Inventory and is based on the latest information from the USEPA AP42.

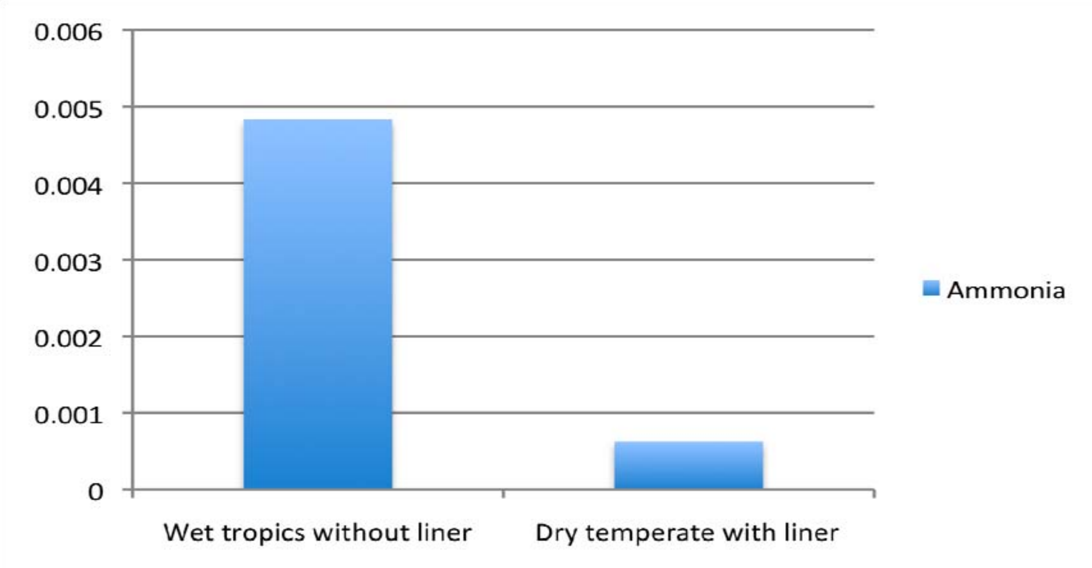
- our estimate of the efficiency of leachate collection systems is the default value used for the estimation of emissions from landfills to the National Pollutant Inventory - 70% efficiency.

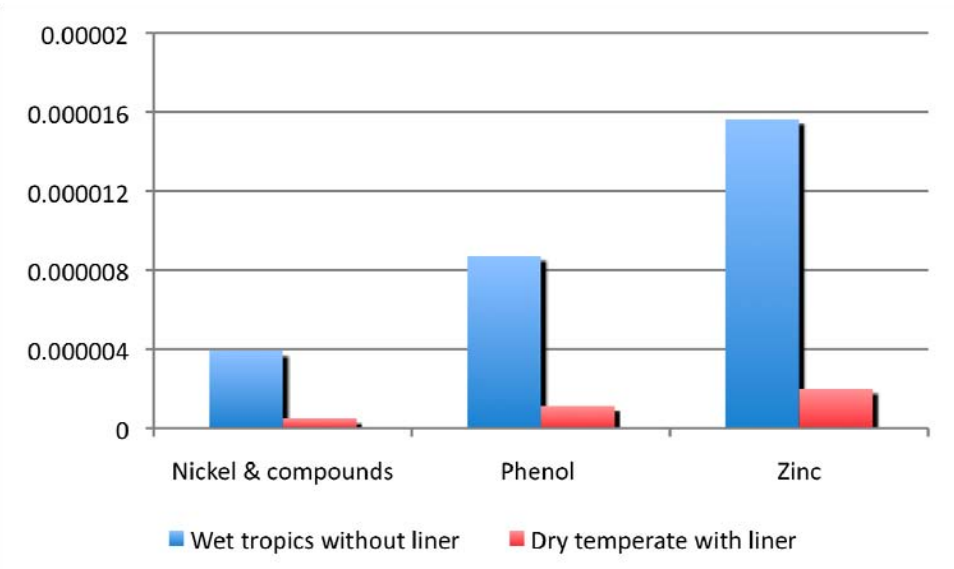
The outcomes of the spreadsheet model for the 24 NPI substances emitted to land or water by wet temperate landfills is shown in Attachment B (as an example). A landfill liner significantly reduces emissions of all pollutants to water and land.

Figure 6.7 shows the range for tonnes of pollutant per tonne of waste for some of the key pollutants – from the highest emission rates in wet conditions with no liner to the lowest emission rates in dry conditions with a liner. The pollutants are grouped according to the scale / quantity of pollutants for presentation purposes only.

Figure 6.7: Range of water emissions from landfills (kg / t of waste)







6.2 Receptors and valuation of physical impacts in dollar terms

Some of the physical loadings identified in section 6.1 will have different impacts in different locations.

6.2.1 Greenhouse gas emissions

Greenhouse gas emissions from landfills have the same global impact wherever they are released. Table 6.3 shows the estimated external costs of greenhouse emissions per tonne of waste disposed to a putrescible landfill with different climatic conditions and gas management. The estimates are based on a damage cost for CO2-e of $40 per tonne (as discussed in section 3.5.2) and a discount rate of 7% for the series of emissions estimated over the 30 years of the life of the landfill (beginning this year) and 50 years after closure.

Table 6.3: External cost of greenhouse emissions per tonne of waste

	Dry temperate	Wet temperate	Wet tropical
No gas collection	$9	$12	$13
Gas collection	$4	$5	$5
Energy recovery over operating life	$0	$0	-$1
Energy recovery over operating life & post closure	-$1	-$1	-$1

The estimates range from -$1 per tonne to $13 per tonne of waste disposed to landfill. The figures for landfills with energy recovery are net of emissions from displaced coal fired power generation.

The sensitivity of the results to both the damage cost for CO2-e and the discount rate is discussed in section 7.3.

6.2.2 Other air emissions

The impact of other air emissions from landfills varies depending on whether they are released in a highly populated urban setting or a less populated regional or rural setting. Tables 6.4 and 6.5 show the estimated external costs of other air emissions per tonne of waste in urban and rural settings.

