FINAL REPORT

Headline economic value for waste and materials efficiency in Australia

Prepared for
The Department of the Environment and Energy

27 October 2017

THE CENTRE FOR INTERNATIONAL ECONOMICS
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CANBERRA

Centre for International Economics
Ground Floor, 11 Lancaster Place
Majura Park

Canberra ACT 2609
GPO Box 2203
Canberra ACT Australia 2601

Telephone +61 2 6245 7800
Facsimile +61 2 6245 7888
Email cie@TheCIE.com.au

Website www.TheCIE.com.au

SYDNEY

Centre for International Economics
Suite 1, Level 16, 1 York Street
Sydney NSW 2000

Telephone +61 2 9250 0800
Email ciesyd@TheCIE.com.au

Website www.TheCIE.com.au

BRISBANE

Centre for International Economics
Suite 1, 888 Brunswick Street
New Farm QLD 4005

Phone +61 419 040 735
Email cie@TheCIE.com.au

Website www.TheCIE.com.au

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1 Introduction

The Department of the Environment and Energy has commissioned the Centre for International Economics (CIE) and its partners (Blue Environment and Envisage Works) to develop and test a method to produce headline economic values related to waste, recycling and the efficient use of materials in the Australian economy at national and state/territory scales.

This report presents findings and results for:

- the volume of wastes generated, treated and disposed in Australia;
- the size of the waste management services activity in Australia from the economic profiling of the industries; and
- the potential benefits of increasing the recovery rate and improving materials efficiency estimated using the CIE-REGIONS model, a computable general equilibrium (CGE) model of the Australian economy.

Main findings

Australia generated 64 million tonnes of waste in 2014-15, of which 26.8 per cent was masonry materials, 20 per cent was organics, and 17 per cent was fly ash. New South Wales, Queensland and Victoria were the largest generators, accounting for 78 per cent of total waste generation.

About 58 per cent of waste generated was recycled or recovered, leaving only 26.8 million tonnes of waste for disposal in landfills. Masonry waste had the highest rate of recycling at about 70 per cent.

Australia’s waste related activities had a total value of $15.5 billion in 2014-15, comprising $12.6 billion from providing waste management services, and $2.9 billion from sales of recovered materials. The waste management services value presents a steady growth over time, while the value from sales of recovered materials has been falling due to fall in material prices especially for metals.

Over 56 per cent of the waste related activities are conducted by private and public trading waste management enterprises, 19.9 per cent by local governments, and the remaining 23.8 per cent by firms in other industries.

The value added by waste-related activities is $6.9 billion, accounting for 0.43 per cent of Australian GDP. It employs 49 160 workers (full time equivalent terms) directly, accounting for about half of one per cent of total employment. NSW, Victoria and Queensland account for over three quarters of the waste activity.

On top of the above direct contribution, under the long run, with full employment and closure, each $100 million expansion in the value of waste-related activities due to productivity improvements is associated with another $350 million and 1 670 jobs indirectly to the nation's GDP and employment. It should be noted that the indirect contribution critically depends on the cause for the expansion. For example, if the expansion is caused by external demand, the indirect contribution would be negative under the long run closure because the waste activity simply draws resources away from other industries. It should also be pointed out that the indirect contribution is only meaningful at the margin, that is, a small expansion of the activity.

Construction industry is the largest user of the waste management services and products, accounting for $4.5 billion in activity (29.4 per cent of total activity). It is followed by the manufacturing industry ($3.6 billion or 23.2 per cent), households ($2.5 billion or 16.4 per cent) and other services ($2.1 billion or 13.5 per cent).

Improving the efficiency of waste-related activities and, more broadly the material efficiency in the economy, may have significant impact on the whole economy. Simulations using CIE-REGIONS, a general equilibrium model of the Australian economy, show that hypothetical 5 per cent increase in the recovery rate of the waste activity may:

- add $1 billion to GDP;
- increase household welfare by $650 million (measured as increase in real consumption level); and
- increase real wage rate by 0.1 per cent (under the long run, full employment, closure).

A hypothetical 5 per cent improvement in material efficiency may have much bigger impact on the economy – GDP up by about $24 billion, welfare up by $14.8 billion and real wage rate up by 2.7 per cent.

Primary industry wastes are considered separately in Section 3 of this report because they have typically been excluded from previous waste data collations and are generally less certain in scope and data sources. We address primary industry wastes in four sections: mining, agriculture, forestry and fisheries.

This review focuses on primary production wastes such as those produced by the mining, forestry, agriculture and fishing industries. General wastes from the primary industry sectors are not examined, although, in the case of mining, they may be disposed of on-site.

The focus of this part of the data and literature review was to identify 'factors' comprising waste quantities per unit activity that could be used in combination with economic data to generate waste quantity estimates.

Structure of the report

The rest of the report is structured as follows:

- Section 1 presents estimates of the headline values for waste:
  - Chapter 2 reports the volume of waste generated and disposed;

  - Chapter 3 reports the costs of waste fates and transport;
  - Chapter 4 reports the size of the waste activity in Australia and its composition;
  - Chapter 5 discusses the uses of the waste management services and products;
- Section 2 presents analysis of the contribution of the waste activity and impact of improvements in materials efficiency:
  - Chapter 6 discusses the indirect contribution of the waste activity, and the indirect contribution should be interpreted at the marginal level;
  - Chapter 7 summarises the simulation results of hypothetical 5 per cent increase in recovery rate of the waste activity and 5 per cent improvement in material efficiency economy wide;
- Section 3 presents data about primary industry wastes:
  - Chapter 8 reports quantities of mining waste generated;
  - Chapter 9 reports quantities of agricultural waste generated;
  - Chapter 10 reports quantities of forestry waste generated;
  - Chapter 11 reports quantities of fisheries waste generated.

Acknowledgement

The authors of the note would like to thank Sarah Coleman and Ben Loughton from the Australian Bureau of Statistics (ABS), Joe Pickin from Blue Environment and Kyle O'Farrell from Envisage Works for their help in understanding and providing access to various datasets.

PART I

Headline economic values of waste

2 Waste generated and disposed

KEY POINTS

- **The total amount of waste generated in Australia in 2014/15 was 63 871 kilotonnes, of which 17 745 kilotonnes was hazardous waste.**
- **Of this waste, 58 per cent is recycled or sent to energy recovery, with the remainder being disposed at landfill.**
- **There is a greater diversity of fates and types of hazardous waste compared to non-hazardous waste.**

This chapter summarises the data available indicating the quantities of waste generated, disposed, recycled or used for energy recovery. Where available, this chapter also summarises data on transport, disposal and external costs of waste in Australia.

Waste categorisation

Table 2.1 shows our classification of non-hazardous and hazardous wastes respectively. This is the categorisation used in the *National Waste Report 2016*. [1]

2.1 Waste classification

Category	Sub-category
Masonry materials	Asphalt
	Bricks
	Concrete
	Rubble (incl. non-haz. foundry sands)
	Plasterboard & cement sheeting
Metals	Steel
	Aluminium
	Non-ferrous metals (ex. aluminium)
Organics	Food organics
	Garden organics
	Timber
	Other organics
	Biosolids (non-contaminated)

1 Blue Environment and Randell Economic Consulting, 2017, *Australian National Waste Report 2016*, prepared for the Department of the Environment and Energy, May 2017.

Category	Sub-category
Paper & cardboard	Cardboard
	Liquid paperboard (LPB)
	Newsprint and magazines
	Office paper
Plastics	Polyethylene terephthalate (PET)
	High density polyethylene (HDPE)
	Polyvinyl chloride (PVC)
	Low density polyethylene (LDPE)
	Polypropylene (PP)
	Polystyrene (PS)
	Other plastics
Glass	Glass
Other	Leather & textiles
	Rubber, excluding tyres
	Tyres
Hazardous	Plating and heat treatment
	Acids
	Alkalis
	Inorganic chemicals
	Reactive chemicals
	Paints, resins, inks, organic sludges
	Organic solvents
	Pesticides
	Oils
	Putrescible/ organic waste
	Organic chemicals
	Contaminated soils
	Asbestos
	Other soil/sludges
	Clinical and pharmaceutical
	Tyres
	Other miscellaneous
	Fly ash

Source: CIE.

We have also sought to separately identify packaging (including plastics as a sub-category), mattresses and e-waste, however these categories are more difficult to identify. These wastes are already partly or fully (depending on the waste type) accounted for in the categories listed in table 2.1.

- Packaging would include proportions of each of the glass, paper, plastics and metals wastes, but wouldn't cover the entirety of any of them:

  - the Australian Packaging Covenant Organisation monitors consumption and recycling of packaging, and has identified that the total consumption of all packaging materials was 4.74 megatonnes in 2014-15, out of which 2.91 megatonnes was recovered or recycled.[2]
- E-waste and mattresses are included to some extent in the data on materials (i.e. metals, plastics and textiles). In theory, they should be wholly included; in practice, it's likely they are partially included. These categories form minor portions of the material streams so the consequences of incorrect estimates are not high.

Waste generation

The quantity of waste generated by category and state is reported in the *National Waste Report 2016*.[3] This report supplements data obtained from state and territory governments with national industry data or other national estimates. Table 2.2 presents the total volume of waste generated by waste category and state. The total amount of waste generated in Australia is 63 871 kilotonnes, of which 78 per cent is generated in New South Wales, Queensland and Victoria.

2.2 Waste generation quantities

Waste category	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	National
	kt	kt	kt	kt	kt	kt	kt	kt	kt
Masonry materials	198	5 493	142	2 798	1 303	66	4 258	2 892	17 151
Metals	29	1 490	53	981	340	29	1 495	750	5 168
Organics	323	3 797	156	2 755	1 379	232	2 803	1 361	12 807
Paper & cardboard	76	1 163	39	1 007	300	127	2 000	558	5 270
Plastics	35	588	53	647	85	74	649	389	2 520
Glass	23	298	13	202	73	35	298	125	1 068
Other	10	1 590	14	159	58	21	201	89	2 142
Hazardous (including fly ash)	80	4 542	41	7 162	882	362	3 545	1 130	17 745
Total	**774**	**18 961**	**494**	**15 713**	**4 422**	**947**	**15 408**	**7 295**	**63 871**

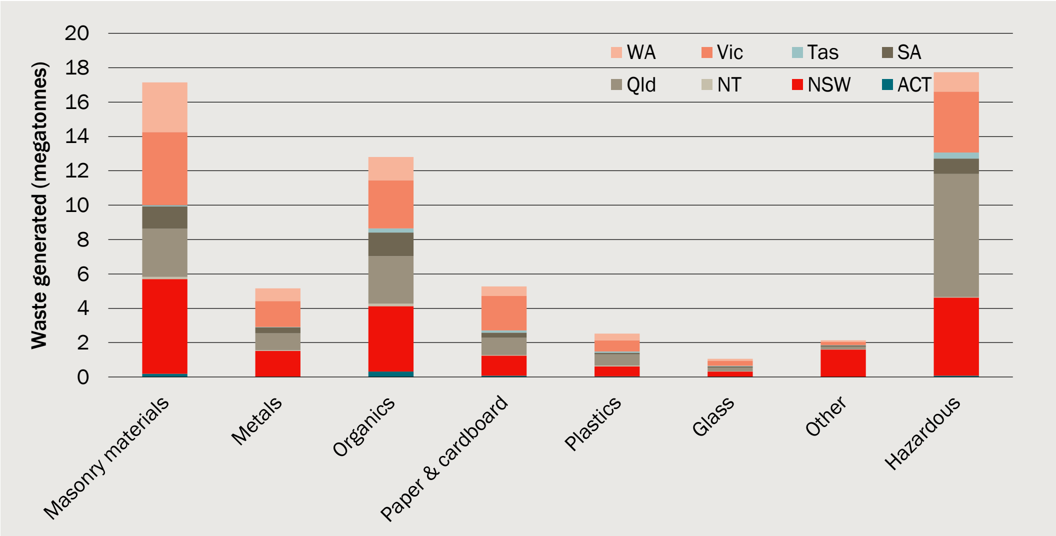
Source: *National Waste Report 2016*, CIE.

The majority of waste generated is masonry materials, organics, fly ash, and hazardous waste. Chart 2.3 presents the volume of waste generated by type and state.

2 See http://www.packagingcovenant.org.au/data/APC_Media_-_Recycling_rate_2015.pdf

3 Blue Environment and Randell Economic Consulting, 2017, *Australian National Waste Report 2016*, prepared for the Department of the Environment and Energy, May 2017.

2.3 Waste generation by type



Note: The quantity of hazardous waste generated shown on this chart includes fly ash.

Source: National Waste Report 2016, CIE.

Waste treatment and disposal

The fates of waste are categorised into three streams:

- disposal – depositing solid waste in a landfill or incinerator[4];
- recycling – activities where solid wastes are converted into raw materials to be used in the production of new products;
- energy recovery – recovery of embodied energy from waste (not including waste sent to landfill for energy recovery)[5].

Table 2.4 summarises the quantities of waste by fate, category and state. The overall resource recovery rate (which includes both recycling and energy recovery) is 58 per cent.

4 Disposal includes waste sent to landfill from which landfill gas was captured and used for generating electricity. This waste is categorised as going to energy recovery by the *National Waste Report 2016*, however because the waste goes to landfill we have categorised it as disposal. This difference in categorisation is used because the costs of this waste stream are likely to be more similar to disposal at landfill than other energy recovery. The decision to depart from the categorisation of fate in the *National Waste Report 2016* has been made following discussion with the authors of the *National Waste Report 2016*.

5 These definitions are sourced from the *National Waste Report 2016*, pp. iv-v.

2.4 Waste fate by state

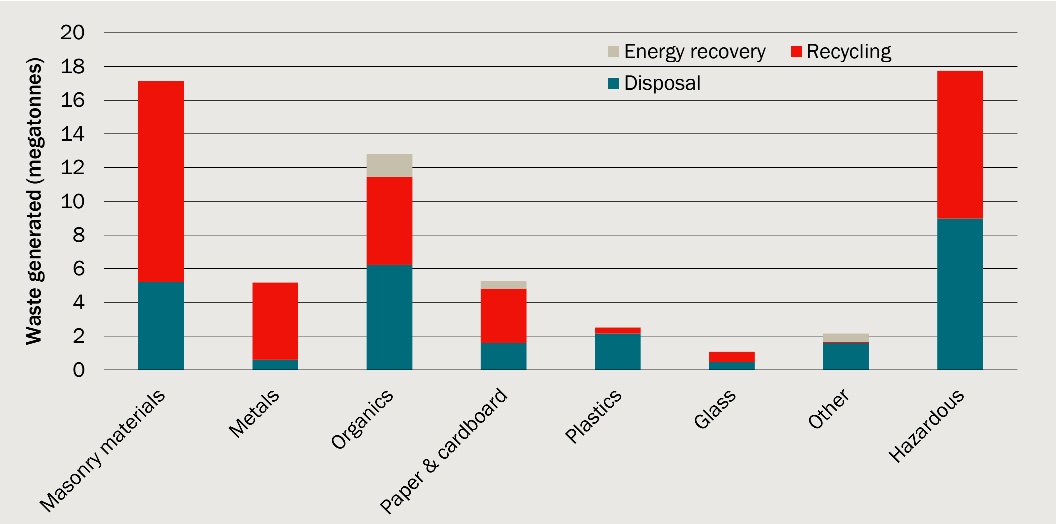
Waste category	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	National
	kt	kt	kt	kt	kt	kt	kt	kt	kt
Disposal									
Masonry materials	14	773	139	1 480	217	63	932	1 578	5 194
Metals	5	145	14	175	22	14	82	142	599
Organics	102	2 112	121	1 697	328	188	1 790	1 046	7 383
Paper & cardboard	46	456	33	512	68	58	556	313	2 042
Plastics	32	496	40	611	47	69	488	373	2 157
Glass	10	106	10	133	12	15	101	78	466
Other	9	1 561	8	159	30	21	174	85	2 047
Hazardous	9	1 822	17	5 270	338	96	1 154	271	8 977
Total	**228**	**7 472**	**382**	**10 037**	**1 062**	**523**	**5 277**	**3 884**	**28 865**
Recycling									
Masonry materials	185	4 719	3	1 318	1 087	3	3 327	1 314	11 957
Metals	24	1 345	38	806	318	15	1 413	609	4 569
Organics	221	1 655	36	908	1 018	44	1 013	316	5 210
Paper & cardboard	30	706	5	495	233	69	1 443	245	3 228
Plastics	3	92	12	36	21	5	161	16	346
Glass	13	192	3	69	61	20	197	47	602
Other	1	30	6	0	23	1	27	4	90
Hazardous	70	2 720	25	1 892	544	267	2 391	859	8 768
Total	**547**	**11 459**	**129**	**5 525**	**3 304**	**423**	**9 972**	**3 411**	**34 770**
Energy recovery									
Masonry materials	0	0	0	0	0	0	0	0	0
Metals	0	0	0	0	0	0	0	0	0
Organics	0	30	0	151	33	0	0	0	214
Paper & cardboard	0	0	0	0	0	0	0	0	0
Plastics	0	0	0	0	17	0	0	0	17
Glass	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	6	0	0	0	6
Hazardous	0	0	0	0	0	0	0	0	0
Total	**0**	**30**	**0**	**151**	**55**	**0**	**0**	**0**	**236**

Note: The quantities of waste going to disposal and energy recovery may not align to reported quantities in the *National Waste Report 2016* because we have defined disposal to include solid waste going to a landfill from which landfill gas was captured and used for generating electricity. The *National Waste Report 2016* categorises this waste stream as energy recovery. The quantities of hazardous waste by fate shown in this table include fly ash.

Source: National Waste Report 2016, CIE.

Chart 2.5 shows the quantities of waste that go to each fate (disposal, recycling and energy recovery). It shows that recycling and energy recovery rates vary significantly between categories. For example, while plastics are almost all disposed (86 per cent), around 70 per cent of masonry materials are recycled. Among the three largest categories (masonry materials, organics and hazardous waste) the recycling rate is 56 per cent. Only 3.6 per cent of waste goes to energy recovery.

2.5 Waste fate by category



Note: The quantities of hazardous waste by fate shown on this chart include fly ash.

Source: National Waste Report 2016, CIE.

Hazardous waste exhibits significant variation between sub-categories in terms of the proportion that is recycled or disposed. Chart 2.5 shows the quantities of hazardous waste that were disposed and recycled according to the *National Waste Report 2016*. Data is also available for a more specific categorisation of fates for hazardous waste. This categorisation does not directly align to the disposal/recycling/energy recovery categorisation. This categorisation identifies seven main subcategories of hazardous waste fates:

- recycling;
- chemical/physical treatment;
- landfill;
- biodegradation;
- thermal destruction;
- storage or transfer; and
- other.

Table 2.6 presents the quantities of each hazardous waste subtype going to each subcategory of fate. There are a wider range of fates available for hazardous waste compared to non-hazardous waste. This reflects the broad range of materials that compose hazardous waste and the different treatment, disposal and recycling options available or necessary to deal with the waste.

2.6 Fate of hazardous waste

Hazardous waste type	Recycling	Chemical/ physical treatment	Landfill	Biodegradation	Thermal destruction	Storage or transfer	Other	Total
	kt	kt	kt	kt	kt	kt	kt	kt
Plating & heat treatment	0	2	2	0	0	4	0	9
Acids	7	32	2	0	0	3	13	57
Alkalis	108	11	33	0	1	106	0	259
Inorganic fluorine (spent potliner)	48	2	10	0	0	24	9	92
Mercury & compounds	1	4	0	0	0	2	0	7
Lead and compounds	89	6	11	0	0	17	28	150
Zinc compounds	1	1	1	0	0	0	0	4
Non-toxic salts (coal seam gas wastes)	125	9	78	7	0	84	18	321
Other inorganic chemicals	2	5	4	0	0	3	0	15
Reactive chemicals	0	0	0	0	0	0	0	0
Paints, resins, inks, organic sludges	13	14	2	0	2	22	1	54
Organic solvents	3	3	0	0	0	6	0	13
Pesticides	1	2	0	0	0	1	0	4
Oils	63	28	2	0	0	42	1	135
Waste oil/water mixtures	63	112	7	5	0	161	3	352
Grease trap wastes	167	191	4	67	0	64	20	513
Other putrescible / organic wastes	193	82	10	71	0	15	5	376
PCB wastes	0	5	8	0	0	10	1	24
Other organic halogen compounds	0	0	0	0	0	0	0	0
Other organic chemicals	3	5	1	0	0	4	0	13
Contaminated soils	19	30	1 296	11	0	10	25	1 391
Biosolids	0	0	0	0	0	0	0	0
Other industrial treatment residues	174	386	218	69	0	189	101	1 137
Asbestos containing material	0	0	775	0	0	10	2	787
Other soil/sludges	93	57	332	2	0	155	6	645
Clinical and pharmaceutical	6	25	13	0	16	22	1	83
Tyres	172	111	95	0	1	57	6	442
Other miscellaneous	1	1	0	0	0	2	0	5
(Not classified)	0	0	0	0	0	0	0	0
All categories	**1 353**	**1 124**	**2 904**	**234**	**20**	**1 015**	**242**	**6 891**

Note: Data was available indicating the management of hazardous waste arisings for 2014-15 in NSW, Queensland, Victoria and WA. The share of arisings being handled by each management path (e.g. recycling, landfill, etc.) in this data has been applied to total generation quantities by state from the *National Waste Report 2016*. For states where management path data was not available (i.e. ACT, NT, SA, and Tasmania), we have applied the shares going to each management path for the total arisings among NSW, Queensland, Victoria and WA. That is, we are assuming that the management of hazardous waste by waste type is the same in ACT, NT, SA and Tasmania as it is for the other states. Fly ash has been excluded from hazardous waste quantities shown in this table because data was not available indicating the fate of fly ash according to this subcategorisation of fates.

Source: Blue Environment, CIE.

3 Estimated costs of waste fates and transport

KEY POINTS

- **The total cost of transporting, disposing and recycling hazardous and non-hazardous waste was $6.5 billion in 2014/15.**
- **Per tonne costs of hazardous waste fates are higher for hazardous waste than non-hazardous waste. A greater proportion of hazardous waste is disposed or recycled interstate compared to non-hazardous waste, which contributes to a higher cost of transport per tonne.**
- **While there are significant external costs of waste, these have generally not been quantified. A case study of asbestos-related disease suggests that productivity losses of over $40 million and quality-of-life of over 5400 Disability-adjusted Life Years were associated with asbestos waste in 2015.**

In this chapter we calculate a bottom-up estimate of the cost of disposal, recycling and other 'fates' of hazardous and non-hazardous waste. The costs of fates and transport are a subset of economic value of the waste activity. Thus, these results should not be directly compared to the estimated headline values presented elsewhere in this report.

The total costs of waste fates and transport we estimate are shown in table 3.1.

3.1 Summary of estimated cost of waste fates and transport

Cost category	Costs of waste fates and transport
	$million
Non-hazardous waste disposal	2 858
Non-hazardous waste recycling	1 330
Non-hazardous waste energy recovery	29
Hazardous waste fates (including treatment)	1 468
Intrastate transport	729
Interstate transport	87 [a]
Total	**6 499**

Source: CIE.

Transport costs

The assumptions for distance travelled will differ between interstate and intrastate transport. Additionally, a higher proportion of interstate transport than intrastate transport would be via rail.

Intrastate transport

Transport costs in general are estimated according to the following equation

$$Transport\ cost = quantity \times \overline{time} \times \frac{price}{t.hour}$$

where

- $Quantity$ is the volume (in tonnes) of waste that is transported;
- $\overline{time}$ is the average travel time of waste from generation to fate; and
- $\frac{Price}{t.hour}$ is the price per tonne hour to transport waste.

Cost of waste transport

Marsden Jacobs Associates (2014)[6] estimate a cost of $10 per tonne hour for solid hazardous waste and $12.50 for liquids.[7] These amounts are $10.40 and $12.98 in $2017 respectively.[8] We assume that solid non-hazardous waste has the same transport cost as solid hazardous waste.[9]

Since liquid and non-liquid hazardous waste have different costs per tonne hour, we must estimate the proportion of each hazardous waste type which is liquid to determine the average transport cost by waste type. The cost of transport per tonne hour is calculated according to the following equation:

$$Cost\ of\ transport = Liquid\ proportion \times \$12.98 + Non - liquid\ proportion \times \$10.38$$

where $Liquid\ proportion$ and $Non - liquid\ proportion$ are the proportion of quantity generated of each hazardous waste type which is liquid or non-liquid respectively.

6 Marsden Jacob Associates (2014), *Estimate of the cost of hazardous waste in Australia*, July 2014, p.30, available at: https://www.environment.gov.au/system/files/resources/d1889716-2b06-44e1-a62c-3e67ff3d595f/files/cost-hazardous-waste.pdf

7 This price does not include the costs of collecting Municipal Solid Waste, which may be higher than the transport costs of C&I and C&D waste. MSW is collected from kerbside bins. In this chapter we also separately estimate the costs of collecting, transporting, disposing and recycling MSW.

8 We have adjusted for inflation using ABS Cat. 6401.0 – CPI, Australia, Jun 2016', available at: http://www.abs.gov.au/ausstats/abs@.nsf/mf/6401.0

9 One source of difference between hazardous waste and non-hazardous waste transport costs is insurance, which may be somewhat more expensive for hazardous waste transport due to greater risk of harm from spills, material falling out of trucks, and other sources. We have not been able to quantify the insurance costs of hazardous and non-hazardous waste transport, but note that this factor suggests that we are somewhat overestimating waste transport costs for non-hazardous waste relative to hazardous waste.

3.2 Cost of transport by hazardous waste type

Hazardous waste type	Proportion of waste type which is liquid	Cost of transport
	Per cent	$/tonne.hour
Plating and heat treatment	11	10.66
Acids	90	12.73
Alkalis	93	12.80
Inorganic chemicals	1	10.42
Reactive chemicals	78	12.41
Paints, resins, inks, organic sludges	76	12.36
Organic solvents	92	12.77
Pesticides	75	12.33
Oils	77	12.40
Putrescible/ organic waste	62	12.00
Organic chemicals	39	11.40
Contaminated soils	0	10.38
Asbestos	0	10.38
Other soil/sludges	0	10.40
Clinical and pharmaceutical	0	10.38
Tyres	0	10.38
Other miscellaneous	8	10.60
Fly ash	0	10.38

Source: MJA (2014), CIE.

