Sustainable Built Environment National Research Centre AUSTRALIA

The capacity of existing end markets in Australian jurisdictions

Research Report 2

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SBEnrc P1.75 Creation and Stimulation of End-Markets for Construction and Demolition Waste

Date: February 2021

ACKNOWLEDGEMENTS

This research has been developed with funding and support provided by Australia's Sustainable Built Environment National Research Centre (SBEnrc) and its partners.

Core Members of SBEnrc include BGC Australia, Government of Western Australia, Queensland Government, Curtin University, Griffith University and RMIT University.

Core Partners: This research would not have been possible without the ongoing support of our core industry, government, and research partners:

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Citation: Maqsood, T., Shooshtarian, S., Wong, P., Khalfan M., Yang R. (2021) The capacity of existing end markets in Australian jurisdictions. SBEnrc 1.75 - Creation and Stimulation of End-Markets for Construction and Demolition Waste. https://sbenrc.com.au/research-programs/1-75/

EXECUTIVE SUMMARY

In the 2018 National Waste Policy Strategy 14 (market development and research), it is recommended that all Australian governments and businesses generate and report information to support creating and maintaining markets for recycled materials. Drawing on this recommendation, this report explores the capacity of existing end markets in Australian jurisdictions and provides strategies to stimulate and create markets for recycled C&D waste materials. This report complements the findings in Report No. 1 (Objective 1. Review and identify jurisdictional regulations/specifications/guidelines/standards affecting the development and operation of end-markets for C&D waste streams)[1]. In total, more than 120 documents and reports were reviewed to shed light on the market capacity of recycled C&D waste products across Australian states and territories. For each jurisdiction, specific recommendations were made to assist public organisations to develop and stimulate end markets for recycled C&D waste materials. The review findings show that market development activities significantly differ in various states and territories. Hence, a national effort towards sustainable end-market development and stimulation is urgently required.

Furthermore, the report investigated the major barriers to transition towards a circular economy and several strategies to overcome these barriers are suggested accordingly.

The major barriers include:

- Increase in energy and transport costs
- Limited knowledge of recycled products
- Limited technologies for waste recovery
- Low quality and reduce performance
- Lack of market availability of the products
- Limitations caused by specifications, standard and permits
- Limited acceptability and negative perception.

For each of these barriers, relevant mitigation strategies were recommended as below:

- Increase community awareness and education on recycled products
- Develop supportive regulations, policies and specifications
- Facilitate sustainability programs
- Promote product certification
- Advocate targeted technologies and innovative practice.

[1]Maqsood, T., Shooshtarian, S., Wong, P., Khalfan M., Yang R. 2021. Review and identify jurisdictional regulations/ specifications/ guidelines/standards affecting the development and operation of end-markets for C&D waste streams. SBEnrc 1.75 - A National Economic Approach to Improved Management of Construction and Demolition Waste. https://sbenrc.com.au/research-programs/1-75/

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List of abbreviations

Abbreviation	Extended word
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
C&D waste	Construction and Demolition waste
C&I waste	Commercial and Industrial waste
CE	Circular Economy
EfW	Energy from Waste
EPA	Environmental Protection Authority
GISA	Green Industries SA
IPWEA	Institute of Public Works Engineering Australasia
kt	Kilo tonne
MRF	Material Recycling Facility
MSW	Municipal Solid
Mt	Million tonnes
NSW	New South Wales
NT	Northern Territory
NWP	National Waste Policy
Qld	Queensland
RCA	Recycled Concrete Aggregate
RCG	Recovered Crushed Glass
RPA	Reclaimed Pavement Asphalt
SA	South Australia
SV	Sustainability Victoria
t	Tonne
Tas	Tasmania
Vic	Victoria
WA	Western Australia

1. Introduction

1.1. Overview

Within the Australian context, the circular economy of waste has five principles, the third of which is to 'increase the use of recycled material and build demand and markets for recycled products'; that is, market development. In the Australian National Waste Policy, Strategy 14 places emphasis on market development and research. Estimations, based on the current solid waste generation rates in Australia, project that Australian recycling capacity must increase by 400% by 2040 to address the issue of solid waste in the future. Furthermore, the influence of China's new waste policy and anti-waste movements in other countries, including Thailand, Malaysia and the Philippines urgently necessitates the development of domestic market capacity in Australia.