The estimates are based on the damage costs set out in section 3.5.2. We have estimated average annual physical emissions and assumed this average occurs each year over the 30 year life of the landfill and 50 years after closure. With discounting this is likely to understate the external costs as emissions would be higher in earlier years and reduce over time. The costs have been discounted over time at a discount rate of 7%. Inclusion of values for the benefit of reduced emissions by displacing coal fired power generation requires an assumption about the location of the displaced impacts. We have used urban damage values for landfills in urban areas and rural damage values for landfills in rural areas to provide indicative values.

In an urban setting the estimates range from around $0.50 - $1 per tonne of waste disposed to landfill. In a rural setting they range from around $0.10 to $0.25 per tonne of waste landfilled.

Table 6.4: External cost of other air emissions per tonne of waste in urban areas

	Dry temperate	Wet temperate	Wet tropical
No gas collection	$0.67	$0.68	$0.66
Gas collection	$0.54	$0.55	$0.54
Energy recovery	$0.96	$0.97	$0.96

Table 6.5: External cost of other air emissions per tonne of waste in rural areas

	Dry temperate	Wet temperate	Wet tropical
No gas collection	$0.21	$0.21	$0.20
Gas collection	$0.23	$0.24	$0.23
Energy recovery	$0.08	$0.09	$0.08

In urban locations, the external costs of landfills with energy recovery are estimated to be higher than those without. In rural areas, the external costs of landfills with energy recovery are estimated to be lowest. Overall, the external costs of air emissions from landfills are estimated at less than $1 per tonne.

6.2.3 Water emissions (leachate)

The impact of leachate from landfills may vary depending on the location of release, however we have not been able to derive any damage values reflecting this variation. Table 6.6 shows the estimated external costs of leachate emissions per tonne of waste. The estimates are based on the damage costs set out in section 3.5.2.

Similar to the air emissions we have estimated average annual physical emissions and assumed this average occurs each year over the 30 year life of the landfill and 50 years after closure. With discounting this is likely to understate the external costs as emissions would be higher in earlier years and reduce over time. The costs have been discounted over time at a discount rate of 7%.

The estimates range from less than $0.01 - $0.03 per tonne of waste disposed to landfill.

Table 6.6: External cost of leachate per tonne of waste

	Dry temperate	Wet temperate	Wet tropical
No liner	$0.01	$0.02	$0.03
Liner	$0.00	$0.01	$0.01

6.2.4 Amenity

As indicated in section 3.5.2 we assume external costs of disamenity of $1 per tonne for best practice landfills. For landfills that do not meet best practice for amenity management the costs are estimated at $10 per tonne for urban areas and $5 per tonne for rural areas.

6.2.5 Summary of external costs per tonne

The external costs of landfilling putrescible waste are estimated to range from around $1 - $24 per tonne in urban areas around $1 - $19 per tonne in rural areas. Figures 6.7 and 6.8 summarise the estimates of external costs per tonne in urban and rural areas.

Figure 6.7: External cost per tonne of waste disposed in urban area

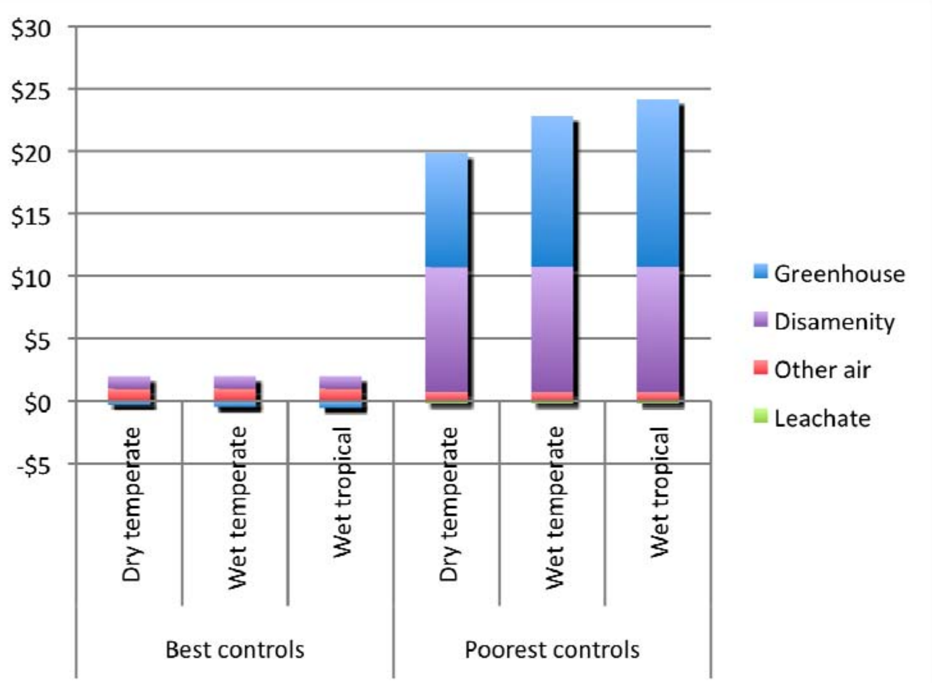
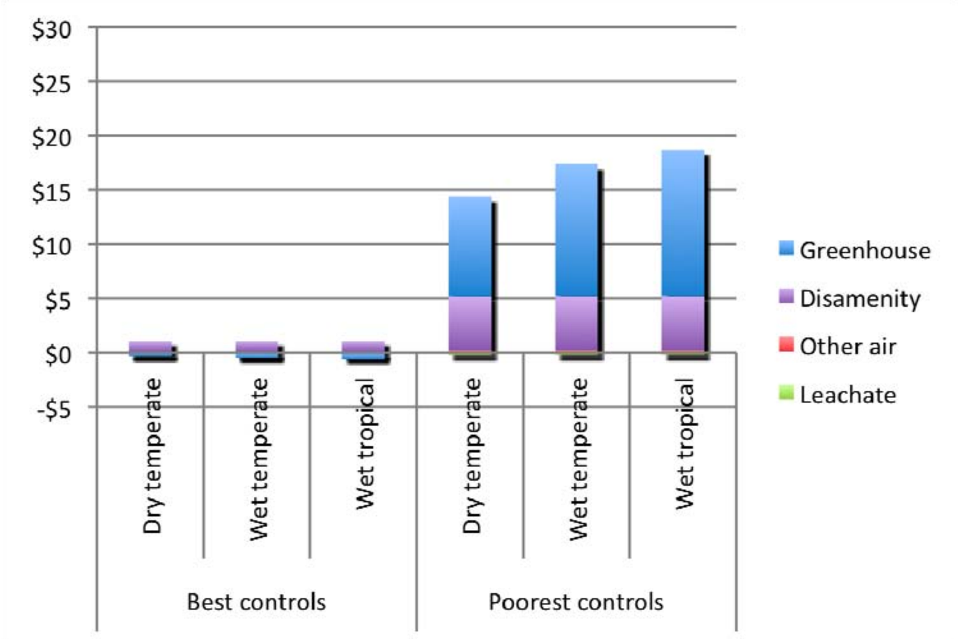