Travel time of waste from generation to fate

Estimating the transport time of waste is difficult. State-based regulators (such as Victoria EPA) only track certain wastes, such as hazardous waste. Without tracking of waste movements, it is not possible to determine the travel time in each state for untracked waste.

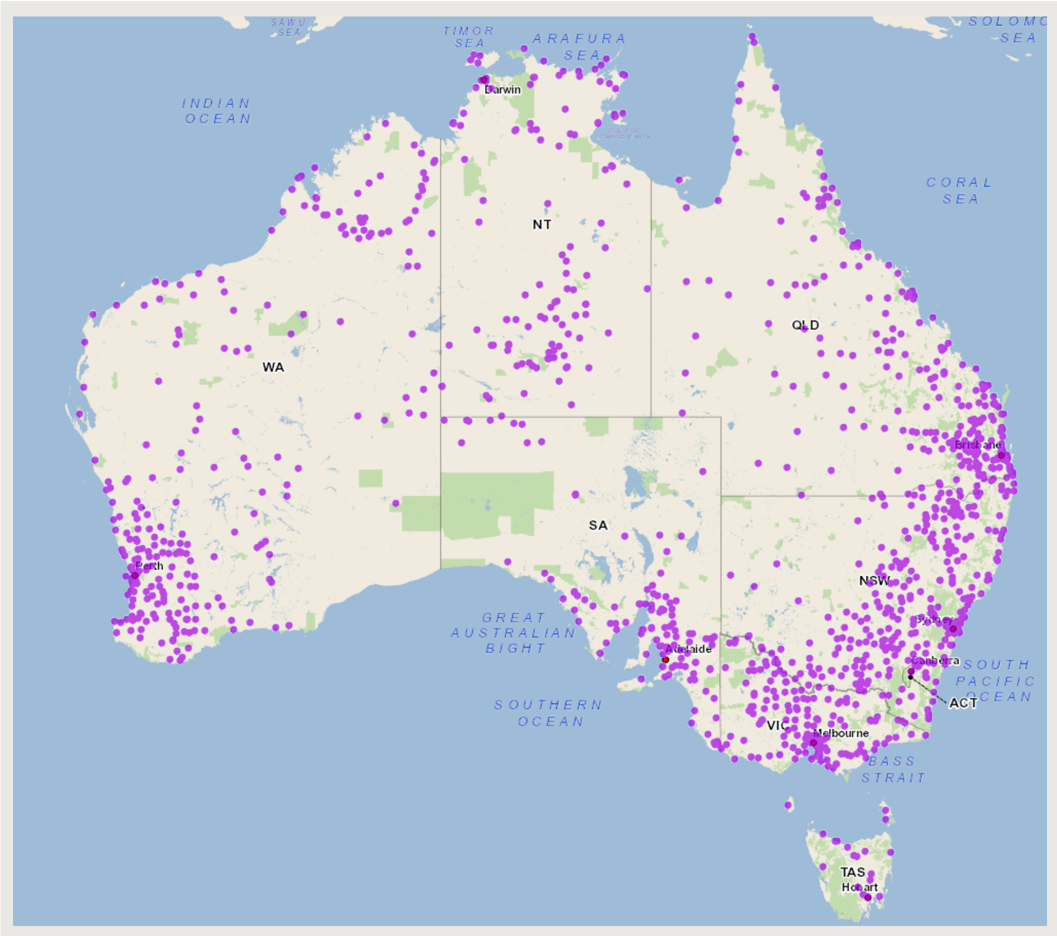
Therefore, our best source of data for travel distances of waste is the tracking data from hazardous waste. Using hazardous waste tracking data, we have estimated that the average travel time of hazardous waste in Victoria is 1.1 hours.[10] This may overstate the travel time for non-hazardous waste, which may be less commonly generated in regional areas compared to hazardous waste from locations such as mines. On the other hand, this travel time does not include travel legs to transfer facilities, since it is not known how

10 Using a dataset of hazardous waste generation and fate flows by postcode pairs in Victoria, we have estimated the weighted average driving for hazardous waste according to the following process. Firstly, the straight-line distance between each postcode pair is determined using the GIS mapping software package 'MapInfo'. Secondly, for a sample of postcode pairs driving time is determined using Google Maps, and the relationship between straight-line distance and driving time is estimated using an OLS (Ordinary Least Squares) regression model. This model allows us to estimate the driving time for all hazardous waste flows in Victoria, and yields a weighted average (by tonnes of each waste flow) of 1.1 hours.

much non-hazardous waste goes to transfer facilities and their location relative to generation and fate locations.

Distances between landfills can be larger in some states such as WA, which is more dispersed than Victoria. However, chart 3.3 shows that all states and territories have numerous landfills (shown by purple dots). It is difficult to infer relative travel times to landfills in each state, given that the relationship between landfill location and the generation locations of waste is not known.

3.3 Location of landfills in Australia



Note: The purple dots show the location of all landfills in Australia.

Data source: © Commonwealth of Australia (Geoscience Australia) 2015, © PSMA Australia Limited 2014, available at: http://www.environment.gov.au/webgis-framework/apps/nwr-wide/nwr-wide.jsf

Total cost of intrastate transport

Tables 3.4 presents our estimates of the total cost of waste transport within each state/territory. The total costs of intrastate waste transport are $729 million.

3.4 Intrastate transport cost

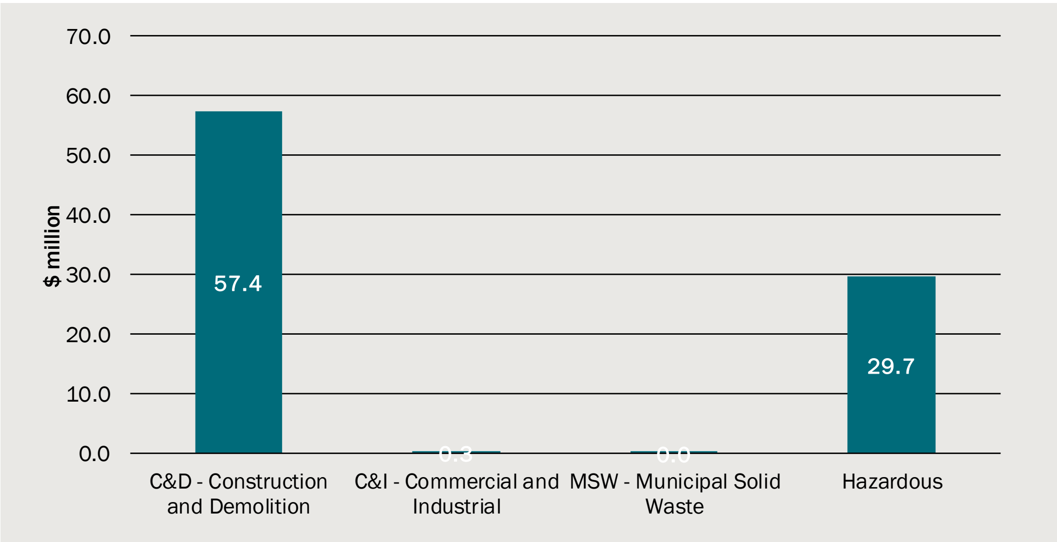
Waste category	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	National
	$million	$million	$million	$million	$million	$million	$million	$million	$million
Masonry materials	2	62	2	32	15	1	48	33	195
Metals	0	17	1	11	4	0	17	9	59
Organics	4	43	2	31	16	3	32	15	145
Paper & cardboard	1	13	0	11	3	1	23	6	60
Plastics	0	7	1	7	1	1	7	4	29
Glass	0	3	0	2	1	0	3	1	12
Other	0	18	0	2	1	0	2	1	24
Hazardous	1	52	0	83	10	4	41	13	205
Total	**9**	**216**	**6**	**180**	**50**	**11**	**174**	**83**	**729**

Source: CIE.

Interstate transport

The CIE (2017)[11] estimate that the total economic resource cost associated with the interstate transport of hazardous and non-hazardous waste in Australia is $87.4 million per year. The majority of the inter-state waste transportation costs are attributed to construction and demolition waste (about two thirds) and hazardous waste (one third) (chart 3.5). The CIE found little evidence in the available data of interstate transportation of commercial and industrial and municipal solid waste.

3.5 Economic costs of interstate waste transport



Data source: CIE.

[11] The CIE, 2017, *Estimate of the total cost of interstate waste transport* for NSW EPA, pp. 32-34

Costs of waste fates

The economic costs of waste fates are considered separately for non-hazardous and hazardous wastes because there is a significantly wider range of fates and costs for different types of hazardous waste.

The price charged for disposal can provide an accurate estimate of economic costs. The economic costs of disposal exclude landfill levies, which are merely transfers between disposers of waste and government.

Non-hazardous waste

We follow a straightforward approach to estimating the total cost of non-hazardous waste fates, reflecting the lack of detailed data about the cost or pricing structure for these wastes and fates. In general, the cost of a fate of non-hazardous waste is defined by the following equation

$$Cost\ of\ fate_{type} = Quantity_{type,fate} \times \frac{Price_{type,fate}}{t}$$

where

- $Quantity_{type,fate}$ is the volume of non-hazardous waste by type and fate
- $\frac{Price_{type,fate}}{t}$ is the price of the fate by waste type.

Disposal costs

There are two main methods of disposal:

- landfill disposal, with waste going to either inert landfills (masonry materials and metals) or putrescible landfills (other non-hazardous waste); and
- incineration.

The quantities of non-hazardous waste that are incinerated are small. Therefore, we assume that the price of disposal is equal to the price of landfill disposal for simplicity.

The assumed average price of disposal at landfill across all non-hazardous waste types by state is shown in table 3.6. This accounts for the lower price of disposal of masonry materials and metals in NT, Queensland, Tasmania, Victoria and WA that is disposed at inert landfills, while other states dispose of these wastes at putrescible landfills. Prices have generally been obtained through landfill/council websites or advice from Blue Environment or Envisage Works (based on industry consultations or other project experience). These prices exclude landfill levies, which are a financial but not an economic cost.

Estimates for the price of disposal by waste type are not presented because differences between the price of disposal by waste type are not expected to be large and robust data indicating these differences has not been obtained. In general, price differences will be more significant based on the quantity of waste to be disposed with landfills sometimes giving discounts to large customers and not to small customers. The price estimates shown in table 3.6 are averages across waste types and believed to be representatives across large and small customers.

3.6 Price assumptions for disposal of non-hazardous waste

Waste category	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne
All non-hazardous waste	92	219	130	130	109	85	112	98

Source: Envisage Works, Blue Environment, CIE.

Table 3.7 shows our estimates of disposal costs. The total cost of disposing all non-hazardous waste is $4.0 billion, of which more than 40 per cent is associated with disposal of organics.

3.7 Disposal costs excluding landfill levies

	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	National
	$million	$million	$million	$million	$million	$million	$million	$million	$million
Masonry materials	1	170	18	192	24	5	84	142	636
Metals	0	32	2	23	2	1	10	15	85
Organics	9	463	16	221	36	16	211	110	1 081
Paper & cardboard	4	100	4	67	7	5	66	33	286
Plastics	3	109	5	79	5	6	58	39	304
Glass	1	23	1	17	1	1	12	8	66
Other	1	342	1	21	3	2	21	9	399
Total	**20**	**1 239**	**47**	**620**	**79**	**36**	**460**	**356**	**2 858**

Source: Envisage Works, Blue Environment, CIE.

Recycling costs

There are six main data points used to inform our assumptions of prices for recycling of non-hazardous waste. Points 1-3 are estimates for specific states, while estimates 4-6 are estimates for all of Australia (which are used if a state-specific estimate is not available):

1 masonry materials in SA: $30/tonne[12];

2 metals, paper and cardboard, plastics, glass and other non-hazardous waste in NSW: $40/tonne[13];

12 See https://www.portaugusta.sa.gov.au/contentFile.aspx?filename=Gate%20Fees.pdf, https://www.fleurieuregionalwasteauthority.com.au/wp-content/uploads/2017/07/Goolwa-Site-Price-from-1-July-2017-updated-docx.pdf

13 See http://www.lgnsw.org.au/files/imce-uploads/90/LGSA%20CDS%20Impact%20Study%20100812a.pdf

3 metals, paper and cardboard, plastics, glass and other non-hazardous waste in Queensland: $80/tonne[14];

4 organics in all states: $70/tonne;

5 masonry materials in all states: $49/tonne;

6 metals, paper and cardboard, plastics, glass and other non-hazardous waste in all states: $38/tonne[15].

These assumptions are shown in table 3.8. These price assumptions are intended to be averages of the prices charged across groups of waste types (e.g. metals, paper, plastics, etc.) rather than estimates of the price charged for each particular waste type.

3.8 Price assumptions for recycling of non-hazardous waste

Waste category	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne
Masonry materials	49	49	49	49	30	49	49	49
Metals	38	40	38	80	38	38	38	38
Organics	70	70	70	70	70	70	70	70
Paper & cardboard	38	40	38	80	38	38	38	38
Plastics	38	40	38	80	38	38	38	38
Glass	38	40	38	80	38	38	38	38
Other	38	40	38	80	38	38	38	38

Source: Envisage Works, Blue Environment, CIE.

These price estimates do not account for differences in commodity values, which vary substantially over time and have a large impact on prices charged by Materials Recovery Facilities (MRFs) and other recyclers. To illustrate, the 2016/17 contract prices for outputs of a MRF are as follows:

- aluminium cans — $1200;
- paper/cardboard — $55–60;
- high-density polyethylene (HDPE) — $750–800;
- mixed plastics — $50–80;
- polyethylene terephthalate (PET) — $100–190.

These differences in the value of outputs from recycling will affect the prices charged by recyclers for the input (e.g. aluminium can waste) to recycling. The prices presented in table 3.8 do not account for the differences in price due to commodity values of recycling outputs, and therefore are individually not likely to be precise estimates of prices/costs

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14 See http://www.cassowarycoast.qld.gov.au/documents/1422210/8483497/Solid%20Waste%20Management%20Strategy%202013-2023

15 See https://www.environment.gov.au/system/files/resources/dc87fd71-6bcb-4135-b916-71dd349fc0b8/files/australian-recycling-sector.pdf

for each particular waste type. However, they do yield accurate estimates of the total costs of recycling across waste types.

Table 3.9 presents our estimates of recycling costs for non-hazardous waste. The total cost of recycling all non-hazardous waste is $1.3 billion.

3.9 Recycling costs

	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	National
	$million	$million	$million	$million	$million	$million	$million	$million	$million
Masonry materials	9	231	0	65	33	0	163	64	565
Metals	1	54	1	64	12	1	54	23	210
Organics	15	116	2	64	71	3	71	22	365
Paper & cardboard	1	28	0	40	9	3	55	9	145
Plastics	0	4	0	3	1	0	6	1	15
Glass	0	8	0	6	2	1	7	2	26
Other	0	1	0	0	1	0	1	0	3
Total	**27**	**442**	**5**	**241**	**129**	**7**	**357**	**122**	**1 330**

Source: Blue Environment, CIE.

Energy recovery costs

Only a small proportion of non-hazardous waste is sent to energy recovery. We have assumed that the cost of energy recovery is $135/tonne for paper & cardboard and plastics, and the cost of energy recovery is $120/tonne for organics. Table 3.10 show that the total cost of energy recovery for non-hazardous waste is $29 million.

3.10 Energy recovery costs

	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	National
	$million	$million	$million	$million	$million	$million	$million	$million	$million
Masonry materials	0	0	0	0	0	0	0	0	0
Metals	0	0	0	0	0	0	0	0	0
Organics	0	4	0	18	4	0	0	0	26
Paper & cardboard	0	0	0	0	0	0	0	0	0
Plastics	0	0	0	0	2	0	0	0	2
Glass	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	1	0	0	0	1
Total	**0**	**4**	**0**	**18**	**7**	**0**	**0**	**0**	**29**

Source: Blue Environment, CIE.

Hazardous waste

The economic cost of treating hazardous waste[16] is estimated according to the following equation

$$Cost\ of\ treatment_{type} = Quantity_{type,treatment} \times \frac{Price_{type,treatment}}{t}$$

- $Quantity_{type,fate}$ is the volume of hazardous waste that is treated by waste type and treatment type;

- $\frac{Price_{type,fate}}{t}$ is the price of treatment by waste type and treatment type.

One notable, recent study which provides estimates of market prices for the fates of hazardous waste is Marsden Jacobs Associates ('MJA', 2014)[17]. The fate cost assumptions we have used are shown in table 3.11 below. These estimates reflect the correspondence of hazardous waste categories and fate types to specific treatment pathways identified by MJA (2014). The cost assumed for some waste type and fate combinations is undefined if there is no quantity of this type generated.

3.11 Cost of hazardous waste fates by type

Hazardous waste type	Recycling	Chemical/ physical treatment	Landfill	Biodegradation	Thermal destruction	Storage or transfer	Other
	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne
Plating & heat treatment	200	324	175	329	399	200	
Acids	200	797	175	831	831	200	349
Alkalis	200	818	108	829	828	200	443
Inorganic fluorine (spent potliner)	200	724	175			200	344
Mercury & compounds	200	735	175		747	200	344
Lead and compounds	200	283	105			200	292
Zinc compounds	200	283	101			200	282
Non-toxic salts (coal seam gas wastes)	200	751	144	749	750	200	515
Other inorganic chemicals	200	300	152	295		200	434
Reactive chemicals	200	203	175		30	200	217

16 Fly ash is categorised as a hazardous waste, but we have excluded it from this analysis because it is often processed on-site and the costs of its fate are uncertain. This is consistent with MJA (2014) which excluded fly ash from coal-fired power stations.

17 Marsden Jacob Associates ('MJA'), 2014, *Estimate of the cost of hazardous waste in Australia*, July 2014, p.30, available at: https://www.environment.gov.au/system/files/resources/d1889716-2b06-44e1-a62c-3e67ff3d595f/files/cost-hazardous-waste.pdf

Hazardous waste type	Recycling	Chemical/ physical treatment	Landfill	Biodegradation	Thermal destruction	Storage or transfer	Other
	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne
Paints, resins, inks, organic sludges	200	61	107	53	50	200	53
Organic solvents	200	58	175	51	50	200	52
Pesticides	200	581	98	449	617	200	194
Oils	200	31	101	32	38	200	349
Waste oil/water mixtures	200	231	102	227	226	200	336
Grease trap wastes	200	20	96	17	15	200	99
Other putrescible / organic wastes	200	43	105	201	423	200	410
PCB wastes	200	4261	175	559	4029	200	344
Other organic halogen compounds	200	32	175		32	200	344
Other organic chemicals	200	211	142	245	283	200	337
Contaminated soils	200	247	178	246		200	259
Biosolids							
Other industrial treatment residues	200	277	175	196	673	200	344
Asbestos containing material	200	277	230	196	673	200	344
Other soil/sludges	200	740	140	736	740	200	676
Clinical and pharmaceutical	200	739	175	776	758	200	533
Tyres	200	408	175	426	426	200	425
Other miscellaneous	200	680	175	648	645	200	680

Source: CIE.

For landfills, this correspondence of waste types and fates to treatment pathways will reflect landfill prices that vary with the level of hazard of the waste. There are a variety of subcategories of hazardous waste, and only certain landfills are able to accept more highly contaminated hazardous waste. These landfills (referred to as 'high containment' by MJA (2014)) are generally more expensive. For example, Victorian 'best-practice' landfills cost between $50-100 per tonne yet are only suitable for disposal of low-level contaminated soils and solids. The high contamination landfill in Victoria (Suez Landfill at Lyndhurst) is the only landfill licenced to accept more highly contaminated wastes or immobilised waste. This landfill has gate fees of around $600-800. Table 3.12 shows the estimates of landfill gate fees obtained from MJA (2014).

3.12 MJA (2014) estimates of landfill gate fees for hazardous waste

State/territory	Landfill type	Landfill cost
		$/tonne
ACT	No landfills for hazardous waste, MJA(2014) assumes all waste is exported to NSW	
NSW	Restricted solid waste	250-500
	Immobilised solid waste	180-300
NT	No landfills for hazardous waste, MJA (2014) assumes all waste is exported to SA	
Qld	High containment	80-120
	Conventional waste	25-55
SA	High containment	200-300
	Best practice[a]	110-170
Tas	No landfills for hazardous waste, MJA (2014) states that almost all waste is exported to the mainland at a cost of $200/tonne plus the gate fee	
Vic	High containment waste	250-500
	Best practice[a]	50-100
WA	High containment waste	200-450
	Best practice[a]	50-90

[a] Best practice landfills are landfills designed to best practice engineering standards, and are able to accept low level waste (see Marsden Jacobs Associates, 2014: p.34).

Source: Marsden Jacobs Associates (2014), CIE.

Using these cost estimates (table 3.11) we have estimated the cost of fates of hazardous waste. Table 3.13 summarises the total costs of hazardous waste fates. Contaminated soils, treatment residues, asbestos and other soils and sludges comprise a majority of costs of hazardous waste fates. Approximately one-third of costs are attributable to landfills.

3.13 Hazardous waste fate costs by type

	Recycling	Chemical/ physical treatment	Landfill	Biodegradation	Thermal destruction	Storage or transfer	Other	Total
	$m	$m	$m	$m	$m	$m	$m	$m
Plating & heat treatment	0.1	0.8	0.4	0.0	0.0	0.8	0.0	2.0
Acids	1.5	25.4	0.3	0.0	0.0	0.7	4.4	32.3
Alkalis	21.5	8.8	3.6	0.3	0.6	21.3	0.1	56.2
Inorganic fluorine (spent potliner)	9.5	1.4	1.7	0.0	0.0	4.8	3.0	20.5
Mercury & compounds	0.2	2.7	0.1	0.0	0.0	0.5	0.1	3.5

	Recycling	Chemical/ physical treatment	Landfill	Biodegradation	Thermal destruction	Storage or transfer	Other	Total
	$m	$m	$m	$m	$m	$m	$m	$m
Lead and compounds	17.7	1.6	1.1	0.0	0.0	3.5	8.2	32.1
Zinc compounds	0.3	0.3	0.1	0.0	0.0	0.1	0.1	0.9
Non-toxic salts (coal seam gas wastes)	25.0	6.5	11.2	5.4	0.0	16.9	9.5	74.5
Other inorganic chemicals	0.4	1.6	0.7	0.1	0.0	0.6	0.1	3.5
Reactive chemicals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Paints, resins, inks, organic sludges	2.7	0.9	0.2	0.0	0.1	4.4	0.1	8.3
Organic solvents	0.6	0.2	0.0	0.0	0.0	1.3	0.0	2.1
Pesticides	0.3	1.0	0.0	0.1	0.0	0.1	0.0	1.6
Oils	12.5	0.9	0.2	0.0	0.0	8.3	0.5	22.3
Waste oil/water mixtures	12.7	25.8	0.7	1.2	0.0	32.3	1.2	73.8
Grease trap wastes	33.4	3.9	0.4	1.2	0.0	12.7	1.9	53.5
Other putrescible / organic wastes	38.6	3.5	1.1	14.2	0.0	3.0	2.1	62.5
PCB wastes	0.1	21.5	1.5	0.0	0.1	1.9	0.2	25.2
Other organic halogen compounds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other organic chemicals	0.6	1.1	0.1	0.0	0.0	0.7	0.1	2.6
Contaminated soils	3.8	7.4	230.7	2.6	0.0	2.0	6.6	253.1
Biosolids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other industrial treatment residues	34.9	106.9	38.3	13.5	0.1	37.7	34.6	266.0
Asbestos containing material	0.0	0.1	164.5	0.0	0.2	2.1	0.6	167.5
Other soil/sludges	18.5	42.4	46.5	1.7	0.1	31.1	4.2	144.4
Clinical and pharmaceutical	1.2	18.7	2.2	0.0	12.2	4.3	0.7	39.3
Tyres	22.7	45.3	10.9	0.0	0.2	11.4	2.4	93.0
Other miscellaneous	0.1	0.9	0.0	0.1	0.0	0.5	0.0	1.7
Total	**258.7**	**329.3**	**516.4**	**40.4**	**13.8**	**203.1**	**80.8**	**1442.4**

Source: CIE.

Table 3.14 presents hazardous waste total costs, generation and cost per tonne across all waste types. The cost per tonne is highest in NSW and lowest in Queensland, which are also the two states with the highest amount of hazardous waste generation.

3.14 Costs of hazardous waste fates by state

Variable	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Total cost ($million)	17	464	8	349	149	75	256	125
Generation (kt)	80	1 802	41	1 946	736	362	1 340	584
Cost per tonne ($/tonne)	216	257	183	179	202	207	191	214

Source: CIE.

Another approach to estimating costs of household Municipal Solid Waste

As an alternative approach to that described above, we have estimated the costs of Municipal Solid Waste (MSW) collection, transport and disposal/recycling based on an estimated cost per household. The results presented below provide additional information about the costs of waste in Australia.

Sustainability Victoria (2016)[18] estimated the total costs of household MSW including the collection, transportation, and disposal/recycling of waste. This report estimated the cost per household in Victoria for metropolitan and regional areas, as well as breaking down costs by waste type (garbage, recyclables, and green organics). The total cost of MSW in Victoria was estimated to be $379 million in 2014-15.

Applying the estimated cost per household for Victoria in metropolitan areas and non-metropolitan areas by waste type, we estimate the cost across all Australian states and territories. Tables 3.15 and 3.16 below summarise the estimated costs of household MSW collection, transportation and disposal/recycling for metropolitan and non-metropolitan areas respectively. The total cost of MSW disposal is $946 million in metropolitan areas and $562 million in non-metropolitan areas.

