



FINAL REPORT

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Estimate of the cost of hazardous waste in Australia

Report prepared for the Department of the
Environment

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Executive summary

Introduction and background

The Environment Protection Branch of the Department of the Environment has engaged Marsden Jacob Associates (Marsden Jacob), Sustainable Resource Use (SRU) and Nolan Consulting to provide estimates of the current and potential future costs of managing and regulating hazardous waste in Australia.

Hazardous waste, as defined in the *Hazardous Waste (Regulation of Exports and Imports) Act 1989*, comprises wastes listed in the *Basel Convention* including:

- clinical wastes;
- waste oils/water, hydrocarbons/water mixtures, emulsions;
- wastes from the production, formulation and use of resins, latex, plasticizers, glues/adhesives;
- wastes resulting from surface treatment of metals and plastics;
- residues arising from industrial waste disposal operations;
- wastes which contain certain compounds such as: copper, zinc, cadmium, mercury, lead and asbestos.

Economic costs assessed include:

- direct market costs such as treatment, transport and disposal costs; and
- indirect and non-market costs such as government regulatory costs, workplace injury and illness and environmental and social costs associated with disposal of waste to landfill.

The distributional impacts of levies and fees are also assessed.

Cost analysis

A total of 6.6 million tonnes of tracked hazardous waste was generated in Australia in 2012. The total cost of regulating, transporting, treating and disposing of this waste is estimated to have been \$2,417 million (see Table ES.1).

Direct market costs are estimated to have been \$2,217 million in 2012. Cost of treatment is the single largest direct cost category, with treatment and subsequent disposal costs estimated to have been \$945 million. These costs were the result of 2.2 million tonnes of waste being treated and subsequently disposed to landfill.

Indirect and non-market costs of hazardous wastes are estimated to have been \$207 million in 2012. Workplace injury and illness represents the biggest share of these costs at \$110 million.

Table ES.1: Economic costs of hazardous wastes by category and jurisdiction (\$ million, 2012)

	Direct market	Indirect & non-market	Total
New South Wales	537.0	56.0	593.0
Victoria	338.9	40.4	379.2
Queensland	700.6	51.0	751.6
South Australia	299.0	21.6	320.5
Western Australia	248.3	20.2	268.6
Tasmania	56.0	7.2	63.2
Northern Territory	8.8	2.2	11.0
ACT	27.9	2.2	30.2
Australia	2,216.5	200.7	2,417.3

A large proportion of hazardous waste costs reside with waste producing industries. It is likely that most of these costs are passed on to consumers through price increases to products and services. Most industry costs are direct market costs (\$2,217 million), but landfill levies and license fees (\$385 million) represent an additional financial cost to industry. Levies and fees are transfers from industry to government and, as such, are not economic costs.

Scrutiny of the waste categories and consideration of their likely sources suggest that the industries most likely to bear these costs include:

- Food product manufacturing (ANZSIC C11);
- Petroleum product manufacturing (ANZSIC C17);
- Basic chemical and chemical product manufacturing (ANZSIC C18);
- Polymer product manufacturing (ANZSIC C19);
- Non-metallic mineral product manufacturing (ANZSIC C20);
- Primary metal and metal product manufacturing (ANZSIC C21);
- Building and construction; (ANZSIC E); and
- Motor vehicle servicing and parts, principally related to the disposal of tyres (ANZSIC G39).

While a significant proportion of direct market costs are likely to be linked to industry compliance with government regulations, it is not feasible to precisely quantify the proportion of the costs that are compliance related. All levies and fees are a compliance cost to industry. Additionally, a significant proportion of the treatment, recycling and energy recovery costs are also likely to be compliance-related, linked to environmental, safety and dangerous goods regulations. As well, there are administrative costs associated with the transport, storage and disposal to landfill of hazardous waste. Preliminary analysis suggests that total hazardous waste

compliance costs (including treatment, recycling, energy recovery, landfill levies, license fees and administrative costs) are in the range of 0.01-0.2% of total revenue for most industries.

The costs of hazardous wastes in Australia are projected to increase from \$2,417 million in 2012 to \$2,588 million in 2024, a growth of approximately 7% in real terms or 0.5% per year. The greatest cost growth in absolute terms will be to direct market costs, with these costs being driven principally by expected growth in the volume of hazardous wastes from 6.6 million tonnes in 2012 to 7.0 million tonnes in 2024, a growth of 6%.

The absence of reliable time series data for hazardous wastes means that projections are highly uncertain. Nevertheless, the projected growth rate could well be conservative since it does not take into account the potential for increased costs associated with tighter hazardous waste regulatory frameworks and a broader range of hazardous wastes.

The present value of hazardous wastes costs over the years 2012 to 2020 (covered by the National Waste Policy) is estimated to be \$17,194 million, assuming a discount rate of 7%.

1. Introduction

1.1 Study purpose

The Environment Protection Branch of the Department of the Environment has engaged Marsden Jacob Associates (Marsden Jacob), Sustainable Resource Use (SRU) and Nolan Consulting to provide estimates of the current and potential future costs of managing and regulating hazardous waste in Australia.

Estimates of these costs were sought recognising that Australian governments have a limited understanding of the total cost of hazardous waste to the Australian economy and the distribution of this cost across sectors and state and territories. A base estimate of the cost of hazardous waste is important to support possible future reforms of the management of wastes and an Australian Government requirement that reforms should be subject to cost benefit analysis and regulation impact assessment.

This study builds on a previous study of the cost of non-hazardous commercial and industrial (C&I) waste to the Australian economy (Encycle and SRU 2013). That study estimates that the cost of managing C&I waste in Australia is approximately \$2.2 billion per year, of which \$1.4 billion is spent on disposing waste to landfill.

1.2 Focus and scope of the analysis

1.2.1 Focus and scope

The focus of the cost analysis is on the economic and distributional costs associated with hazardous waste in Australia as defined in the *Hazardous Waste (Regulation of Exports and Imports) Act 1989* (see Section 2).

Economic costs refer to costs to the Australian community of regulating, transporting, treating and disposing of hazardous and include both direct market costs and indirect and non-market costs. A list of the costs covered in the analysis is provided in Table 1. Costs have been compiled for a base year (2012), with annual cost projections also provided to 2024.

Direct market costs represent the major component of these costs. They have been assessed on a volumetric basis drawing on comprehensive hazardous waste databases compiled for the Department of the Environment (Blue Environment 2014, KMH 2013), with unit cost estimates (\$/tonne) included for each NEPM 75 waste category and cost type. The unit costs have been estimated drawing on information provided by the waste management industry and jurisdictions.

The direct market costs are aggregated with non-market costs in an integrated financial and economic model, which enables costs to be presented by sectoral group and by state and territory. License fees and (landfill) levies are also included in the assessment. The fees and levies represent a transfer from industry to government and, as such, are not an economic cost but they are a financial cost to industry and conversely, are a negative cost to government.

Details of the methods and assumptions applied to assessing all of the costs are provided in Section 4.

Table 1: Economic costs assessed by category and type

Category	Type
Direct market	Treatment costs Transport costs Disposal costs <ul style="list-style-type: none"> - Disposal to landfill - Recycle - Reuse - Energy recovery - Storage
Indirect and non-market	Government regulatory costs <ul style="list-style-type: none"> - Data monitoring and reporting - Other regulatory including approvals, licensing, site inspection, audits etc. Workplace injury and illness <ul style="list-style-type: none"> - Injury and illness associated with handling of hazardous wastes Residual landfill costs <ul style="list-style-type: none"> - Greenhouse gas emissions - Other air pollutants - Leachate - Disamenity

1.2.2 Limitations of analysis

Unquantified costs

The focus of the cost assessment is on hazardous wastes that are tracked by territory and state data systems and limited to extant hazardous waste data. While estimates of hazardous wastes and associated costs have been adjusted to account for some non-tracked wastes, costs associated with material that is not tracked are not covered in the estimate. Excluded are some wastes that are small in volume, and unlikely to have significant costs:

- Costs of waste generated and disposed on-site, for example some hospital clinical waste.
- Costs of wastes that have been illegally disposed.
- Costs of hazardous wastes disposed by households.

Other excluded wastes are likely to more substantial though, including:

- Some mineral processing and combustion residues, such as the bauxite refining residue ‘red mud’ and fly ash from power stations.
- Costs of hazardous wastes treated and retained on-site, for example soils contaminated with hydrocarbons.

The exclusion of these wastes means that base year costs and cost projections are likely to be understated.

Data uncertainties

Assessed costs are dependent on data assumptions that underpin the variables listed in Table 2. Although considerable background analysis has gone into assigning suitable values to the variables (see Section 4), in practice there are still uncertainties around the estimated costs. The indirect and non-market costs in particular are subject to uncertainties:

- government regulatory and administration costs due to the way in which jurisdictions assign costs to their functions;
- workplace injury and illness costs due to the way in which workplace injury and illness data is compiled;
- residual landfill costs due to uncertainty about the emissions factors applying to different waste categories and differences in perspective on how emissions should be costed.

Even the direct market costs are subject to uncertainty due, for example, to fluctuations in market values over time and differences in market values from region to region.

Reflecting these uncertainties we have sought to place low-high error bands against cost estimates presented in Section 3.

Cost projections are also highly uncertain due to a lack of reliable time series waste data.

1.3 Report structure

The rest of this report is presented in three major sections:

- Section 2 provides background information on hazardous wastes including the regulatory framework governing management of hazardous wastes in Australia.
- Section 3 presents results of the cost analysis.
- Section 4 details the methods and assumptions applied to assessing the costs.

2. Background

2.1 Hazardous waste in Australia

Hazardous waste, as defined in the *Hazardous Waste (Regulation of Exports and Imports) Act 1989*, comprises wastes listed in Annex I to the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal*, including:

- clinical wastes;
- waste oils/water, hydrocarbons/water mixtures, emulsions;
- wastes from the production, formulation and use of resins, latex, plasticizers, glues/adhesives;
- wastes resulting from surface treatment of metals and plastics;
- residues arising from industrial waste disposal operations;
- wastes which contain certain compounds such as: copper, zinc, cadmium, mercury, lead and asbestos;

provided they have any of the characteristics mentioned in Annex III of the Convention such as:

- explosive;
- flammable;
- poisonous;
- toxic;
- ecotoxic; or
- contain infectious substances.

The National Environment Protection (Movement of Controlled Waste between States and Territories) Measure (Controlled Waste NEPM) categorises hazardous waste into 75 waste types according to the source, contaminant type or hazard of the waste (NEPM 75). There is also a broader list of 15 categories which are used for summary and interstate reporting (NEPM 15). NEPM 15 categories are listed in Table 2 below, with NEPM 75 categories and volumes discussed in more detail in Section 4.

Table 2: Hazardous wastes, NEPM 15

Waste Code	Description
A	Cyanides
B	Acids
C	Alkaline wastes
D	Inorganic chemicals
E	Reactive chemicals
F	Paints, lacquers, varnish, resins, inks, dyes, pigments, adhesives
G	Organic solvents, solvent residues
H	Pesticides (includes herbicides and insecticides)
J	Oils, hydrocarbons, emulsions
K	Putrescible/organic wastes
L	Industrial wash waters
M	Organic chemicals
N	Solid/sludge wastes requiring special handling
R	Clinical and pharmaceutical wastes
T	Miscellaneous

2.2 Regulation of hazardous waste

Whilst each jurisdiction is responsible for managing hazardous waste within its boundaries, the Controlled Waste NEPM provides a national protocol for managing the movement of controlled waste both intrastate and interstate. As previously noted, the Controlled Waste NEPM categorises hazardous waste into 75 waste types according to the source, contaminant type or hazard of the waste.

The *2013 Hazardous Waste Data Assessment* (KMH, Department of Sustainability, the Environment, Water, Population and Communities, 2013) summarises jurisdictional regulations of controlled waste as outlined in the *2009 Review of the Controlled Waste NEPM* (NEPC, 2009). This summary is shown in Table 3.

Table 3: Summary of jurisdictional NEPM implementation frameworks

Jurisdiction	Waste regulations
Commonwealth	The NEPM is implemented administratively.
ACT	The key legislative instruments are the Environment Protection Act 1997 and the Environment Protection Regulations 2005.
New South Wales	The key legislative instruments are the Protection of the Environment Operations Act 1997 and the Protection of the Environment Operations (Waste) Regulation 2005
Northern Territory	The key legislative instruments are the Waste Management and Pollution Control Act and the Dangerous Goods (Road and Rail Transport) Act.
Queensland	The key legislative instruments are the Environmental Protection Act 1994 and the Environmental Protection (Waste Management) Regulation 2000. Requirements for the licensing of controlled waste transporters are included in the Environmental Protection Regulation 2008.
South Australia	The NEPM operates as an Environment Protection Policy under the Environment Protection Act 1993 and is implemented through conditions of licences.
Tasmania	The NEPM is a state policy under the State Policies and Projects Act 1993. The NEPM is implemented under the Environmental Management and Pollution Control Act 1994.
Victoria	The key legislative instruments are the Environment Protection Act 1970, the Environment Protection (Industrial Wastes Resource) Regulations 2009, and the Industrial Waste Management Policy (Movement of Controlled Waste between States and Territories) 2001.
WA	The primary legislative instruments are the Environmental Protection (Controlled Waste) Regulations 2004.