Figure 6.8: External cost per tonne of waste disposed in rural area



The greenhouse and amenity impacts dominate the external costs for landfills with poorer management. For landfills with liners, landfill gas collection, energy recovery and best practice amenity management the greatest impacts in urban areas are from disamenity and air pollutants other than greenhouse. For landfills with best practice controls in rural areas the impacts are dominated by disamenity.

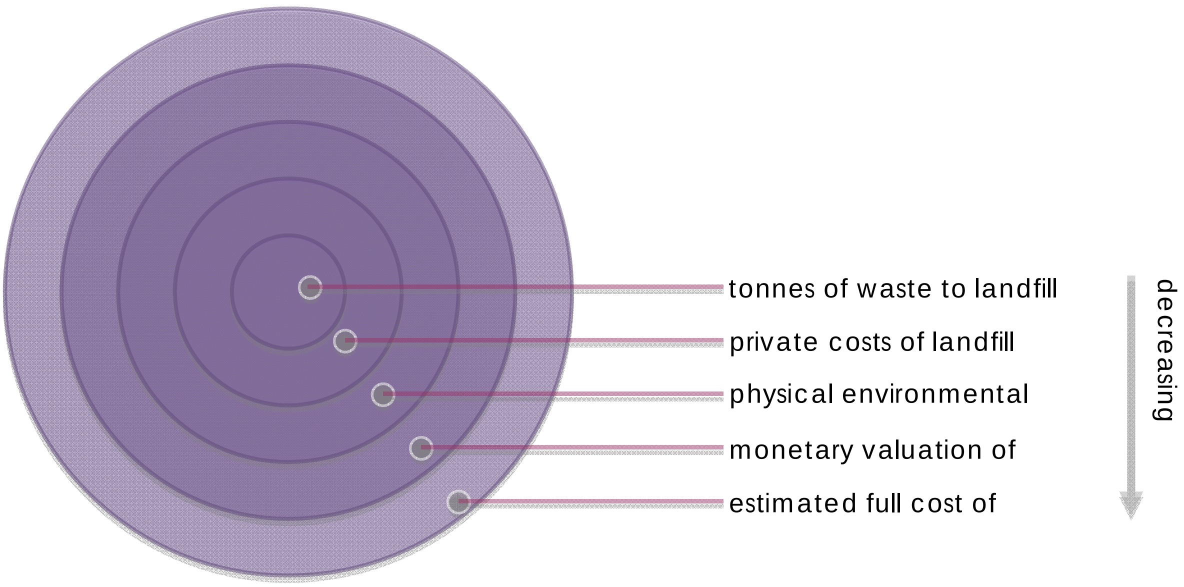
7 ESTIMATED FULL COSTS OF DISPOSAL FOR AUSTRALIAN LANDFILLS

This section consolidates the estimates in previous sections to provide information on the full costs of landfill disposal by classification per tonne of waste disposed. Firstly, we consider the level of certainty surrounding the estimates.

7.1 Levels of certainty over cost components

There are differing levels of certainty over the components of the estimated costs. Figure 7.1 illustrates how the level of confidence varies with the different components underlying cost estimates.

Figure 7.1: External cost per tonne of waste disposed in rural area



There is reasonable confidence in estimates of the tonnes of waste disposed to landfills in Australia as volumes are measured and reported for regulatory purposes. The private costs of landfill management will vary between landfills due to a range of factors, such as managerial skill. The average costs reported in this study are therefore subject to estimation error.

The estimation of physical environmental loadings, including the types, quantities and timeframes for emissions, is difficult to predict, supported by fewer studies and therefore much less certain. The monetary valuation of the externalities is based on even more limited studies across a range of settings, and is premised on a number of simplifying assumptions, introducing the greatest uncertainty of all the components of landfill costs.

7.2 Consolidated estimates of costs of landfill disposal

This section provides indicative estimates of the full cost of disposing of waste to various types of putrescible landfills. It should be noted that estimation of the full costs for any individual landfill will need to take into account site specific factors and identify a specific time profile of emissions.

The full cost of disposing of waste to putrescible landfills is similar in urban and rural areas - estimated at between $42 and $102 per tonne of waste in urban areas and between $41 and $101 per tonne in rural areas. The private cost estimates are taken from section 5 and the external cost estimates from section 6.

Figures 7.1 and 7.2 summarise the breakdown of these costs for putrescible landfills of different sizes comparing costs for landfills with the best controls and climate and those with the poorest controls / climate. The private costs for landfills with “poor” controls exclude the costs of liners, leachate management, gas management and amenity controls.