3.15 Costs of metropolitan household MSW

	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Garbage								
Occupied private dwellings (000s)	151	1 720	50	833	515	90	1 665	732
Cost per household ($/household)	99.8	99.8	99.8	99.8	99.8	99.8	99.8	99.8
Households (000s, based on Sustainability Victoria)	162	1 854	54	898	555	97	1 794	789
Total cost of garbage ($million)	**16.2**	**185.0**	**5.4**	**89.7**	**55.4**	**9.7**	**179.1**	**78.8**
Recyclables								
Occupied private dwellings (000s)	151	1 720	50	833	515	90	1 665	732
Cost per household ($/household)	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1
Households (000s, based on Sustainability Victoria)	159	1 816	53	880	543	95	1 757	773
Total cost of recyclables ($million)	**3.8**	**43.8**	**1.3**	**21.2**	**13.1**	**2.3**	**42.4**	**18.7**

18 Sustainability Victoria, 2016, *Victorian Local Government Annual Waste Services Report 2014-15*, available at: http://www.sustainability.vic.gov.au/publications-and-research/research/victorian-waste-and-recycling-data-results-201415/victorian-local-government-annual-waste-services-report-201415/total--household-kerbside-collection

	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Green organics								
Occupied private dwellings (000s)	151	1 720	50	833	515	90	1 665	732
Cost per household ($/household)	52.4	52.4	52.4	52.4	52.4	52.4	52.4	52.4
Households (000s, based on Sustainability Victoria)	90	1 026	30	497	307	54	993	437
Total cost of green organics ($million)	**4.7**	**53.8**	**1.6**	**26.1**	**16.1**	**2.8**	**52.0**	**22.9**
Total								
Total cost of MSW ($million)	**24.8**	**282.6**	**8.2**	**136.9**	**84.6**	**14.8**	**273.5**	**120.3**

Note: The number of occupied private dwellings has been obtained from the ABS Census 2016. 'Households according to Sustainability Victoria' indicates the number of households that Sustainability Victoria reports there are in Victoria. In order to ensure that the total cost for Victoria aligns to the Sustainability Victoria report, we adjust the number of occupied private dwellings to match the number of households according to sustainability Victoria.

Source: Sustainability Victoria, CIE.

3.16 Costs of non-metropolitan household MSW

	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Garbage								
Occupied private dwellings (000s)	0	1 055	29	958	159	119	578	206
Cost per household ($/household)	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0
Households (000s, based on Sustainability Victoria)	0	1 216	34	1 104	183	138	666	237
Total cost of garbage ($million)	**0.0**	**127.7**	**3.6**	**115.9**	**19.2**	**14.4**	**69.9**	**24.9**
Recyclables								
Occupied private dwellings (000s)	0	1 055	29	958	159	119	578	206
Cost per household ($/household)	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Households (000s, based on Sustainability Victoria)	0	1 209	34	1 098	182	137	662	236
Total cost of recyclables ($million)	**0.0**	**42.3**	**1.2**	**38.4**	**6.4**	**4.8**	**23.2**	**8.3**
Green organics								
Occupied private dwellings (000s)	0	1 055	29	958	159	119	578	206
Cost per household ($/household)	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5
Households (000s, based on Sustainability Victoria)	0	469	13	426	71	53	257	91
Total cost of green organics ($million)	**0.0**	**20.9**	**0.6**	**19.0**	**3.1**	**2.4**	**11.4**	**4.1**
Total								
Total cost of MSW ($million)	**0.0**	**190.8**	**5.3**	**173.3**	**28.7**	**21.6**	**104.5**	**37.2**

Note: The number of occupied private dwellings has been obtained from the ABS Census 2016. The number of occupied private dwellings has been obtained from the ABS Census 2016. 'Households according to Sustainability Victoria' indicates the number of households that Sustainability Victoria reports there are in Victoria. In order to ensure that the total cost for Victoria aligns to the Sustainability Victoria report, we adjust the number of occupied private dwellings to match the number of households according to sustainability Victoria.

Source: Sustainability Victoria, CIE.

External costs of waste

Economic costs include external costs imposed by waste on others. These costs may be referred to as indirect or non-market costs[19] to differentiate them from direct market costs paid by handlers of waste. These costs are generally higher for hazardous waste. Some of the external costs of waste are summarised below:

- costs of environmental damage caused by waste, including:
  - emissions of greenhouse gases and other air pollutants at landfill;
  - leachate emissions;
  - emissions from the collection and transfer of wastes;
- amenity impacts, such as those associated with noise or odour;
- infrastructure costs, use of natural resources and costs of damage to equipment, where these are not borne by the generators or handlers of waste;
- government costs associated with regulating and administering wastes;
- costs associated with illnesses and injuries to workers or others who handle or are exposed to waste.

We have not quantified the magnitude of these costs.

Costs of asbestos-related disease

A notable illness associated with waste is mesothelioma, which is one of a number of diseases that are caused by exposure to asbestos. Mesothelioma generally leads to death, and has significant health and productivity costs. While asbestos has been banned from production or use in Australia, many workers who were exposed to asbestos before it was banned are now contracting the disease.

Exposure to asbestos may lead to diseases including:

- mesothelioma;
- asbestosis;
- lung cancer;
- larynx cancer; and
- ovarian cancer.

These diseases lead to economic costs including the following:

- health system expenditure: sufferers of asbestos-related disease require healthcare, including hospital, general practitioner, specialist and other health services. Additionally, sufferers of asbestos-related disease incur costs associated with pharmaceuticals, which are used for pain relief, as part of treatment programs, or in other ways;

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19 Marsden Jacob Associates ('MJA'), 2014, *Estimate of the cost of hazardous waste in Australia*, July 2014, p.34, available at: https://www.environment.gov.au/system/files/resources/d1889716-2b06-44e1-a62c-3e67ff3d595f/files/cost-hazardous-waste.pdf

- productivity losses: Living with an asbestos-related disease compromises an individual's ability to participate in the paid and unpaid workforce. 'Productivity losses' also flow through to carers who are no longer able to participate in work and the community as they otherwise would;
- lost quality-of-life: Living with an asbestos-related disease is a burden for patients and their families, who experience a compromised quality of life. Anxiety about discovering or being exposed to asbestos at home, work or elsewhere can reduce quality-of-life for people not suffering from asbestos-related disease. Quality –of-life may also be reduced by pain, discomfort, lack of mobility and social disengagement experienced by patients and their carers. The losses associated with reduced quality of life can be represented in Disability-Adjusted Life Years (DALYs), which measure the sum of years lost to disability and years of life lost due to death.

The CIE has recently completed a report for the Asbestos Safety and Eradication Agency (ASEA) about the economic costs of asbestos-related disease in Australia. Key findings include:

- in 2015 there were an estimated 4 152 deaths in Australia due to asbestos-related diseases, and 10 444 prevalent cases of disease;
- hospital and primary healthcare costs associated with treating asbestos-related disease are an estimated $185 million for 2015-16;
- productivity losses were an estimated $321 million in 2015-16, with 85 per cent of losses due to disease caused by occupational exposure (distributed evenly across paid and unpaid work) to asbestos;
- in 2015 there were an estimated 58 754 DALYs lost due to asbestos-related disease, excluding asbestosis (for which prevalence data was not available).

Costs of asbestos-related disease associated with asbestos waste

In this section we seek to identify the costs of asbestos-related disease for the subset of disease cases that are associated with asbestos waste, rather than asbestos products, mining, manufacturing or other exposure types.

Disease caused by exposure to asbestos may be associated with different stages of the asbestos life-cycle. The life cycle of asbestos and key groups at risk of exposure are as follows:

- mining: asbestos miners;
- asbestos product manufacturing: workers for asbestos product manufacturers such as James Hardie;
- installation or work with Asbestos-Containing Materials (ACMs): tradespeople who used ACMs are at risk of exposure;
- presence of ACMs in homes or workplaces: home renovators, workers in ACM buildings and the general population;
- removal, handling and disposal of waste-phase asbestos products: asbestos removalists, waste transporters and workers at landfills that dispose of asbestos.

Table 3.17 summarises the sources of exposure and cases attributable to each source. The three categories of exposure type used by Finity Consulting (2016)[20] in a report commissioned by the ASEA are:

- occupational;
- environmental; and
- non-occupational.

'Asbestos removalists' is the only occupational category included in table 3.17 that relates to asbestos waste (rather than asbestos products).

3.17 Split of mesothelioma cases (2013) according to exposure type

Exposure source	Male cases	Female cases	Total cases
	Number	Number	Number
Occupational			
Asbestos mining / milling	1	0	1
Asbestos removalist	0	0	0
Cement factory worker	5	0	5
Furnace industry	4	0	4
Insulator	4	0	4
Land transport	25	0	25
Textile worker	1	2	2
Trades	305	3	308
Water transport	39	0	39
Other occupation	45	19	64
Total	**428**	**24**	**452**
Environmental			
Dusty family	11	22	34
Lived near industry	1	2	3
Asbestos towns	3	4	7
Other exposure	15	4	19
Total	**31**	**32**	**63**
Non-occupational			
Serviced brakes and clutch	23	0	24
Lived in asbestos house	9	9	18
Home renovation	44	18	62
Lived in house during renovation	26	29	55
Total	**103**	**56**	**158**

20 Finity Consulting, 2016, *The Third Wave: Australian mesothelioma analysis and proje*ction, pg. 69, commissioned by the ASEA, available at: http://www.finity.com.au/publication/the-third-wave-australian-mesothelioma-analysis-projection

Exposure source	Male cases	Female cases	Total cases
	Number	Number	Number
All exposure sources			
Background cases	18	18	35
Grand total	**579**	**129**	**708**

Source: Finity Consulting, CIE.

We allocate environmental exposures between the occupational and non-occupational exposure categories to align to our estimates of the economic cost of asbestos-related disease. Environmental exposure categories have been allocated as follows:

- 'dusty families' exposures occur where the family of someone whose work exposes them to asbestos (such as manufacturing or mining asbestos) is exposed to asbestos on the worker's clothes or other items. We categorise this exposure type as occupational exposure, because it is connected to the asbestos-related occupations;
- 'lived near industry', 'asbestos town', and 'other exposure' have been categorised as non-occupational exposure because they affect people who are not involved in asbestos-related occupations.

Table 3.18 shows the proportions of asbestos-related disease attributable to occupational and non-occupational exposure to asbestos waste for 2013.

3.18 Proportion of asbestos-related disease attributable to asbestos waste

Exposure category	Male	Female	Total
	Per cent	Per cent	Per cent
Occupational	0.0	0.0	0.0
Non-occupational	92.0	85.7	89.1

Source: CIE.

Assuming that these proportions have remained constant between 2013 and 2015 (the base year for our estimate of economic costs of asbestos-related disease) it suggests that productivity losses of $42.5 million and quality-of-life losses of 5394 DALYs are attributable to asbestos waste.

However, these estimates may understate the proportion of future costs of asbestos-related disease which are attributable to asbestos waste. While the Finity (2016) results suggest there were no cases of mesothelioma attributable to asbestos removal this may change as asbestos continues to be discovered and removed from homes. Additionally, the third wave of asbestos exposures (relating to exposures from sources other than asbestos manufacturing and product use) is projected to be responsible for an increasing proportion of asbestos-related disease. Exposure of landfill employees to asbestos may have occurred, but the long lag period (up to 40 years) between exposure and disease may mean these costs are not borne for many years. These sources of uncertainty suggest that our estimates of the costs of asbestos-related disease attributable to asbestos waste are underestimates of current costs and that costs should be expected to rise in the future.

4 Economic value of waste activities in Australia

KEY POINTS

- **In 2015-15 the total value of waste activity in Australia was $15.5 billion:**
  - **$12.6 billion was from providing waste management services, and $2.9 billion from sales of recyclable and recovered waste materials;**
  - **the value of recyclable and recovered waste material sales has been affected by the fall in material prices, especially metal price. If the prices of recovered materials were kept at the level in early 2000s, the value of sales could have been doubled;**
  - **about 56 per cent of the values were generated by private waste management service businesses, 20 per cent by local governments, and the remaining 24 per cent by businesses in other industries.**
- **Waste activities contributed $6.9 billion, or 0.43 per cent, to the nation's gross domestic product.**
- **There were 49 160 full equivalent employment jobs provided by waste activities, accounting for about half a per cent of total employment.**

In Australian statistics, industry and activity are two different, yet related, concepts. The Australian and New Zealand Standard Industrial Classification (ANZSIC) classifies industries into four levels, ranging from industry division (broadest level) to industry class (finest level). Activities are narrowly defined within the industry class level, which is defined by a four-digit code. Usually, an activity is primarily defined to one class. However, some activities may be primary to more than one class.

In the case of waste related industry and activities, ANZSIC has defined a narrower sub-division of waste industry (see below). By contrast, waste related activities are broader, and are classified into other industries as well. One of the objectives of this project is to measure the economic value of waste related activities across the whole economy. We will therefore look into waste activities beyond the waste industry as defined by the ANZSIC.

The waste industry and waste activities

The Australian and New Zealand Standard Industrial Classification (ANZSIC) defines the Waste Industry as: sub-division D29 - Waste Collection, Treatment and Disposal Services. This sub-division includes four classes:

- 2911: Solid Waste Collection Services;
- 2919: Other Waste Collection Services;

- 2921: Waste Treatment and Disposal Services; and
- 2922: Waste Remediation and Materials Recovery Services.

An individual business entity is assigned to an industry based on its *predominant* activity. In reality, waste activity is broader than this ANZSIC sub-division, and this section is concerned with measuring the value of waste activity across the whole economy.

Waste goods and services may also be classified in other ANZSIC industries. For example, some businesses classified to Manufacturing may undertake recycling activities, and some businesses classified to Mining may operate landfills.

Waste management services provided by local governments (7530) such as kerb side rubbish bin collection etc. should also be included in the waste activity. The ABS' 2009-10 industry survey of Waste Management Services included these activities.

A list of the likely waste products/sectors that could be included in the waste activity is provided in table A.1. The products and/or sectors are classified according to the Input-Output Product Classification (IOPC) system. The IOPC is consistent with the ANZSIC, with the first two digits in IOPC being the same as the two-digit sub-division in ANZSIC. The products/sectors are identified in the table according to the significance of the waste-related activity in the products/sectors' whole economic activities in the following way:

- ww – the ANZSIC Sub-division D29;
- w – all of the products/sectors classified in other industries should be included in the waste activity;
- wp – part of the products/sectors classified in other industries should be included in the waste activity; and
- pp – a very small proportion of the products/sectors classified in other industries should be included in the waste activity.

Existing sources of data

The ABS reports four sets of data on waste industry/activity value and/or employment:

- the Australian Industry (Cat. No. 8155.0) with the latest data for 2015-16;
- the Waste Management Services, Australia (Cat. No. 8698.0) which is ceased, with the latest data for 2009-10;
- the Waste Account (Cat. No. 4602.0.55.006) which is ceased, with latest data for 2010-11; and
- the Input-Output tables (Cat. No. 5209.0.55.001) with the latest data for 2014-15.

The *Australian Industry* presents estimates of the economic and financial performance of Australian industry (ANZSIC). The estimates are produced annually using a combination of directly collected data from the annual Economic Activity Survey (EAS), conducted by the ABS, and Business Activity Statement (BAS) data provided by businesses to the Australian Taxation Office (ATO).

The *Waste Management Services, Australia, 2009-10* presents estimates of the financial performance of waste management services businesses/organisations. It also provides information on waste facilities operated, waste activities undertaken, quantities of waste received and processed and factors hampering resource recovery. Estimates were produced from directly collected data from the Waste Management Services Survey, comprising the EAS and Local Government Survey conducted by the ABS.

The *Waste Account Australia* (WAA) is based on the United Nations System of Environmental-Economic Accounts (SEEA). It is an activity-based account, presenting data on waste activity beyond Sub-Div 29 to describe waste activity for Australia. It presents estimates of physical as well as monetary supply and use of waste goods and services within Australian economy. Monetary supply and use tables illustrate the economic transactions associated with the income generated by the supply of waste management services (WMS) and sales of recovered waste material and expenditure on the use of WMS and purchase of recovered waste material.

Income from supply of WMS and sales of recyclable/recovered material for the WMS industry in the WAA is derived from the *Waste Management Services, Australia*. Income from the supply of WMS and sales of recyclable/recovered material for non-WMS industries was directly collected from the EAS.

Tables 4.1 and 4.2 summarises the gross value and employment, respectively, of the waste industry or activity from these sources.

It can be seen from the tables that the GVP and employment numbers in the input-output tables are much smaller than those in the Australian Industry and the Waste Account. This is because they are showing different things. Figures from Australian Industry show income related to ANZSIC subDiv29 (Waste Management Services Industry). Sales and service income is income related to WMS activities, total income includes other (non-WMS) income. The Waste Account numbers show Total Supply of waste management activities (goods and services) across the economy – that is it is not the Waste Industry. The IO figures are known underreporting probably due to commodity flow balance adjustment, and are due to be revised in the future.[21]

If applying the identification of waste industry/activity reported in table A.1 to the 2013-14 IO Product Details Table (Cat. No. 5215.0.55.001),[22] the total value of 'ww' and 'w' products/sectors is $10.8 billion. Although this figure is close to that in the Australian Industry account, it is largely a coincidence as undertaking this activity would be more akin to producing the Waste Account figures (ie identifying waste activity, not waste industry), and in theory should end up being a much larger figure than the Australian Industry figure which is subDiv 29 only.

21 pers communication with ABS

22 The Product Details Table corresponding to the 2014-15 Input-Output Table was not available when this report was prepared.

4.1 Supply of waste management products - 3 different views

	Australian Industry (8155.0)		Waste Account (4602.0.55.006)			Input-Output Table (5209.0.55.001)
	Sales and service income	Total income[a]	Non- public[b,c]	Public[b,d]	Total	
	$m	$m	$m	$m	$m	$m
2009-10	9 383	9 478	11 536	2 554	14 090	3 731
2010-11		10 559	12 943	2 766	15 709	
2011-12	11 842	12 098				
2012-13	11 581	11 156				5 081
2013-14		12 124				5 143
2014-15	12 108	12 503				5 215
2015-16	11 686	12 063				

[a] Including other income not from providing the waste management services or sales of recycled or recovered waste material, such as interest; [b] Income from waste management services and from sales of recyclable/recovered waste material; [c] Private and public trading enterprises providing waste management services in the WMS industry and other industries; [d] Local government authorities

Note: Total income is less than income from sales and service in Australian Industry data for 2012-13 is probably due to significant losses reported in the "other income" data item. It is also probably due to the unusually large presence of government units in this industry. Division D is the only industry for which General Government units are included, and they will normally operate on a cost recovery basis, so profit margins for this industry will be much tighter than any other due to the sheer prevalence of GG units.

Source: ABS.

4.2 Employment in the waste collection, treatment and disposal industry

	Australian Industry (8155.0)	Input-Output Table (5209.0.55.001)
	'000	'000
2009-10	29.0	26.0
2010-11	27.0	
2011-12	31.0	
2012-13	33.0	23.7
2013-14	31.0	
2014-15	32.0	
2015-16	30.0	

Source: ABS.

Most of the 'wp' products/sectors involve primary and secondary recovery activities. According to the ANZSIC Explanatory Notes:[23]

> 2.4 Activities undertaken which belong to classes other than that to which the unit is classified, are described as its 'secondary activities'. The secondary activities of a unit play no part in assigning the class to which the unit is classified, but are useful for coverage and specialisation ratio analysis. Refer to paragraph 2.20 for the definition of coverage and specialisation ratios.
>
> …
>
> 2.21 It is highly desirable that the specialisation and coverage ratios exceed 70 per cent for the formation of individual classes. This minimises the extent to which the output of each class includes output of activities which belong to other classes. As a consequence, users of industry

23 ABS Cat. No. 1292.0 – Australian and New Zealand Standard Industrial Classification (ANZSIC), 2006 (Revision 2.0), Explanatory Notes

statistics should note that classes do not contain all of the units which undertake the activities belonging to that class. Units engaging in these activities on a secondary basis will be classified to a different class according to their predominant activity.

It can be interpreted that the primary activity makes up at least 70 per cent of the economic activity of the code. In other words the range of economic activity of the secondary activity is somewhere between 0–30 per cent. If we assume 15 per cent of activities of the code can be included in the waste activity (except for the government administration and regulatory services), the total value of waste activity would be $13.6 billion in 2013-14. This is in the same order of the supply value of waste goods and services by private WMS institutions and other industries in the Waste Account.

Approach to estimate the waste activity value

From the discussion above, it is appropriate to estimate the waste activity value for local government authorities (the public part) and for the private and public trading enterprises in the waste management services sector and to measure the extent of waste activity in other industries (the non-public part) separately.

Public WMS sector (local government)

For the public part, we first calculate the share of public WMS value in the total value of Public Administration and Regulatory Services (IOIG 7501) in the 2009-10 Input-Output (IO) table, and then apply the share to 2014-15 IO data to estimate the value of public WMS in later years. We also assume that the public WMS sector has the same cost structure as the IOIG 7501 in the latest Input-Output table.

To estimate the employment, we first calculate the ratio of employment to gross value of the Public administration from the 2011 Census data and the National Accounts, and then apply this ratio to the above-mentioned public WMS value estimates.

Non-public WMS sectors

For the non-public part, we use the following procedure:

- first aggregate the Australian production value in the 2009-10 IO table into broader groups (e.g. private WMS, agriculture, mining, manufacturing, construction, wholesale trade, retail trade, transportation and other);
- then calculate the ratio of the WMS value in the Waste Account to the relevant Australian production value for each group; and
- finally apply these ratios to 2014-15 IO tables to estimate the recent non-public WMS values.

As for the cost structure for the non-public part, we used the weighted average cost structure of relevant industries in the latest IO table. The weights are the share of identified WMS value for the products as reported in table A.1 to the total Australian production value of the relevant IOIG industry. For example, the Australian production value of 'Scrap waste from the manufacture of food and food products' (IOPC 11991970) is $158 million, while the Australian production value of corresponding IOPG 1109 – Other food product manufacturing is $8,455 million, so the weight is 0.0187 for IOPG 1109.

To estimate the employment, we first calculate the ratio of employment per million dollar of income from the Australian Industry Account, and then apply this ratio to the total value of income as estimated above.

Income from sales of recoverable/recovered materials

Income from sales of recoverable/recovered materials is estimated using the waste recycling and energy recovery data in table 2.4 and the assumed unit prices of recovered materials.

Prices of recoverable/recovered materials changed dramatically in recent years, especially for metals and plastics (table 4.3). The imputed unit value from ABS waste account for metals was $561/tonne in 2009-10 and $704/tonne in 2010-11. The assumed value for metal in South Australia's Recycling Activity Survey (RAS) was $400/tonne during 2012-13 and 2013-14, and dropped to only $240/tonne in 2015-16.

4.3 Unit value of recoverable/recovered materials

	ABS waste account		SA RAS Survey		
	2009-10	2010-11	2012-13	2013-14	2015-16
	$/tonne	$/tonne	$/tonne	$/tonne	$/tonne
Paper and cardboard	171	232	225	225	220
Organic material	7	10	35	35	35
Metal	561	704	400	400	240
Other	78	96			23.45
Masonry			15	15	15
Plastics			280	250	400
Glass			90	90	90
Other materials			10	10	10
Separately reported materials & clean fill			15	15	15
Average	**157**	**195**			**82**

Source: ABS Cat. No. 4602.0.55.006; Zero Waste SA (2014, 2015); Green Industries SA (2017)

Similarly the imputed unit value in ABS waste account for broad 'other' materials category (which includes masonry, plastics, glass, other materials and hazardous waste) was between $78-96 per tonne for 2009-10 and 2010-11, and the weighted average unit price assumed in the 2015-16 SA RAS was only $23.45 per tonne.

On the other hand, the price for plastics has increased from $250-280/tonne to $400/tonne in 2015-16. But plastics account for a small proportion of recovered wastes.

4.4 Supply of waste goods and services by industry in Australia, 2014-15, basic price

	Waste management service		Other industries								Total
	Private	Public	Agriculture[a]	Mining	Manuf	Construct	Wholesale	Retail	Transport	Other	
	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m
Income from Waste Management Services											
Non-recyclable	6 034	2 542	n.a	81	53	825	2	0	163	337	10 038
Recyclable	1 163	489	n.a	91	103	188	208	13	199	98	2 552
Total waste services	**7 197**	**3 031**	**n.a**	**172**	**156**	**1014**	**210**	**13**	**362**	**435**	**12 590**
Income from sales of recyclable/recovered waste material											
Paper and cardboard	501	6	3	29	53	12	55	53	0	5	718
Organic material	41	20	2	15	49	6	28	27	0	3	190
Metal	573	9	14	120	233	51	225	216	0	20	1 462
Other	389	6	2	13	24	6	25	24	0	2	489
Total recyclable/ recovered waste material	**1 504**	**40**	**21**	**178**	**359**	**76**	**332**	**319**	**0**	**30**	**2 859**
Total income	**8 701**	**3 072**	**21**	**349**	**515**	**1 089**	**542**	**332**	**362**	**465**	**15 449**

[a] based on the ABS assumption there is zero income generated by this industry

Source: CIE estimates

Because the waste volume data was for 2014-15, we use the average unit value assumed by the SA RAS for 2013-14 and 2015-16 to calculate the value of recovered materials.

Results

Table 4.4 reports the monetary supply of waste goods and services by industry in Australia in 2014-15. The values are at basic price, that is, without including taxes and margins.

In total, the gross value of the waste activity in Australia is about $15.5 billion. Over 80 per cent of the gross value is income from providing waste management services ($12.6 billion, or 81.5 per cent), and the remaining is income from sales of recyclable and recovered waste material ($2.9 billion).

Over 56 per cent (or $8.7 billion) of the gross value is provided by private and public trading enterprises in the waste management services sector (the Private column in the table). Almost 83 per cent of the income of the private waste management services sector is from providing the service ($7.2 billion), which is slightly higher than the overall share.

About 20 per cent of the gross value is supplied by the local government authorities (the Public column in the table). Local government authorities almost entirely involve in the provision of the waste management services - $3,031 million or 98.7 per cent out of $3,072 million of waste GVP by public, and provides almost a quarter of the total waste management services.