2.2.1 Waste tracking

Much of the waste generation data used in this analysis is sourced, indirectly, from hazardous waste tracking data. Whilst all jurisdictions report on interstate hazardous waste movements and have done since 1998–99, only New South Wales, Queensland, South Australia, Victoria and Western Australia track intrastate movements. Each of these jurisdictions has its own waste tracking system and own set of waste codes. With the exception of Western Australia, these codes are similar to the NEPM set of 75 tracking codes.

2.2.2 Waste classification

Each jurisdiction also has its own classification system for hazardous waste that informs regulations on its on transport and disposal. In each jurisdiction, highly hazardous waste cannot be disposed to any landfill without treatment to destroy or immobilise the hazardous contaminant. Whilst each jurisdiction has its own classification system, they follow the same principles of assessing waste to determine a hazard rating.

Further information on waste tracking and classification informing the assessment of costs is provided in Section 4.

3. Cost analysis

3.1 Base year costs

3.1.1 Overview

A total of 6.6 million tonnes of tracked hazardous waste was generated in Australia in 2012. The total cost of regulating, transporting, treating and disposing of this waste is estimated to have been \$2,417.3 million (central estimate - Table 4), representing an average cost of about \$332 per tonne of waste. Direct market costs, including transport, treatment and disposal (gate fees), comprise approximately 92% of these costs, with the remaining 8% being non-market and indirect costs.

Uncertainty with cost estimates mean that the total cost of hazardous waste in Australia in 2012 could be as low as \$1,758 million or as high as \$3,153 million. Levels of uncertainty include:

- $\pm 25\%$ for direct market costs linked to uncertainties with transport, treatment and disposal costs; and
- -50% to $+80\%$ for indirect and non-market costs, linked to general data gaps and uncertainties, and differences in perspective on how non-market costs are valued (e.g. greenhouse gas emissions).

Table 4: Estimated economic costs of hazardous wastes by category and jurisdiction (\$ million, 2012)

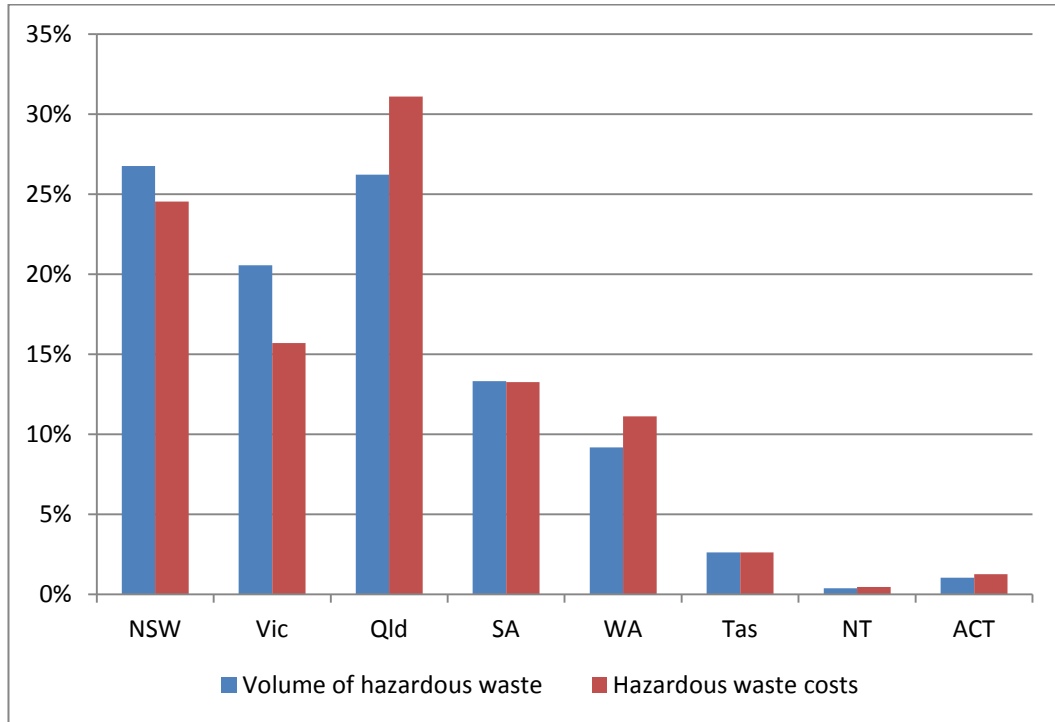
	Direct market	Indirect & non-market	Total (central)	Total (low)	Total (high)
New South Wales	537.0	56.0	593.0	428.7	783.2
Victoria	338.9	40.4	379.2	273.4	500.2
Queensland	700.6	51.0	751.6	549.4	974.5
South Australia	299.0	21.6	320.5	234.9	411.0
Western Australia	248.3	20.2	268.6	196.1	347.9
Tasmania	56.0	7.2	63.2	45.7	82.2
Northern Territory	8.8	2.2	11.0	7.8	14.5
ACT	27.9	2.2	30.2	22.0	39.7
Australia	2,216.5	200.7	2,417.3	1,758.0	3,153.1

There is a significant but not perfect correlation between the volume of hazardous wastes generated in each state and territory and the total costs of wastes in those jurisdictions (Figure 1). Other factors contributing to differences in costs between jurisdictions include:

- differences in the relative volumes of different waste categories between the jurisdictions and different unit costs of transporting, treating and/ or disposing of the different waste categories;

- differences between jurisdictions in the incidence of workplace injuries and illnesses associated with hazardous wastes; and
- different hazardous waste regulatory regimes and associated costs across the jurisdictions.

Figure 1: Percentage breakdown of hazardous waste volumes and costs by state and territory



3.1.2 Direct market costs

Transport, treatment and disposal of hazardous wastes are estimated to have cost just over \$2,216 million in 2012 (range \$1,662 – \$2,771 million) (Table 4). A breakdown of these costs is presented in Table 5, showing costs by waste category and destination. Cost of treatment is the single largest cost category, with treatment costs estimated to have been \$945 million in 2012. These costs were the result of 2.2 million tonnes of waste being treated and subsequently disposed to landfill. Costs associated with waste recycling and reuse are also substantial, being \$583 million in 2012. Alkaline wastes (\$246 million) and solid/sludge wastes (\$1,211 million) are the two most costly waste types in absolute terms. This second category comprises asbestos and wastes with significant organic content. Of the solid/sludge waste, organics based materials (soils and biosolids) make up approximately 80% of the management costs.

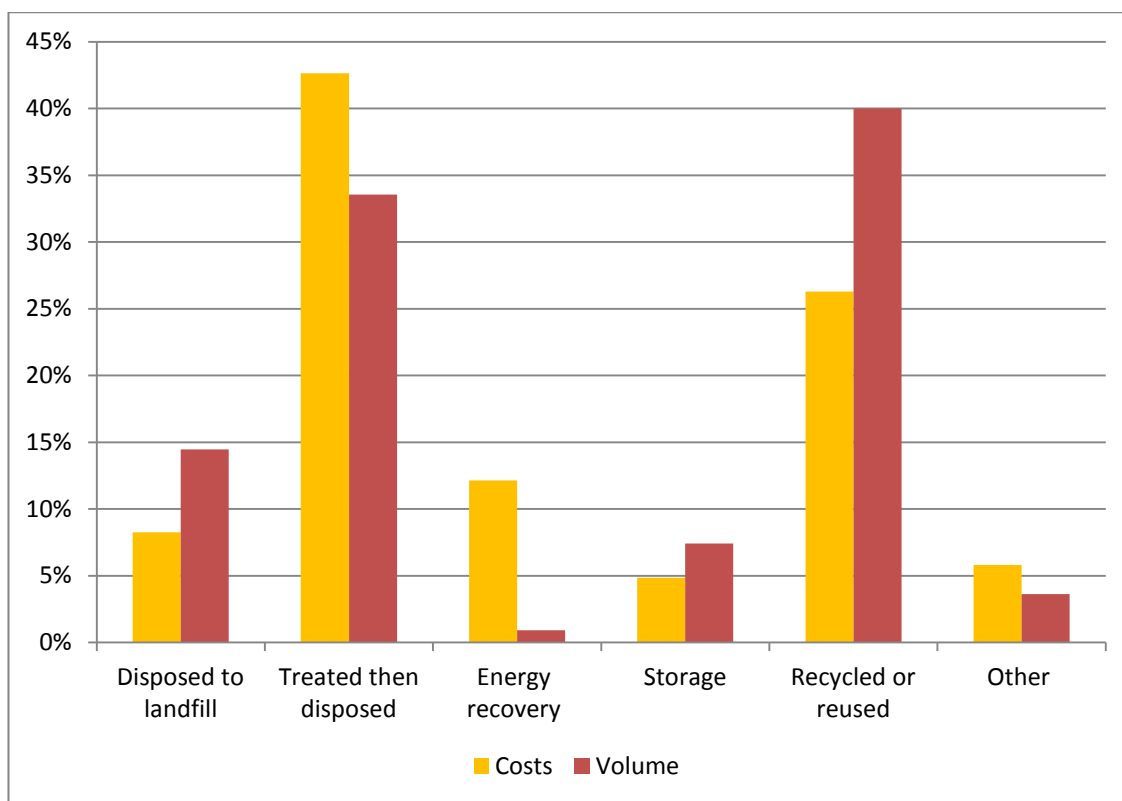
Figure 2 provides a breakdown of hazardous wastes costs and volumes by destination. The figure highlights the high unit costs of waste treatment relative to landfill disposal costs. It also highlights the high costs of energy recovery with these costs being up to \$5,000/tonne for some alkaline based wastes (e.g. C100 basic solutions) (see Section 4.2 for further discussion of these costs).

As noted in section 1.2.2, there are a number of costs that are not included in the analysis. The costs detailed in Table 4 and Table 5 therefore, are likely to be understated. A notable omission is the cost of treating contaminated soils that are retained onsite. This is discussed further in Section 4.2.4.

While there is uncertainty associated with the direct market cost estimates, the level of uncertainty is less marked than for indirect and non-market costs.

Table 5: Direct cost of hazardous wastes by waste category and destination (\$ million, 2012)

NEPM 15 category	Description	Disposed directly to landfill	Treated then disposed to landfill	Energy recovery	Storage	Recycled or reused	Other	Total
A	Cyanides	-	1.5	1.8	0.0	0.5	0.2	3.9
B	Acids	-	28.0	1.6	0.1	2.5	0.6	32.7
C	Alkaline wastes	0.1	81.8	107.3	0.3	45.1	11.7	246.3
D	Inorganic chemicals	0.0	73.3	2.6	4.9	13.7	9.5	104.0
E	Reactive chemicals	-	0.0	-	0.0	-	0.0	0.0
F	Paints, lacquers, varnish, resins, inks, dyes, pigments, adhesives	0.0	4.9	0.1	1.5	4.9	1.0	12.4
G	Organic solvents, solvent residues	-	0.8	0.1	1.2	5.3	0.2	7.6
H	Pesticides (includes herbicides and insecticides)	0.0	0.3	9.3	0.1	0.4	0.1	10.0
J	Oils, hydrocarbons, emulsions	0.0	98.6	11.0	22.5	57.9	0.9	191.0
K	Putrescible/organic wastes	10.5	33.9	32.9	7.8	68.9	0.7	154.5
L	Industrial washwaters	0	0	0	0	0	0	0
M	Organic chemicals	0.0	19.2	1.1	0.8	0.2	0.2	21.4
N	Solid/sludge wastes requiring special handling	172.4	528.7	78.3	54.2	353.6	23.8	1,211.1
R	Clinical and pharmaceutical wastes	-	8.9	-	6.4	0.2	24.5	39.9
T	Miscellaneous	-	65.4	23.1	7.9	29.8	55.4	181.6
Total		183.1	945.3	269.1	107.7	582.8	128.6	2,216.5

Figure 2: Percentage breakdown of hazardous waste volumes and costs by destination

It is important to note that while the costs to industry of hazardous waste transport, treatment and disposal represent a cost to the Australian economy, the costs accrued in managing hazardous wastes, driven by established regulatory frameworks, reduce the negative externalities (social and environmental costs) that would otherwise have occurred in the absence of hazardous waste regulatory requirements. Estimation of these benefits is outside the scope of this study, but a Regulatory Impact Statement (RIS) undertaken into Victorian hazardous industrial waste regulations (EPA Victoria 2009) estimates that in the absence of a strong regulatory framework in Victoria it would be expected that 40% of hazardous wastes would be disposed of incorrectly.

More detailed explanation of the direct market cost components, and how they were assessed, is provided in Section 4.

3.1.3 Indirect and non-market costs

Indirect and non-market costs assessed in this analysis include:

- government costs associated with regulating and administering hazardous wastes;
- costs of injuries and illnesses to workers who handle hazardous wastes; and
- residual environmental and social externalities associated with hazardous wastes disposed to landfill.

Table 6 provides an overview of these costs. In 2012, indirect and non-market costs associated with hazardous wastes are estimated to have been \$207 million. Workplace injury and illness represents the biggest share of these costs at \$110 million. These consist of workers compensation (for death or injury) and associated administration costs, hospitalisation and other

medical costs and lost production and productivity (short term and long term). Government regulatory costs (\$56 million) include costs associated with licensing, approvals and site audits and inspections as well as data monitoring and reporting costs. Residual landfill costs (\$35 million) include including greenhouse gas emissions, other air pollutants, leachate and noise and amenity impacts.