Figure 7.1: Private and external costs for putrescible landfills in urban areas

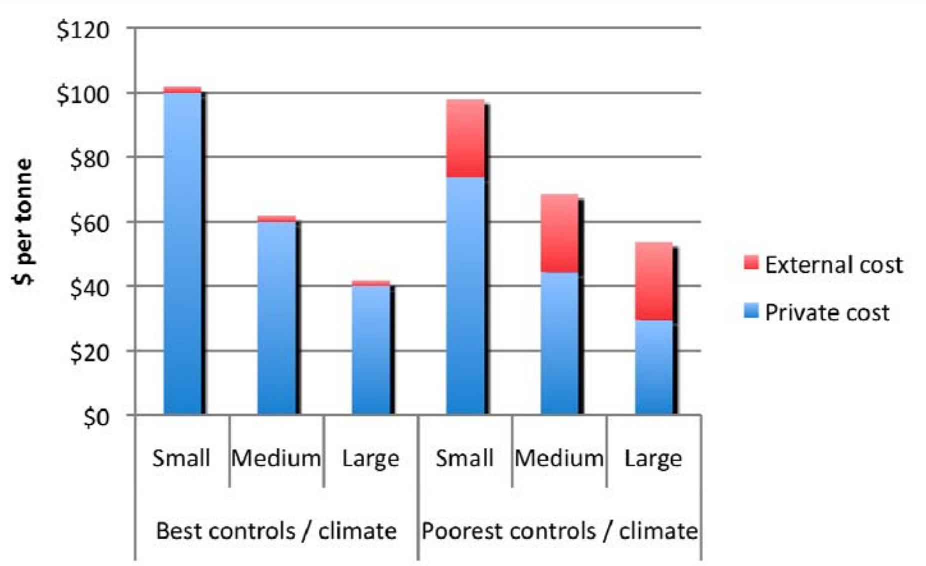
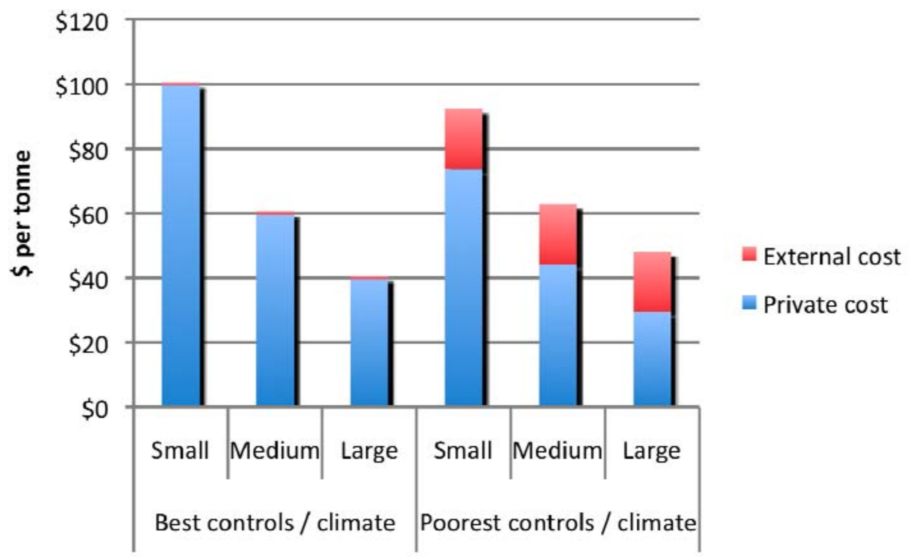


Figure 7.2: Private and external costs for putrescible landfills in rural areas



The contribution of external costs to total costs is significant for putrescible landfills with the poorest controls and climate, making up 25%-45% of total costs for landfills in urban areas and 20%-40% of total costs for landfills in rural areas. The contribution of external costs to total costs is much lower for landfills with best practice controls at less than 4% in urban areas and less than 1% in rural areas. Attachment C provides a series of tables with the individual results for all landfill classifications and a breakdown of the components.

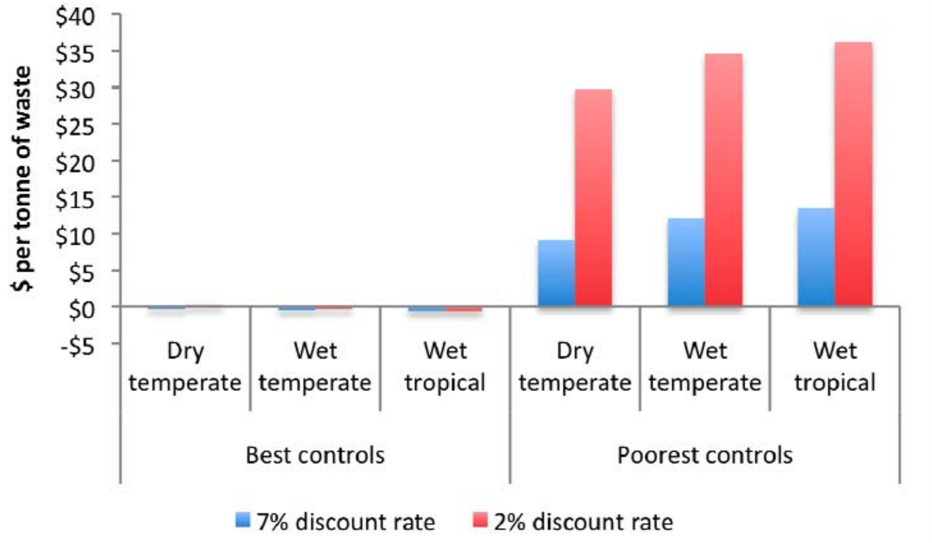
7.3 Sensitivity analysis

The greenhouse impacts make up a significant component of the external costs and there are some important assumptions influencing the valuation of these impacts. Sensitivity analysis has been carried to examine how changes in two key variables affect the outcomes for the costs of landfill disposal. These are the

- discount rate; and
- assumed damage cost for CO2-e emissions.