The remaining 24 per cent (or $3.7 billion) of the gross value is supplied by enterprises in other industries. These enterprises derive proportionately more income from sales of recyclable and recovered waste material ($1.3 billion or 36 per cent) than private and public waste management service providers do (13 per cent). This is understandable. Other enterprises with their primary activities not in the waste management services business are engaging in the WMS activities because they can get direct economic benefit from recycling and recovery of waste materials.

Comparison with historical and other data sources

Table 4.5 compares the estimated waste activity GVP with ABS Australian Industry account and Waste Account values. Waste Account and CIE estimates are split by provider (non-public versus public) and by income source (waste management services versus sales of recoverable/recovered materials).

It can be seen that the value of waste management services and recovered material sales provided by non-public service providers is close to the value in Australian Industry account ($12.4 billion versus $12.5 billion).

The estimated value of providing waste management services increases from $9.5 billion in 2009-10 to $12.6 billion in 2014-15, presenting a similar growth rate of the waste industry value in the Australian Industry account – about 32 per cent increase from 2009-10. As shown in table 4.6, total waste generated increases by 19 per cent during the same period, and the remaining 13 per cent growth in value is due to rise in input costs (producer price increases by 9.8 per cent during the same period) and compositional change in wastes.

4.5 Comparison with ABS Australian Industry and Waste Account

	Australian	ABS Waste Account/CIE estimate					
	Industry	Non public	public	Total	Services	Sales	Total
	$m	$m	$m	$m	$m	$m	$m
2009-10	9 478	11 536	2 554	14 090	9 548	4 543	14 090
2010-11	10 559	12 943	2 766	15 709	10 345	5 364	15 709
2011-12	12 098						
2012-13	11 156						
2013-14	12 124						
2014-15	12 503	**12 377**	**3 072**	**15 449**	**12 590**	**2 859**	**15 449**

Note: Values of ABS Waste Account and CIE estimates breakdown by providers (public vs non-public) and by sources (services vs sales of recovered materials).

Source: ABS Cat. No. 8155.0; 4602.0.55.006; CIE estimates

4.6 Total waste generated and recovered

	Total wastes generated			Total recovery		
	2009-10	2010-11	2014-15	2009-10	2010-11	2014-15
	kt	kt	kt	kt	kt	kt
Paper & cardboard	6 415	4 977	5 270	3 928	3 253	3 228
Glass	1 420	1 071	1 068	955	628	602
Plastics	1 454	2 200	2 520	205	310	362
Metals	5 142	6 317	5 168	4 559	5 761	4 569
Organics	12 804	13 650	12 807	6 212	7 196	5 424
Masonry materials	19 825	16 258	17 151	10 956	11 386	11 957
Other	3 209	5 438	2 142	619	2 142	96
Hazardous	3 485	3 125	17 745	455	119	8 768
Total	**53 753**	**53 036**	**63 871**	**27 888**	**30 795**	**35 006**

Source: ABS Cat. No. 4602.0.55.006 and NWR 2016

In contrast, the value of sales of recovered materials falls by 37 per cent from 2019-10 to 2014-15 because of the drop in material prices discussed above (table 4.3). If material prices were kept at the 2009-10 levels, the value of sales of recovered materials would have been doubled, being about $5.8 billion.

State breakdown

Table 4.7 reports the state breakdown of incomes from providing waste management services and from sales of recyclable/recovered waste material of the waste activity in 2014-15. The state/territory distribution of the waste activity is largely related to the overall size of the state/territory economy.

Table 4.8 reports the cost structure of the Australian waste activity in 2014-15. In general the waste activity is relatively more intensive in material use than the whole Australian economy – the share of intermediate inputs costs in the waste activity is 46.4 per cent, compared to 43.4 per cent for the whole economy. It is also labour intensive – the labour cost share is 33.5 per cent in the waste activity, compared to 25.7 per cent for the whole economy. On the other hand, the share of gross operating surplus is smaller – only 10.4 per cent for the waste activity, less than a half of the 22.3 per cent for the whole economy.

4.7 Income of waste activity by state, 2014-15

	Income from Waste Management Services	Sales of recyclable/ recovered waste material	Total income	State share of total income
	$m	$m	$m	%
NSW	3 726	807	4 533	29.3
VIC	3 151	967	4 119	26.7
QLD	2 642	472	3 114	20.2
SA	1 098	233	1 332	8.6
WA	1 303	303	1 606	10.4
TAS	295	29	324	2.1
NT	180	20	200	1.3
ACT	194	28	222	1.4
Total	**12 590**	**2 859**	**15 449**	**100.0**

Source: CIE estimates

4.8 Cost structure of the waste activity in Australia, 2014-15

	$m	%
Agriculture	373.5	2.41
Mining	946.3	6.10
Manufacturing	1 860.5	12.00
Utilities	534.2	3.45
Waste collection, treatment and disposal services	13.4	0.09
Construction	229.8	1.48
Wholesale trade	430.8	2.78
Retail trade	120.3	0.78
Transportation	720.9	4.65
Other Services	1 962.9	12.66
Total intermediate inputs	**7 192.6**	**46.40**
Labour	5 189.2	33.48
GOS	1 613.3	10.41
Net taxes on production	124.7	0.80
Total value added	**6 927.3**	**44.69**
Net taxes on products	103.5	0.67
Competing imports	1 278.2	8.25
Total costs	**15 501.6**	**100.00**

Source: CIE estimates

Table 4.9 reports the state/territory breakdown of the industrial value added and employment (full-time equivalent, FTE) of the waste activity in 2014-15. In aggregate, the waste activity account for less than half of one per cent of Australia's GDP and a little over a half of one per cent of total employment. Some states have relatively higher proportion, such as Tasmania, South Australia, Victoria and Queensland, all having higher share in GSP and employment than the national average.

It can also be found from the table that the waste activity in some states/territories is relatively more labour intensive than that in other places. For example, the waste activity in Western Australia contributes to about 0.29 per cent of the state's GSP, but it employs about 0.45 per cent of the state's total labour force. By contrast, the waste activity in Tasmania contributes to about 0.63 per cent of the state's GSP, but it employs only 0.6 per cent of the state's total labour force.

4.9 Value added and employment of waste activity by state, 2014-15

	Value Added		Employment	
	Value	% of GSP/GDP	FTE	% of state/nation
	$m	%	'000	%
NSW	2 045	0.40	14.57	0.48
VIC	1 730	0.48	12.30	0.51
QLD	1 450	0.48	10.29	0.52
SA	599	0.61	4.41	0.68
WA	716	0.29	5.07	0.45
TAS	162	0.63	1.15	0.60
NT	100	0.43	0.65	0.55
ACT	107	0.31	0.73	0.41
Australia	**6 909**	**0.43**	**49.16**	**0.51**

Source: CIE estimates

Discussion

As introduced in the previous section, some of the components of headline value estimates are based on shares and the structure reflected in the Waste Account and Waste Management Services statistics compiled the ABS in early 2010s. These statistics have not been updated since then. If these statistics are updated regularly, the accuracy of the estimation of those components could be enhanced. Alternatively, some small scale, specifically targeted, surveys could be conducted to further improve the accuracy.

5 *Use of waste management services activity*

KEY POINTS

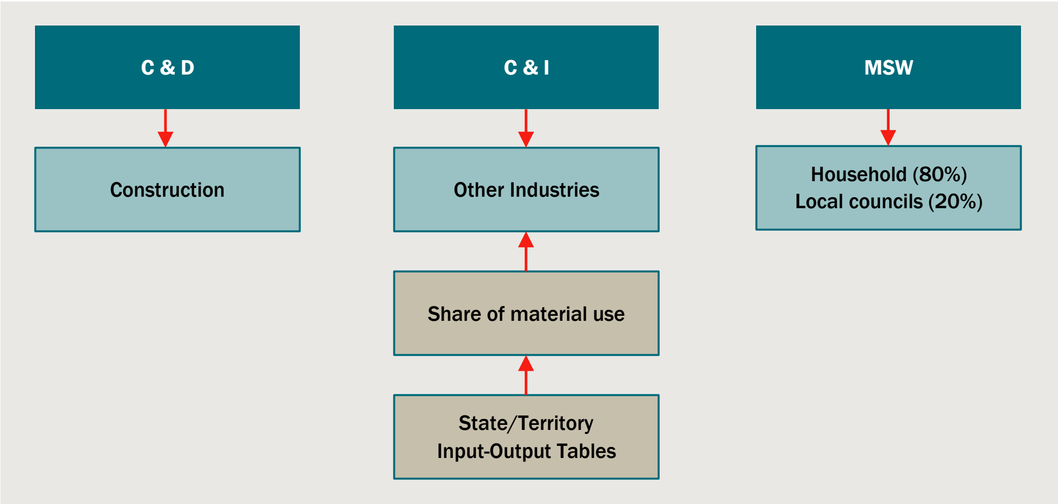
- **Construction is the biggest user of waste management activities, accounting for 29.4 per cent of total waste activity values.**
- **Manufacturing is the second biggest user of waste activities, accounting for 23.2 per cent of total value.**
- **Households are the third largest user of the waste activities, accounting for 16.4 per cent of total value.**

To complete the waste module for the general equilibrium model, CIE-REGIONS, it is necessary to identify the use of waste management (collection, transport, treatment and disposal) services and products by individual industries. It involves allocating the waste generation to industries and households, and then linking the waste generation to the use of waste management services and products.

Allocating waste generated

We adopt a similar approach to the ABS Waste Account (ABS Cat. No. 4602.0.55.005) to allocate total waste generation to various sources. Chart 5.1 illustrates the approach.

5.1 Allocating waste generation to industries, governments and households



Data source: CIE.

The construction and demolition (C&D) wastes can be directly attributed to the construction sector. The municipal solid wastes (MSW) are generated by households and local government activities such as park maintenance. According to the 2014-15 survey conducted by the NSW EPA, about 80.2 per cent of MSW was generated by households.[24] We apply this ratio to split MSW generated in NSW and other states and territories into households and local governments.

The commercial and industrial (C&I) wastes are generated by all other sectors including agriculture, mining, manufacturing and services in the economy. To attribute C&I wastes to individual sectors, we first compile the waste materials list as shown in table 5.2. The table is similar to that used by ABS for compiling the Waste Accounts, except that some sub-categories of waste materials are included in others category (in the parentheses in the waste material column in the table). We then use the state and territory input-output tables to work out these waste material use by each industry, and allocate C&I wastes to each industry according to the waste material use share.

5.2 Correspondence list of waste materials

IOPC	Products	Waste material	Type of breakdown
1501+1502	Pulp, Paper and Paperboard Manufacturing+ stationary	Paper & Cardboard	ANZSIC
2001	Glass and Glass Product Manufacturing	Glass	ANZSIC
1901	Polymer Product Manufacturing	Plastics	ANZSIC
2101+2102+2201 +2202+2203+220 4	Iron and steel, Basic Non-Ferrous Metal +Forged metal+ Structural Metal Product +Containers + Other metal Manufacturing	Metals	ANZSIC
1101-1205	Meat, fruit, beverages Manufacturing	Organics	ANZSIC
3001+3002+3101 +3201	Construction Services	Masonry	ANZSIC
2401+2403+2404	Professional, Scientific, Computer and Electronic +Electrical +Domestic Equipment Manufacturing	Electrical & Electronic (other)	ANZSIC and households
1701+1801+1802 +1803+1804	Petroleum and coal production + Pharmaceuticals + Basic Chemical + Cleaning compounds and toiletry Manufacturing	Hazardous Waste	ANZSIC
1301-1306	Textile, leather, clothing, footwear Manufacturing	Leather & textiles (other)	ANZSIC
1902	Natural Rubber Product Manufacturing	Tyres & other rubber (hazardous and other)	ANZSIC

24 NSW EPA 2016, *NSW Local Government Waste and Resource Recovery Data Report 2014-15*, available at http://www.epa.nsw.gov.au/resources/wastestrategy/waste-resource-recovery-data-report-1415-160719.pdf

IOPC	Products	Waste material	Type of breakdown
1401 – 1402	Sawmill Product Manufacturing and Other Wood Product Manufacturing	Timber, wood products (organics)	ANZSIC
	All remaining IOPC codes	Inseparable/Unknown (other)	ANZSIC and households

Source: ABS

Table 5.3 summarises the estimated sourcing of waste generated in Australia. Construction is the largest waste generator (19.7 million tonnes, or 30.8 per cent of total wastes), followed by manufacturing (14.5 million tonnes, or 22.7 per cent), services (11.8 million tonnes, or 18.4 per cent) and households (11.4 million tonnes, or 17.8 per cent).

5.3 Sources of waste generation in Australia

	Agriculture and forestry	Mining	Manufacturing	Electricity, gas and water services	Waste management	Construction	Services	Local governments	Househo lds	Total
	kt	kt	kt	kt	kt	kt	kt	kt	kt	kt
Masonry materials	62	163	64	113	5	14 719	1 278	149	600	17 151
Metals	19	153	1 382	27	4	1 466	559	309	1 249	5 168
Organics	831	27	2 094	4	26	1 292	1 285	1 438	5 810	12 807
Paper & cardboard	26	30	1 420	24	12	213	1 632	380	1 534	5 270
Plastics	44	46	624	18	5	170	398	241	973	2 520
Glass	3	4	129	2	3	13	97	162	655	1 068
Other	45	104	356	56	7	389	493	137	555	2 142
Hazardous	312	1 262	8 406	208	110	1 427	6 020	0	0	17 745
Total	**1 342**	**1 788**	**14 475**	**452**	**172**	**19 690**	**11 760**	**2 816**	**11 376**	**63 871**

Source: CIE estimates.

The composition of wastes varies significantly across industries. For example, about three quarters of wastes generated in construction is masonry materials, over 58 per cent and 51 per cent of wastes generated in manufacturing and services, respectively, are hazardous wastes. On the other hand, about 62 per cent and 51 per cent of wastes generated by agriculture and forestry and the households, respectively, are organics.

Uses of waste management services and products

Industrial and household uses are estimated separately for waste management services and products (recovered materials).

Use of waste management services by industry and household is closely related to the amount of waste generated. Table 5.4 compares the share of waste generation with the use shares in the Waste Account and the Input-Output tables. The "Narrow" column is for the narrower classification of waste management industry – 2901 Waste collection, treatment and disposal services, while the "Broad" column is for the broader classification of waste management activity including all the waste-related activities as listed in table A.1.

5.4 Use share of WMS and share of waste generation by industry and household

	Waste Account, Australia		Waste generation	2014 Input-Output table	
	2009-10	2010-11	2014-15	Narrow	Broad
	%	%	%	%	%
Waste industry	30.25	30.98	4.64	0.67	0.49
Agriculture and forestry	0.56	0.56	2.10	2.26	2.06
Mining	0.65	0.64	2.80	0.79	0.82
Manufacturing	7.01	6.90	22.66	7.13	26.65
Construction	17.92	17.65	30.83	13.10	10.73
Wholesale	2.58	2.54	2.86	5.29	6.26
Retail	3.37	3.32	1.39	0.77	0.58
Transport	2.94	2.89	0.98	4.99	3.66
Other services	16.92	16.68	13.94	51.39	38.11
Households	17.79	17.84	17.81	13.62	10.63
Exports	0.00	0.00	0.00	0.00	0.00
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Note: "Narrow" is for 2901 Waste collection, treatment and disposal services; "Broad" is for 2901 and other relevant waste management activities as listed in table A.1.

Source: ABS and CIE.

It can be seen from the table 5.4 that the share of waste generation is broadly consistent with the use share in the IO table for both definitions of the waste management industry. It appears that the use share by waste industry in the Waste Account is too high – 30 per cent compared to less than 5 per cent for the waste generation share or use share in the IO table.

It might be due to the fact that the Waste Account assigned costs of the Waste Management Services industry as the uses by the industry. According to the Explanatory Notes for Waste Account, Australia, 2010-11 (ABS cat. no. 4602.0.55.006):

> **48** Intermediate consumption expenditure of waste management services … by the Waste Management Services industry were sourced from Tables 8 and 9 of Waste Management Services, Australia, 2009-10 (cat. no. 8698.0). …
>
> **49** In-scope expenditure items included:
>
> - contract and subcontract expenses for waste management services for recyclables and non-recyclables
> - fees for the treatment/processing/disposal of waste, and
> - waste disposal levies/contributions paid to the Environmental Protection Authority (EPA)

These were the same expenditure items asked for across the economy – subDiv 29 Waste Industry and all other industries were asked the same question. It probably makes intuitive sense that subDiv 29 businesses would have large expenses in relation to these items as this is what they do, that is in their case it is not necessarily going to directly correlate with the amount of waste they generate, as they are handling everyone else's waste.

We therefore use the share of waste generation to proportionate total waste management services value to industrial and household use by state/territory. The results are summarised in the first row (WMS) of table 5.5.

As for the use of recovered waste materials, we again use the input-output table to estimate the use shares by industry, household and exports for each of the recovered materials as classified in table 5.2. These use shares are then applied to the sales value of recovered materials as reported in the previous chapter to estimate the uses. The results are summarised in the "Recovered materials" section of table 5.5.

Consistent with the above discussion, construction industry is the largest user of waste management services and products, amounting $4.5 billion (29.4 per cent of total). It is followed by manufacturing industry at $3.6 billion (23.2 per cent), households at $2.5 billion (16.4 per cent) and other services at $2.1 billion (13.5 per cent).

5.5 Use of waste goods and services by industry and household

	Waste industry	Ag and forestry	Mining	Manufac-turing	Constructi on	Wholesale	Retail	Transport	Other services	House-holds	Exports	Total use
	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m
WMS	**592.8**	**273.4**	**327.5**	**2 819.0**	**3 906.5**	**354.3**	**175.0**	**120.3**	**1 741.2**	**2 279.9**	**0.0**	**12 589.9**
Recovered materials												
Masonry materials		0.0	4.4	2.5	116.6	4.4	1.8	5.0	42.8	1.2	0.6	179.4
Metals		0.0	42.4	403.2	387.2	33.6	12.8	29.3	97.2	25.2	430.9	1 461.9
Organics		18.6	0.5	49.2	8.7	2.0	3.8	0.2	22.8	57.3	26.7	189.9
Paper & cardboard		0.0	4.5	229.9	38.8	74.7	40.7	6.9	144.2	120.1	58.4	718.3
Plastics		0.0	1.6	38.6	35.3	4.8	1.7	1.5	14.9	10.9	14.0	123.2
Glass		0.0	0.2	9.3	30.7	2.0	0.2	0.2	4.2	5.1	2.2	54.2
Other		0.0	3.6	32.6	14.6	3.3	1.1	0.8	17.6	34.0	24.8	132.5
Total use of materials		**18.6**	**57.3**	**765.3**	**631.9**	**124.8**	**62.3**	**44.0**	**343.7**	**253.7**	**557.6**	**2 859.3**
Total use	**592.8**	**292.0**	**384.9**	**3 584.3**	**4 538.4**	**479.1**	**237.4**	**164.3**	**2 084.9**	**2 533.6**	**557.6**	**15 449.1**

Source: CIE estimates.

PART II

Analysis of materials efficiency

6 *Indirect contribution of the waste activity*

KEY POINTS

- **Indirect contribution of an industry or activity is only meaningful at the marginal level, that is, with the activity increasing by a small amount.**
- **Indirect contribution is dependent on the cause of the expansion in an industry or activity, as well as the market situation. Therefore, there is no single indirect contribution 'multiplier':**
  - **in general, demand induced expansion leads to smaller indirect contribution than productivity induced expansion.**
- **For $100 million expansion in the waste activity, the indirect contribution to GDP could be as low as -$68.4 million (long run, full employment closure) or $6.1 million (short closure) if the expansion is induced by demand growth, or as high as $348 million (long run) or $972 million if it is induced by productivity improvement. The indirect contribution to employment could be between a loss of 356 full time equivalent jobs and a gain of 9 930 jobs, depending on the causes of expansion and the closure.**

Chapter 4 reports the estimates of the headline values of Australia's waste related activity in terms of gross value of product, value added and employment. These values can be viewed as the direct contribution to the Australian economy. It is often argued that an industry/activity also has indirect contributions because of the linkages between the interested industry/activity and the rest of the economy. For example, production in the industry/activity needs inputs from other industries, meaning expansion in the industry/activity would lead to expansion in other industries. Moreover, the industry/activity employs workers and generates income for households who would end up with more consumption of the income, leading to further expansion of the economy due to the higher demand.

In this chapter we will estimate and discuss the indirect contribution of the waste activity more thoroughly with different assumptions about an expansion in the waste activity.

Methodology

The above mentioned flow-on effects, or indirect contributions, had been traditionally estimated through input-output analysis and end up with the input-output multipliers. However, the conventional input-output analysis approach was built in some strong assumptions which may not necessarily hold in the real world. These assumptions include:[25]

- no change in prices;
- no change in technology and labour productivity within sectors;
- fixed import shares; and
- no supply limits on the factor inputs such as capital, labour, land and natural resources.

As a result, the input-output analysis tends to be 'abused':[26]

> Abuse primarily relates to overstating the economic importance of specific sectoral or regional activities. It is likely that if all such analyses were to be aggregated, they would sum to much more than the total for the Australian economy. Claims that jobs 'gained' directly from the cause being promoted will lead to cascading gains in the wider economy often fail to give any consideration to the restrictive nature of the assumptions required for input-output multiplier exercises to be valid. In particular, these applications fail to consider the opportunity cost of both spending measures and alternate uses of resources, and may misinform policy-makers.

We therefore use a general equilibrium model of the Australian economy, CIE-REGIONS, to estimate the direct and indirect contribution of the waste activity at the marginal level (i.e. additional $1 million worth of economic activity in the waste activity). The CGE modelling is able to overcome above mentioned limitations by allowing the change in price signals and in input and output shares as well as imposing supply restrictions such as labour, capital and land.

The model was developed by the Centre for International Economics based on the publicly available MMRF-NRA model developed by the Centre of Policy Studies for the Productivity Commission.[27]

For this project, the waste activity providing waste management services and products is separately identified. A waste module is also added to link the waste generation to economic activities of industries, governments and households.

More details about the model are provided in Appendix 11B.

The procedure to identify the indirect contributions is to first run the model to estimate the total impact, and then deduct the direct impact identified in chapter 4 to estimate the indirect contribution.

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25 Rolfe, John, Daniel Gregg, Galina Ivanona, Reuben Lawrence and David Rynne 2011, 'The Economic Contribution of the Resource Sector by Regional Areas in Queensland', *Economic Analysis and Policy*, **41**(1), p15-36, available at http://www.eap-journal.com/archive/v41_i1_11_02-rolfe.pdf

26 Gretton, Paul 2013, *On input-output tables: uses and abuse*, Staff Research Note, September, Productivity Commission, Canberra, p1, available at http://www.pc.gov.au/__data/assets/pdf_file/0008/128294/input-output-tables.pdf

27 Productivity Commission 2006, *Potential Benefits of the National Reform Agenda*, Report to the Council of Australian Governments, available at http://www.pc.gov.au/research/commissionresearch/nationalreformagenda

Simulations

As we found for other industries[28], expansion in a sector has very different impacts on the wider economy depending on the nature of the expansion. Expansion due to productivity improvement no doubt would enhance the welfare of the society because the resources become more productive which is equivalent to more resources available for the economy. On the other hand, expansion due to pure demand growth may not necessarily lead to higher overall economic activity and welfare because the existing resources are merely changing their uses in most cases.

For this reason, we simulate two types of expansions in the waste activity:

- productivity induced expansion – waste activity productivity improves such that the gross value of product (GVP) of the activity increases by $100 million; and
- demand induced expansion – demand for exports of recovered materials increases such that the GVP of the waste activity increases by $100 million.

Using export demand increase to model the demand induced expansion is due to the modelling technical consideration. It is relatively easier to model the export growth as the variable could be easily turned into an exogenous one. By contrast, domestic demand is determined with a much more complicated demand system of taste, prices and incomes. It is therefore more meaningful to explore the underlying factors affecting domestic consumption rather than the consumption itself. The price and income changes could in turn be results of other factors such as productivity changes. A taste change affecting domestic demand for a particular good or service is similar to external demand change.

Moreover, assumption of the economic environment, or the choice of closure in economic modelling term, is also critical for the impacts of expansion in one industry. Two typical candidates of closures are related to the labour market – a full employment closure and a perfectly elastic labour supply closure. The former is often termed the long run closure while the latter the short run closure.

A perfectly elastic labour supply (unconstrained labour market) is an unlikely extreme case because it assumes that there are additional workers readily available at no extra cost if demand increases. This is why it is termed short run because the higher demand for labour is mainly met by longer working hours as a temporary arrangement.

Table 6.1 summarises the four simulations – two causes of expansion multiply by two closures – of same $100 million increase in the GVP of the waste activity.

28 For example, see CIE 2012, *Construction and the wider economy: A general equilibrium analysis*, report prepared for Housing Industry Association (HIA), November; Borrell, Brent, Tingsong Jiang, David Pearce and Ian Gould 2014, 'Payoffs from research and development along the Australian food value chain: A general equilibrium analysis', *Australian Journal of Agricultural and Resource Economics*, **58**(3), pp409-29.

6.1 Simulations to identify indirect contributions of the waste activity

		Closure	
		Long run	Short run
Cause of expansion	Productivity	$100 million increase in waste activity GVP due to productivity improvement in the industry, operating in a full employment labour market	$100 million increase in waste activity GVP due to productivity improvement in the industry, operating in a labour market with unconstrained labour supply
	Demand	$100 million increase in waste activity GVP due to higher export demand, operating in a full employment labour market	$100 million increase in waste activity GVP due to higher export demand in a unconstrained labour supply market

Source: CIE

Results

Table 6.2 summarises the total impacts of $100 million expansion in the waste activity due to different causes and under different closures.

6.2 Total impacts of different types of expansion in the waste activity

		Productivity induced		Demand induced	
		Long Run	Short Run	Long Run	Short Run
Waste activity					
GVP	$m	100.0	100.0	100.0	100.0
Value added	$m	43.1	43.1	43.1	43.1
Employment	FTE	-1 668	-1 467	356	356
Whole economy					
GDP	$m	390.7	1 014.9	-25.3	49.1
Real wage	%	0.07		0.00	
Employment	FTE		8 463		597

Source: CIE-REGIONS simulations

By definition, long run closure means full employment while the short run closure assumes fixed real wage rate. Therefore the cells for employment under the long run closure and those for real wage rate under the short run closure are left blank.