There is considerable uncertainty attached to the estimates of indirect and non-market costs, with the lower and upper bounds for these costs ranging from \$96 million to \$382 million respectively. Residual landfill costs are especially uncertain (range of \$7 million to \$139 million) stemming in particular from uncertainty over greenhouse gas emissions factors and differences in perspective on whether abatement cost or social cost estimates should apply to these emissions. These issues are discussed further in Section 4.

Table 6: Indirect and non-market costs of hazardous wastes (\$ million, 2012)

	Government regulatory	Workplace illness and injury	Residual landfill	Indirect and non-market total
New South Wales	14.3	30.0	11.7	56.0
Victoria	11.0	22.5	6.9	40.4
Queensland	12.8	28.7	9.4	51.0
South Australia	4.8	14.6	2.2	21.6
Western Australia	7.0	10.0	3.1	20.2
Tasmania	3.6	2.9	0.7	7.2
Northern Territory	1.7	0.4	0.1	2.2
ACT	1.1	0.5	0.6	2.2
Australia	56.3	109.6	34.8	200.7

3.2 Distributional analysis

Costs of hazardous wastes fall on different sectors or groups at different levels. Distributional analysis identifies where those costs fall.

Industry costs

Figure 3 and Table 7 reveal that a substantial proportion of the costs of hazardous wastes are borne by waste producing industries. It is likely however, that most if not all of these costs are passed on to consumers through price increases to products and services. In 2012 the cost to industry of hazardous wastes was over \$2,600 million. Lack of access to ANZSIC coded industry source data in the waste tracking system means that it is not possible to accurately attribute industry costs to specific sectors and industries.

However, scrutiny of waste categories and consideration of their likely sources, suggests that the industries that bear many of the costs are likely to include:

- Food product manufacturing (ANZSIC C11);
- Petroleum product manufacturing (ANZSIC C17);

- Basic chemical and chemical product manufacturing (ANZSIC C18);
- Polymer product manufacturing (ANZSIC C19);
- Non-metallic mineral product manufacturing (ANZSIC C20);
- Primary metal and metal product manufacturing (ANZSIC C21);
- Building and construction; (ANZSIC E); and
- Motor vehicle servicing and parts, principally related to disposal of tyres (ANZSIC G39).

Most industry costs are direct market costs (\$2,217 million), but landfill levies and license fees represent an additional financial cost to industry. Levies and fees are estimated to be approximately \$385 million in 2012 (see Table 8). These are transfers from industry to government and, as such, are not included in the economic cost estimates, but they are a financial cost to industry.

Figure 3: Costs of hazardous wastes on different groups, Australia (\$ million, 2012)

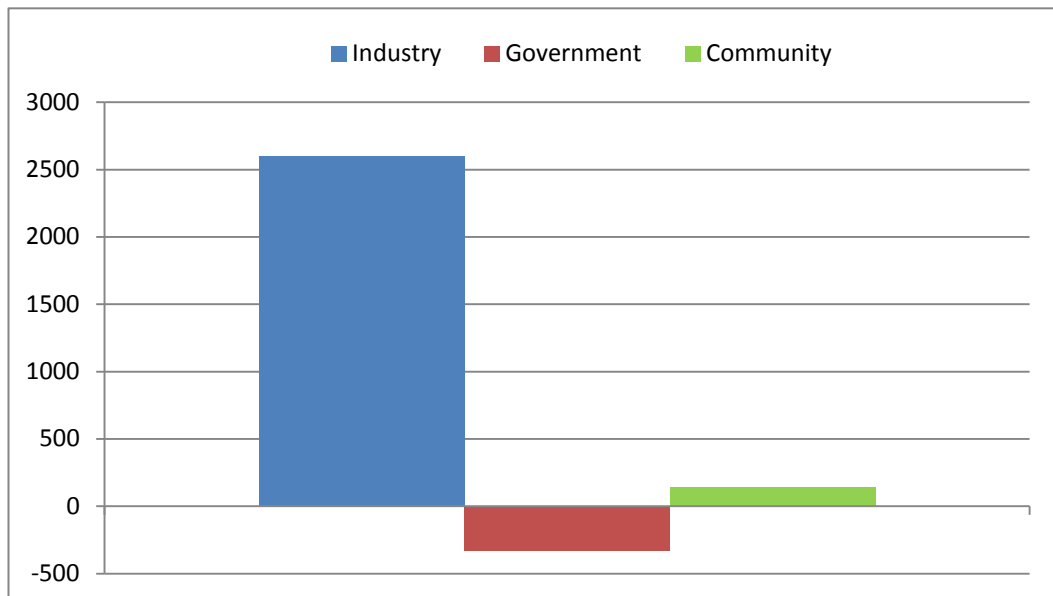


Table 7: Costs of hazardous wastes on different groups, by jurisdiction (\$ million, 2012)

	Industry	Government	Community
New South Wales	793.9	-242.6	41.7
Victoria	394.9	-45.1	29.4
Queensland	736.2	-22.8	38.2
South Australia	308.4	-4.6	16.8
Western Australia	250.8	4.6	13.2
Tasmania	79.5	-19.9	3.6
Northern Territory	8.9	1.5	0.5
ACT	29.0	0.1	1.1

Table 8: Levies and license fees, by jurisdiction (\$ million, 2012)

	Landfill levies	License fees	Total
New South Wales	57.0	199.9	256.9
Victoria	54.7	1.3	56.0
Queensland	35.6	0.0	35.6
South Australia	9.4	0.0	9.4
Western Australia	2.4	0.0	2.4
Tasmania	23.5	0.0	23.5
Northern Territory	0.1	0.0	0.1
ACT	1.0	0.0	1.0
Australia	183.9	201.2	385.1

Compliance costs

While a significant proportion of direct market costs are likely to be linked to industry compliance with government regulations, it is not feasible to precisely quantify the proportion of the costs that are compliance related or the significance of these costs to waste producing industries. All levies and fees are a compliance cost to industry. Additionally, a significant proportion of the treatment, recycling and energy recovery costs are also likely to be compliance-related, linked to environmental, safety and dangerous goods regulations.

As well, there are administrative costs associated with the transport, storage and disposal to landfill of hazardous waste. These costs include permit application processes, record keeping and understanding of the relevant regulations. As an indication, the RIS undertaken into Victorian hazardous industrial waste regulations (EPA Victoria 2009) estimates that administrative costs represent about 15% of all industry regulatory costs of \$137 million (\$2008-09) covering treatment costs, recycling costs, levies and fees¹.

These figures do not provide an indication of how significant the compliance costs are to waste producing industries however, in the context of their total costs. Previous analysis by Marsden Jacob for a state regulatory agency² though, indicates that the cost of landfill levies there, applied to hazardous wastes represent less than 0.35% of revenue for all industry categories and for most waste producing industry categories (4-digit ANZSIC classification) represent <0.001-0.02% of revenue. Taking these figures, together with all costs presented in this study, would suggest that for most hazardous waste producing industries, total hazardous waste compliance costs (including treatment, recycling, energy recovery, landfill levies, license fees and administrative costs) cost at most 0.01-0.2% of total revenue, with compliance costs on two or three industries producing large quantities of hazardous waste being up to a maximum of 1-3% of revenue³.

¹ It is expected that these costs will be reflected in the charges for those activities.

² Unpublished, containing in-confidence information.

³ Assuming landfill levies represent approximately 10-20% of all compliance costs.

Government and community costs

The revenue from these fees and levies are the primary reason why governments have a negative cost from the management of hazardous wastes, with levy and fee revenue substantially outweighing their regulatory and administration costs.

Costs to the community (covering community groups and individuals) of hazardous wastes reflect residual landfill externality costs including greenhouse gas emissions plus costs associated with workplace-related injuries and illnesses (net of workers compensation which is assumed to be borne by industry).

3.3 Cost projections

Table 9 sets out hazardous waste cost projections to 2024. The costs of hazardous wastes in Australia are projected to increase from \$2,417 million in 2012 to \$2,588 million in 2024, a growth of approximately 7% in real terms or 0.5% per year. The greatest cost growth in absolute terms will be to direct market costs, with these costs being driven principally by expected growth in the volume of hazardous wastes from 6.6 million tonnes in 2012 to 7.0 million tonnes in 2024, a growth of 6%. Hazardous wastes disposed to landfill (either directly or following treatment) are expected to grow from 3.2 million tonnes in 2012 to 3.4 million tonnes in 2024, a growth of 6%.

As explained further in Section 4.4, the absence of reliable time series data for hazardous wastes means that projections are highly uncertain. Instead, projections were derived by examining recent trends and projected future growth of the major hazardous waste producing industries and applying growth rates for these industries to the major hazardous wastes in each of the jurisdictions on a weighted basis. The projected growth rate for direct market costs of 0.52% per annum reflects a quite complex picture. While some hazardous waste producing industries are experiencing significant growth, others have been experiencing a decline in output. Overall, structural change to the Australian economy over the next few years seems likely to slow the growth of hazardous wastes and associated direct market costs.

The projected growth rate could well be conservative though. This is because it does not take into account the potential for:

- tighter hazardous waste regulatory frameworks in jurisdictions leading, for example, to additional waste categories being classified as hazardous;
- higher real unit costs for existing treatments, also linked to tighter regulations;
- change in the destinations of hazardous wastes to more costly treatments.

The greatest growth in hazardous waste costs in absolute terms is expected to occur in Queensland (\$55 million) and NSW (\$34 million), with the greatest rates of growth being in Queensland, South Australia and Tasmania (see Figure 4).

Based on these hazardous waste cost projections, the present value of hazardous wastes costs over the years 2012 to 2020 is estimated to be \$17,194 million, assuming a discount rate of 7%. This period covers the delivery timeframe of the National Waste Policy. Assumed discount rates of 10% and 3% give present value cost estimates of \$15,609 million and 19,808 million respectively.

The present value of hazardous wastes costs to 2024 is 22,263 million dollars assuming a 7% discount rate (Table 10).

Figure 4: Projected growth in total costs of hazardous wastes, by jurisdiction (\$ million, real values)

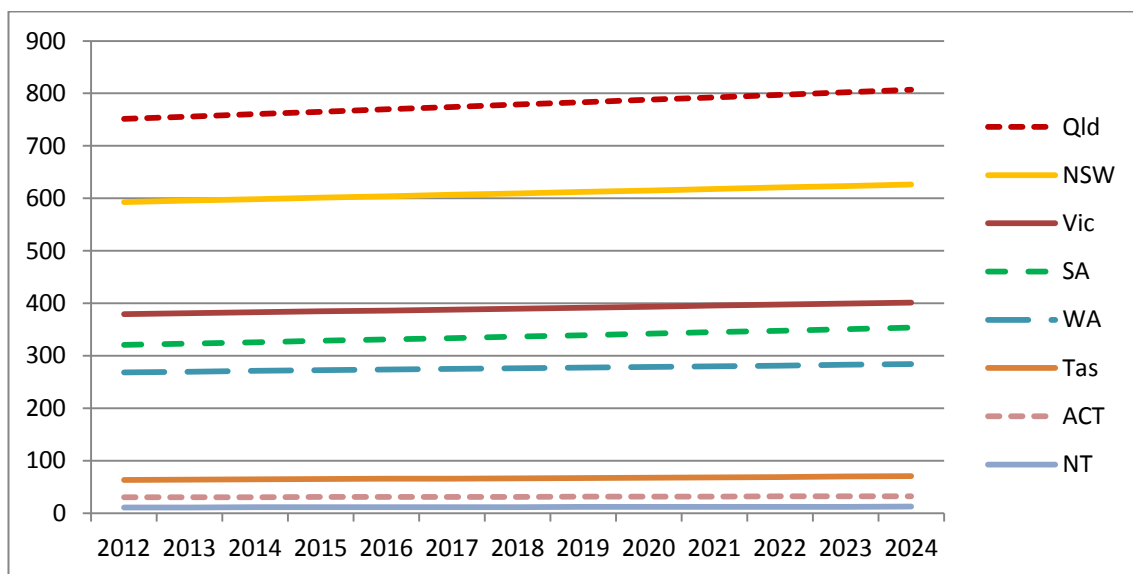


Table 9: Projected growth in the costs of hazardous wastes (\$ million, real values)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Direct market	2216.5	2228.0	2239.5	2251.1	2262.8	2274.5	2286.3	2298.2	2310.1	2322.1	2334.1	2346.3	2358.5
Government regulatory	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3	56.3
Workplace injury & illness	109.6	111.6	113.6	115.7	117.7	119.9	122.0	124.2	126.5	128.8	131.1	133.4	135.8
Residual landfill	34.8	35.0	35.1	35.3	35.5	35.6	35.8	36.0	36.1	36.3	36.5	36.7	36.9
Total	2,417.3	2,430.9	2,444.6	2,458.4	2,472.3	2,486.3	2,500.5	2,514.7	2,529.0	2,543.5	2,558.0	2,572.7	2,587.5

Table 10: Present value of hazardous waste costs, 2012-2020 and 2012-2024, assuming different discount rates (\$ million)

	7% discount rate		10% discount rate		3% discount rate	
	2012-2020	2012-2024	2012-2020	2012-2024	2012-2020	2012-2024
New South Wales	4,202	5,430	3,815	4,737	4,839	6,667
Victoria	2,688	3,475	2,441	3,031	3,096	4,266
Queensland	5,351	6,931	4,857	6,043	6,165	8,515
South Australia	2,301	2,991	2,088	2,606	2,652	3,679
Western Australia	1,904	2,461	1,728	2,146	2,192	3,021
Tasmania	455	592	413	516	524	729
Northern Territory	80	104	72	91	92	128
ACT	215	278	195	243	248	342
Australia	17,194	22,263	15,609	19,413	19,808	27,348

4. Methods and data assumptions

4.1 Classification and quantification of waste

4.1.1 Waste generation

National waste generation was estimated according to the source jurisdiction, NEPM 75 waste code, and material destination (be that treatment, disposal, recycling, reuse, or energy recovery).