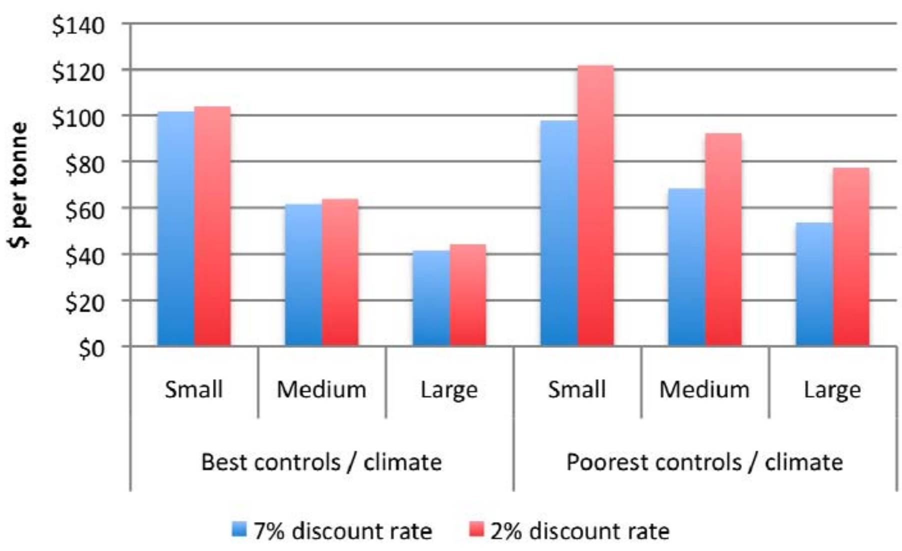
The choice of a discount rate is important. Several commentators suggest that the discount rate should be lowered where impacts are likely to occur over long timeframes, as is the case for greenhouse emissions. Attachment D provides a summary of relevant literature on choosing an appropriate discount rate. We assess how the costs of landfill disposal change greenhouse emissions for a landfill in a wet tropical climate with a lower discount rate of 2% (rather than 7%). Figure 7.2 shows how the estimates of the external costs of greenhouse emissions change.

Figure 7.2: Impact of chosen discount rate on the costs of greenhouse emissions



The selection of the discount rate has a big impact on the estimates of external costs for landfills with poor controls and significant greenhouse gas emissions. For the selected discount rates, the externality cost of greenhouse emissions per tonne of waste disposed more than doubles. Figure 7.3 shows the impact on the full disposal costs to landfill (for urban landfills as an example).

Figure 7.3: Impact of chosen discount rate on full costs of disposal for urban landfills



The lowering of the discount rate (applicable only to greenhouse gas cost impacts) has a relatively small impact on the overall cost of landfilling where good controls are employed. For landfills with poorer controls / climates the total costs of landfill disposal significantly increase. With the lower discount rate, the estimated contribution of external costs to total costs increases from 25-45% to around 40-60% for urban landfills with poor controls / climate.

Section 3.3.1 reviewed the emission damage values used for greenhouse emissions in various waste studies and other related studies, and indicated a range from $5 - $65 per tonne of CO2-e. The estimates of the external costs of greenhouse emissions vary directly in proportion with any changes in damage costs. Figure 7.4 shows how the external costs of greenhouse emissions are estimated to change with damage costs at $20, $40 and $60 per tonne of CO2-e.

Figure 7.4: Impact of varying damage cost on external costs of greenhouse emissions

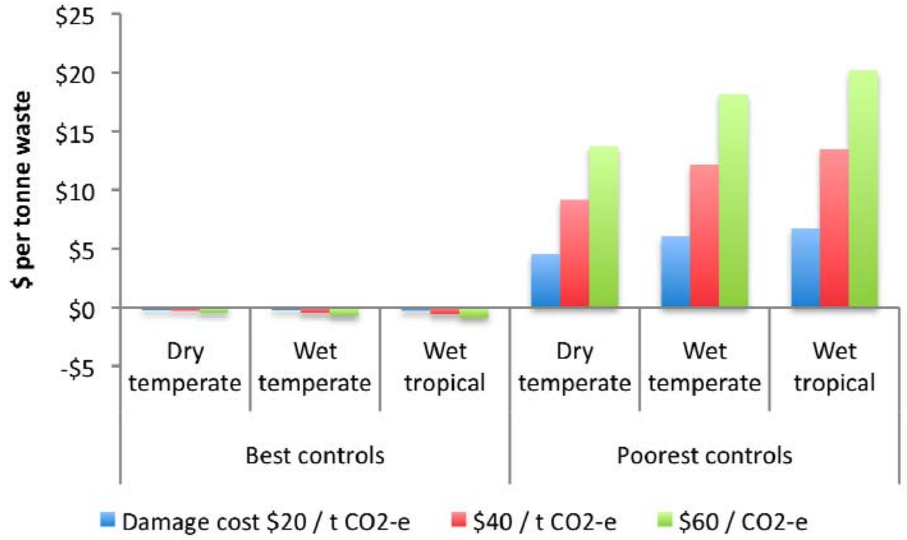
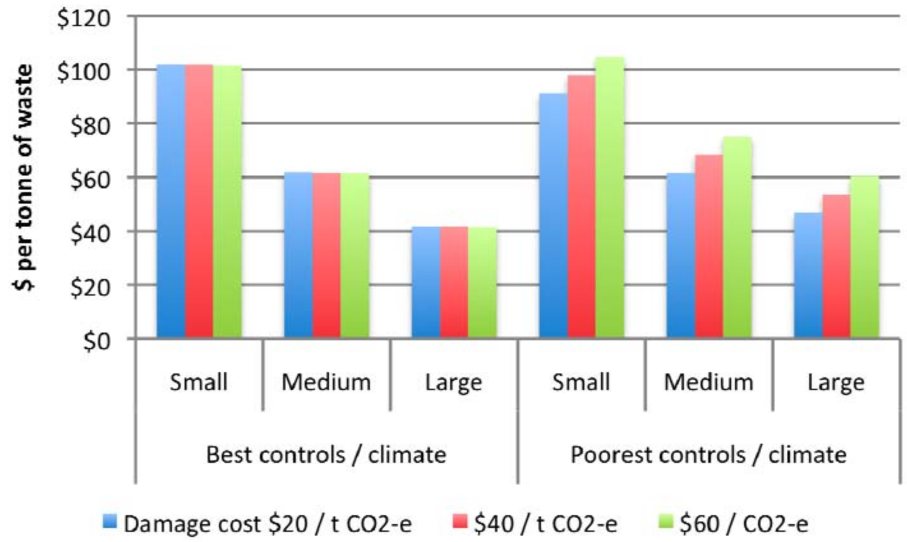


Figure 7.5 shows how the estimated *total* costs of landfill disposal are estimated to change with damage costs at $20, $40 and $60 per tonne of CO2-e.