Some observations may be made from the table:

- As discussed above, an expansion due to productivity improvement has bigger impact on the economy. For example, under the long run closure, the increase in GDP for the same $100 million expansion is $390 million for the productivity induced, compared to a fall of $25 million in GDP for the purely demand driven expansion. The key factor is that with the productivity improvement, the resources can be used more effectively, and some of the resources may be freed up to boost the growth in other sectors. This is evident by the fall in the waste activity's employment (1668 under the long run closure and 1467 under the short run closure) even though its output value increase by $100 million. By contrast, without productivity improvement in the activity, the higher demand means more resources (e.g. about 356 workers) have been used by the expanding activity.

- The choice of closure also affects the results. For the same cause of expansion, a short run closure would lead to bigger impacts than the long run closure. For example, the $100 million expansion in waste GVP due to productivity improvement would increase Australia's GDP by a little over $1 billion under the short run closure, compared to only $390 million under the long run closure. This is due to a similar reason as discussed above. Under the short run, there is no constraint on the labour supply – workers can be hired without extra cost even if the demand is higher. As a result, the flow-on effects are not limited by the availability of workers.
- The reported demand-induced impacts are for exported demand change results. We have run simulations of domestic demand increase due to pure taste change. The impacts are similar and are therefore not separately reported.
- It is therefore evident that a single-value multiplier is not appropriate to describe the relationship of expanding one industry to the wider economy.

Indirect contributions of the waste activity

As discussed above, the indirect contribution of the expansion in the waste activity is estimated by deducting the direct contribution from the total impact. Table 6.3 summarises the indirect contribution to the nation's GDP and employment.

6.3 Indirect contribution of $100 million expansion in the waste activity

		Productivity induced		Demand induced	
		Long Run	Short Run	Long Run	Short Run
GDP	$m	347.6	971.8	-68.4	6.1
Employment	FTE	1 668	9 930	- 356	241

Source: CIE estimates based on CIE-REGIONS simulations

Because of the fixed level of employment assumed under the long run closure, the indirect contribution to total employment is either the saved labour resource by the waste activity in the case of productivity improvement, or a corresponding reduction in total employment due to higher direct employment in the activity in the case of demand induced expansion.

As with the pattern of total impacts, the indirect contributions of the expansion are quite different.

The indirect contribution to GDP by $100 million expansion from productivity improvement is between $350 million under the long run closure and $970 million under the short run closure. The same $100 million expansion in the waste activity indirectly contributes 1 668 FTE under the long run closure or 9 930 FTE under the short run closure.

By contrast, the indirect contribution of demand induced expansion is either negative ($68 million fall in GDP and 356 FTE loss of employment) under the long run closure or small positive ($6 million rise in GDP and 241 FTE increase in employment) under the short run closure.

7 Economic benefits of improving recovery and materials efficiency

KEY POINTS

- **Two stylised simulations are carried out for a 5 per cent increase in waste recovery rate, and a 5 per cent improvement in material use efficiency across the Australian economy.**
- **The material efficiency improvement has much higher positive impacts on the economy than the recovery rate increase:**
  - **the 5 per cent increase in material efficiency increases $24 billion (or 1.5 per cent) to GDP and $14.8 billion in welfare (consumption);**
  - **the 5 per cent increase in recovery rate leads to $ 1 billion (or 0.07 per cent) increase in GDP and $654 million increase in welfare.**
- **The 5 per cent increase in recovery rate will see a fall in waste intensity by 0.07 per cent although waste generation increases slightly by 0.02 per cent because the overall economic activity is higher. By contrast, the 5 per cent material efficiency improvement will lead to a fall in both waste generation (down by 3.26 per cent) and waste intensity (down by 5.36 per cent).**

The Department is interested in the economic benefits of:

- 5 per cent increase in the total recovery rate (recycling and energy recovery); and
- 5 per cent improvement in average materials efficiency across the Australian economy.

We use the CIE-REGIONS, a general equilibrium model of the Australian economy, to estimate the benefits of these improvements. For this project, the waste activity providing waste management services and products is separately identified. A waste module is also added to link the waste generation to economic activities of industries, governments and households. More details about the model are provided in Appendix 11B.

Waste efficiency and material efficiency

Resource and materials efficiency

Understanding “resource efficiency”, “materials efficiency” and related concepts is important for the modelling. However, there do not appear to be generally accepted definitions.

Sustainability Victoria defines resource efficiency and materials efficiency at the firm level, rather than the economywide level. According to Sustainability Victoria: [29]

> "Resource efficiency is about deriving the most value from material and energy inputs by efficiently converting them into finished products or services, while minimising environmental impacts. Material resources refer to everything a business purchases to produce its products or services, including raw materials, stock, stationary, produce and chemicals."

and

> "Materials efficiency is about doing more with less and ultimately saving money. It means producing a product or service using less input materials or producing more product or service for the same amount of material. There are many actions that businesses can take to improve materials efficiency ranging from process or systems changes to reduce wastage or improve productivity; through changing how input materials are measured and loaded; to redesigning products and services so they use less material to make."

According to the European Commission: [30]

> "Resource efficiency means using the Earth's limited resources in a sustainable manner while minimising impacts on the environment. It allows us to create more with less and to deliver greater value with less input."

Resource and materials productivity

Productivity is closely related to the concept of efficiency. Productivity is a measure of output per unit of input.

According to the OECD: [31]

- resource productivity refers to the effectiveness with which an economy or a production process is using natural resources;
- materials productivity refers to the effectiveness with which an economy or a production process is using materials extracted from natural resources.

The OECD goes on to note that the two terms are often used as synonyms, although materials productivity does not cover all resources (e.g. water is not usually included).

Other frameworks makes a distinction between energy and materials. For example, the KLEMS framework includes intermediate inputs, including energy (E), materials (M) and services (S), as well as the standards capital (K) and labour (L).

This implies that energy may be excluded from 'materials productivity', but presumably included in 'resource productivity'.

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29 Sustainability Victoria website, http://www.sustainability.vic.gov.au/services-and-advice/business/energy-and-materials-efficiency-for-business/what-is-resource-efficiency, accessed 23 March 2017.

30 European Commission website, http://ec.europa.eu/environment/resource_efficiency/index_en.htm, accessed 27 March 2017.

31 OECD, Measuring Material Flows and Resource Productivity, Volume I: The OECD Guide.

Unlike “energy efficiency” where the number of energy types is limited and the conversion of different type of fuels into a common energy unit is well established, the number of materials used in an economy is very large, and there is no easy way to convert different types of materials into a common unit (e.g volume, or toxicity). Therefore, it is more challenging to define a single materials efficiency measure.

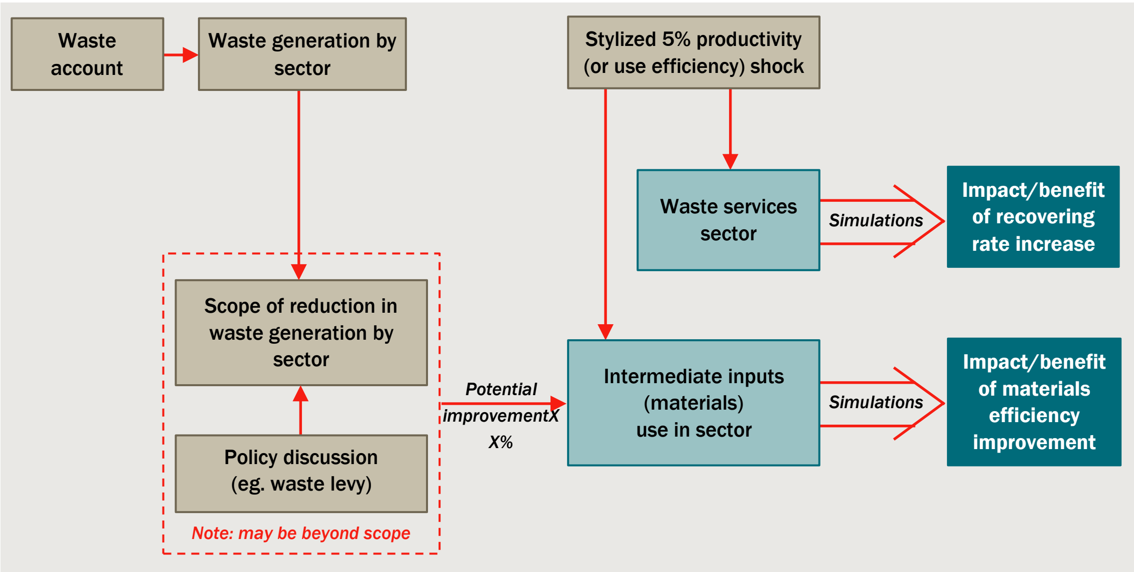
The relevant shocks

According to the above discussion, the increase in recovery rate of waste material and energy is equivalent to a productivity improvement in the waste activity, while the materials efficiency improvement is the increase in use efficiency of materials in the economy. As such, two stylised shocks are simulated:

- a 5 per cent productivity improvement in the waste management and services sector – the recovery rate increase shock; and
- a 5 per cent use efficiency improvement of materials used in the production of goods and services – the materials efficiency improvement shock.

Chart 7.1 illustrates the modelling framework of evaluating the benefits of increasing the recovery rate and improving the material efficiency using the CIE-REGIONS model.

7.1 Modelling framework



Data source: CIE.

The material efficiency shocks apply to the material use as defined in table 5.2.

Long term closure is assumed, that is, the labour market is in full employment status – no change in national total employment, and the impact on the labour market is reflected in the change in real wage rate. As discussed in the previous chapter, a short run closure assuming perfectly elastic supply of labour (any amount of labour is available at no extra cost) is an unlikely extreme case and could only happen temporarily. By contrast, the long run, full employment, closure is closer to the current Australian labour market.

Case studies

Box 7.2 presents a case study of recovery rate and materials efficiency improvements achieved by Bluescope Steel. These examples illustrate the types of changes which may form the basis of the shocks modelled in this chapter.

7.2 Bluescope Steel reduce waste to landfill[32]

BlueScope Steel's Western Port plant manufactures a variety of products from steel. In 1999 the plant was sending 4.0 kilograms of Prescribed Industrial Waste (PIW, the term used to refer to hazardous and other wastes which must be tracked in Victoria) to landfill for each tonne of steel produced.

By 2006, BlueScope had reduced their output of PIW to landfill to 1.4 kilograms per tonne of steel. This reduction was enabled by improvements to management including:

- engagement of site-based environmental committee focusing on avoidance and reuse;
- implementation of a glove and rag recycling program;
- changes to management of filter cake (residual from treatment of water used in steel processes).

These changes enabled a reduction in waste produced per unit of manufactured product.

Box 7.3 presents another case study of recovery rate and materials efficiency improvements achieved by Maton Guitars.

32 See http://www.epa.vic.gov.au/~/media/Publications/1091.pdf

7.3 Maton Guitars reduce raw material requirements and waste[33]

Maton Guitars are a guitar manufacturing company based in Box Hill, Melbourne. By engaging a consultant to undertake a comprehensive resource assessment, the company was able to reduce the quantity of inputs required for their manufacturing process and reduce the amount of waste produced and sent to landfill.

The focus of the resource assessment was optimising usage of materials inputs. The company identified that their expenditure on materials was 25–35 per cent of total operating costs. In order to improve resource efficiency, a number of recommendations were made in relation to optimising materials use, monitoring and reporting, and workplace improvements. This included the following:

- Maton Guitars began tracking rejected timber inputs to the manufacturing process to determine why it had to be rejected and whether it could be reused or value added. For example, rejected timber intended for use as the 'face' of the guitar could be used to make smaller bodied instruments such as mini guitars or ukuleles.
- Accuracy of cutting and assembly were improved to reduce wastage of input materials mainly caused by errors. This was achieved through the purchase of superior tolls such as jigs, gauges and clamps.
- Processes were put in place to identify faults earlier in the production process rather than when the whole guitar was nearing completion. While not reducing the quantity of input material required, it prevented labour time from being wasted on guitars that would be ultimately rejected, and thus increased the quantity of production for a given level of output.

These changes were focussed on producing a greater level of output for a given quantity of material inputs. Thus, they illustrate what a materials efficiency improvement may look like in practice.

In addition to improvements to materials efficiency, Maton Guitars made improvements to their processes to increase the recovery rate for waste. Timber offcuts were able to be reused by local woodworking and craft groups, a greater proportion of metal was recycled (and thus diverted from landfill) and used guitar strings were able to be reused by a local sculptor. These changes illustrate an improvement to the recovery rate of waste.

Simulation results

Table 7.4 reports the impacts on gross state product (GSP) and gross domestic product (GDP) of increasing the recovery rate and improving material efficiency in the economy by 5 per cent respectively.

33 See http://www.sustainability.vic.gov.au/services-and-advice/business/energy-and-materials-efficiency-for-business/case-studies/manufacturing-case-studies/maton-guitars

7.4 Impact on GSP and GDP

	Recovery rate increase		Material efficiency improvement	
	$m	%	$m	%
NSW	644	0.13	10 114	1.97
VIC	305	0.08	6 404	1.78
QLD	98	0.03	2 989	0.98
SA	31	0.03	301	0.31
WA	-55	-0.02	2 905	1.17
TAS	6	0.02	188	0.73
NT	7	0.03	674	2.91
ACT	12	0.03	510	1.47
GDP	**1 049**	**0.07**	**24 085**	**1.50**

Source: CIE-REGIONS simulations

It can be seen from table 7.4 that the impact of material efficiency improvement (GDP increase by $24 billion or 1.5 per cent) is much larger than the impact of recovery rate increase (GDP increase by $1 billion or 0.07 per cent). This is because the coverage of material efficiency improvement is much wider, involving the whole economy in terms of material use, while the recovery rate increase is related only to the waste activity.

Another interesting observation from table 7.4 is the difference in impacts across the states and territories. For example, New South Wales has the highest GSP impact, in terms of the percentage change, from increasing the recovery rate, while Western Australia has a small reduction in its GSP.

The difference in impacts across states and territories is caused by the competition effect which, in the case of WA, dominates the expansion effect. Higher efficiency in an economy tends to boost the economy. This is so called the expansion effect. But at the same time states and territories have to compete for other resources to support the expansion. WA has the lowest share of waste activity in GSP (table 4.9), which means that the same 5 percent increase in the recovery rate has the smallest impact on the whole state economy. As a result, the competition effect from other states and territories outweighs the expansion effect, leading to a small negative impact on WA GSP. If increasing the recovery rate in a state or territory only, the impact on the state or territory economy is inarguably positive. For example, a 5 per cent increase in the recovery rate in WA only would lead to $430 million (or 0.17 per cent) boost to the state's GSP, although other states and territories may suffer $240 million loss in their GSP.

By contrast, the material efficiency improvement simulation sees the expansion effect dominating the competition effect (positive results for all states and territories) because the material efficiency improvement is widely distributed. Nevertheless, the impacts vary across jurisdiction too. For example, South Australia has the lowest percentage change in GSP from improving material efficiency. This reflects the fact that South Australia economy is relatively less material use intensive than other states and territories.

Similar patterns present for the impact on household consumptions (table 7.5). Household consumption is a more important variable than the GSP/GDP in measuring the benefit or welfare change in an economy because the ultimate goal is to enhance people's utility through more consumption.

7.5 Impact on household consumption

	Recovery rate increase		Material efficiency improvement	
	$m	%	$m	%
NSW	331	0.11	6 029	1.96
VIC	174	0.08	3 895	1.73
QLD	75	0.04	2 064	1.16
SA	32	0.05	457	0.77
WA	11	0.01	1 272	1.26
TAS	8	0.05	195	1.15
NT	8	0.08	323	3.19
ACT	16	0.10	575	3.62
Australia	**654**	**0.07**	**14 810**	**1.62**

Source: CIE-REGIONS simulations.

It should also be pointed out that higher consumption level does not necessarily mean higher waste generation. This is certainly the case for improvement in material efficiency as shown in table 7.8 later. Higher material efficiency means less materials used, and thus less waste generated, for certain amount of goods and services. It is therefore likely to achieve higher consumption with lower waste generation.

As discussed above, the long run closure means the labour market is in full employment situation and the impact on labour market is reflected by the change in real wage rate. Table 7.6 reports the percentage change in real wage rate from the two stylised shocks. Both have positive results on real wage rates although the materials efficiency improvement has much bigger impact. The impacts spread relatively more even across states and territories because the labour force is assumed to be mobile (imperfectly) across borders and the equilibrium wage rate change tends to be close. Labour mobility means that workers are able to move to seek higher pay employment opportunities. If there is a shortage for certain skills in one place, the wage rate would rise to reflect this shortage. Workers with the required skills would then move to place to fill the gap, driving down the wage rate. Eventually the wage rate will reach at the similar level across regions.

7.6 Change in real wage rate

	Recovery rate increase	Material efficiency improvement
	%	%
NSW	0.13	2.84
VIC	0.12	2.76
QLD	0.11	2.52
SA	0.13	2.45
WA	0.10	2.53
TAS	0.12	2.53
NT	0.12	2.80
ACT	0.11	2.59
Australia	**0.12**	**2.69**

Source: CIE-REGIONS simulations.

Table 7.7 reports the percentage change in industrial output from the assumed shocks. Industries are grouped into waste, materials and other sectors.

Increasing recovery rate boosts the waste activity output – with the same amount of inputs the activity is able to produce more. And other sectors benefit from the boost in the waste activity too. But these are the second order impact, so the magnitude of impact is smaller.

Material efficiency improvement has different pattern of impacts. With higher materials efficiency, less materials would be needed to produce the same amount of output (the efficiency gain). However at the same time the higher level of economic activity means higher demand for materials (the expansion effect). The efficiency gain and the expansion effect works in the opposite direction for the final level of material industry output. For most of the states and territories except Northern Territory and the nation as a whole, the former dominates the latter, leading to a fall in materials industry output.

For NT, three factors lead to the increase in materials industry output – although it has relatively smaller share of the materials industry in the NT economy, it has the highest material share in its intermediate inputs because it has a larger share of materials demand sourced from outside the NT. The highest share of material inputs means the material efficiency improvement has the biggest impact on overall economic activity for NT (eg GSP increases by 2.86 per cent as shown in table 7.4). This increase in overall economic activity leads to higher demand for materials. The higher demand for materials, or the expansion effect, outweighs the lower demand due to efficiency improvement, leading to net increase in the material industry output. Moreover, materials industry in NT has higher material inputs share than other states and territories. This reinforces the dominance of the expansion effect in the materials industry in NT.

7.7 Change in industrial output

	Recovery rate increase				Material efficiency improvement			
	Waste	Materials	Other	Total	Waste	Materials	Other	Total
	%	%	%	%	%	%	%	%
NSW	0.02	0.06	0.15	0.13	-2.58	-0.15	1.69	1.36
VIC	0.29	0.02	0.09	0.08	-3.22	-0.40	1.19	0.88
QLD	0.74	0.02	0.09	0.08	-3.87	-1.12	0.45	0.15
SA	0.63	-0.01	0.02	0.02	-4.27	-1.88	-0.50	-0.80
WA	0.57	-0.02	0.01	0.01	-3.47	-0.05	0.91	0.73
TAS	0.76	-0.05	-0.06	-0.06	-3.76	-1.58	0.17	-0.23
NT	0.97	-0.03	0.00	0.00	0.30	0.73	3.35	3.07
ACT	0.42	0.01	0.01	0.02	-2.22	-1.19	1.12	0.96
Australia	**0.35**	**0.00**	**0.01**	**0.01**	**-3.15**	**-0.57**	**1.07**	**0.77**

Source: CIE-REGIONS simulations

Table 7.8 reports the percentage change in waste generation from recovery rate increase and materials efficiency improvement. The recovery rate increase leads to a small increase (0.02 per cent) in waste generation. This is because the overall economic activities are higher, leading to higher demand for materials and thus higher waste generation. It is worth noting that, however, as the overall economy grows by 0.07 per cent (table 7.4), the waste intensity, measured by the amount of waste generation per unit of GDP, falls by about 0.07 per cent.

7.8 Change in waste generation and waste intensity

	Recovery rate increase		Material efficiency improvement	
	Waste generation	Waste intensity	Waste generation	Waste intensity
	%	%	%	%
NSW	0.07	-0.10	-2.58	-5.36
VIC	0.04	-0.08	-3.22	-5.58
QLD	-0.01	-0.06	-3.87	-5.27
SA	0.00	-0.04	-4.27	-4.64
WA	-0.03	0.00	-3.47	-5.35
TAS	-0.03	-0.06	-3.76	-4.63
NT	0.03	-0.02	0.30	-4.00
ACT	0.01	-0.03	-2.22	-4.06
Australia	**0.02**	**-0.07**	**-3.26**	**-5.36**

Source: CIE-REGIONS simulations.

With the fall in waste generation, the direct demand for waste management services falls accordingly, which is evident by the reduction in waste industry output reported in table 7.7. The reduction in waste industry output is only marginally smaller than the reduction in waste generation – 3.15 per cent versus 3.26 per cent.

That said, the above figures may overstate the fall in the waste management services output as it is closely tied to waste generation. There may be more demand for waste management services before the wastes are generated, which may help to improve the material efficiency and thus to reduce the waste generation. In order words, some of the waste management services may be moved from the end of a production process of other products/services up to the middle of the process, and/or integrated into the ordinary production process.

PART III

Primary industry waste

8 Mining waste

KEY POINTS

- **Five mining sectors are considered in detail to quantify primary wastes generation, namely: aluminium and iron, coal, copper and zinc.**
- **Among mining wastes, the following volumes are known to be generated:**
  - **overburden and waste rock: 3 594 mt of bauxite, iron ore and coal, with generation of copper and zinc unknown;**
  - **ore processing wastes: 637 mt across all mining sectors;**
  - **overburden and waste rock: 235 mt across all mining sectors except zinc, for which waste generation is unknown.**

The list of minerals selected for consideration under the review are based on Geoscience Australia published data on mine production during 2015.[34] Five mining sectors are covered in some detail to quantify primary wastes generation. These sectors are: aluminium and iron, coal, copper and zinc. The minerals were selected because they are extracted at levels approaching or exceeding a megatonne (Mt).

The focus has been on obtaining Australian data, otherwise international data has been identified and adopted.

There are a number of different categories of primary mining-related waste materials which vary in their physical and chemical composition, their potential for environmental contamination, and how they are managed. For the purposes of this literature review these mining waste types are defined as follows. These waste definitions are largely based on the information provided on the Mining Facts website: [35]

Overburden and waste rock

Overburden includes the soil and rock that is removed to gain access to the ore deposits at open pit mines. It is usually piled nearby on the surface at mine sites to minimise transport costs and where it will not impede further expansion of the mining operation,

[34] Geoscience Australia, 2016. Australia's Identified Mineral Resources Table 1 – As at December 2015. [Online] Available at: http://www.ga.gov.au/scientific-topics/minerals/table1 [Accessed 8 June 2017].

[35] Mining Facts, 2012. How are waste materials managed at mine sites?. [Online] Available at: http://www.miningfacts.org/Environment/How-are-waste-materials-managed-at-mine-sites/[Accessed 3 August 2017].

as moving large volumes of material is expensive. Overburden generally has a low potential for environmental contamination, and is often used at mine sites for landscape contouring and revegetation during mine closure.

The initial removal of overburden is called development stripping. Interburden removal also occurs, which is production stripping during the normal course of production.

Waste rock is ore material that contains target minerals in concentrations below commercial viability. Waste rock is often stored in heaps or dumps on the mine site, but may be stored underwater with tailings if it contains a lot of sulfide minerals and has a high potential for acid mine drainage formation. Waste rock dumps can be backfilled to mine pits, but are generally covered with soil and revegetated following mine closure.

Ore processing wastes

Ore processing wastes include beneficiation wastes which result from the process of physically separating ore from gangue (waste material) prior to subsequent processing of the beneficiated ore, and includes sizing/grinding and the wastes resulting from mineral concentration processes, such as tailings.

Tailings are finely ground rock and mineral waste products of mineral processing operations. Tailings can also contain leftover processing chemicals, and are usually deposited in the form of a water-based slurry into tailings ponds (sedimentation lagoons enclosed by dams built to capture and store the tailings).

Smelting wastes

Smelting wastes include slags and other wastes such as spent pot liner from aluminium smelting. Slags are (mostly) non-metallic by-products from metal smelting, and are typically high in silicon, oxygen, residual metals and many trace elements.

Other wastes

Other wastes generated through mining and ore processing activities include; mine water, water treatment sludges, gaseous wastes and (non-primary) solid wastes (e.g. end-of-life products such as tyres, waste oil and other consumables). These wastes are not considered to be primary wastes, and are excluded from this literature review.

It is also worth noting that there is a significant difference between opencast and underground mines, with significantly less waste typically generated by underground mines.[36] In part, this is because underground mines generally have significantly higher ore grade and much smaller quantities of overburden and waste rock for removal. In addition, underground mines will often backfill waste rock into mined cavities, avoiding the need to transport it to the surface.

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36 BRGM, 2001. Management of mining, quarrying and ore-processing waste in the European Union, Paris: Report prepared by the Bureau de Recherches Geologiques et Minieres (BRGM) on behalf of the Environment Directorate-General of the European Commission.

Summary primary mining wastes generation data

Factoral data on the quantities of each waste type produced by each sector per unit activity is provided in the following three tables. The waste types are: overburden and waste rock; ore processing wastes; and smelting wastes.

8.1 Primary mining wastes generation in Australia, 2015 – Overburden and waste rock

Product	Production[1]	Waste generated[2]		Comments
	kilotonnes	Tonnes waste/tonne product extracted	kilotonnes (mid-point value)	
Bauxite	81 000	2.0–4.0	243 000	Bauxite mining.
Iron ore	811 000	1.1–2.1	1 297 600	Iron ore mining.
Coal	604 000	1.9–4.9	2 053 600	Aggregate of black and brown coal.
Copper (metal)	971	Unknown	Unknown	No estimate available. Probably low as the two major copper mines in Australia are underground.
Zinc (metal)	1 611	Unknown	Unknown	No estimate available. Probably low as most zinc mines in Australia are underground.