Waste generation for the 2012 calendar year⁴ was estimated using the 2014 study prepared for the Department of Environment (Blue Environment 2014) that compiled and verified waste generation and tracking data from each jurisdiction, by the 75 NEPM classifications. The data used in that study was suitable for estimating overall generation by jurisdiction and NEPM code. These calculations were provided to the project team for use in this project. Whilst data provided by jurisdictions was based on material tracking systems where available, adjustments were made throughout that study to account for non-tracked materials and data not provided by jurisdictions. The full methodology for that study should be consulted for further information.

Hazardous waste generation is estimated at over 6.6 million tonnes in 2012 in the Blue Environment study (2014). This assessment includes waste generation by jurisdiction and split according to the 75 codes that make up the NEPM (Movement of Controlled Waste) classification as shown in Table 11.

Whilst this is adjusted to account for non-tracked wastes, waste material generated and disposed on-site (for example hospital clinical waste) is not tracked and may not be included in the estimate.

4.1.2 Data flows

As different waste types require different treatments, further research was undertaken through consultation with the waste management industry. This consultation incorporated interviews with industry experts from which an indication of the material flow paths was obtained. Thirty-eight individual flow paths were identified containing one or more of the following elements:

- Transport
- Initial treatment
- Transport for subsequent treatment(s)
- Subsequent treatment(s)
- Transport for disposal of residual from treatment
- Disposal of residual from treatment.

The flow charts that outline these thirty-eight flow paths can be seen in Figures 5 and 6.

⁴ The 2012 calendar year was chosen, as this period had the latest, comprehensive, waste generation data available.

Table 11: Hazardous waste generation by jurisdiction 2012 (tonnes)

NEPM Code	Description	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Total		67,000	1,765,000	23,000	1,729,000	874,000	172,000	1,360,000	600,000
A100	Waste resulting from surface treatment of metals and plastics	-	22	-	4 362	136	-	-	1 430
A110	Waste from heat treatment and tempering operations containing cyanides	-	-	-	-	-	-	-	-
A130	Cyanides (inorganic)	-	5	-	540	14	-	28	47
B100	Acidic solutions or acids in solid form	3	14 380	14	13 140	535	41	13 555	3 058
C100	Basic solutions or bases in solid form	4	5 215	127	167 498	65 576	1	8 595	88 355
D100	Metal carbonyls	-	-	28	95	28	-	9	7
D110	Inorganic fluorine compounds excluding calcium fluoride	-	560	-	246	26	-	3	21
D120	Mercury; mercury compounds	18	230	22	416	96	-	18	62
D130	Arsenic; arsenic compounds	-	61	-	828	3	-	68	17
D140	Chromium compounds (hexavalent and trivalent)	-	686	-	1 156	2	-	271	59
D150	Cadmium; cadmium compounds	-	11	-	18	4	5	10	14
D160	Beryllium; beryllium compounds	-	-	-	-	1	-	-	8
D170	Antimony; antimony compounds	-	-	-	-	-	-	9	18
D180	Thallium; thallium compounds	-	-	-	-	-	-	6	1
D190	Copper compounds	-	10	-	592	28	-	211	431
D200	Cobalt compounds	-	51	-	-	-	-	-	1
D210	Nickel compounds	-	9	-	124	14	-	267	30
D220	Lead; lead compounds	290	10 240	410	7 402	18 209	318	2 197	393
D230	Zinc compounds	-	473	-	462	35 277	95 246	12 578	425
D240	Selenium; selenium compounds	-	-	-	-	-	-	-	-

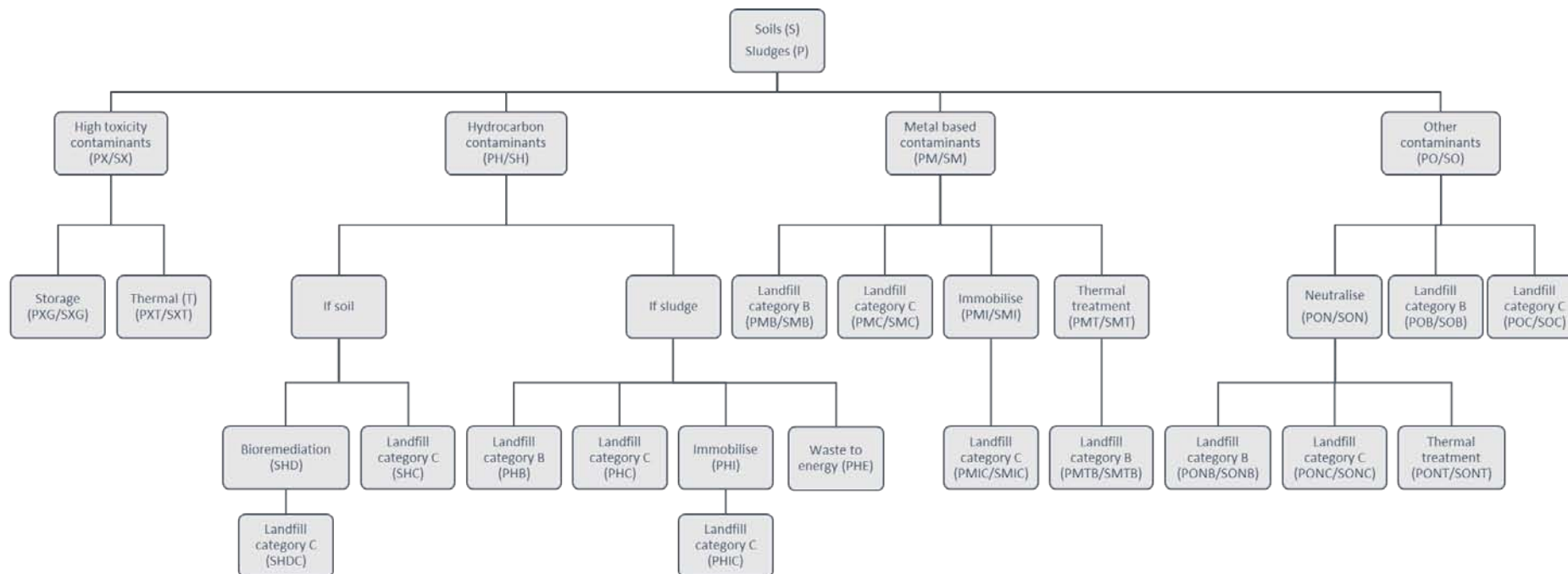
NEPM Code	Description	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
D250	Tellurium; tellurium compounds	-	-	-	-	-	-	-	-
D270	Vanadium compounds	-	47	-	-	-	-	-	-
D290	Barium compounds (excluding barium sulphate)	-	-	-	-	-	-	6	-
D300	Non-toxic salts	-	15 286	-	40 804	4 473	3 291	3 574	6 746
D310	Boron compounds	-	79	-	2	-	-	5	4
D330	Inorganic sulfides	-	-	-	342	-	-	1	18
D340	Perchlorates	-	-	-	-	-	-	5	56
D350	Chlorates	-	-	-	134	-	-	5	65
D360	Phosphorus compounds excluding mineral phosphates	-	23	-	428	-	-	-	-
E100	Waste containing peroxides other than hydrogen peroxide	-	180	-	48	2	-	29	-
F100	Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish	127	13 094	36	13 384	2 287	-	20 648	1 990
F110	Waste from the production, formulation and use of resins, latex, plasticisers, glues and adhesives	1	7 426	1	1 260	232	-	2 442	445
G100	Ethers	-	-	-	148	4	-	1 295	77
G110	Organic solvents excluding halogenated solvents	34	3 130	7	2 120	1 126	-	4 699	5 671
G150	Halogenated organic solvents	8	225	1	146	123	482	177	10
G160	Waste from the production, formulation and use of organic solvents	-	935	-	12 496	7	43	1 048	-
H100	Waste from the production, formulation and use of biocides and phytopharmaceuticals	1	376	-	2 000	49	-	467	1 104
H110	Organic phosphorous compounds	-	23	-	56	61	-	15	1
H170	Waste from manufacture, formulation and use of wood-preserving chemicals	-	15	-	244	148	-	-	25
J100	Waste mineral oils unfit for their original intended use	1 263	133 754	583	87 524	1 149	-	19 203	102 130
J120	Waste oil/water, hydrocarbons/water mixtures or emulsions	1 977	106 309	205	169 400	2 541	99	79 269	51 307

NEPM Code	Description	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
J160	Waste tarry residues arising from refining, distillation, and any pyrolytic treatment	-	261	8	516	46	280	685	66
K100	Animal effluent and residues (abattoir effluent, poultry and fish processing wastes)	-	68 173	2 194	49 674	15 447	4 779	56 008	15 694
K110	Grease trap waste	5 599	168 412	5 421	133 834	38 159	11 806	99 175	68 858
K140	Tannery wastes (including leather dust, ash, sludges and flours)	-	-	-	6 150	-	-	557	-
K190	Wool scouring wastes	-	-	-	32 800	-	-	557	-
M100	Waste substances and articles containing or contaminated with polychlorinated biphenyls, polychlorinated naphthalenes, polychlorinated terphenyls and/or polybrominated biphenyls	18	1 927	71	2 056	13	-	462	214
M150	Phenols, phenol compounds including chlorophenols	-	118	-	908	-	-	1	74
M160	Organo halogen compounds—other than substances referred to in this Table or Table 2	-	5	-	24	2	-	29	279
M170	Polychlorinated dibenzo-furan (any congener)	-	-	-	-	-	-	-	-
M180	Polychlorinated dibenzo-p-dioxin (any congener)	-	-	-	-	-	-	-	-
M210	Cyanides (organic)	-	-	-	-	-	-	-	-
M220	Isocyanate compounds	-	82	-	48	2	-	23	33
M230	Triethylamine catalysts for setting foundry sands	-	-	-	360	2 402	-	96	237
M250	Surface active agents (surfactants), containing principally organic constituents and which may contain metals and inorganic materials	-	10 066	12	1 932	19	9	569	274
M260	Highly odorous organic chemicals (including mercaptans and acrylates)	-	-	-	-	17	-	29	6
N100	Containers and drums that are contaminated with residues of substances referred to in this list	11	13 312	29	-	390	14	21 368	3 259
N120	Soils contaminated with a controlled waste	205	504 500	-	216 854	439 462	-	373 764	6 443

NEPM Code	Description	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
N140	Fire debris and fire wash waters	-	1 326	-	636	4	-	592	109
N150	Fly ash, excluding fly ash generated from Australian coal fired power stations	-	-	-	4 782	496	-	439	165
N160	Encapsulated, chemically-fixed, solidified or polymerised wastes referred to in this list	-	12 327	-	15 120	76	-	24 724	13 367
N190	Filter cake contaminated with residues of substances referred to in this list	-	3 600	-	5 944	443	-	4 968	87
N205	Residues from industrial waste treatment/disposal operations	55 156	345 919	4 867	501 496	166 084	35 821	431 660	112 497
N220	Asbestos	20	199 000	4 846	116 480	21 385	10 554	74 775	50 198
N230	Ceramic-based fibres with physico-chemical characteristics similar to those of asbestos	-	-	-	-	26	-	70	-
R100	Clinical and related wastes	276	13 003	124	23 914	6 475	6	10 861	866
R120	Waste pharmaceuticals, drugs and medicines	2	9 985	-	1 308	326	26	999	866
R140	Waste from the production and preparation of pharmaceutical products	-	330	-	44	-	-	401	866
T100	Waste chemical substances arising from research and development or teaching activities, including those which are not identified and/or are new and whose effects on human health and/or the environment are not known	38	2 601	124	860	397	12	1 037	454
T120	Waste from the production, formulation and use of photographic chemicals and processing materials	33	216	-	370	20	5	843	4
T140	Tyres	3 225	100 968	5 389	88 055	56 449	9 942	84 113	67 269
T200	Waste of an explosive nature not subject to other legislation	-	10	-	1 816	-	-	11	-