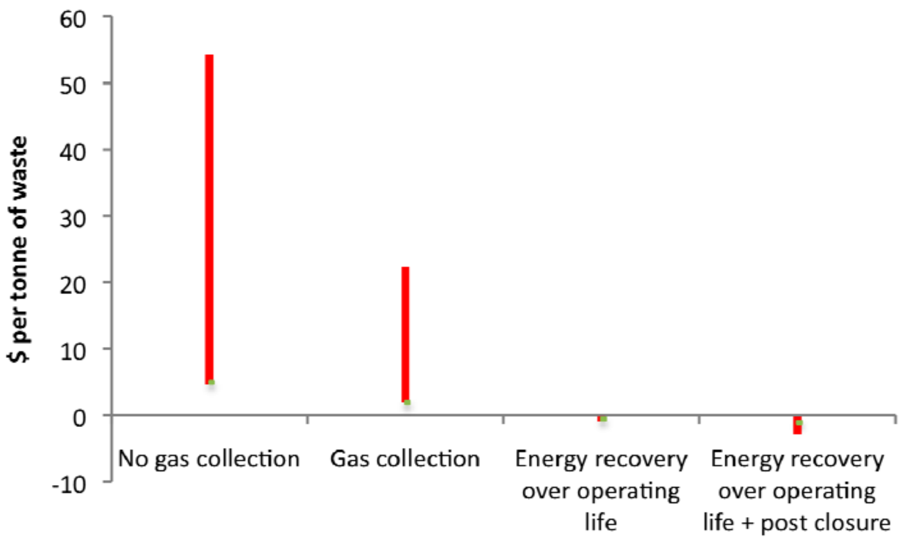
Figure 7.5: Impact of varying damage cost on full costs of disposal for urban landfills



The estimated contribution of external costs to total costs only changes significantly for the landfills with poorer controls / climates. The contribution falls as low as 20% under some landfill classifications with the lower damage cost of $20 per tonne of CO2-e. It increases as high as 50% with the higher damage cost of $60 per tonne of CO2-e.

We have combined the results of the sensitivity testing scenarios for the external costs of greenhouse emissions. Figure 7.6 shows the highest and lowest values for the external costs of greenhouse emissions in different climates for the range of discount rates and damage costs considered above.

Figure 7.6: Sensitivity testing outcomes for external cost of greenhouse emissions



To summarise, the estimates of values for the impact of greenhouse emissions for landfills with poorer controls / climates are particularly sensitive to the discount rate chosen. With the lower discount rate, the full costs of landfill disposal can increase by up to 45% for some landfill classifications. The estimated contribution of external costs to total costs increases to around 60% for some classifications.

GLOSSARY

Valuation methods

Benefit transfer method estimates values by transferring existing benefit estimates from studies already completed for another location or issue.

Contingent valuation method is a 'stated preference' method of valuing intangible impacts. It involves asking people to state directly their willingness to pay (or to accept compensation) for a particular outcome.

Contingent choice method is similar to the above method, but is based on asking people to make trade-offs among sets of outcomes with associated costs.

Damage cost avoided, replacement cost and substitute cost methods estimate the values of ecosystem services based on either the costs of avoiding damages due to lost services, the cost of replacing environmental assets, or the cost of providing substitute services. An example is the value of clean water measured by the cost of cleaning the water up, or by stopping it from becoming polluted in the first place.

Hedonic pricing estimates costs or benefits of a characteristic with no market price, on the basis of how the market price of another good that has the characteristic is affected. For example, variations in prices of similar houses in different neighbourhoods may reflect the value of local environmental attributes.

Productivity method estimates values for ecosystems or environmental systems that contribute to the production of commercially marketed goods (eg the value of certain insects by measuring their impacts on crop productivity through better pollination).

Travel cost method assumes the value of a recreational site is reflected in how much people are willing to pay to travel to visit the site.

Other terms

Alternative Waste Technology: may include mechanical separation methods, biological processes, thermal technologies and mechanical biological treatment with the aim of recovering resources from the waste stream and minimising the environmental impacts of disposal.

Anaerobic: in the absence of oxygen.

Inert: not chemically reactive, stable.

Leachate: liquid moving through a landfill.

Methane: an odourless in flammable gas, formed from decaying organic matter and found in coal mines. It has 21 times the greenhouse effect of carbon dioxide.

Putrescible waste: the part of the waste stream that will spoil or decay. Putrescible waste usually breaks down in a landfill to create landfill gases and a liquid by-product called leachate.

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ATTACHMENT A: Environmental valuation techniques

The range of environmental valuation techniques can be grouped under three broad approaches – market-based, revealed preferences and stated preferences. Each approach has different levels of theoretical sophistication, data requirements, ease of application, reliability, and so on.

The key techniques are listed in Table A.1.

Table A.1: Main environmental valuation techniques

Market based techniques	Revealed preference (or surrogate market techniques)	Stated preference (or survey techniques
Productivity method	Travel cost method	Contingent valuation
Human capital approach	Hedonic price method	Choice modelling
Defensive expenditures method	Proxy good	
Replacement/repair cost method		

The estimation of damage costs seeks to directly identify the cost of changes in health or environmental outcomes that would be realised under new policy settings and in the absence of any preventative expenditure. In effect this is an estimate of the compensation needed or willingness of the community to accept such damage.

The preventative expenditures or replacement cost technique involves the estimation of how much it would cost to provide actions that prevented, offset or replaced lost environmental benefits. These surrogate measures do not directly identify willingness to pay or economic value, but provide a useful first approximation of minimum values where the environmental benefits from the 'make-good' action are close substitutes for the lost benefits, and there is confidence that such actions will occur.

A key valuation issue is separating potential impacts from actual impacts. While some pollutants for example may be very harmful from a human health perspective, if they are discharged in locations where there is little human contact and no persistent effects, actual impacts may be small. Therefore it is important in identifying the context of impacts when assigning values, such as if changes in pollution loads will occur in metropolitan or sparsely populated regions.

The benefit transfer technique borrows estimates of value obtained from other situations that have been studied ('study sites') for application to the policy and situation that must be evaluated (the 'policy site'). Although the term implies that only benefits can be transferred, estimates of environmental damage costs can also be transferred.

While benefit transfer is not a 'valuation technique' in the sense that it is used to derive new values directly for the environmental impact at hand, it is a way of postulating a value.