Sources: 1) 34
2) Refer to detailed literature review sections for primary mining wastes (pp. 74–81)

8.2 Primary mining wastes generation in Australia, 2015 – Ore processing wastes

Product	Production[1]	Waste generated[2]		Comments
	kilotonnes	Tonnes waste/tonne product extracted	kilotonnes (mid-point value)	
Bauxite	81 000	0.5–1.4	77 000	Waste is red mud. A significant proportion of this waste is not generated in Australia.
Iron ore	811 000	0.1–0.6	284 000	A significant proportion of this waste is not generated in Australia.
Coal	604 000	0.1–0.6	211 000	A significant proportion of this waste is not generated in Australia.
Copper (metal)	971	50	48 550	Approximate estimate only.
Zinc	1 611	10	16 110	Approximate estimate only.

Sources: 1) 34
2) Refer to detailed literature review sections for primary mining wastes (pp. 74–81)

8.3 Primary mining wastes generation in Australia, 2015 – Smelting wastes

Product	Production[1]	Waste generated[2]		Comments
	kilotonnes	Tonnes waste/tonne product extracted	kilotonnes (mid-point value)	
Bauxite	81 000	0.002–0.004	243	Estimate is for spent pot liner only. A significant proportion of this waste is not generated in Australia.
Iron ore	811 000	0.17–0.27	178 000	A significant proportion of this waste is not generated in Australia.
Coal	604 000	0.08–0.11	57 380	A significant proportion of this waste is not generated in Australia.
Copper (metal)	971	0	0	No smelting waste for copper.
Zinc	1 611	Unknown	Unknown	No estimate available.

Sources: 1) 34

2) Refer to detailed literature review sections for primary mining wastes (pp. 74–81)

Aluminium

Overburden and waste rock

The Australian aluminium industry literature reviewed was silent on specific quantities of overburden generated through the open cut mining of bauxite.

Rio Tinto reporting provided partial ore production data of 360 million tonnes, and an estimate of aggregated mineral waste generation of 1,781 million tonnes, of which 81% was related to overburden and waste rock.[37] [38] This allows the calculation of an upper bound for an aggregated overburden generation rate for bauxite, coal and iron ore of 4.0 tonnes overburden and waste rock per tonne of ore. The product streams as ores were bauxite, coal and iron ore, with an ore production mass split of 14%, 8% and 78% respectively.

Rio Tinto reporting also appears to indicate that a bauxite mine overburden generation to ore production design factor of 10:1 was being allowed for in financial estimates, however this seems high, and the interpretation of this figure is uncertain. [39]

European Union data provides estimated ratios for a number of mineral ores on the ratios between ore production and waste moved (e.g. overburden) in the extraction process.[36] The report finds that for every tonne of bauxite ore won, around 2.0 tonnes of spoil is generated. The report does not differentiate between potentially environmentally problematic mining spoil and uncontaminated mining spoil.

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[37] Rio Tinto, 2017a. 2016 Annual report, London: Rio Tinto.

[38] Rio Tinto, 2017b. 2016 Sustainable development report, London: Rio Tinto, p.80

[39] Rio Tinto, 2017a. 2016 Annual report, London: Rio Tinto, p.8

Based on the data outlined above a range of 2.0–4.0 tonnes spoil/tonne bauxite ore mined is adopted.

With respect to the management of overburden and waste rock at bauxite mines in Australia, overburden is usually stored out of the way on site, and may be used to back-fill the mine during mine remediation/closure activities. The scale of overburden backfilling in Australian bauxite mines is unknown.

Ore processing wastes

The International Aluminium Institute provides estimates of the quantity of 'bauxite residue' (red mud) produced per tonne of alumina (Al_2O_3) as typically being between 0.7–2.0 tonnes of residue (assumed dry weight) per tonne of alumina produced, with a mid-point of 1.4 tonnes of residue.[40] The steady state moisture content of red mud, once dewatered and stockpiled for long-term storage, is assumed to be around 25–45%, with a mid-point moisture content of 35%.[41] This indicates a range of around 1.1–3.1 tonnes red mud (wet weight)/tonne alumina.

This is consistent with Alcoa reported data. In 2016 Alcoa generated 22.9 million tonnes of red mud to achieve an estimated 12.8 million tonnes of alumina production globally, a generation rate of 1.8 tonnes red mud (wet weight)/tonne alumina. Alcoa alumina production is around 70% Australian based.[42] [43]

It is also consistent with Alumina Limited report data, which operates an Australian bauxite mine, alumina refinery and an aluminium smelter (Portland – 55% ownership). Alumina Limited estimates that one tonne of alumina production results in the generation of 1.5 tonnes of bauxite residue (red mud).[44]

With respect to the ratio of bauxite ore to red mud generation, the IAI report provides estimates of alumina of between 30–65% of bauxite ore (assumed 50% average).[40] Assuming that bauxite–alumina refining recovers 90% of the available alumina, then this allows the calculation that every tonne of mined bauxite typically generates around 270–450 kg of alumina, and that therefore a tonne of bauxite generates 0.5–1.4 tonnes of red mud (wet weight).

Bauxite red mud is typically managed by stockpiling it in tailings dams, or through dewatering and stacking it, usually to bunded areas co-located with alumina refineries.

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40 IAI, 2015. Bauxite Residue Management: Best Practice, London UK: International Aluminium Institute (IAI), p.5

41 IAI, 2017. Mining and Refining – Bauxite Residue Management. [Online] Available at: http://bauxite.world-aluminium.org/refining/bauxite-residue-management/[Accessed 8 June 2017].

42 Alcoa, 2017b. Sustainability report 2016, New York City: Alcoa Corporation, p.65

43 Alcoa, 2017a. Annual report 2016, New York City: Alcoa Corporation, p.14-15

44 Alumina Limited, 2017. Annual Report 2016, Melbourne: Alumina Limited, p.12

Red mud can be used as a soil amender, in waste water treatment and as a raw material in bricks and ceramics manufacture.[35]

Smelting wastes

Aluminium smelting involves the electrolytic reduction of Al_2O_3 to Al metal and O_2. The major waste product considered in this literature review is spent pot liner (SPL). Alcoa identifies that in 2016 it generated around 17 kg of SPL/tonne of aluminium produced.[45]

Alumina is 53% by mass aluminium, so assuming 100% recovery of the aluminium present in alumina, around 4.2–7.0 tonnes of bauxite is typically required to generate one tonne of aluminium, and so the mining of one tonne of bauxite results in the generation of around 2.4–4.0 kg of SPL.

Significant legacy stockpiles of SPL material are stored at various locations across Australia. However, a significant proportion of newly generated SPL material is now recycled relatively soon after it is generated.[46]

The cement industry uses spent pot lining as both a fuel and raw material, and it is also used as an input in clay brick manufacture and rockwool insulation manufacture, however the scale of these last two activities in Australia is unclear.[47]

Iron

Overburden and waste rock

Across a mix of the 2015–16 financial year and 2016 calendar year (depending on the adopted financial reporting periods), BHP Billiton, Fortescue and Rio Tinto mined an estimated 690 million tonnes of iron ore, which is around 85% of the 811 million tonnes of iron ore known to have been mined in Australia during 2015.[34 48 49 50]

Fortescue Metals Group Ltd reports on total ore mined and total overburden mined, the ratio of which is 1.1 tonnes overburden/tonne ore.[51]

As outlined earlier in this report Rio Tinto reporting provides partial ore production data and an estimate of aggregated overburden generation, which allowed the calculation of an upper bound for an aggregated overburden generation rate for bauxite, coal and iron ore of 4.0 tonnes overburden/tonne ore.[38 50]

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[45] Alcoa, 2017b. Sustainability report 2016, New York City: Alcoa Corporation, p.53

[46] Alcoa, 2017b. Sustainability report 2016, New York City: Alcoa Corporation, p.54

[47] Regain, 2017. Regain Materials corporate website. [Online] Available at: http://www.regainmaterials.com/[Accessed 7 August 2017].

[48] BHP Billiton, 2016a. Annual Report 2016, Melbourne: BHP Billiton, p.240-242

[49] Fortescue, 2016. Annual Report 2016, Perth: Fortescue Metals Group Limited.

[50] Rio Tinto, 2017a. 2016 Annual report, London: Rio Tinto, p.219-222

[51] Fortescue, 2016. Annual Report 2016, Perth: Fortescue Metals Group Limited, p.64

BHP Billiton does not collect data or report on the amounts of overburden and rock it generates for any mineral product stream.[52]

European Union data provides estimated ratios for a number of mineral ores on the ratios between ore production and waste moved (e.g. overburden) in the extraction process.[53] The report finds that for every tonne of iron ore won, 2.1 tonnes of spoil is generated.

Based on the data outlined above a range of 1.1–2.1 tonnes overburden/tonne iron ore mined is adopted.

With respect to the management of overburden and waste rock, the Fortescue Metals Group Limited annual report states that:[51]

> *...overburden removed to access Fortescue's ore bodies, is disposed of onsite with much of the waste put back into mined out pits. Within the Chichester region, 81.5 per cent of overburden was returned to pits as backfill.*

Note that Fortescue only mines and processes iron ore.

The most recent Rio Tinto 2016 Sustainable development report identifies that:[54]

> *Mineral waste* (which includes waste rock, tailings and slag) *is usually permanently stored on site where it is used as in pit backfill or held in engineered repositories.*

Ore processing wastes

Most iron ore produced in Australia is high quality ore that is close to suitable for direct feed into blast furnaces, however some gangue material (waste rock that is closely mixed with the ore product) typically needs to be removed.

BHP Billiton reporting provides partial ore production data for the 2015 financial year and an estimate of aggregated tailings generation, which allowed the calculation of an upper bound for an aggregated tailings generation rate for coal and iron ore of 0.4 tonnes ore processing wastes/tonne ore.[55] [56]

Fortescue Metals Group Ltd reports on total ore mined and tailings generated, the ratio of which is 0.1 tonnes ore processing waste/tonne ore.[57] Note that Fortescue only mines and processes iron ore.

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52 BHP Billiton, 2015c. Sustainability Reporting Navigator 2015, Melbourne: BHP Billiton, p.13

53 BRGM, 2001. Management of mining, quarrying and ore-processing waste in the European Union, Paris: Report prepared by the Bureau de Recherches Geologiques et Minieres (BRGM) on behalf of the Environment Directorate-General of the European Commission, p.33

54 Rio Tinto, 2017b. 2016 Sustainable development report, London: Rio Tinto, p.95

55 BHP Billiton, 2015a. Annual Report 2015, Melbourne: BHP Billiton, p.34

56 BHP Billiton, 2016b. Sustainability Report 2016, Melbourne: BHP Billiton, p.62

57 Fortescue, 2016. Annual Report 2016, Perth: Fortescue Metals Group Limited, p.64

Rio Tinto reporting provided partial ore production data of 360 million tonnes, and an estimate of aggregated mineral waste generation of 1,781 million tonnes, of which 13% was related to ore processing.[58] [59] This allows the calculation of an upper bound for an aggregated ore processing wastes generation rate for bauxite, coal and iron ore of 0.6 tonnes ore processing wastes per tonne of ore.

Based on the data outlined above a range of 0.1–0.6 tonnes of ore processing wastes/tonne iron ore mined is adopted.

Smelting wastes

The two blast furnaces operating in Australia are in Whyalla (SA) and Port Kembla (NSW). The major smelting waste from these facilities is slag.

There are two main types of slag produced at a blast furnace, which are:

- blast furnace slag – generated in the production of pig iron from iron ore;
- steel slag – which is generated in the production of steel from pig iron.

In 2015 Arrium reported consumption of 1,763 kilotonnes of iron ore, against the following slag production:[60]

- blast furnace slag of 260 kilotonnes, or 0.15 tonnes of slag per tonne of iron ore;
- steel slag of 216 kilotonnes, or 0.12 tonnes of slag per tonne of iron ore.

This provides the estimate of both slag-producing steps generating around 0.27 tonnes of slag per tonne of processed iron ore, or applying the range of 0.1–0.6 tonnes of ore processing wastes/tonne iron ore mined determined above, 0.17–0.25 tonnes of slag per tonne of unprocessed iron ore.

Consistent with Arrium estimates, the US Geological Survey Minerals Yearbook 2001 identifies the following slag to product factors:[61]

- blast furnace slag – typical range of 0.22–0.37 tonnes of slag per tonne of pig iron product (assuming a high grade iron ore of 60–65% iron);
- steel slag – average of 0.06 tonnes of slag per tonne of steel product.

In aggregate the USGS data for both slag-producing steps estimates that around 0.27 tonnes of slag per tonne of iron ore is generated.

Based on the data outlined above a range of 0.17–0.27 tonnes of slag/tonne iron ore mined is adopted.

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58 Rio Tinto, 2017a. 2016 Annual report, London: Rio Tinto, p.219-222

59 Rio Tinto, 2017b. 2016 Sustainable development report, London: Rio Tinto, p.80

60 Arrium, 2015. Sustainability Report 2015, Sydney: Arrium Limited.

61 USGS, 2001. US Geological Survey Minerals Yearbook 2001 – Slag – Iron and steel, s.l.: United States Geological Survey with report section prepared by Kalyoncu, R. and Kaiser, R..

Coal

Overburden and waste rock

As outlined earlier in this report Rio Tinto reporting provides partial ore production data and an estimate of aggregated overburden generation, which allowed the calculation of an upper bound for an aggregated overburden generation rate for bauxite, coal and iron ore of 4.0 tonnes overburden/tonne ore.[58]

BHP Billiton does not collect data or report on the amounts of overburden and rock it generates for any mineral product stream.[52]

European Union data provides estimated ratios for a number of mineral ores on the ratios between ore production and waste moved (e.g. overburden) in the extraction process.[62] The report finds that for every tonne of black coal and brown coal mined there is 1.9 tonnes and 4.9 tonnes of overburden and waste rock generated respectively.

Based on the data outlined above a range of 1.9–4.9 tonnes overburden and waste rock/tonne of coal mined is adopted.

For open cut coal mines, the management approach for overburden and waste rock is probably similar to that undertaken at bauxite and iron ore mines. Mine overburden is usually stored out of the way on site, and may be used to back-fill the mine during mine remediation/closure activities. The scale of overburden backfilling in Australian coal mines is unknown.

Ore processing wastes

BHP Billiton reporting provides partial ore production data for the 2015 financial year and an estimate of aggregated tailings generation, which allowed the calculation of an upper bound for an aggregated tailings generation rate for coal and iron ore of 0.4 tonnes ore processing wastes/tonne ore.[55 56]

Rio Tinto reporting provided partial ore production data of 360 million tonnes, and an estimate of aggregated mineral waste generation of 1,781 million tonnes, of which 13% was related to ore processing.[58 59] This allows the calculation of an upper bound for an aggregated ore processing wastes generation rate for bauxite, coal and iron ore of 0.6 tonnes ore processing wastes per tonne of ore.

Based on the data outlined above, and the lower bound for the iron ore processing waste generation rate (the best available proxy) a range of 0.1–0.6 tonnes of ore processing wastes/tonne coal ore mined is adopted.

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62 BRGM, 2001. Management of mining, quarrying and ore-processing waste in the European Union, Paris: Report prepared by the Bureau de Recherches Geologiques et Minieres (BRGM) on behalf of the Environment Directorate-General of the European Commission, p.36

Combustion wastes

Based on US data, for every tonne of (processed) coal combusted, around 0.12 tonnes of combustion products is generated.[63] With consideration of the coal processing wastes outlined above, this allows the estimation of 0.08–0.11 tonnes of coal combustion products generated for every tonne of raw coal (run-of-mine) coal that is mined.

Copper

Overburden and waste rock

Copper production in Australia is concentrated at the poly-metallic Olympic Dam copper-uranium-gold deposit in South Australia and the Mount Isa copper-lead-zinc deposit in Queensland.[64] Both these mines are underground mines, resulting in likely relatively low quantities of overburden generated per tonne of copper ore removed. However, the Australian sources reviewed were silent on the quantities of overburden and waste rock generated at Australian copper mines.

European Union data provides estimated ratios for a number of mineral ores on the ratios between ore production and waste moved (e.g. overburden) in the extraction process.[62] The report finds that for every tonne of copper metal produced, the quantity of overburden and waste rock generated is 450 tonnes. However, this figure likely includes a large proportion of open cut mining, so is probably very high for Australian mining operations and is not adopted.

Due to the lack of available data it is assumed that all overburden and waste rock is used for backfill underground in Australian copper mines.

Ore processing wastes

Little Australian data was discovered on the quantity of ore processing wastes generation during the processing of copper ore. Glencore reporting indicates that Mount Isa copper ore is around 2% copper on average, so every tonne of copper (metal) production will result in the generation of 49 tonnes of waste material, albeit with a proportion of this sent to atmosphere.[65] For want of a better estimate, it is assumed that each tonne of copper (metal) production results in 50 tonnes of ore processing wastes.

Smelting wastes

Copper ore processing, as discussed immediately above, results in electrolytically pure (99.99%) copper, and so there is no subsequent smelting process.

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[63] Kalyoncu, R. S., 2002. Coal combustion products, s.l.: United State Geological Service (USGS), p.1

[64] Geoscience Australia, 2015. Australian atlas of minerals resources, mines and processing centres – copper fact sheet. [Online] Available at: http://www.australianminesatlas.gov.au/education/fact_sheets/copper.html[Accessed 7 August 2017].

[65] Glencore, 2017. Annual Report 2016, Sydney: Glencore.

Zinc

Overburden and waste rock

Due to the lack of available data it is assumed that all overburden and waste rock is used for backfill underground in Australian zinc mines. Australian zinc mines are largely underground mines.[64]

Ore processing wastes

Little Australian data was discovered on the quantity of ore processing waste generation during the processing of zinc ore. Glencore reporting indicates that Mount Isa and Macarthur River zinc ore is around 7–10% zinc on average, so every tonne of zinc (metal) production will result in the generation of around 10 tonnes of waste material, albeit with a proportion of this sent to atmosphere.[66] For want of a better estimate, it is assumed that each tonne of zinc (metal) production results in 10 tonnes of ore processing wastes.

Smelting wastes

Zinc ore processing, as discussed immediately above, can be undertaken either via an electrowinning process or through a smelting process, however the split between these was not identified and smelting wastes have not been estimated.

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[66] Glencore, 2017. Annual Report 2016, Sydney: Glencore, p.215

9 *Agricultural waste*

KEY POINTS

- **Agricultural waste is composed of:**
  - **general wastes;**
  - **biomass.**
- **There are difficulties in identifying biomass and estimating the quantities produced.**

Wastes from the agricultural sector can be thought of in two parts – general wastes similar to those produced by other industries and commercial operations, and biomass of plant or animal origin. Biomass wastes are of widely differing types and there is no straightforward method to comprehensively identify those types, the quantities produced or their management methods. There are particular difficulties in the sector in defining the scope of what material streams should be considered 'wastes', noting that biological material is typically considered to improve soil.

A $6m project is currently underway titled the Australian Biomass for Bioenergy Assessment Project (ABBA)[67], run by the Australian Renewable Energy Agency. Starting in late 2015, the project was initially due to release draft databases in late 2016 but does not appear to be meeting that schedule.

As an example of where the work is headed, the text below reports a Qld project undertaken under the ABBA on assessing the biomass resource available from the sugarcane industry.

Sugarcane biomass wastes

The Queensland Department of Science, Information Technology and Innovation (DSITI 2017) developed technical methods for determining the quantity of waste from harvesting sugarcanes. There are two main types of sugarcane waste (or residue) generated, these are bagasse (mill residues) and trash (field residues). The total quantity of residue can be calculated based on the cane production figures for each mill supply area (expressed in tonnes per ha harvested). Production figures for Queensland and NSW are published by Canegrowers (the peak body for Australian sugarcane growers). Residue data for bagasse and trash is also published by ABBA.

Bagasse is generated when sugarcane is milled. The total bagasse generated can be estimated using the following equation which is derived from the industry standard relationship with sugarcane production.

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67 https://arena.gov.au/projects/the-australian-biomass-for-bioenergy-assessment-project/

Total bagasse (t DM) = mc x 0.95Fc/(100-Mb-Bb)

Where, mc is the green cane production (in tonnes)

Fc is the fibre content of cane (typically 15%)

Mb is the moisture content (typically 50%)

Bb is the brix of the final bagasse (typically 2.5%).

Note bagasse is the main source of fuel used in milling operations to produce steam. It is useful to further calculate the available quantity of bagasse that would not be used for steam generation. Generally, an operating mill has a steam on cane (SOC) requirement of 45%.

Trash refers to sugarcane leaves, tops and other organic matter remaining after harvesting. There are benefits to keeping sugarcane trash on harvested areas such as reducing soil erosion, enhancing moisture retention, minimising weed growth and improving soil health. Quantities of trash generated can be estimated based on the cane yield as follows:

total trash (t/ha DM) = 0.18 x yc – 2.5

where, yc is the freshweight yield of cane (t/ha).

10 *Forestry waste*

KEY POINTS

- **Forest industry waste is composed of field residues and sawmill residues. Data on residue produced from softwood plantations and native forests is published, however has been aggregated due to confidentiality and data availability issues.**

There are two main forms of waste produced from forest industries: field residues (or harvest residues) and sawmill residues. Field residues refer to foliage and branches that remain in forests while sawmill residues are solid wood, shavings and sawdust which are generated from saw milling operations. Data on residue produced from softwood plantations and native forests is published by ABBA, however it is only provided as an aggregate due to lack of available data on individual harvesting processes from privately owned forests and confidentiality reasons for sawmill operators.

The ABBA has developed the following calculation methods to estimate residues in Queensland. These estimates are based on the quantity of yearly wood products produced.

Field residues (dry tonnes) = total log volume (sawlogs m^3) x basic density x (1- field product recovery) x breakdown by residue type.

Basic densities can be obtained from Table 10.1 below while field recovery and breakdown of residue by type can be obtained from Table 10.2.

10.1 Densities of trees harvested in Queensland

	Estimated average proportion of timber harvested	Basic density
	%	Kg/m3
Softwood plantations		
Exotic pine	85	450
Native pine	15	450
Softwood plantation density used in calculations	0	450
Native forests		
Cypress	80	580
Spotted Gum	10	740
Red ironbarks [a]	10	910
Blackbutt [b]	0	710
Weighted average for hardwoods used in calculations		754

[a] Broad leafed and narrow leafed, representing a group of dense hardwood species.

[b] Representing a group of light hardwood species.

10.2 Product recovery rates and ratios of field residues

Resource type	Proportion recovered to timber products	Final residue proportion by type			
		Branches	Bark	Cones	Needles
Softwood plantations					
Exotic and native pine	81.2%	12.2%	0.8%	1.9%	3.9%
		Stump	Bark	Branches	Foliage
Native forests					
Cypress	45%	10%	0%	35%	10%
Hardwood	40%	10%	15%	33%	2%

Source: Exotic and native pine – Ghaffariyan & Apolit, 2015. Cypress – Burrows et al 2001, Taylor et al 2005. Hardwood – Ximenes et al 2006, 2016.

Sawmill residues by category (dry weight) can be calculated using the equation below:

> Saw mill residues (dry tonnes) = total log volume (sawlogs only m3) x basic density x (1- sawn product recovery) x breakdown by residue type.

Sawn product recovery rates and breakdown of residue types can be obtained from Table 10.3.

10.3 Sawn timber recovery rates and ratios of field residues

Resource type	% recovered to timber products	Sawmill residue proportion by type			
		Woodchip	Bark [a]	Sawdust, other fines	Shavings
	%	%	%	%	%
Softwood Plantations					
Softwood	47	35	6	7	5
Native forests					
Cypress	40	30	10	20	-
Hardwood	35	40	0	25	-

[a] In Queensland all hardwood logs are debarked in the bush whereas cypress and plantation logs are transported to the mill with barks on. The bark proportion for softwood plantations is reported after a log has been debarked.

Source: Softwood – Goble and Peck 2013, Cypress – SEFE 2011, Goble and Peck 2013. Hardwood – Taylor et al 2005.

This method does not consider a range of factors which would affect the amount of residue produced. Key assumptions made are provided below (DSITI, 2017):

- different sawmill technologies produce the same amount of wood products and residue;

- all plantation harvesting is done by cut-to-length (CTL) operations (does not consider different harvesting operations have different production recovery rates);
- field residue does not include below-ground materials and plantations does not include stump;
- moisture content is based on dry materials (12-14%);
- softwood plantation residue does not include pulplog and native forest residue does not include residue logs from public forests (note data for softwood plantation pulplogs are published annually);
- residue does not include waste from failed plantations or thinnings from plantations or native forests;
- does not consider the residue already accounted for internally within and between sawmills and processing facilities;
- does not take into account large residues generated from natural disasters.