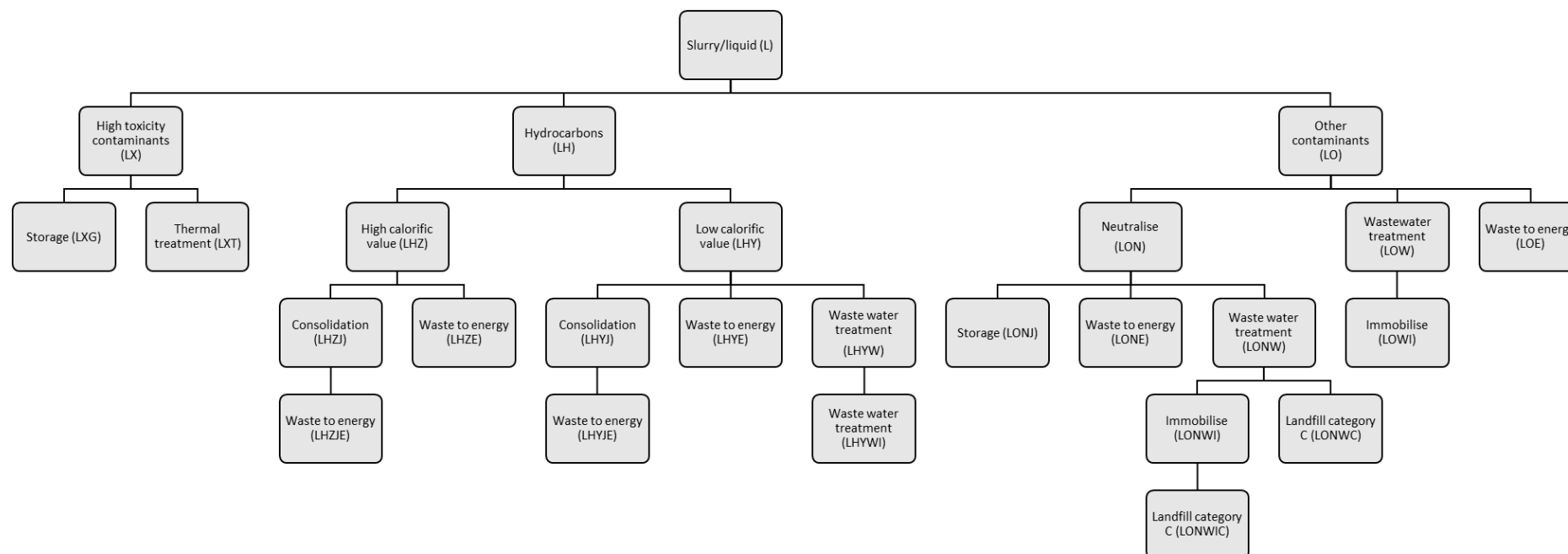
Note dashes (-) in fields represent zero values.

Figure 5: Soils, sludges and filtercake flow paths (and classifications)



Note: explanations for the codes shown above can be seen in Table 12 and Table 13.

Figure 6: Liquid and slurry material flow paths



To establish the material flows, materials were coded according to their phase (solid, sludge, liquid) and contaminant type. Treatment activities were also coded against a legend developed specifically for this project as shown in Table 12.

Table 12: Material coding legend

Category type	Category description	Category ID
Material phase	Liquid or slurry	L
	Soil	S
	Solid/Filtercake/Sludge	P
Contaminant type	High toxicity contaminant	X
	Hydrocarbon contamination	H
	Metal contamination	M
	Other contamination	O
	Asbestos / SMF	A
Additional contaminant information	High calorific value	Z
	Low calorific value	Y
Treatment type	Thermal treatment	T
	Specialist treatment	K
	Bioremediation	D
	Immobilisation	I
	Neutralisation	N
	Consolidation	J
	Waste to Energy	E
	Waste water treatment	W
Fate	Storage	G
	High level landfill (Cat B)	B
	Low level landfill (Cat C)	C
	Recycling	R
	Liquid or slurry	U

Combinations of material phase, contaminant type, treatment type(s) and final fate were used to build up the following list of classifications for the material flow paths. This list is informed by the flow charts developed in industry consultation and can be seen in Figures 4 and 5. Following treatment, most waste materials are then sent to a final fate (being landfill, storage, recycling or reuse).

Table 13: Material flow path classifications

Classification	Classification description
PXG	Solid/Filtercake/Sludge, High toxicity contaminant, Storage
SXG	Soil, High toxicity contaminant, Storage
PXK	Solid/Filtercake/Sludge, High toxicity contaminant, Specialist treatment
SXK	Soil, High toxicity contaminant, Specialist treatment
SHD	Soil, Hydrocarbon contamination, Bioremediation
PHI	Solid/Filtercake/Sludge, Hydrocarbon contamination, Immobilisation
PHE	Solid/Filtercake/Sludge, Hydrocarbon contamination, Waste to Energy
PMI	Solid/Filtercake/Sludge, Metal contamination, Immobilisation
SMI	Soil, Metal contamination, Immobilisation
PMT	Solid/Filtercake/Sludge, Metal contamination, Thermal treatment

Classification	Classification description
SMT	Soil, Metal contamination, Thermal treatment
POD	Solid/Filtercake/Sludge, Other contamination, Bioremediation
POI	Solid/Filtercake/Sludge, Other contamination, Immobilisation
PON	Solid/Filtercake/Sludge, Other contamination, Neutralisation
SOI	Soil, Other contamination, Immobilisation
POT	Solid/Filtercake/Sludge, Other contamination, Thermal treatment
POJT	Solid/Filtercake/Sludge, Other contamination, Consolidation, Thermal treatment
PONT	Solid/Filtercake/Sludge, Other contamination, Neutralisation, Thermal treatment
SONT	Soil, Other contamination, Neutralisation, Thermal treatment
LXG	Liquid or slurry, High toxicity contaminant, Storage
LXK	Liquid or slurry, High toxicity contaminant, Specialist treatment
LHZJE	Liquid or slurry, Hydrocarbon contamination, High CV, Consolidation, Waste to Energy
LHZE	Liquid or slurry, Hydrocarbon contamination, High CV, Waste to Energy
LHYJE	Liquid or slurry, Hydrocarbon contamination, Low CV, Consolidation, Waste to Energy
LHYE	Liquid or slurry, Hydrocarbon contamination, Low CV, Waste to Energy
LHYW	Liquid or slurry, Hydrocarbon contamination, Low CV, Waste water treatment
LOE	Liquid or slurry, Other contamination, Waste to Energy
LON	Liquid or slurry, Other contamination, Neutralisation
LONJ	Liquid or slurry, Other contamination, Neutralisation, Consolidation
LONE	Liquid or slurry, Other contamination, Neutralisation, Waste to Energy
LOW	Liquid or slurry, Other contamination, Waste water treatment
LOWI	Liquid or slurry, Other contamination, Waste water treatment, Immobilisation
LONW	Liquid or slurry, Other contamination, Neutralisation, Waste water treatment
LONWI	Liquid or slurry, Other contamination, Neutralisation, Waste water treatment, Immobilisation

As each jurisdiction classifies waste according to hazard characteristics and this influences the pathways available and cost of treatment or disposal, it was necessary to split each waste for NEPM code into hazard categories. In the absence of comprehensive, published, hazard categorisation data for each jurisdiction, representative values from Victoria in 2009 were used in this assessment (EPA Victoria, 2011). Whilst this may add some uncertainty to the analysis, it is understood to be quite minor and has been further reduced by applying the hazard categorisation to the level of NEPM15 codes. As waste generation varies year on year, this limits the variation in individual waste codes.

4.1.3 Waste destinations

Hazardous waste is generally required to undergo some form of treatment prior to disposal at landfill in order to reduce or contain the hazard to humans and the environment. Each jurisdiction has different legislation regarding classifications of materials, as well as treatment and disposal requirements. This is often captured using the hazardous waste tracking systems in place in many jurisdictions.

Waste material destination was not estimated in the Blue Environment study and as such a different data source was required to understand the end of life fate of different hazardous waste materials in each jurisdiction. Some jurisdictions (New South Wales, Victoria, and Queensland) collect reliable data on material destinations through their waste tracking systems. That data was assessed and synthesized by KMH in the 2013 Hazardous Waste Data Assessment (KMH 2013). However, the KMH study noted that data provided by other jurisdictions was unreliable and was therefore not reported. Calculations used in that study provided the basis of the destination split for each of those three jurisdictions in the 2010–11 financial year. As this was a different base year to the generation data used for this study, it was used as the basis for a proportional split of material destinations and not in absolute terms. In the jurisdictions for which there was not a proportional split available, the national average was used.

The New South Wales, Victoria and Queensland jurisdictions have tracking systems that capture flows of materials from generators to treatment facilities and are built to avoid double counting. These jurisdictions included a split between the following destinations:

- Delivered to transfer stations – this was not used in this analysis and any material delivered to transfer stations is assumed to have been landfilled
- Disposed to landfill – this only applies to waste that is of a low enough hazard that it is sent directly to landfill
- Disposed to trade waste – this was not used in this analysis. The 2013 report also included no material disposed to trade waste
- Treated – material sent for treatment was assigned as per the flow charts in Section 2. Each of the treatment options has a different cost structure and costs were assigned accordingly. Energy recovery was included as a treatment option in this study as in some cases material sent for energy recovery is tracked as treatment
- Energy recovery – material sent directly to energy recovery
- Storage – material sent for long term secure storage
- Reuse – material reused without reprocessing
- Recycled – material reprocessed into a new raw material
- Other – as per the 2013 report, material included in the other category includes that material incorrectly labelled or sent to a treatment destination not listed on the tracking system.

The KMH analysis used 2010–11 data, and is the only pre-existing national data available for destinations of hazardous waste by jurisdiction and NEPM waste code. For this study, it was used to proportion 2012 waste flows in each jurisdiction to destinations on a pro-rata basis. For New South Wales, Queensland, and Victoria this was done using the proportional splits for those jurisdictions as identified in the previous analysis. For ACT and Tasmania, material flows almost exclusively to New South Wales and Victoria respectively for treatment and disposal. As such, the proportional splits for those jurisdictions were used. South Australia and Western Australia had no data available on destination splits and as such a national average was used. These flows can be seen in data supplied accompanying this report.

4.2 Estimates of direct market costs⁵

The direct market costs of hazardous waste management are made up of treatment costs, transport costs to the treatment facility, disposal costs (of treated residual) and additional transport costs to landfill. Consultation with senior waste management and recycling industry representatives was used to define cost estimates for each of the process stages for each treatment type. These cost estimates were expressed as a tonnage rate and excluded all levies and other government charges.

Each classification option has an individual cost structure based on the six elements laid out in Table 13 and this cost structure differs according to the jurisdiction in which it is applied (mainly in transport costs and disposal charges).

4.2.1 Transport costs

Transport costs are incurred both from the generator site to the treatment or disposal facility and again from the treatment facility to the final disposal location for any residual. The amount of residual depends on the treatment process employed. As generators are dispersed and there are a limited number of treatment and disposal facilities in each jurisdiction, transport costs can vary significantly between jurisdictions and treatment type.

Solid waste and liquid waste have different transport characteristics. Solids, sludges and soils are generally transported in 20 tonne tippers (covered to prevent material egress) at a rate of \$150/hour to \$250/hour. For these materials, a median rate of \$100/hour was converted into a cost of \$10/hour.tonne.

Liquid waste is more problematic to transport, usually in specialised tankers. Such tankers have a median capacity of 12 tonnes and transport costs can range from \$100/hour to \$200/hour. A median rate of \$150/hour was converted to a rate of \$12.50/hour.tonne.

4.2.2 Treatment costs

The costs of waste treatment and fates depend largely on the type and complexity of process, chemical type and the size of the market and the use of any residual or by product from treatment. For example, some hazardous waste is treated by creating a fuel product for use in cement kilns. For this process, the cost of treating a hydrocarbon with high calorific value is significantly lower than treating highly toxic, low calorific value chemicals, sometimes by orders of magnitude. A

The treatment types and costs applied in the analysis are detailed in Table 14. All costs are reported as dollars per tonne and exclude any disposal costs for residual material and landfill levies.

⁵ All cost estimates discussed in this section are based on data provided through consultations with industry and jurisdictional stakeholders unless otherwise stated.