Importantly, it can be undertaken quickly and at modest cost, whereas many of the primary valuation techniques cannot. The robustness of the method depends largely on the quality of results for the study sites and the presence of similar conditions at both the study site and the policy site.

A number of organisations have developed comprehensive searchable environmental economics database to facilitate benefit transfers in benefit-cost analyses. Of these, the database provided by the NSW Department of Environment and Conservation, ENVALUE, is now generally dated (with no new studies being listed since the late 1990s) with few relevant Australian studies. The database maintained by Environment Canada, EVRI, provides a larger collection of international studies. However most studies either do not provide impact values per unit (eg: $/t of pollutant emissions) or have been developed in contexts that could not be robustly transferred to Australia.

ATTACHMENT B: Estimated emissions from landfills

The tables below shows the estimated emissions of 34 NPI substances. The results for wet temperate landfills are shown.

Table B.1: Air emissions from wet temperate landfills (kg / t waste)

Pollutant	No gas collection	Gas collected and flared	Gas collected for internal combustion engine
Acetone	3.35E-04	1.36E-04	1.40E-04
Acetonitrile	4.42E-05	1.79E-05	1.84E-05
Benzene	1.62E-04	6.54E-05	6.74E-05
Carbon disulfide	9.65E-06	3.91E-06	4.02E-06
Carbon monoxide	5.89E-04	8.46E-03	9.71E-02
Chloroethane	2.20E-04	9.09E-05	9.71E-05
Chloroform	7.29E-06	3.02E-06	3.22E-06
Cumene	4.46E-05	0	0
Cyclohexane	7.50E-05	0	0
Dichloroethane	9.72E-04	4.02E-04	4.30E-04
Dichloromethane	4.50E-04	1.86E-04	1.99E-04
Ethanol	9.14E-06	3.70E-06	3.81E-06
Ethyl acetate	1.43E-04	0	0
Ethylbenzene	4.45E-04	1.80E-04	1.85E-04
Formaldehyde	4.40E-08	0	0
Hexane	2.30E-04	9.32E-05	9.60E-05
Hydrochloric acid	0	1.82E-05	5.55E-05
Hydrogen sulfide	9.40E-04	3.78E-04	4.54E-04
Mercury & compounds	2.11E-08	2.11E-08	2.11E-08
Methyl ethyl ketone	4.41E-04	1.78E-04	1.84E-04
Methyl isobutyl ketone	1.61E-04	6.54E-05	6.73E-05
Oxides of nitrogen	0	7.24E-03	1.33E-01
Particulate Matter 10.0 um	0	3.10E-03	2.66E-03
Polychlorinated dioxins & furans	0	6.59E-12	0
Styrene	3.69E-05	0	0
Sulfur dioxide	0	1.56E-03	1.56E-03
Tetrachloroethylene	2.90E-04	0	0
Toluene	2.34E-03	9.48E-04	9.76E-04
Total volatile organic compounds	3.86E-02	1.56E-02	1.61E-02
Trichloroethane	1.82E-05	7.52E-06	8.03E-06
Trichloroethylene	9.38E-05	0	0
Vinyl chloride monomer	7.65E-05	3.17E-05	3.38E-05
Xylenes	8.45E-04	3.42E-04	3.52E-04
Particulate Matter 2.5 um	0	2.94E-03	2.53E-03

Notes: the figures represent kilograms of pollutant in the 15th year of operation divided by the annual tonnes of waste disposed to landfill

Table B.2: Leachate emissions from wet temperate landfills (kg / t waste)

Pollutant	No liner	Liner
Ammonia	3.45E-03	1.03E-03
Antimony	1.08E-06	3.25E-07
Arsenic	2.30E-07	6.90E-08
Benzene	6.08E-07	1.82E-07
Beryllium	7.88E-08	2.37E-08
Cadmium	2.30E-07	6.90E-08
Chlorine	9.69E-03	2.91E-03
Chloroform	4.76E-07	1.43E-07
Chlorophenols	8.38E-09	2.51E-09
Chromium (III)	6.90E-07	2.07E-07
Chromium (VI)	2.96E-07	8.87E-08
Copper	8.87E-07	2.66E-07
Dichloroethane	1.64E-07	4.93E-08
Dichloromethane	7.23E-06	2.17E-06
Ethylbenzene	9.53E-07	2.86E-07
Lead	1.03E-06	3.10E-07
Mercury	9.86E-09	2.96E-09
Nickel	2.79E-06	8.38E-07
Phenol	6.24E-06	1.87E-06
Polychlorinated dioxins and furans	5.26E-12	1.58E-12
Polycyclic aromatic hydrocarbons	4.11E-09	1.23E-09
Toluene	6.73E-06	2.02E-06
Vinyl chloride monomer	6.57E-07	1.97E-07
Zinc and compounds	1.12E-05	3.35E-06

Notes: the figures represent kilograms of pollutant in the 15th year of operation divided by the annual tonnes of waste disposed to landfill

ATTACHMENT C: Estimated costs by landfill classification

Table C.1: Costs of landfill disposal for small urban landfills ($ per tonne of waste)

	Best controls			Poor controls		
	Dry temperate	Wet temperate	Wet tropical	Dry temperate	Wet temperate	Wet tropical
Private costs	$100	$100	$100	$74	$74	$74
Greenhouse emissions	-$0.3	-$0.5	-$0.6	$9.2	$12.1	$13.5
Other air emissions	$1.0	$1.0	$1.0	$0.7	$0.7	$0.7
Leachate	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Disamenity	$1.0	$1.0	$1.0	$10.0	$10.0	$10.0
Total	*$101.7*	*$101.5*	*$101.4*	*$93.6*	*$96.6*	*$97.9*

Table C.2: Costs of landfill disposal for medium urban landfills ($ per tonne of waste)

	Best controls			Poor controls		
	Dry temperate	Wet temperate	Wet tropical	Dry temperate	Wet temperate	Wet tropical
Private costs	$60	$60	$60	$44	$44	$44
Greenhouse emissions	-$0.3	-$0.5	-$0.6	$9.2	$12.1	$13.5
Other air emissions	$1.0	$1.0	$1.0	$0.7	$0.7	$0.7
Leachate	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Disamenity	$1.0	$1.0	$1.0	$10.0	$10.0	$10.0
Total	*$61.7*	*$61.5*	*$61.4*	*$64.1*	*$67.1*	*$68.4*