11 Fisheries waste

KEY POINTS

- **The Australian fisheries and aquaculture industry is estimated to have produced between 101-178 kilotonnes of waste in 2014-15.**
- **Different estimation approaches were taken for:**
  - **fish and organic waste – based on fishery method tonnage production and an estimate of waste generation from low to high within each category;**
  - **fishery vessels and equipment waste – based on either the number of vessels or the number of employees in Australian fisheries.**
- **The main categories of fisheries waste are waste produced during:**
  - **processing (58-82kt) – offal, shells, frames;**
  - **during harvest/catch (17-36kt) – bycatch and discards;**
  - **prior to harvest (11-23kt) – fish waste, dead fish;**
  - **end-of-life (EoL) vessels (7-28kt) – boats.**

Type and number of fisheries in Australia

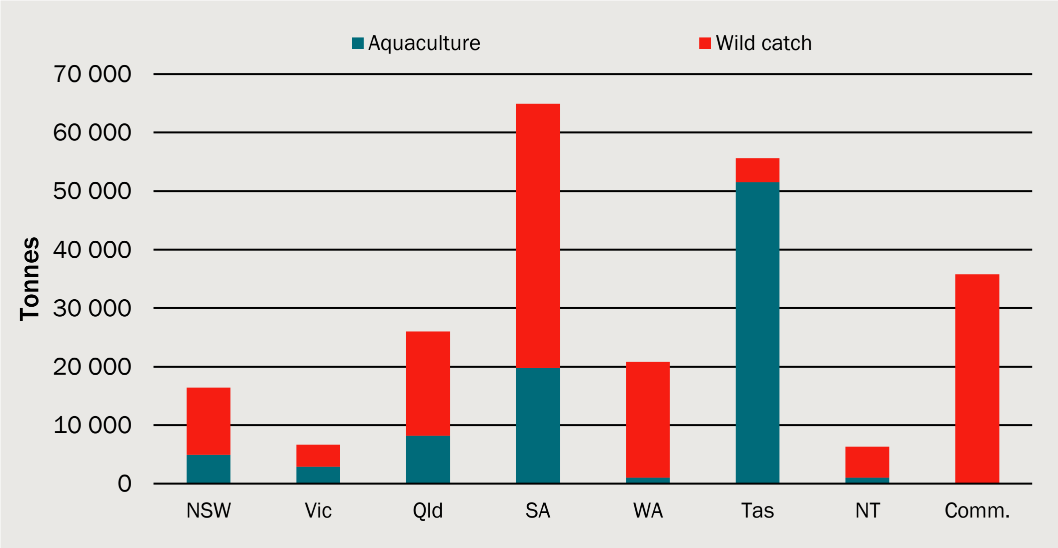
The Australian fisheries and aquaculture industry has operations in each state and territory (except for the ACT) as well as within Commonwealth waters. Reporting on fishery catch quantity and economic value is provided by the Australian Bureau of Agricultural and Resource Economics and Sciences and is split into wild catch and aquaculture quantities for targeted species in each state and territory and wild catch caught in Commonwealth managed fisheries (there are no aquaculture operations within Commonwealth fisheries).[68] According to ABARES (2016), the industry consists of approximately 76 wild catch fisheries and 43 aquaculture operations targeting over 140 different marine species. Wild-catch fisheries contribute the largest quantities in all states except Victoria and Tasmania. In Tasmania, up to 93% of the total fisheries catch is from aquaculture with the majority of this coming specifically from sea cages in the salmon industry. The mix of aquaculture and wild catch for each jurisdiction is presented in Chart 11.1

As part of our investigations into waste from the fisheries industry it was necessary to group each species into likely taxonomic groups as well as the main method used in fishery systems. Targeted species were grouped according to whether they were fish, crustaceans, molluscs or "other" and then into fishery types. Table 11.2 summarises the

[68] Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) (2016) Australian fisheries and aquaculture statistics 2015, Canberra, December

fishery methods used in our analysis and provides a description and example of the types of species targeted.

11.1 Tonnes caught in aquaculture and wild-catch fisheries, 2014-15



Data source: Blue Environment.

11.2 Wild-catch and aquaculture fishery type groups

Method	Description
Aquaculture	
Land-based ponds/dams	Closed system of fish rearing, usually for freshwater species[69]. Example target: barramundi, prawns.
Longlines	Suspended horizontal rope lines run for about 100 to 200 metres in length which support a large number of 5 metre ropes which allow mussels to attach and grow.[69] Example target: mussel.
Rack tray and stick	Racks and trays are placed in natural open waterway systems and stocked with filter feeder species.[69] Example target: oyster.
Recirculation flow through systems	Closed system of fish rearing with water recirculation technology implemented which cycles water through filtration processes and returns it back into the aquaculture system.[69] Example target: warm water fish, eel.
Sea cages	Buoyant enclosures are placed in natural waterways and are anchored to the sea floor.[69] Example target: salmon, tuna.
Wild catch	
Diving	Species being collected by diving are hand-picked, taken off structures or dug out by hand.[70] Example target: abalone.

69 GoodFishBadFish (2017) Aquaculture Methods, available from: http://goodfishbadfish.com.au/?page_id=33

70 Australian Fisheries Management Authority (AFMA) (2017a) Fishing gear, available from: http://www.afma.gov.au/portfolio-item/harvesters/

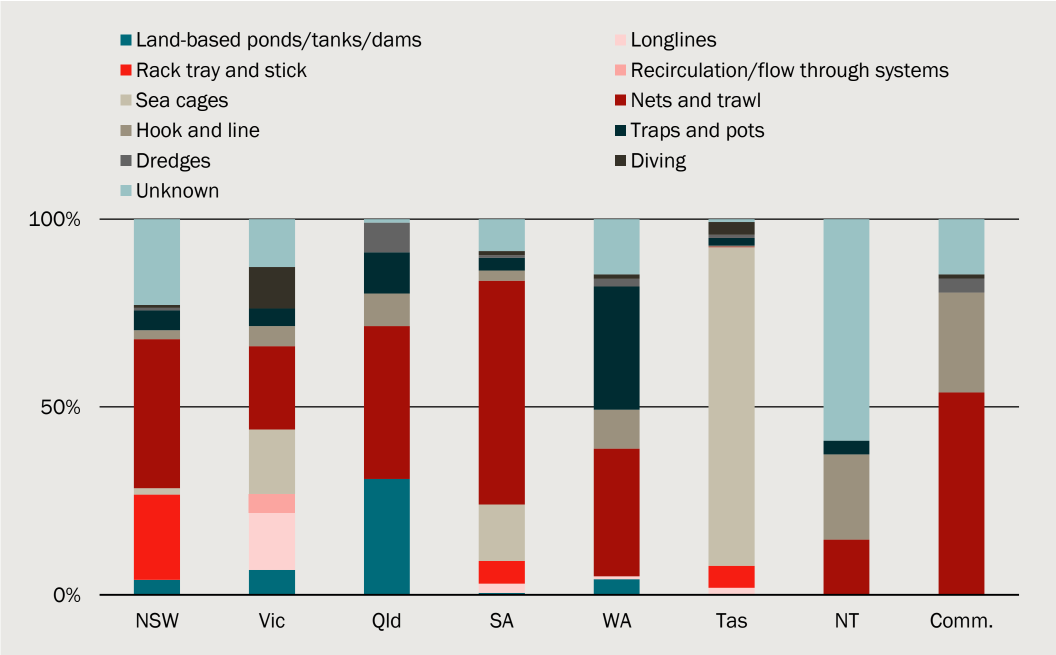
Method	Description
Dredges	A heavy steel frame, covered with steel mesh, is towed along the sea floor collecting species living in or on the sand and mud.[70] Example target: scallop, pipi.
Hooks and lines	Hooks and lines are set with a main anchor at one and a float at the other. Each hook is connected to the main line via a short "snood" and are left to soak. The number of hooks can vary depending on fishery and operation from hundreds to thousands[70]. Example target: tuna, snapper, squid.
Nets and trawls	Includes Danish seine, gillnets, purse seine, mesh net, bottom trawl and midwater trawl. All involve a net either dragged behind a boat manipulated to trap fish against shorelines or with the current[70]. Example target: prawn, sardine.
Traps and pots	Weighted to sit on the sea floor and are designed in a way so that targeted species cannot escape once inside the trap[70]. Example target: crab, rock lobster.

It should be noted that, for a single species, a range of fisheries methods may be used in different jurisdictions or even within the same fishery location. As a result, we have grouped species according to the most common fishery method noted in literature according to ABARES (2016) and FRDC (2016).[68] [71] A number of fisheries were also classed as "other" in the ABARES (2016) data, usually for confidentiality or data issues associated with specific fisheries. These catch figures were not assigned a catch method and are therefore not included in waste generation estimates. The "other" fisheries makes up approximately 12% of the total fisheries catch by weight.

Chart 11.3 presents the proportion of catch represented by the fishery methods as defined above. Most jurisdiction use some form of net and trawl for wild-catch fisheries, the largest proportion for which is in South Australia. The largest single use for any particular method across all jurisdictions is for sea cages in Tasmania which makes up 85% of all fishery methods for the state.

[71] Fisheries Research & Development Corporation (2016) Jurisdiction, available from: http://fish.gov.au/Jurisdiction

11.3 Proportion of catch from grouped fishery methods, 2014-15



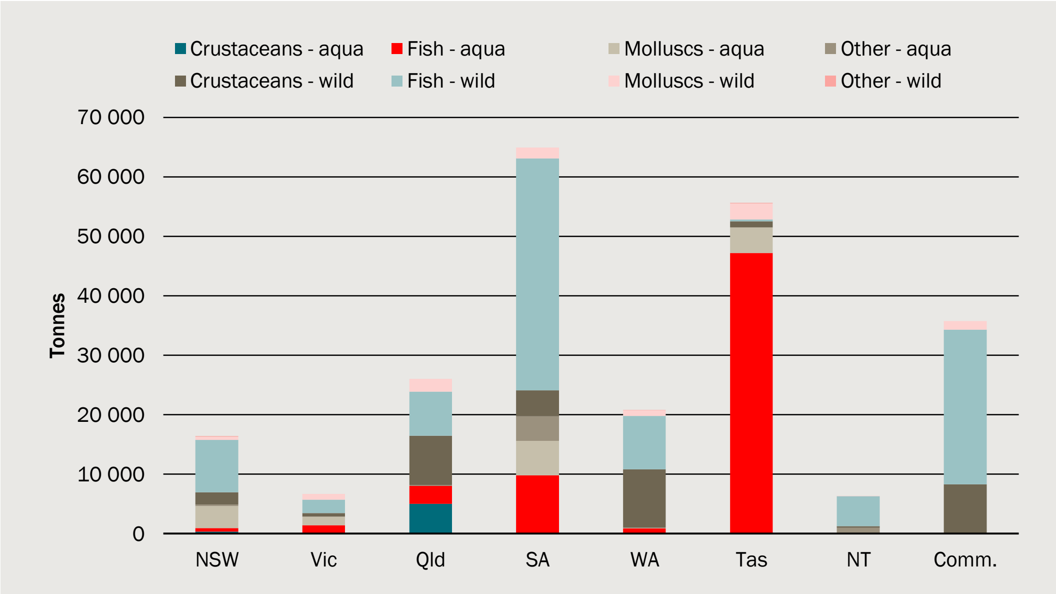
Data source: Blue Environment.

Catch quantity and value

ABARES (2016) estimate that approximately 240,700 tonnes of fishery product were captured by the fisheries industry in 2014-15.[68] Of this, 151,400 tonnes were from wild-catch fishers with 109,600 tonnes of this coming from jurisdictional wild-catch fisheries and the remaining from Commonwealth wild-catch fisheries (41,900). The aquaculture sector produced around 89,200 tonnes. The total value of the industry was estimated to be $2.8 million, with 58% of this coming from wild-catch and 42% from aquaculture.

The largest jurisdictional producer of fishery catch is South Australia (64,900 tonnes) followed by Tasmania (55,600 tonnes) and the combined Commonwealth (41,900 tonnes) fisheries, each contributing approximately $468,000, $825,000 and $350,000 in economic value respectively. 11.4 shows the tonnage output from each state and territory by species and fishery type.

11.4 Tonnes of catch by species and fishery type, 2014-15



Data source: Blue Environment.

Sources of waste

The fisheries industry was examined to determine the main points in the supply chain where waste is likely to be generated. These were assessed as waste generated:

- prior to harvesting (applicable to aquaculture but not wild-catch fisheries);
- as discards from by-catch;
- from processing of whole organism catch;
- from end-of-life (EoL) vessels;
- from operational waste arisings on vessels;
- from fishery equipment and gear.

We attempted to estimate the quantity of waste arising at each of these generation points as well the pathways that waste takes to disposal, recovery or recycling.

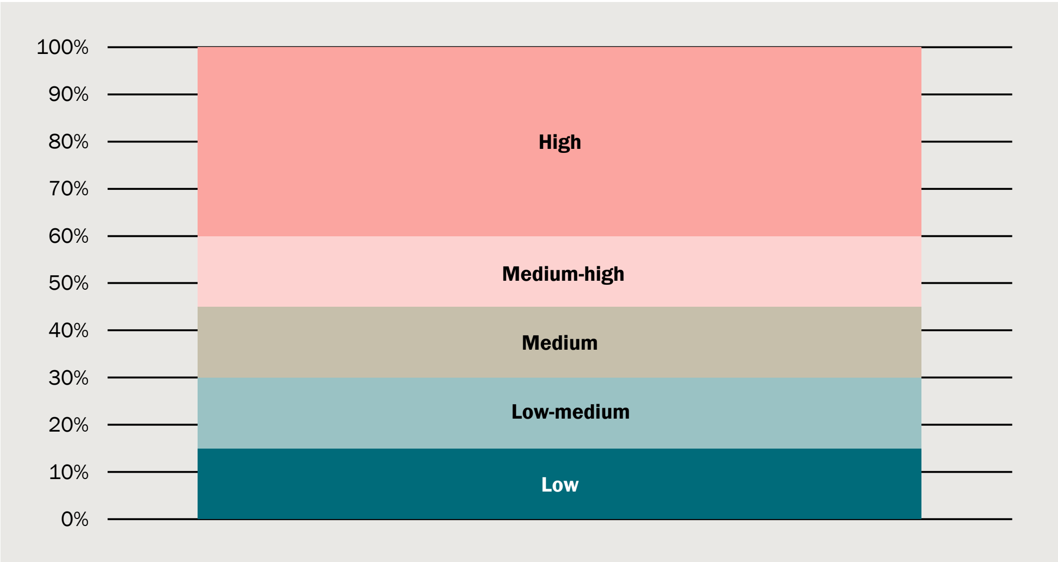
Method for estimating quantity of waste

Due to the number of fisheries and the complex nature of fisheries management and waste generation, an in-depth examination of the waste generated from each fishery was not possible. From preliminary research, it was evident that waste generation can vary significantly among species, mainly based on fishery method but also geography (for example, fisheries in different states that target the same species may have differing proportions of discarded by-catch). Additionally, detailed waste generation information for each species is difficult to find or, in most cases, is non-existent. As a result, we used two methods to estimate waste from different sources in the industry, split by fish/organic waste and vessel and equipment waste.

Fish and organic waste

We conducted a high-level assessment of waste generation based on fishery method, using example species/fisheries as indicators within each of the first three waste generation categories identified above. As part of our assessment we estimated waste quantities based on fishery method tonnage production and an estimate of waste generation from low to high within each category. Chart 11.5 shows the waste generation categories and range of values that apply to each. Information was sourced from peer-reviewed scientific journals, jurisdictional and Commonwealth Government reports and websites, industry reviews/reports and major industry players. Research was first targeted towards information specific to species and fisheries in Australia. Where this was not available, comparable international research and information was used to provide an estimate of waste generation.

11.5 Waste generation categories



Data source: Blue Environment.

Vessel and equipment waste

Waste estimates associated with fishery vessels and equipment were based on either the number of vessels or the number of employees in Australian fisheries, both of which are available by jurisdiction from ABARES (2016).[68] Using these figures, we applied estimates of per unit waste generation or used primary research to estimate the waste generated. Research was first targeted towards information specific to species and fisheries in Australia. Where this was not available, comparable international research and information was used to provide an estimate of waste generation.

A detailed description of waste generation estimates from each source is provided below.

Waste prior to harvest

In aquaculture fisheries, waste prior to harvesting originates from uneaten feed, waste excretions, organism mortalities and wastewater treatment. Aquaculture is often conducted to produce a high concentration of large individuals in a relatively small or confined space. The resulting increase in waste load can have a detrimental impact on the environment. In wild-catch systems, waste prior to harvest is considered to be part of natural ecosystem functions. Table 11.6 provides an estimate of waste generation prior to harvest for aquaculture fisheries. Waste generation is considered to be in addition to the total catch recorded in ABARES (2016) data, calculated as a proportion of the total catch from each fishery type.[68]

For aquaculture fisheries based in natural estuaries we have assumed that the entirety of waste production is deposited in the natural environment, none of which would be captured in national waste data. Land based pond and recirculation systems treat wastewater to remove waste products. The pathway for this waste is likely to be recovery via land application (75%) with the remaining disposal of waste to landfill. It is assumed that 50% of material to land application, and all waste to landfill, is captured in national waste data.

Waste during harvest/landing (by-catch and discards)

The Australian Fisheries Management Authority defines by-catch as “Species that physically interact with fishing vessels and/or fishing gear and are not usually kept by commercial fishers” and discards as “Any part of the catch which is returned to the sea, dead or alive”.[72] By-catch arises when non-target organisms are captured in fishery catch equipment (e.g. nets). It includes target species which cannot be kept because they are undersize or where trip catch limits apply, as well as other non-target organisms including sharks, rays, turtles and birds. By-catch is highly variable and the frequency and quantity is dependent on the fishery target species, the fishery method employed and the geographic location of operations.

By-catch is expected from most wild-catch fisheries and from aquaculture fisheries which are set in estuaries. Some fisheries are much more selective in their catch methods and reduce by-catch and discards to nil. For example, the diving method of fishing (targeting abalone or rock lobster) is conducted by hand, meaning catch can be identified and assessed prior to removal. Other fisheries have developed by-catch avoidance equipment which allow non-target or undersized species to avoid capture. The development of by-catch avoidance equipment is the subject of worldwide research and approved methods are often implemented across entire fisheries where possible. Table 11.7 provides an estimate of the expected rate of by-catch and discards from wild catch and aquaculture fisheries. Waste generation is considered to be in addition to the total catch recorded in ABARES (2016) data, calculated as a proportion of the total catch from each fishery type.[68]

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[72] Australian Fisheries Management Authority (AFMA) (2017b) Bycatch and discarding, available from: http://www.afma.gov.au/sustainability-environment/bycatch-discarding/

The pathways for all fishery by-catch and discards are likely to be to the surrounding environment, none of which would be captured in national waste reporting. This is due to the fact that the majority by-catch is identified at the point of harvest/landing and would be dealt with on individual vessels. The use of by-catch for fish feed or bait is not considered to be a waste product.

Waste during processing

According to Ghaly et al (2013) approximately 70% of fishery catch is processed before final sale.[73] This means that 30% of catch is sold as whole product and so is not considered in waste generation estimates from fishery processing. The processing required for fishery product is highly dependent on the biology of each species and the degree of processing can be influenced by supermarket or consumer demand.

Generally, processing of fish involves stunning, grading, slime removal, de-heading, washing, scaling, gutting, cutting of fins, meat and bone separation and filleting.[73] Significant quantities of waste are generated from this process. Table 2.2 provides an estimate of the waste generated from fish processing. In estimating waste generation from fishery catch processing, we have used an example species that represents each fishery type. Waste generation is considered to be a proportion of the total catch recorded in ABARES (2016) data.[68] In our calculations, we have used the 70% figure noted above to estimate the proportion of fishery catch that is sent for processing, multiplied by the waste generation proportions estimated below.

There are a number of recovery options available for fish processing waste, including:[74] [75]

- processing into aquaculture or pet feed;
- extraction of oils, lipids, antioxidants, flavours or pigments;
- used directly as fertilizer, fish bait, animal feed or as an input to compost or energy recovery.

Little data is available regarding the use of these recovery options in Australia. As a result, we have applied the assumption that 80% of processing waste is recovered and 20% sent for landfill disposal. Of the waste that is recovered, we have assumed that 10% would be captured in national waste data (the majority of recovery/reprocessing would occur at the same location as fish processing). All waste material landfilled would be captured in national waste data.

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[73] Ghaly AE, Ramakrishnan VV, Brooks MS, Budge SM and Dave D (2013) Fish Processing Wastes as a Potential Source of Proteins, Amino Acids and Oils: A Critical Review, Journal of Microbial and Biochemical Technology, 5:4

[74] Asian Institute of Technology (AIT) (2007) Seafood Processing, available from: http://www.fpeac.org/seafood/industrialwasteabatement-seafood.pdf

[75] Queensland Government (2010) Reusing solid waste and product recovery – R3, available from: http://www.ecoefficiency.com.au/Portals/56/factsheets/foodprocess/waste/ecofoodwaste_fsr3.pdf

11.6 Factors for waste generation prior to fishery harvest

Fishery method	Estimated generation	Evidence	Waste pathway
Aquaculture			
Land-based ponds/dams	Low-medium	Prawn: "...survivals of 55–91 percent..."[76], "...a further 70-80 percent survival rate is achieved in this stage..."[77]	Recovery - land application, landfill disposal
Longlines	Low	Mussel: waste excretions	Surrounding environment
Rack tray and stick	Low	Oyster: waste excretions	Surrounding environment
Recirculation flow through systems	Low	Fish: "Investigations by the Alabama Fish Farming Centre suggest that annual mortality of catfish in ponds is about 10 to 20% [76]	Recovery - land application, landfill disposal
Sea cages	Low-medium	Salmon: "4,000 tonnes of fish requires 5,400 tonnes of feed. Of food fed, around 20% will be waste (LGTF). 12% is waste, 1% not eaten food, 13% waste [77]	Surrounding environment

76 Food and Agriculture Organization of the United Nations (FAO) (2017a) Cultured Aquatic Species Information Programme Penaeus vannamei, available from: http://www.fao.org/fishery/culturedspecies/Penaeus_vannamei/en

77 Food and Agriculture Organization of the United Nations (FAO) (2017b) Cultured Aquatic Species Information Programme Penaeus monodon, available from: http://www.fao.org/fishery/culturedspecies/Penaeus_monodon/en

11.7 Factors for waste generation from fishery by-catch and discards

Fishery method	Estimated generation	Evidence	Waste pathway
Aquaculture			
Land-based ponds/dams	Nil		
Longlines	Low-medium	Mussel: "Biofouling has emerged as the main bottleneck to production in the mussel farming industry. For example, since 2003, mussel production has declined by approximately 70% in Victoria."[78]	Surrounding environment
Rack tray and stick	Low-medium	Oyster: "Biofouling has emerged as the main bottleneck to production in the mussel farming industry. For example, since 2003, mussel production has declined by approximately 70% in Victoria."	Surrounding environment
Recirculation flow through systems	Nil		
Sea cages	Nil	Salmon: "Since these cages are closed off and do not contain nets, they do not produce any bycatch."[79]	
Wild catch			
Diving	Nil	Rock Lobster: "Rock Lobster pots are generally considered to be a benign fishing method that targets particular species and size ranges, while allowing for release of by-catch and by-product in good condition."[80]	
Dredges	Low-medium	Scallop: "The U.S. Atlantic sea scallop fishery catches several bottom-living fish species such as monkfish, flounders, and skates, undersized scallops, and sometimes loggerhead sea turtles. The bycatch can be 10-30% of the total catch."[81]	Surrounding environment
Hooks and lines	Low	Fish: "...a by-catch study for the commercial sector indicated that the targeting of Snapper with either handlines or longlines resulted in relatively low levels of discards which primarily involved under-sized Snapper and some non-commercial species. Most non-commercial by-catch species were discarded in good condition, however the under-sized Snapper were often in poor condition, suffering from barotrauma."	Surrounding environment

78 Fisheries Research & Development Corporation (FRDC) (2014) Tackling a critical industry bottleneck: developing methods to avoid, prevent & treat biofouling in mussel farms, available from: http://frdc.com.au/research/Final_reports/2010-202-DLD.pdf

79 Nissly C (2017) Deep sea aquaculture cage farming, available from: https://prezi.com/3i4xgysmet6f/deep-sea-aquaculture-cage-farming/

80 Primary Industries and Resources SA (PIRSA) (2015) Status of South Australian Fisheries Report: Fisheries snapshot for 2012-13, available from: http://www.pir.sa.gov.au/__data/assets/pdf_file/0020/262028/SAFS_Status_Report_v7.pdf

81 Brown E (2016a) Fishing Gear 101: Dredges – The Bottom Scrapers, available from: http://safinacenter.org/2015/05/fishing-gear-101-dredges-the-bottom-scrapers/

11.8 Factors for waste generation from fish processing

Fishery method	Estimated generation	Evidence	Waste type	Waste pathway
Aquaculture				
Land-based ponds/dams	Medium-high	Prawn: "Yield of meat from whole shrimp is variously quoted as ranging from 20 to 45 per cent."[82]	Head, shell	Recovery, landfill disposal
Longlines	High	Mussel: "For example, a New Zealand Green Lipped Mussel (Perna canaliculus) has about a 55% meat to shell ratio… a Blue Mussel (Mytilus edulis) has a 25% meat to shell ratio, with it much heavier shell."[83]	Shell	Recovery, landfill disposal
Rack tray and stick	High	Oyster: "We can roughly estimate that the shell's weight is close to 90% of the total weight in C. gigas…"[84]	Shell	Recovery, landfill disposal
Recirculation flow through systems	Medium-high	Fish: "During the processing of fish generally only the fillets are retained while the bulk of product (up to 66%) is discarded."[85], "About 70% of the fish is processed before final sale."[73]	Head, skin, bones, fins, viscera	Recovery, landfill disposal
Sea cages	Low-medium	"Salmon: 26% processing waste, average of five different species"[86], "About 70% of the fish is processed before final sale."	Head, skin, bones, fins, viscera	Recovery, landfill disposal
Wild catch				
Diving	High	Abalone: "The waste generated from one black-lip abalone is 67%."[87]	Shell, viscera	Recovery, landfill disposal

82 Food and Agriculture Organization of the United Nations (FAO) (2001a) Handling and Processing Shrimp, available from: http://www.fao.org/wairdocs/tan/x5931e/x5931e01.htm

83 Saito, G (2012) How much edible meat does a pound of molluscs yield?, available from: https://www.quora.com/How-much-edible-meat-does-a-pound-of-mollusks-yield

84 Mori, K (2014) Recycling of waste oyster shells: Production of clean and bactericidal drinking water, available from: http://www.fftc.agnet.org/library.php?func=view&style=volumes&id=20140325103938&type_id=87

85 Knuckey L, Sinclair C, Aravind A and Ashcroft W (2014) Utilisation of seafood processing waste – challenges and opportunities, in Proceedings of the 3rd Australian New Zealand Soils Conference, Sydney, December, available from: http://www.regional.org.au/au/asssi/supersoil2004/s7/oral/1662_knuckeyi.htm

86 Food and Agriculture Organization of the United Nations (FAO) (2013) Prospects for Fisheries and Aquaculture, available from: http://www.fao.org/docrep/019/i3640e/i3640e.pdf

87 Queensland Bioprocessing Technonolgy (2004) Use of abalone processing waste, available from https://www.google.com.au/patents/EP1444266A1?cl=en

Fishery method	Estimated generation	Evidence	Waste type	Waste pathway
Dredges	High	Scallop: "The yield of edible flesh in scallops varies from 10 to 16 per cent of the weight in shell."[88]	Shell	Recovery, landfill disposal
Hooks and lines	Medium-high	Fish: "During the processing of fish generally only the fillets are retained while the bulk of product (up to 66%) is discarded."	Head, skin, bones, fins, viscera	Recovery, landfill disposal
Nets and trawls	Medium-high	Fish: "During the processing of fish generally only the fillets are retained while the bulk of product (up to 66%) is discarded."	Head, skin, bones, fins, viscera	Recovery, landfill disposal
Traps and pots	Medium-high	Crab: "...meat accounts for only around 40% of a crab's mass." [89]	Shell, viscera	Recovery, landfill disposal

88 Food and Agriculture Organization of the United Nations (FAO) (2001b) Catching and Processing Scallops and Queens, available from: http://www.fao.org/wairdocs/tan/x5923e/x5923e01.htm

89 Yan N and Chen X (2015) Sustainability: Don't waste seafood waste, Nature, 524:7564

End-of-life vessels

Waste from EoL vessels was estimated as:

- the number of fishery vessels in Australia, estimated to be approximately 8,330. This was derived from ABARES (2016) data for:[68]
  - the number of “vessels”, “licences”, "shareholding" or "entitlement" for all Australian fisheries, each of which was assumed to be assigned to a single vessel;
  - the number of fisheries likely to use a vessel;
- the expected life of a fishery vessel, estimated to be 30 years as noted by Watanabe and Tahara (2016).[90] It was assumed that vessel age is spread evenly among the entire fishery fleet (for example, 100 boats are 1 year old, 100 boats are 2 years old, etc). This means that approximately 280 vessels reach their EoL per year;
- the average weight of a fishery vessel, estimated from FAO (2017c) for a range of different vessel types.[91] A minimum and maximum weight was established as 25 and 100 tonnes respectively. This means that between 6,900 and 27,800 tonnes of material, in the form of EoL vessels, is generated as waste per year;
- the vessel material composition of the fishery fleet.[92] This was based on assumed values for main material types used in vessel building for recyclable/reusable (wood, steel and aluminium) and non-recyclable (fibreglass) materials.