Table 14: Treatment costs applied to the analysis

Material state	Contaminant type	First treatment stage	Second treatment stage	Third treatment stage	Total treatment cost/ tonne (\$)
Solid / filtercake / sludge	High toxicity	Storage	N/A	N/A	\$10 000+
		Specialist treatment	N/A	N/A	\$4 100 to \$4 500
	Hydrocarbon	Immobilisation	N/A	N/A	\$160 to \$200
		Waste to energy	N/A	N/A	\$500 to \$550
	Metal	Immobilisation	N/A	N/A	\$160 to \$200
		Thermal	N/A	N/A	\$500 to \$650
		Bioremediation	N/A	N/A	\$30 to \$70
	Other	Immobilisation	N/A	N/A	\$200 to \$300
		Thermal	N/A	N/A	\$650 to \$850
		Consolidation	Thermal	N/A	\$700 to \$900
		Neutralisation	Thermal	N/A	\$700 to \$900
Soil	High toxicity	Storage	N/A	N/A	\$10 000+
		Specialist treatment	N/A	N/A	\$4 100 to \$4 500
	Hydrocarbon	Bioremediation	N/A	N/A	\$120 to \$180
	Metal	Immobilisation	N/A	N/A	\$160 to \$200
		Thermal	N/A	N/A	\$500 to \$650
	Other	Immobilisation	N/A	N/A	\$150 to \$250
		Neutralisation	Thermal	N/A	\$1 100 to \$1 500
Liquid	High toxicity	Storage	N/A	N/A	\$10 000+
		Specialist treatment	N/A	N/A	\$4 000 to \$4 500
	Hydrocarbon (High calorific value)	Consolidation	Energy recovery	N/A	\$30 to \$110
		Energy recovery	N/A	N/A	\$10 to \$30
	Hydrocarbon (Low calorific value)	Consolidation	Energy recovery	N/A	\$3 500 to \$5 100
		Energy recovery	N/A	N/A	\$3 500 to \$5 000
		Waste water treatment	N/A	N/A	\$8 to \$16
		Energy recovery	N/A	N/A	\$3 000 to \$4 000
	Other	Neutralisation	N/A	N/A	\$20 to \$80
		Consolidation	Neutralisation	N/A	\$80 to \$120
		Neutralisation	Energy recovery	N/A	\$3 100 to \$5 500
		Waste water treatment	N/A	N/A	\$8 to \$16
		Waste water treatment	Immobilisation	N/A	\$20 to \$50
		Neutralisation	Waste water treatment	N/A	\$15 to \$40
		Neutralisation	Waste water treatment	Immobilisation	\$75 to \$100

4.2.3 Disposal costs

Disposal destinations for hazardous waste depend on the hazard of the material and/or the treatment processes undertaken prior to final disposal. Each jurisdiction deals with hazardous waste disposal slightly differently, with different design specifications for landfills and different regulations about which material can be disposed to landfill. This impacts disposal costs and as such landfill availability and disposal costs vary from state to state.

Additional to landfill costs are the jurisdictional landfill levies. These also vary by location in both scale and application. Differences in levies can create flows of waste between jurisdictions. It is well reported (McKenny 2013) that the lack of a landfill levy in Queensland has led to conventional waste being transported interstate from New South Wales and anecdotally the same happens with hazardous waste. This is borne out in the NEPM reporting for 2012–13 (NEPC, 2014) that shows over 15,000 tonnes of controlled waste flowing north. The detailed interstate movements have not been included in the overall analysis as the available data was only reported at the NEPM15 level and without destination information.

ACT

There are no landfills located within the ACT that accept hazardous waste (excluding asbestos and low level contaminated soil which can be accepted at the Mugga Lane Landfill and the West Belconnen Resource Management Centre) and all waste is sent for disposal is exported to NSW.

New South Wales

New South Wales does not permit landfilling of any untreated hazardous waste. In New South Wales, “Restricted Solid Waste” is that requiring disposal at a high containment landfill, of which there is only one facility in the state. This is located at Kemps Creek in Western Sydney at the Elizabeth Drive precinct and is operated by SITA. Industry advice is that gate fees for this landfill are between \$250/tonne and \$500/tonne depending on a range of factors including demand and size of consignment.

Waste that has been treated to an acceptable standard is referred to as within the New South Wales EPA as “Immobilised Solid Waste” and can be disposed at a number of landfills around the state. The official designation for immobilised solid waste is either General Solid Waste (putrescible) or General Solid Waste (non-putrescible). These generally charge a gate fee from \$180/tonne to \$300/tonne.

New South Wales administers a location based landfill levy based on three broad areas, the Sydney Metropolitan Area (\$95.20/tonne), the Extended Regulated Area (\$93.00/tonne) and the Regional Regulated Area (\$42.40/tonne). There is also a levy on trackable liquids (liquid waste that fits the NEPM classification) of \$66.60/tonne. An additional levy on coal washery reject material has not been applied in this study.

Northern Territory

As for the ACT, the NT has no waste tracking system beyond collecting data on interstate waste transport. The NT does not have any landfills or treatment facilities licensed to accept hazardous waste. As such, all waste has been assumed to be exported to South Australia for treatment and disposal.

Queensland

Queensland has one high containment landfill facility located at Swanbank, west of Brisbane. The Swanbank facility is operated by Remondis and industry consultation suggests that landfill gate fees for high containment waste are between \$80/tonne and \$120/tonne. There are a number of other landfills in the state able to accept conventional waste, charging from \$25/tonne to \$55/tonne.

In 2012 the new Queensland state government repealed the state's landfill levy, effective 1 July of that year. As such, landfill levies were only applied in this study to waste generated for half of 2012. Prior to the repeal, the levy for high hazard waste was \$150/tonne and lower hazard waste \$50/tonne.

South Australia

Transpacific Industries operates South Australia's only high containment landfill at Inkerman, approximately 1 hour north of Adelaide. It is understood that gate fees for this facility range from \$200/tonne to \$300/tonne for high containment waste. There are best practice engineered landfills in the state that can accept low level waste at a gate fee of \$110/tonne to \$170/tonne.

Similarly to NSW, SA operates a location based landfill levy alongside a trackable liquid levy. For waste generated and/or disposed in the Adelaide metropolitan area a levy of \$47/tonne is applied, and \$23.50/tonne for waste generated and disposed in non-metro areas. All trackable wastes in liquid form attract a levy of \$17.95/tonne.

Tasmania

Tasmania does not have a high containment landfill or treatment facilities for hazardous waste within the state and almost all waste is exported to the mainland for treatment or disposal at a cost additional to the gate fee of approximately \$200/tonne.

Victoria

Victoria refers to hazardous waste as Prescribed Industrial Waste (PIW). PIW categorisation ranges from Category A (highest hazard) to Category C. Category A waste cannot be landfilled and must be sent for treatment or destruction. Category B waste can be sent to Victoria's only high containment landfill, which is located at Lyndhurst, south east of Melbourne. The facility is operated by SITA and industry advice is that gate fees for this landfill are between \$250/tonne and \$500/tonne. As per the Elizabeth Drive landfill in NSW, the actual gate fee varies according to consignment type, size and current demand at the facility. Best practice landfills in Victoria charge a gate fee of \$50/tonne to \$100/tonne for conventional and low level waste.

Victoria charges landfill levies based on the hazard category of waste being disposed. Category B waste, the highest hazard category for disposal, attracted a levy of \$250/tonne in 2012. The Category C waste levy was \$70/tonne. Packaged asbestos also attracted a levy of \$30/tonne.

Western Australia

WA's high containment landfill is located near to the Kwinana industrial precinct south of Perth. Industry advice suggests a gate fee of \$200 to \$450 per tonne for this landfill and \$50 to \$90 per tonne for best practice landfills elsewhere in the state.

Similarly to Victoria, WA charges a landfill levy based on the hazard category of waste. “Controlled Waste” attracted a levy of \$28/tonne in 2012, whilst “Inert Waste” and packaged asbestos attracted a levy of \$12/tonne.

4.2.4 On-site waste treatment

Some hazardous and contaminated materials may be treated or destroyed onsite and as such are not included in waste tracking systems.

Contaminated soils are the largest of these material types and in an effort to save on transport and treatment costs much is treated at the construction or demolition site. Industry consultations have suggested that as much as 75% of all contaminated soils are treated onsite. These quantities are highly uncertain and the direct and indirect costs associated with their treatment are therefore not been included in this analysis. Given offsite treatment of soils is estimated at 1.5 million tonnes for 2012 however, onsite treatment could feasibly be up to 4.5 million tonnes. Soils suitable for onsite treatment are typically those contaminated with hydrocarbons as these can be treated with bioremediation. Whilst onsite treatment is generally cheaper than offsite at \$35/tonne to \$50/tonne compared with \$100/ to \$200/tonne, it is a slow process. This means that land where contaminated soil is being treated cannot be used for six to twelve months. Applying the upper bound estimates of treatment costs to volumes would imply maximum additional direct costs of \$225 million for contaminated soils treated on site, plus some additional costs for short term quarantining of land.

Clinical waste is often destroyed onsite at hospital incinerators. As these wastes are not subject to a tracking, much of this waste is also not included in this analysis. Many major hospitals run incinerators to dispose of bio-hazardous waste onsite.

4.3 Indirect and non-market costs

Indirect and non-market costs assessed for the cost analysis fall into three broad areas:

- government costs associated with regulating and administering hazardous wastes;
- costs associated with injuries and illnesses to workers who handle hazardous wastes; and
- residual environmental and social externalities associated with hazardous wastes disposed to landfill⁶.

Methods and assumptions associated with estimating these costs are discussed in turn below.

Regulatory and administration costs

As discussed in section 2.2, each jurisdiction is responsible for regulating and administering hazardous waste within its boundaries. The time and money spent on these regulatory functions fall into two areas.

Costs associated with hazardous waste data tracking and reporting

These costs include administration costs associated with data tracking and reporting under jurisdictional legislation and national and international obligations such as the Controlled Waste NEPM and the Base Convention. Jurisdictions were able to provide estimates of these costs

⁶ Note the costs associated with greenhouse gas emissions and other pollutants produced by the treatment and transport of hazardous waste were not assessed for this study but are estimated to be minor.

which are summarised in Table 15. As can be seen, they are relatively minor and reflect staff time devoted to data compilation and reporting.

Table 15: Jurisdictional administration costs associated with data tracking and reporting (\$)

Cost item	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Administering the controlled waste NEPM	540	15,000	339	6,573	2,250	737	3,750	3,508
Monitoring and reporting for the NEPM	296	10,000	186	3,599	1,500	403	-	1,921
Basel monitoring and reporting	747	25,000	469	9,092	3,749	1,019	300	4,852
Jurisdictional specific administration	18,681	450,000	11,745	227,457	67,490	25,498	209,250	121,391
Total	20,263	500,000	12,740	246,720	74,989	27,658	213,300	131,672

Costs associated with regulating the management of hazardous wastes

These are costs associated with regulating the management of hazardous wastes and include licensing, approvals, site inspections and audits, monitoring and dealing with illegal dumping of hazardous wastes. These costs were more difficult to establish. Discussions with jurisdictions indicated that budgeting and cost allocation within jurisdictional regulatory agencies (EPAs or equivalent) does not enable costs associated with hazardous regulation to be specifically identified. This is understandable given that the regulatory functions of agencies are generally performed at the site and to some extent industry levels rather than being directed at particular wastes or pollutants.

To get around this problem and to make an estimate of the regulatory costs of hazardous wastes, the total operational budgets of each jurisdiction's EPA or regulatory equivalent were established (ignoring grants and other non-operational expenditures) drawing on annual reports and plans. The functions of each agency were then established and, depending on the range and nature of each agency's functions, costs associated with the regulation for hazardous wastes were estimated as a proportion of its operational budget. Apportionments were estimated to be generally in the order of 15% to 20% of total operating budgets (see Table 16). Reflecting the uncertainty of these apportionments, estimates of these costs are considered to have an error margin of +/- 40% around the central estimate.

Table 16: Total operating budgets of jurisdictional EPAs or equivalent, and estimated costs allocated to regulating hazardous wastes 2012-13 (\$m)

	NSW	Vic	Qld	SA	WA	Tas	ACT	NT
Total operational budget, EPA or equivalent	86.1	65.8	76.7	28.9	42.2	18.0	5.6	10.0
Hazardous waste regulatory component	14.3	11.0	12.8	4.8	7.0	3.6	1.1	1.6

Costs associated with workplace injuries and illnesses

The handling of hazardous wastes, either in-situ or off site may lead to workplace related illness and injury (including death in extreme circumstances).

Injury and illness data is broadly classified at the highest level by industry, occupation, and by injury and disease classification (Table 17).

Table 17: Injury and illness data classifications

Classification	Details
Industry classification	The industry classification codes are in accordance with the Australian and New Zealand Standard Industrial Classification (ANZSIC) published by the Australian Bureau of Statistics. The classification codes are based on a hierarchical structure consisting of one digit codes (broadest level) down to four digit codes (finest level).
Occupation classifications	The occupation classifications are in accordance with the Australian Standard Classification of Occupations 2nd Edition (ASCO), for data reported up to and including the year 2008-09, and the Australian and New Zealand Standard Classification of Occupations First Edition (ANZSCO), for data reported from the year 2009-10 onward.
Injury and disease classification	<p>The injury and disease classification groupings and descriptions are the standard terms taken from the Safe Work Australia (formerly Australian Safety and Compensation Council) publication: Type of Occurrence Classification System (TOOCS, ASCC 2008).</p> <p>The following four classifications are used to describe the type of injury or disease sustained by the worker and the way in which it was inflicted:</p> <ul style="list-style-type: none"> - Nature of Injury/Disease; - Bodily Location of Injury/Disease; - Mechanism of Injury/Disease; and - Agency.

Depending on the classification, injuries and illnesses have economic costs including:

- workers compensation (for death or injury);
- medical costs and rehabilitation costs;
- lost of future earnings by injured or killed workers;
- lost production at work sites; and
- associated administration costs.

Safe Work Australia compiles data of workers compensation claims at industry (ANZSIC classification) level, according to the injury and illness classification. Data is also compiled on specific chemicals and biological substances as agency of injury/disease. However, Safe Work Australia notes that the quality of information held on disease causing agents in particular tends to be of relatively poor quality owing to difficulties in proving a link between exposure and disease, exceptions being where there is a very specific cause (e.g. mesothelioma and asbestos, ASCC 2008). Furthermore, data is not compiled in a format that allows for direct calculation of work place deaths, injuries and illnesses that can be attributed to “hazardous wastes”. Although there is data on workplace related injuries and illnesses in the “Electricity, Gas, Water and Waste Services” sector, this data does not distinguish between hazardous and non-hazardous wastes. More importantly, the data only reflects injuries and illnesses specific to the waste management sector and does not cover injuries and illnesses related to hazardous waste that occur in sectors that are the sources of hazardous wastes such as mining and manufacturing.