Table C.3: Costs of landfill disposal for large urban landfills ($ per tonne of waste)

	Best controls			Poor controls		
	Dry temperate	Wet temperate	Wet tropical	Dry temperate	Wet temperate	Wet tropical
Private costs	$40	$40	$40	$30	$30	$30
Greenhouse emissions	-$0.3	-$0.5	-$0.6	$9.2	$12.1	$13.5
Other air emissions	$1.0	$1.0	$1.0	$0.7	$0.7	$0.7
Leachate	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Disamenity	$1.0	$1.0	$1.0	$10.0	$10.0	$10.0
Total	*$41.7*	*$41.5*	*$41.4*	*$49.3*	*$52.3*	*$53.7*

Table C.4: Costs of landfill disposal for small rural landfills ($ per tonne of waste)

	Best controls			Poor controls		
	Dry temperate	Wet temperate	Wet tropical	Dry temperate	Wet temperate	Wet tropical
Private costs	$100	$100	$100	$74	$74	$74
Greenhouse emissions	-$0.3	-$0.5	-$0.6	$9.2	$12.1	$13.5
Other air emissions	$0.1	$0.1	$0.1	$0.2	$0.2	$0.2
Leachate	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Disamenity	$1.0	$1.0	$1.0	$5.0	$5.0	$5.0
Total	*$100.8*	*$100.6*	*$100.5*	*$88.1*	*$91.1*	*$92.4*

Table C.5: Costs of landfill disposal for medium rural landfills ($ per tonne of waste)

	Best controls			Poor controls		
	Dry temperate	Wet temperate	Wet tropical	Dry temperate	Wet temperate	Wet tropical
Private costs	$60	$60	$60	$44	$44	$44
Greenhouse emissions	-$0.3	-$0.5	-$0.6	$9.2	$12.1	$13.5
Other air emissions	$0.1	$0.1	$0.1	$0.2	$0.2	$0.2
Leachate	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Disamenity	$1.0	$1.0	$1.0	$5.0	$5.0	$5.0
Total	*$60.8*	*$60.6*	*$60.5*	*$58.6*	*$61.6*	*$62.9*

Table D.6: Costs of landfill disposal for large rural landfills ($ per tonne of waste)

	Best controls			Poor controls		
	Dry temperate	Wet temperate	Wet tropical	Dry temperate	Wet temperate	Wet tropical
Private costs	$40	$40	$40	$30	$30	$30
Greenhouse emissions	-$0.3	-$0.5	-$0.6	$9.2	$12.1	$13.5
Other air emissions	$0.1	$0.1	$0.1	$0.2	$0.2	$0.2
Leachate	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Disamenity	$1.0	$1.0	$1.0	$5.0	$5.0	$5.0
Total	*$40.8*	*$40.6*	*$40.5*	*$43.9*	*$46.9*	*$48.2*

ATTACHMENT D: The choice of a discount rate

In cost-benefit analysis, the incremental benefits over time of a policy need to be compared to the incremental costs over time, using discounting. Discounting takes account of people's preference for producing or consuming goods and services now as opposed to some time in the future. Specifically, the discount rate is the rate of trade-off between having something now or later.

However as noted by Quiggin (2007), the selection of an appropriate discount rate has been one of the longest-running controversies in welfare economics. Given alternative approaches to determining a discount rate, most government guidance documents recommend a range of discount rates be used.

For example, in NSW the discount rate set by the NSW Treasury to be used in the assessment of public policy and investments is 7%, but with sensitivity testing at 4% and 10% (NSW Treasury 2007). Similarly, the Commonwealth level, the Office of Best Practice Regulation suggests using a discount rate of 7%, and with sensitivity analysis at 3% and 11% (Australian Government 2007). On the other hand, the Victorian Government (2003) recommends that for public infrastructure investment projects where all systematic risks in the project are retained by government, the discount rate should be set equal to the ten-year Commonwealth bond rate, at around 3%. The Queensland Government (QDIP 2008) does not prescribes a specific discount rate but provides a number of 'reference points' that can be used in determining the discount rates for projects (such as the ten-year Queensland Government bond rate) and that a 'ready reference on discount rates is included in HM Treasury 2003.

Where policy impacts are likely to occur over extended timeframes, such as is often the case with environmental reforms targeting for example biodiversity protection, climate change and so on, several commentators suggest that the discount rate should be lowered. The issue was highlighted with the release of the Stern report (Stern 2007) on the economics of climate change, where discount rates of 1.6% and 2.1% were used.

Stern's approach was broadly consistent with guidance from the UK Treasury (HM Treasury 2003) that recommends that a standard real discount rate of 3.5% be used; but where the appraisal of a proposal depends materially upon the discounting of effects in the very long term, a declining discount rate should be used that reflects uncertainty about the future. The following discount rates are recommended:

Period of years	0–30	31–75	76–125	126–200	201–300	301+
Discount rate	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%

Similarly, the US EPA guidelines for cost benefit analysis (US EPA 2000) recommend two different discount rates, depending on whether inter-generational issues are critical, or whether intra-generational issues are of more importance. If inter-generational issues are prominent, it is recommended to use both a 2-3% and a 7% rate (which is the rate recommended by the US Office of Management and Budget guidelines to federal agencies). If there are longer term environmental impacts, which will affect future generations, the EPA recommends:

- Including a “no discounting” option, where the stream of costs and benefits over time are presented (this is different from a zero discount rate);
- Using a range from 2-3% and 7%; and also:
- Presenting scenarios from 1.5% to 3%.

Locally, a Queensland EPA guide to non-market valuation (Queensland Government 2003) recommends using a range of discount rates from zero to 10% if there are significant environmental impacts.

Finally, in light of the controversy surrounding the use of discount rates by Stern and more broadly in the economics literature, Quiggin (2007) presents a useful critique of the perspectives of Stern and his critics to the discounting issue. In his paper he reviews the theoretic foundations of discounting and the arguments put forward by Stern and others. Following a comprehensive assessment he concludes that '... *the case for a low (discount) rate such as that chosen by Stern seems overwhelming*.'