Our final estimate of waste from EoL vessel ranged from 6,900 to 27,800 tonnes of waste material. We estimated that between 550 and 2,200 tonnes of this is reused (for replacement parts/material), between 2,150 and 8,600 tonnes is recycled and between 4,200 and 16,900 tonnes is sent to landfill. It is assumed that all materials sent to recycling or landfill are be captured in national waste data while materials that are reused would not be captured.

Estimates for waste from each jurisdiction are derived based on the total estimate of EoL vessel waste generation multiplied by the proportion of vessels from each jurisdiction to the total number of vessels.

Vessel operational waste

Waste from vessel operations was estimated according to:

- the number of equivalent full-time employees (EFTEs) as sourced from ABARES (2016). [68] EFTEs were estimated to be 6,240 in wild-catch fisheries and 6,210 in aquaculture, 12,450 in total;

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[90] Watanabe K and Tahara K (2016) Life Cycle Inventory Analysis for a Small-Scale Trawl Fishery in Sendai Bay, Japan, Sustainability, 8:399

[91] Food and Agriculture Organization of the United Nations (FAO) (2017c) Search Technology Fact Sheets, available from: http://www.fao.org/fishery/vesseltype/search/en

[92] Food and Agriculture Organization of the United Nations (FAO) (1991) Fishing boat construction: 2 Building a fibreglass fishing boat, available from: http://www.fao.org/docrep/003/T0530E/T0530E00.htm#TOC

- waste generation per EFTE. Data derived from EMSA (2017) provided per unit waste generation rates for oily bilge wastewater, sewage, plastic, food and domestic waste.[93] Figures were provided in m3 per person per day or m3 per boat per day and were translated into kg/person or boat per day using standard waste density conversion factors.

Our total estimate of solid waste generation from vessel operations is approximately 7,290 tonnes per year. Wastewaters, such as oily bilge wastewater and sewage were not included in estimates because these would not be included in national waste data. Based on the waste type and likely treatment pathway, we estimated that 7,300 tonnes were sent to landfill. All waste generated would already be captured by current national waste data systems.

There is likely to be other waste generated through the operation of fishery vessels, such as waste generated from antibiofouling paint removal and replacement, however it is considered that this waste would be managed through established disposal pathways and as a result captured in national data systems.

Fishery equipment and gear waste

Waste from fishery equipment and gear was estimated based on data from EMSA (2017) which noted that "The waste estimated per tonne of fish farmed or captured in Norway is 1 kg plastic from fishing nets and trawl equipment per tonne of output production and 11 kg plastic waste from aquaculture per tonne of output."[93] Using these figures and data for tonnes of catch from each fishery type, we estimated the waste generation from fishery equipment and gear to be 1,100 tonnes per year (±25%, 820-1,360 tonnes).

Little data was available on the pathways of this waste. As a result, we have assumed that 50% of this waste is lost during fishery operations (550 tonnes per year) to the environment and the remainder is sent to landfill. All waste lost to the environment would not be captured in national waste data.

Estimated waste quantities

The total waste generated by the fisheries industry was estimated to be between 101,000 and 177,800 tonnes in 2014-15. Table 11.9 shows the estimated total waste generated from the source sectors identified above. The largest sector of waste generation is from the processing of fish. Chart 11.10 shows that this contributes 50% to total waste generation, followed by waste generated during harvest/landing (by-catch and discards, 19%) and waste from EoL vessels (13%).

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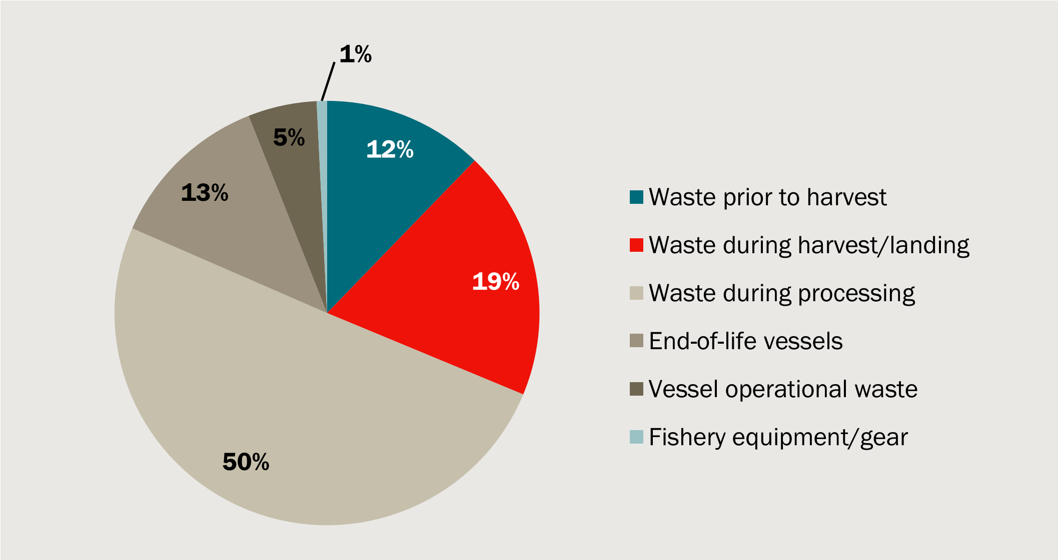
[93] European Maritime Safety Agency (EMSA) (2017) The Management of Ship-Generated Waste On-board Ships, available from: http://www.emsa.europa.eu/news-a-press-centre/external-news/item/2925-the-management-of-ship-generated-waste-on-board-ships.html

11.9 Total waste generation by waste source (tonnes), 2014-15

Waste generation point	Description	Waste estimate (tonnes)	
		Minimum	Maximum
Fish waste			
Prior to harvest	Fish waste, dead fish	11 160	22 920
During harvest/ catch	Bycatch and discards	16 970	36 370
Processing	Offal, shells, frames	57 740	82 410
Vessel and equipment waste			
EoL vessels	Boats	6 940	27 770
Operational vessel	General waste, food	7 290	7 290
Equipment/gear	Nets, lines, traps	820	1 360
Total		**101 000**	**177 800**

11.10 Total waste generation by source (proportion of average tonnes), 2014-15



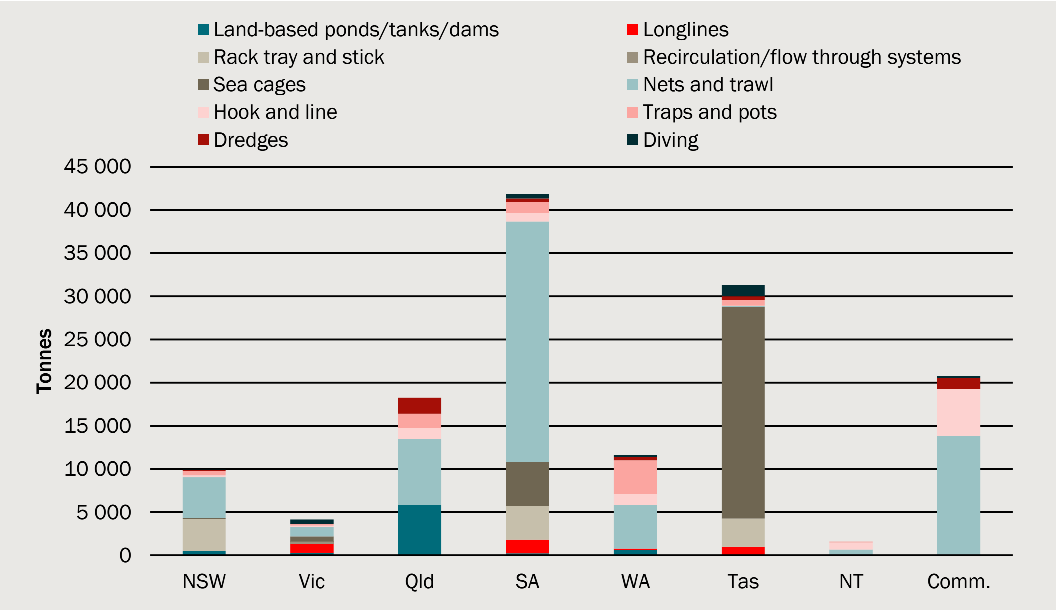
Data source: Blue Environment.

From the different fishery types identified, the ‘nets and trawl’ fishery of the wild caught sector is the largest generator of waste (between 46,600 and 75,200 tonnes). This is followed by waste generation from ‘sea cages’ in the aquaculture sector (between 20,330 and 40,350 tonnes) as shown in Table 11.11. Chart 11.12 shows that most jurisdictions have ‘net and trawl’ fisheries, with the most waste from this fishery type generated in South Australia. Conversely, few jurisdictions have ‘sea cage’ aquaculture, with the majority of waste generation from this sector originating from Tasmania.

11.11 Total waste generation by fishery type (tonnes), 2014-15

Waste generation point	Description	Waste estimate (tonnes)	
		Minimum	Maximum
Aquaculture			
Land-based ponds/tanks/dams		5 800	9 380
Longlines		2 490	4 900
Rack tray and stick		7 320	14 470
Recirculation/flow through systems		190	300
Sea cages		20 320	40 350
Wild catch			
Nets and trawl		47 120	75 200
Hook and line		7 190	13 260
Traps and pots		4 280	10 700
Dredges		3 190	5 680
Diving		2 050	3 580
Total		**101 000**	**177 800**

11.12 Total waste generation by fishery type and location (tonnes), 2014-15



Data source: Blue Environment.

The amount of waste estimated to be additional to current national waste data is provided for each jurisdiction in table 11.13 along with the type of waste and its disposal/management pathway. From this table, it is evident that large quantities of organic waste are generated but not captured in current reporting. The largest pathway for organic waste is recovery following fish processing which includes the processing of offal, shells, frames and unmarketable fish into usable products such as aquaculture feed, pet feed, oils, flavourants or pigments, or the use of whole fish as fertilizer, fish bait, animal feed or input to composting processes. The majority of tonnes generated from these sources are likely to be hidden from waste data collection systems due to the fact that much of the reprocessing of waste would take place at the same location as the processing of whole organisms and so may be considered as a product rather than a waste when leaving the plant.

Disposal of organic waste to the environment is the next largest generation point. This includes uneaten fish food, waste secretions and organism mortalities from aquaculture as well as the disposal of by-catch as discards from both wild catch and aquaculture fisheries. The capture of this data is likely to be near impossible due to the nature and unpredictability of by-catch and discard mortalities.

11.13 Additional waste quantities by fishery location, type and management pathway (tonnes), 2014-15

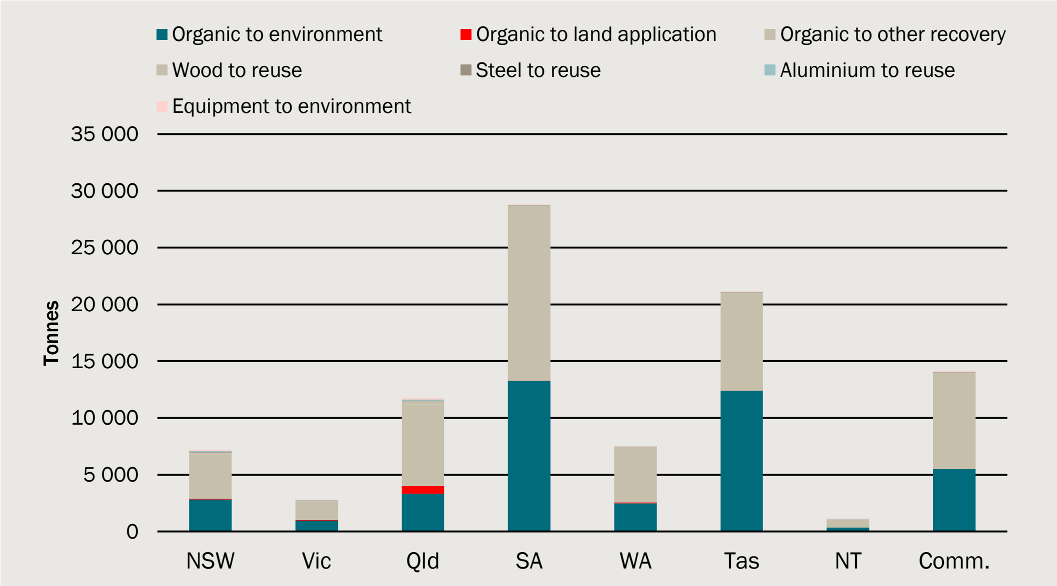
Waste type	Pathway	Fishery location																	
		NSW		Vic		Qld		SA		WA		Tas		NT		Commonwealth		Total	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Organic	Environment	1 740	3 920	590	1 330	2 070	4 560	8 800	17 730	1 310	3 650	8 360	16 420	160	530	3 390	7 610	26 460	55 770
	Land application	40	80	50	90	480	910	20	40	60	100	10	10	0	0	0	0	640	1 210
	Recovery	3 200	4 580	1 310	1 940	6 130	8 210	12 800	17 830	4 190	5 540	6 170	10 890	590	790	7 200	9 580	41 570	59 340
Wood	Reuse	70	300	30	110	110	430	30	120	10	60	40	150	10	40	50	190	350	1 390
Steel	Reuse	10	60	10	20	20	90	10	20	0	10	10	30	0	10	10	40	70	280
Aluminium	Reuse	30	120	10	40	40	170	10	50	10	20	10	60	0	10	20	80	140	560
Equipment	Environment	90	150	30	50	130	210	30	60	20	30	40	70	10	20	60	90	410	680
Total		**5 180**	**9 210**	**2 030**	**3 580**	**8 980**	**14 580**	**21 700**	**35 850**	**5 600**	**9 410**	**14 640**	**27 630**	**770**	**1 400**	**10 730**	**17 590**	**69 640**	**119 230**

Data source: Blue Environment.

Chart 11.14 presents the estimated average (of minimum and maximum estimates) for additional waste quantities by fishery location, type and management pathway. South Australia, followed by Tasmania and Commonwealth fisheries, generates the largest quantity of waste. Again, for all jurisdictions, additional waste tonnages are dominated by organic waste to the environment and organic waste to other recovery.

Chart 11.15 highlights the proportion of waste generation that is likely to be captured in current reporting systems by fishery location. The estimated lowest proportion of captured data is in Tasmania, followed by South Australia and Queensland. The highest proportion is captured in the Northern Territory; however, they have the lowest total catch for all jurisdictions.

11.14 Average additional waste quantities by fishery location, type and management pathway (tonnes), 2014-15



Data source: Blue Environment.

11.15 Estimated proportion of fisheries waste included (or not) in national data (proportion of average tonnes), 2014-15

Data source: Blue Environment.

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Zero Waste SA 2015, *South Australia's Recycling Activity Survey: 2013-14 Financial Year Report*, February, available at https://www.google.com.au/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwi0h8qalNbVAhVLTLwKHZTBDssQFggtMAA&url=http%3A%2F%2Fwww.greenindustries.sa.gov.au%2F_literature_165427%2FRecycling_Activity_in_South_Australia_2013-14&usg=AFQjCNEB-yF3NpnZF-fyEEPqKBXCvGoUSw

A Waste related products, sectors and activities

The following table provide a list of the likely waste products, services and activities that could be included in the waste industry. The products and/or sectors are classified according to the Input-Output Product Classification (IOPC) system. The IOPC is consistent with the ANZSIC, with the first two digits in IOPC being the same as the two-digit sub-division in ANZSIC. The products/sectors are identified in the table according to the significance of the waste-related activity in the products/sectors' whole economic activities in the following way:

- ww – the ANZSIC Sub-division D29;
- w – all of the products/sectors classified in other industries should be included in the waste industry;
- wp – part of the products/sectors classified in other industries should be included in the waste industry; and
- pp – a very small proportion of the products/sectors classified in other industries should be included in the waste industry.

A.1 Economic activities related to waste management

included in the waste industry?	IOPC	IOPC Description
pp	05210010	Cotton (ginned); cotton seed, waste from cotton and cotton ginning services
w	11991970	Scrap waste from the manufacture of food and food products (1111-1199)
w	12141970	Scrap waste from the manufacture of beverages (incl. alcohol) (1211-1214)
w	12201970	Scrap waste from the manufacture of tobacco products (1220)
w	13131970	Scrap waste from the manufacture of textiles (1311-1313)
w	13201970	Scrap waste from the manufacture of dressed fur and leather products (1320)
w	13341970	Scrap waste from the manufacture of textile products (1331-1334)
w	13401970	Scrap waste from the manufacture of knitted products (1340)
w	13511970	Scrap waste from the manufacture of clothing (1351)
w	13521970	Scrap waste from the manufacture of footwear (1352)
w	14991970	Scrap waste from the manufacture of wood product manufacturing (1411-1499)
w	15291970	Scrap waste from manufacture of pulp and paper product manufacturing (1510-1529)
w	16201970	Scrap waste from the printing trade and media reproduction services (1611-1620)

included in the waste industry?	IOPC	IOPC Description
w	17091970	Scrap waste from the manufacture of Petroleum and Coal products (1701-1709)
wp	18210080	Plastics in primary forms, mixed/compounded with other substances; regranulated, single thermoplastic scrap material
w	18321970	Scrap waste from the manufacture of basic chemicals (1811-1832)
w	18411970	Scrap waste from the manufacture of pharmaceutical goods for human use (1841)
w	18421970	Scrap waste from the manufacture of pharmaceutical goods for veterinary use (1842)
w	18521970	Scrap waste from the manufacture of cleaning compounds and toiletry preparations (1851 -1852)
w	18991970	Scrap waste from the manufacture of other basic chemical products (1891-1899)
w	19191970	Scrap waste from the manufacture of polymer products (1911-1919)
w	19201970	Scrap waste from the manufacture of natural rubber products (1920)
w	20901970	Scrap waste from the manufacture of non-metallic mineral products (2010-2090)
w	21221970	Scrap waste from the manufacture of iron and steel (incl slag, dross, sealings) (2110-2122)
w	21320020	Aluminium secondary recovery from purchased scrap
w	21321970	Aluminium scrap from the manufacture of alumina, aluminium and aluminium alloys (2131-2132)
wp	21330010	Silver primary and secondary recovery (excl from purchased scrap)
wp	21330020	Copper (including brass) primary and secondary recovery (excl from purchased scrap)
wp	21330030	Lead primary and secondary recovery (excl from purchased scrap)
wp	21330040	Zinc primary and secondary recovery (excl from purchased scrap)
w	21330050	Silver, copper (including brass), lead and zinc recovery from purchased scrap
wp	21330070	Sulphuric acid from the smelting of copper, silver, lead and zinc.
wp	21390010	Platinum primary and secondary recovery (excl from purchased scrap)
w	21390020	Nickel and tin primary recovery and secondary recovery from drosses, ashes or other waste materials (excl from purchased scrap)
w	21390030	Nickel and tin recovery from purchased scrap
wp	21390040	Gold - primary and secondary (excl from purchased scrap)
wp	21390050	Antimony and other non-ferrous basic metals nec primary and secondary recovery
w	21390060	Basic precious metals (excl silver) secondary recovery from purchased scrap
w	21391970	Scrap waste from the smelting and refining of non-ferrous metals (incl precious) (2133-2139)
w	21491970	Scrap waste from the manufacture of non-ferrous metal products (incl precious) (2141-2149)
w	22101970	Scrap waste from the manufacture of forged iron and steel products (2210)

included in the waste industry?	IOPC	IOPC Description
w	22291970	Scrap waste from the manufacture of structural metal products (2221-2229)
w	22401970	Scrap waste from the manufacture of sheet metal products (2231-2240)
w	23991970	Scrap waste from the manufacture of transport equipment (2311-2399)
ww	29000010	Waste collection (incl skip and portable toilet hire), treatment disposal remediation and materials recovery services
ww	29221980	General government consumption of fixed capital (2911-2922)
wp	75000010	Government administration and regulatory services

Note: ww – ANZSIC waste industry; w – products/sectors should be included in the waste industry; wp – part of the products/sectors should be included in the waste industry; pp – a small part of the products/sectors should be included in the waste industry

Source: CIE construction

B CIE-REGIONS model

CIE-REGIONS model is a general equilibrium model of the Australian economy. It was developed by the Centre for International Economics based on the publicly available MMRF-NRA model developed by the Centre of Policy Studies for the Productivity Commission.[94]

Some of the key aspects that make this model especially suited for this task are that it:

- uses the latest input-output table;
- provides a detailed account of industry activity, investment, imports, exports, changes in prices, employment, household spending and savings and many other factors:
  – this version of the CIE-REGION model identifies 59 industries and commodities with the waste industry being separately identified (table B.1);
- includes a newly developed waste module linking waste generation to economic activities of industries, governments and households;
- accounts for Australia's six states and two territories as distinct regions:
  – accounts for differing economic fundamentals in the states and territories;
  – state and territory results can be further disaggregated down to statistical division (SD) level;
- includes specific details about the budgetary revenues and expenditures of each of the eight state and territory governments and the Australian Government (the government finances in CIE-REGIONS align as closely as practicable to the ABS government finance data):
  – specifically accounts for major taxes including land taxes, payroll taxes, stamp duties and others at the state level, as well as income taxes, tariffs, excise, the GST and other taxes at the federal level (table B.2);
  – traces out the impact of transfers between governments;
- can be run in a static or dynamic mode. The dynamic version allows analysis to trace impacts over time as the economy adjusts, being particularly useful over the medium to longer terms.

The CIE has used CIE-REGIONS to analyse the impacts of a wide range of policy issues, including state tax reform, proposed reform options on accelerated depreciation, energy policy and climate change policy measures, international trade agreements, government R&D policy, local infrastructure development, and industrial development

94 Productivity Commission 2006, *Potential Benefits of the National Reform Agenda*, Report to the Council of Australian Governments, available at http://www.pc.gov.au/research/commissionresearch/nationalreformagenda

strategies, as well as projections of agriculture, mining and energy industries and greenhouse gas emissions.

B.1 CIE-REGIONS industries/commodities and margin services

Industries/commodities			
1	Livestock	31	Electricity generation – other
2	Crops	32	Electricity supply
3	Forestry	33	Gas supply
4	Fishing	34	Water supply
5	Coal	35	Construction
6	Oil	36	Wholesale trade
7	Gas	37	Retail trade
8	Iron ore	38	Mechanical repairs
9	Other metal ores	39	Accommodation and food services
10	Other mining	40	Road passenger transport
11	Food, drink and tobacco	41	Road freight transport
12	Textiles, clothing and footwear	42	Rail passenger transport
13	Wood products	43	Rail freight transport
14	Paper products	44	Pipelines
15	Printing and publishing	45	Ports
16	Petroleum products	46	Transport services
17	Chemicals	47	Water freight transport
18	Rubber and plastic products	48	Ship charter
19	Other non-metal construction materials	49	Air passenger transport
20	Cement	50	Air freight transport
21	Iron and steel	51	Communication services
22	Other metals	52	Finance
23	Metal products	53	Business services
24	Transport equipment	54	Dwellings
25	Other equipment	55	Government administration and defence
26	Other manufacturing	56	Education
27	Electricity generation – coal	57	Health
28	Electricity generation – gas	58	Other services
29	Electricity generation – oil	59	Waste management
30	Electricity generation – hydro		

Source: CIE-REGIONS database.

B.2 Federal and state taxes

Federal taxes	State, territory and local government taxes
Good and service tax (GST)	Payroll tax
Sales taxes	Land tax
Excises and levies	Municipal rates
Labour income tax	Fire surcharges
Company income tax	Stamp duties on - insurance - financials - motor vehicle - residential property - non-residential property - non-residential non-real estate
Non-residents income tax	
Import duties	
Export taxes	

Source: CIE-REGIONS database.

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