However, estimates can be derived by comparing the annual value of WorkCover payments with the total estimated cost of injury and illness reported by Safe Work Australia (2012a). The following approach was taken to derive these estimates:

- Information relating to the economic costs of ‘chemicals and other hazardous substances’ and ‘biological hazards’ was obtained from Safe Work Australia databases.

- This data reveals that the costs of claims for serious accidents relating to ‘chemicals and other hazardous substances’ averaged about \$125 million per year over the five year period 2008-2012. Similarly, claims for serious accidents relating to ‘biological hazards’ averaged about \$88 million.
- Data on workers compensation claims and costs relating to ‘chemicals and other hazardous substances’ and ‘biological hazards’ was used to cross-check this data.
- Safe Work Australia uses a multiplier of 10.2 to determine economic costs of work-related injuries and illnesses from workers claim costs (i.e. on average, the total economic cost of injury and illness is 10.2 times the compensation paid). This was applied to the chemicals and other hazardous substances claims and biological hazards claims to come up with estimates of the total economic costs relating to these substances for 2012 of 1,276 million and 897 million respectively.
- Survey data of workers exposed to hazardous chemicals (Safe Australia 2012b) and biological hazards (Safe Work Australia 2011) was used to ascertain the proportion of the economic costs of ‘chemicals and other hazardous substances’ and ‘biological hazards’ that could be attributed to chemical wastes and biological wastes. These proportions are estimated to be 7% and 3.4% respectively, reflecting the survey data which refers to the proportion of workers exposed to these substances who reported being exposed to hazardous waste (chemical or biological).
- These proportions were then applied to the economic costs of ‘chemicals and other hazardous substances’ and ‘biological hazards’ to estimate the costs of hazardous wastes.
- Costs projections for subsequent years were ascertained taking into account increasing real health costs on the one hand and data indicating that the incidence of workers compensation claims is declining by about 1.2% per year.
- Workers compensation costs were netted from totals to avoid double counting as those costs are likely to be reflected in the direct market costs.
- Costs were apportioned to jurisdictions based on volumes of hazardous waste (see Table 18).

Table 18: Apportionment of the economic costs of hazardous waste-related injuries and illnesses between jurisdictions, 2012 (\$ million)

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Australia
Proportion of hazardous waste	0.27	0.21	0.26	0.13	0.09	0.03	0.00	0.01	1
Gross Cost	33.3	25.1	32.0	16.3	11.2	3.2	0.5	0.6	122.3
Net of workers compensation	-	-	-	-	-	-	-	-	-
	3.3	2.6	3.3	1.7	1.2	0.3	0.1	0.1	12.6
Net Cost	30.0	22.5	28.7	14.6	10.0	2.9	0.4	0.5	109.6

The results of this approach are likely to have a high degree of uncertainty, estimated at +/- 50%.

Residual environmental and social costs associated with hazardous wastes disposed to landfill

Notwithstanding pre-disposal treatment, hazardous wastes disposed to landfill are likely to result in negative environmental and social costs. These ‘downstream externalities’ include greenhouse gas (GHG) emissions, gas, leachate, odour, dust and social amenity. Table 19 summarises these downstream or direct solid waste externalities and the key materials with which they are associated.

Table 19: Major downstream waste externalities

Direct externality	Comment	Key materials
Greenhouse gas	Biologically active materials degrade into landfill gas with methane – potent greenhouse gas	Degradable organic carbon
Leachate	Water that has percolated through waste collecting soluble substances (chemicals heavy metals)	Degradable materials, hazardous
Odour	Trace elements of landfill gas such as sulphides and ammonia	Degradable materials
Dust	Operation of landfill such as dirt roads, unloading and daily cover	Construction and demolition
Social amenity	Landfills are an unwanted ‘NIMBY’ class of infrastructure	All, with sensitivities around hazardous, asbestos and contaminated soils

Source: Warnken ISE analysis for Marsden Jacob 2012

Best practice landfill management will substantially reduce but not completely eliminate these externalities.

There have been numerous Australian and international reviews of the externality costs of wastes disposed to landfill including Productivity Commission (2006), BDA (2009) and Schollum (2010). Based on their reviews BDA (2009) and Schollum (2010) both conclude that the total external costs of landfill is less than \$50 / tonne of waste for the majority of Australian landfills and waste types. Both note that the more significant components of the external costs are GHG emissions, followed by disamenity, with leachate and other air emissions generally being valued at less than \$5 and less than \$1 per tonne of waste, respectively.

Greenhouse gas emissions

Most studies reviewed by BDA (2009) and Schollum (2010) value GHG emissions for landfills at less than \$20 per tonne of waste landfilled. This value per tonne of waste is a function of the quantity of emissions per tonne of waste for various waste streams (emissions factor), the proportion of GHG (methane) collected and the cost of carbon emissions.

Emissions factor

The Department of the Environment (formerly DIICSRTE) publishes emissions factors (quantity of emissions per tonne of waste) for various activities including waste disposed to landfill by broad waste stream category (Table 20).

Table 20: Emissions factors for waste disposed to landfill by broad waste stream category

Waste types	MSW	C&I	C&D
Emission factor (t CO ₂ -e/t waste)	1.2	1.1	0.3

Source: DIICCS RTE (2013)

The key element influencing the relevant emissions factor is organic content of the landfill material. For this study we examined each of the NEPM 75 waste types and determined whether they had organic content (Table 21). Waste types with an organic content were ascribed an emissions factor of 1.1, with the exception of N120 waste (contaminated soils) which was ascribed a factor of 0.3. Materials without organic content were ascribed an emissions factor of 0.

Table 21: Classification of NEPM 75 wastes according to organic content

NEPM 75 Code	Description	GHGs (organic) Y/N?
A100	Waste resulting from surface treatment of metals and plastics	N
A110	Waste from heat treatment and tempering operations containing cyanides	N
A130	Cyanides (inorganic)	N
B100	Acidic solutions or acids in solid form	N
C100	Basic solutions or bases in solid form	N
D100	Metal carbonyls	N
D110	Inorganic fluorine compounds excluding calcium fluoride	N
D120	Mercury; mercury compounds	N
D130	Arsenic; arsenic compounds	N
D140	Chromium compounds (hexavalent and trivalent)	N
D150	Cadmium; cadmium compounds	N
D160	Beryllium; beryllium compounds	N
D170	Antimony; antimony compounds	N
D180	Thallium; thallium compounds	N
D190	Copper compounds	N
D200	Cobalt compounds	N
D210	Nickel compounds	N
D220	Lead; lead compounds	N
D230	Zinc compounds	N
D240	Selenium; selenium compounds	N
D250	Tellurium; tellurium compounds	N
D270	Vanadium compounds	N
D290	Barium compounds (excluding barium sulphate)	N
D300	Non-toxic salts	N
D310	Boron compounds	N
D330	Inorganic sulfides	N
D340	Perchlorates	N
D350	Chlorates	N
D360	Phosphorus compounds excluding mineral phosphates	N
E100	Waste containing peroxides other than hydrogen peroxide	N
F100	Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish	N

NEPM 75 Code	Description	GHGs (organic) Y/N?
F110	Waste from the production, formulation and use of resins, latex, plasticisers, glues and adhesives	N
G100	Ethers	Y
G110	Organic solvents excluding halogenated solvents	Y
G150	Halogenated organic solvents	Y
G160	Waste from the production, formulation and use of organic solvents	Y
H100	Waste from the production, formulation and use of biocides and phytopharmaceuticals	Y
H110	Organic phosphorous compounds	Y
H170	Waste from manufacture, formulation and use of wood-preserving chemicals	Y
J100	Waste mineral oils unfit for their original intended use	Y
J120	Waste oil/water, hydrocarbons/water mixtures or emulsions	Y
J160	Waste tarry residues arising from refining, distillation, and any pyrolytic treatment	Y
K100	Animal effluent and residues (abattoir effluent, poultry and fish processing wastes)	Y
K110	Grease trap waste	Y
K140	Tannery wastes (including leather dust, ash, sludges and flours)	Y
K190	Wool scouring wastes	Y
M100	Waste substances and articles containing or contaminated with polychlorinated biphenyls, polychlorinated naphthalenes, polychlorinated terphenyls and/or polybrominated biphenyls	Y
M150	Phenols, phenol compounds including chlorophenols	Y
M160	Organo halogen compounds—other than substances referred to in this Table or Table 2	Y
M170	Polychlorinated dibenzo-furan (any congener)	N
M180	Polychlorinated dibenzo-p-dioxin (any congener)	N
M210	Cyanides (organic)	Y
M220	Isocyanate compounds	Y
M230	Triethylamine catalysts for setting foundry sands	Y
M250	Surface active agents (surfactants), containing principally organic constituents and which may contain metals and inorganic materials	Y
M260	Highly odorous organic chemicals (including mercaptans and acrylates)	Y
N100	Containers and drums that are contaminated with residues of substances referred to in this list	N
N120	Soils contaminated with a controlled waste	Y
N140	Fire debris and fire wash waters	N
N150	Fly ash, excluding fly ash generated from Australian coal fired power stations	N
N160	Encapsulated, chemically-fixed, solidified or polymerised wastes referred to in this list	N
N190	Filter cake contaminated with residues of substances referred to in this list	N
N205	Residues from industrial waste treatment/disposal operations	Y
N220	Asbestos	N
N230	Ceramic-based fibres with physico-chemical characteristics similar to those of asbestos	N
R100	Clinical and related wastes	N
R120	Waste pharmaceuticals, drugs and medicines	N

NEPM 75 Code	Description	GHGs (organic) Y/N?
R140	Waste from the production and preparation of pharmaceutical products	N
T100	Waste chemical substances arising from research and development or teaching activities, including those which are not identified and/or are new and whose effects on human health and/or the environment are not known	N
T120	Waste from the production, formulation and use of photographic chemicals and processing materials	N
T140	Tyres	N
T200	Waste of an explosive nature not subject to other legislation	N

Emissions collection

The efficiency rate of methane collection varies from landfill to landfill. Current estimates for best practice landfills indicate collection efficiency of 80-90% efficiency. Most landfills, even those designed for hazardous waste disposal have a lower efficiency than this. The national average collection efficiency as applied in the National Greenhouse Gas Inventory is 30% (Department of the Environment 2014). For the purpose of this study we have assumed an average collection efficiency of 60% however, meaning that 40% of emissions are assumed to end up in the atmosphere. The assumed higher collection efficiency reflects the tighter management regime of landfills to which most hazardous wastes are disposed.

Cost of carbon emissions

Some studies use the abatement cost of carbon, suggested by the marginal cost of abatement, as a proxy for the cost of carbon. Garnaut (2011) however, suggests that a 'social cost of carbon' be applied in assessing proposals for regulations. Similarly, Schollum (2010) argues that the marginal abatement cost does not reflect the true social cost of carbon. The United States Government (2013) recommends differing social carbon costs depending on the discount rate applied to future impacts but with costs of emissions rising over time. Its recommended social cost ranges from US\$11-52 in 2010 (A\$13-59) rising to US\$14-70 in 2025 (A\$16-80). Dietz and Stern (2014) argue that the cost of carbon needed to prevent irreversible climate impacts will need to be set at as high as US\$75/ tonne CO_{2-e} (A\$80) in the short term and US\$133/ tonne CO_{2-e} (A\$141) in the longer term. The Australian Treasury (2011) nominally set the cost of carbon at \$29/ tonne of CO_{2-e}.

For this study we have used the Treasury global value of carbon of \$29/ tonne CO_{2-e}. We recognise though, that there is a rationale for using a higher social cost of carbon reflecting the uncertainties about the long term impacts of climate change and have applied a social cost of \$80/tonne CO_{2-e} in sensitivity analysis. This is reflected in the upper bound estimate of indirect and non-market costs.

Summary of greenhouse gas emission cost of hazardous wastes

In summary, an emissions factor of 1.1 applied to most hazardous wastes with an organic content, a collection efficiency of 60% for those emissions, and a carbon cost of \$29/ tonne of CO_{2-e} actually emitted gives an estimated value of \$12.76/ tonne of hazardous waste disposed to landfill. Contaminated soils (N120) are given a value of \$3.48/ tonne of waste based on the lower emissions factor of 0.3. A carbon cost of \$80/ tonne CO_{2-e} gives an upper bound greenhouse gas emission cost of \$35.20/ tonne of hazardous waste disposed to landfill.

Disamenity costs

Most studies of landfill externality costs find that disamenity is the second largest component of the total external costs, following GHG emissions. Disamenity costs are those costs that occur when a landfill is located in an area that is populated or used for recreation or when urban development encroaches on prior landfill sites. Schollum (2010) notes that disamenity externalities have been increasingly internalised over time due to improving standards and placing sites in less populated areas.

Estimates of disamenity have generally been drawn from hedonic pricing studies⁷, either directly or by transferring the relationships between proximity to landfills and house prices established for one or more different housing markets. BDA (2009) uses a disamenity value of \$1 for best practice landfills and \$5-10 for other landfills. Schollum (2010) estimated disamenity values for Perth metropolitan landfills at \$4.09 per tonne of waste.