Construction and demolition (C&D) waste is the largest source of waste in Australia. The latest records[2] show that the annual quantity of waste produced in eight states and territories of Australia is about 27 mt, which is followed by commercial and industrial (C&I: 21.9 mt) and municipal solid waste (MSW: 12.6 mt). Management of such a quantity within Australia requires the adoption of a circular economy approach that is underpinned by resource efficiency and waste recovery enhancement. Market development is believed to be a sustainable option that ideally engages all stakeholders who have a role to play in the construction materials supply chain and their lifecycle extended beyond their end-of-life.

1.2. Research scope and objective

This report aims to achieve the second objective of Project 1.75 (Creation and stimulation of end-markets for construction and demolition waste). The project investigates the factors that impact the operation of the existing market for recycled C&D waste resources and development. The second objective covers the capacity of existing end-markets in Australian jurisdictions and how the existing markets can be stimulated, and new end-markets created for sustainable management of C&D waste.

1.3. Report structure

The report structure comprises 14 sections: Section 1 presents a background to the research and briefly provides the C&D waste market development in Australia; Section 2 provides the methodology used, and Sections 3 to 11 review waste management conditions as well as existing market situations and provide state-specific recommendations to create and stimulate the market for C&D waste materials. In Section 12, barriers to achieving sustainable end-markets are discussed, followed by details on the strategies to remove these barriers (Section 13). Lastly, the concluding remarks to this project are presented.

[2]Blue Environment. National waste report 2020. Retrieved from https://bit.ly/3pnRE5D

2. Methodology

2.1. Overview

The operation of end markets for C&D waste materials is subject to multiple factors. This report, therefore, focuses on the major factors identified as having an impact on the creation and stimulation end-markets for the C&D waste stream. As waste regulation occurs at the state and territory level, the research methodology is designed to individually analyse market conditions across the Australian jurisdictions. In order to define the study scope, five case materials were selected for detailed market analysis. These five materials are concrete, brick, steel, glass and asphalt. The materials were selected from a list of different construction materials by the project industry and government partners using five criteria, the embodied energy, embodied water, embodied greenhouse gas emission, the rate of annual waste and whether the material is considered a priority resource in each state and territory.

2.2. Data collection and processing

A desktop literature review was employed to capture information regarding the operation of existing markets and the development of new markets for recycled C&D waste in Australian states and territories. The document analysis involved reviewing government and industry reports, research publications, industry magazine articles and articles published through online news agencies. To reflect the status quo of market development in Australia, only recent information that was released after 2016 was considered. In total, 121 unique references were used to shape this report.

Waste data were primarily extracted from the latest national waste dataset that was released in late 2020. This dataset includes aggregated and individual waste data both nationally and jurisdictionally and indicates the waste fates (e.g. disposal, recycling and energy from waste recovery). However, in this dataset, the quantity of each waste material generated in states and territories is not specified. Hence, we assume that the total waste generated is equal to the sum of the quantity of waste recycled and landfilled. Furthermore, the recommendations provided for the stimulation of the existing end-markets in each state and territory were primarily based on the experts' views published in different reports and the issues identified for market development in the states and territories.

2.3. Limitations

There were a few limitations that presented challenges in data collection. Below is a selection of these limitations, plus the strategies used to minimise their impact on the study's quality:

Firstly, In the absences of primary data, this report is confined to secondary data that is publicly available. Some of the resources were outdated and might not reflect the current market conditions. Furthermore, due to using desktop research, resources found were not necessarily consistent in terms of the methodology applied. Therefore, a degree of information disparity is to be expected. That said, care was taken to ensure that the most recent studies, reports and resources that were also consistent are used where available. Secondly, the information sensitivity of construction and resource recovery centres hindered the collection of data pertaining to the estimation of market size and strength for the priority materials. For instance, as the market is highly competitive, recycling facilities, suppliers and those who are involved in trading recycled C&D waste products do not tend to reveal their price list on their webpages, and the final price is typically determined after reviewing order size, transport distance and other available quotes. To this end, price averaging was applied to all prices obtained from various available resources to ensure a true reflection of the market for different recycled products under study.