For this study we have used a disamenity value of \$2.67/tonne of waste as a weighted average reflecting \$1/tonne in 80% of landfills to which waste is disposed (best practice) and \$7.50/tonne in the remaining landfills, adjusted to 2012 prices.

Other air pollutants

In addition to emitting GHGs, landfills also emit traces of other air pollutants, such as volatile organic compounds (VOCs), nitrogen dioxide, sulphur dioxide, benzene, hydrogen sulphide, mercury and fine particles, which are potentially damaging to the environment and human health.

Most estimates of these externalities are low - the majority of Australian and international studies value the external costs of other air pollutants (other than GHGs) at below \$1 per tonne of waste landfilled (BDA 2009; Schollum 2010).

BDA (2009) estimated the external costs of other air pollutants for Australian landfills in a dry temperate climate at \$0.54 - \$0.96 per tonne of waste in an urban setting, and \$0.08 - \$0.23 per tonne of waste in a rural setting. The range provided accounts for differences in management practices, with gas collection and/or energy recovery lowering the externality costs. The estimates are higher for urban landfills due to the assumption of greater exposure of the population compared to rural sites.

We have used a value of \$0.96/tonne of waste as a weighted average reflecting \$0.97/tonne in 80% of landfills to which waste is disposed and \$0.24/tonne in the remaining landfills, adjusted to 2012 prices.

Leachate

Leachate is liquid that occurs in landfills and results from precipitation and surface water combining with the biochemicals and physical breakdown of waste; it may contain metals and organic and inorganic compounds, including toxins (Schollum, 2010). Thus, it can potentially cause adverse environmental and human health effects if it escapes into soil and groundwater.

Despite this, most studies agree that the externality costs of leachate are small, provided that landfills are appropriately designed and managed. If a landfill is lined (with clay or plastic) this prevents or significantly reduces the escape of leachate into the environment.

⁷ The hedonic pricing method is used to estimate economic values for environmental services that directly affect market prices. It is most commonly applied to variations in housing prices that reflect the value of local environmental attributes, either positive or (in the case of landfills) negative.

Most Australian and international studies value the external costs of leachate at less than \$1 per tonne of waste landfilled (BDA 2009, Schollum 2010). They distinguished between landfills with liners and those with no liners, which is the primary management practice that influences whether leachate causes environmental damage; landfills with liners are very effective at preventing environmental damage from leachate. Schollum notes that many European studies no longer estimate the value of leachate because they assume appropriate management practices prevent externality costs from leachate occurring. BDA estimated the external costs of leachate at between \$0 for landfills with liners to \$0.01 for landfills with no liner. These are the values for leachate used in this study.

Summary of residual landfill costs

In summary, the values used in this study to estimate the residual costs of waste disposed to landfill are presented in Table 22.

Table 22: Externality values for residual costs (\$/ tonne waste)

	N120 (contaminated soils)	Other waste types (organic)	Other waste types (inorganic)
Greenhouse gas emissions	3.48	12.76	0.00
Other air emissions	0.96	0.96	0.00
Leachate	0.00	0.01	0.00
Disamenity	2.67	2.67	2.67

4.4 Projections

Ideally projections of waste generation data will be made considering historical hazardous waste datasets. The 2010-11 KMH data and 2012 data were available for all jurisdictions but anomalies between the two datasets and the fact that they represent only two data points meant that it was not feasible to establish reliable trends from this data. Hazardous waste datasets, maintained by New South Wales EPA and EPA Victoria date back to 2009 and 2007 respectively. Unfortunately, close perusal of these datasets also revealed substantial anomalies to the extent that they are not likely to be a reliable basis for establishing projections of hazardous waste volumes in NSW, Victoria or in other jurisdictions.

Instead, projections were derived by examining recent trends in the growth of the major hazardous waste producing industries and applying growth rates for these industries to the major hazardous wastes in each of the jurisdictions on a weighted basis (see Table 23). The projected growth rate for direct market costs of 0.52% per annum reflects a quite complex picture. While some hazardous waste producing industries are experiencing significant growth, others have been experiencing a decline in output. Overall, structural change to the Australian economy over the next few years seems likely to slow the growth of hazardous wastes and associated direct market costs especially from industries such as basic chemicals manufacturing, tanneries, polymers manufacturing and petroleum refining.

Indirect and non-market costs are projected to grow at varying rates:

- Residual landfill costs are projected to grow at similar rates to the direct market cost growth rates for each of the jurisdictions, as they are volume related.
- Workplace injury and illness costs are projected to grow at approximately 1.8% annually, reflecting substantial growth in real health costs on the one hand but a decline in workplace

injury and illness rates on the other (drawing on historical trends in workers compensation claims - Safe Work Australia 2013).

- Government regulatory costs are assumed to remain static in real terms.

Given the absence of reliable time series data for hazardous wastes, projected growth rates for hazardous waste costs are highly uncertain. In particular, the projected growth rate for direct market costs could well be conservative. This is because it does not take into account the potential for:

- tighter hazardous waste regulatory frameworks in jurisdictions leading, for example, to additional waste categories being classified as hazardous;
- higher real unit costs for existing treatments, also linked to tighter regulations; and
- changes to the destinations of hazardous wastes to more costly treatments.

Table 23: Estimated average real growth rate in hazardous waste costs by jurisdiction, considering future growth rates of waste producing industries

Waste producing industry	ANZSIC Code	Estimated annual change in output (%)	Estimated proportional contribution of industry to hazardous waste costs								
			Australia	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Food Product Manufacturing	C11	1.1%	7.1%	5.2%	7.7%	6.0%	4.0%	7.7%	6.3%	12.3%	3.8%
Textile, Leather, Clothing and Footwear	C13	-1.4%	0.9%	0.0%	0.2%	2.9%	0.0%	0.0%	0.0%	0.0%	0.0%
Wood Product Manufacturing	C14	-4.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pulp & Paper	C15	-2.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Petroleum Production & Refining	C17	-1.4%	8.5%	10.0%	6.5%	10.5%	0.3%	15.9%	0.2%	2.9%	3.2%
Basic Chemicals and Chemical Products	C18	-1.3%	3.0%	3.7%	4.7%	3.3%	0.4%	2.7%	0.0%	3.1%	0.5%
Polymer Products and Rubber Products	C19	-3.5%	2.0%	1.6%	3.7%	1.7%	0.1%	4.3%	0.2%	0.0%	0.0%
Non-Metallic Mineral Products	C20	2.1%	3.0%	2.3%	1.0%	5.7%	1.4%	2.0%	3.8%	0.0%	0.0%
Primary Metal and Metal Products	C21	0.7%	15.2%	3.8%	7.0%	18.5%	22.3%	28.8%	50.3%	2.8%	0.4%
Waste Collection, Treatment and Disposal	D29	0.5%	29.5%	27.0%	33.1%	32.6%	26.8%	21.4%	29.3%	27.3%	86.9%
Building & construction	E	0.2%	20.9%	37.5%	26.1%	9.1%	34.2%	4.1%	2.0%	12.7%	0.2%
Motor Vehicle Parts Retailing (tyres)	G39	2.7%	7.9%	6.9%	8.9%	6.4%	8.6%	12.5%	7.9%	28.8%	4.6%
Public Order, Safety Services	O	5.1%	0.1%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Tertiary Education	P	3.3%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.9%	0.0%
Health	Q	4.9%	1.7%	1.6%	0.9%	2.9%	1.8%	0.5%	0.0%	1.2%	0.3%
Total			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Weighted average annual real growth rate in hazardous waste costs			0.52%	0.40%	0.40%	0.55%	0.77%	0.43%	0.89%	1.21%	0.59%

Data sources: ABS 2014a-f; IBISWorld 2014a-c; SRU direct costs database

Glossary

Word / abbreviation	Description
ANZSIC	Australian and New Zealand Standard Industry Classification. The system of industry classification used for the purpose of industry data collation and reporting.
Basel Convention	<i>The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal</i> is an international treaty to control and minimise the export of hazardous waste.
Best practice engineered landfill	A landfill designed, operated and regulated to minimise harm to the environment of the disposal of conventional waste.
Bioremediation	Treatment of soils and sludges through the use of natural biological processes. Bioremediation is commonly used to treat hydrocarbon contaminated soils and sludges.
Blending	Mixing of materials to obtain desirable chemical and physical properties for recycling or energy recovery
C&D waste	Waste generated by the Construction and Demolition sectors of the economy.
C&I waste	Waste generated by the Commercial and Industrial sectors of the economy. This classification includes all industry except Construction and Demolition
Consolidation	Consolidation of small containers of hazardous material into larger containers for transport and treatment.
Controlled Waste	A waste that is included in the NEPM (Movement of Controlled Waste).
Distributional impact	The distribution of costs and benefits across different sectors, groups or regions. These may or may not constitute broader economic costs.
Economic costs (benefits)	Community wide costs (benefits). These include market and non-market costs (benefits).
Energy recovery	The process of recovering energy from waste materials. This usually involves thermal destruction of material and harnessing the heat generated for either industrial processes or electricity generation.
Externalities	Where an activity has positive (benefits) or negative (cost) on others who are not direct parties to a transaction (e.g. pollution).
Financial costs	Costs to individuals, businesses, sectors or groups. These may or not represent economic costs.
Gate fee	The amount charged by a facility to accept material for treatment or disposal

Word / abbreviation	Description
Hazardous Waste	(a) waste prescribed by the regulations, where the waste has any of the characteristics mentioned in Annex III to the Basel Convention; or (b) wastes covered by paragraph 1(a) of Article 1 of the Basel Convention; or (c) household waste; or (d) residues arising from the incineration of household waste; but does not include wastes covered by paragraph 4 of Article 1 of the Basel Convention.
High Containment Landfill	A specialised landfill designed and regulated to accept waste material that is at a higher hazard category than best practice engineered landfills
Immobilisation	Chemical or physical treatment of waste that renders contaminants unreactive.
Levy	Many jurisdictions operate a landfill levy scheme, where the levy is charged on top of landfill gate fees for disposal. The landfill is applied at a \$ per tonne rate.
Liquid waste	Any waste that: (a) has an angle of repose of less than five degrees above horizontal, or (b) becomes free-flowing at or below 60 degrees Celsius or when it is transported, or (c) is generally not capable of being picked up by a spade or shovel.
MSW	Municipal Solid Waste. Waste generated by households and in municipal public spaces
NEPM	The National Environmental Protection Measures are a set of national environmental objectives to assist in protecting and managing particular aspects of the environment.
NEPM (Movement of Controlled Waste)	The National Environmental Protection (Movement of Controlled Waste) Measure provides a basis for ensuring that controlled wastes moved between jurisdictions are properly identified, handled and tracked. It is administered by jurisdictions.
NEPM15	The 15 high level categories of the National Environmental Protection (Movement of Controlled Waste) Measure. The describe
NOS	Not otherwise specified
Non-tracked materials	Hazardous waste collected outside of the formal tracking systems of each jurisdiction. In some cases, materials may have no arrangements for tracking and others may include shadow transportation outside of official systems
Neutralisation	Mixing of waste materials to render them inactive, particularly acids and alkalis
Present value	Costs (or benefits) that occur in the future discounted to reflect their current value.

Word / abbreviation	Description
Recycling	The collection, sorting and processing of materials to form new raw materials to be used in the production of new products.
Resource recovery	The processes of capturing resources from waste materials, whether by reuse, recycling or energy recovery.
Reuse	The use of materials for a beneficial purpose without reprocessing. This may be for its original use or some other future use.
Solid waste	Any waste that: <ul style="list-style-type: none"> (a) has an angle of repose of greater than five degrees above horizontal, or (b) does not become free-flowing at or below 60 degrees Celsius or when it is transported, or (c) is generally capable of being picked up by a spade or shovel.
Specialist treatment	Any treatment for highly hazardous material that treats low quantities and has high handling and management requirements. This can include plasma arc destruction of materials like PCBs.
Storage	Secure, long term storage of waste materials for which there isn't a disposal or treatment option at present.
Thermal destruction	Use of high energy to chemically destroy contaminants. This can include incineration and energy recovery, particularly in cement kilns where high temperatures and long burning periods allow destruction of persistent contaminants without formation of more harmful by-products. Plasma arc gasification, using superheated ionised gas, is another method of thermal destruction.
Tracked materials	Materials whose transport is tracked and monitored according to the formal tracking systems of jurisdictions
Tracking system	Transport of controlled waste is tracked in many jurisdictions in Australia. These tracking systems may be online, paper based or a combination of both. Tracking systems exist in NSW, Queensland, SA, WA and Victoria.
Transfer	A redistribution of income from one group to another group in the market (e.g. through government taxes).

Word / abbreviation	Description
Treatment	<p>The processing of waste prior to reuse, recycling, disposal or energy recovery. Treatment may include:</p> <ul style="list-style-type: none"> ▪ bioremediation ▪ blending ▪ consolidation ▪ energy recovery (in this study) ▪ immobilisation ▪ neutralisation ▪ thermal destruction ▪ waste water treatment
Waste code	Tracking code used by jurisdictions to identify waste materials
Waste water treatment	Treatment of liquid waste to remove contaminants or reduce concentrations prior to further treatment, disposal or destruction

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