Thirdly, the availability of waste data in the smaller states and territories (e.g., NT) was another barrier. While it is possible that there is a market for recycled C&D waste materials in these regions, the lack of documented information impedes our ability to capture market operation in these areas. To minimise the impact of this, the public authorities responsible for waste management in these

states and territories were contacted, a strategy that did not always result in the required information being acquired. Lastly, there is a caveat regarding the use of the national waste dataset; it does not provide complete data for the waste fates of the priority case materials in each category and territory. Therefore, where available, supplementary data were sought from jurisdictional reports and datasets.

3. Analysis of Existing C&D waste End markets: Australia

3.1. Overview

This section of the report presents an analysis of the capacity of existing C&D waste end markets in Australia. The analyses are based on C&D waste statistics, the economics of C&D waste, and existing markets for recycled C&D waste resources.

3.2. C&D waste data

The C&D waste stream is the largest source of waste in Australia. The quantity of waste materials generated in the C&D waste stream has increased since 2016[2]. The latest data shows that in the fiscal year of 2018-19 about 22.7 mt of C&D waste was generated (Figure 1), which was the largest contributor to the total solid waste (91.7%) in Australia.

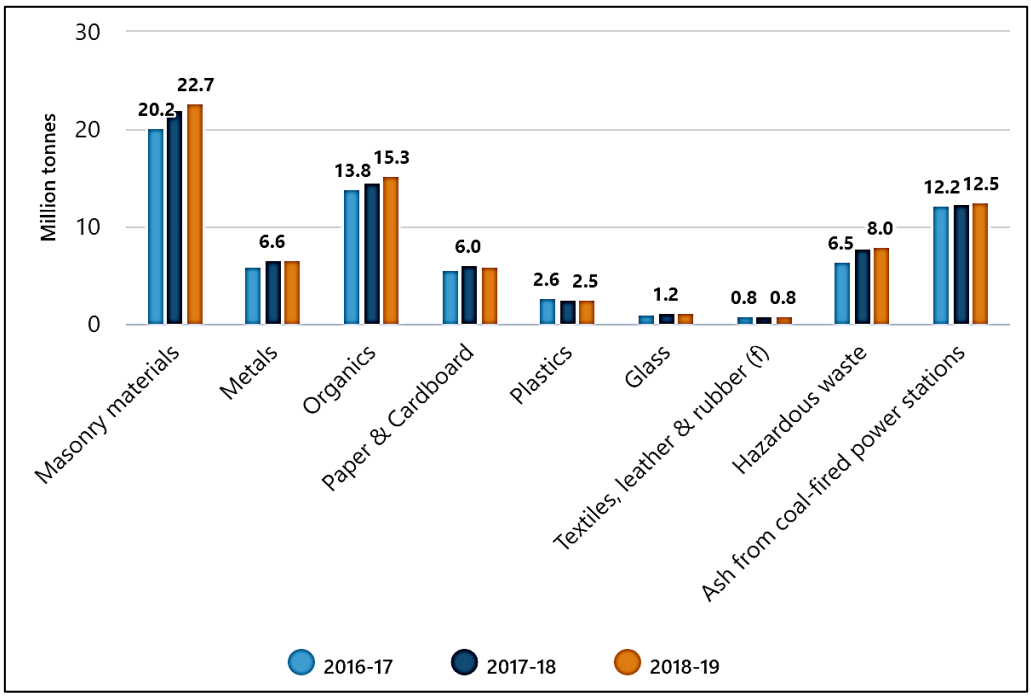

Figure 1. Waste generation by waste material in Australia (2016-2019)
Source: ABS (2020)

In 2018-19, the construction and manufacturing industries generated the largest quantity of waste (12.8 mt) followed by electricity, gas and water & waste services (12.3 mt). The waste quantity has increased by 23% (Figure 2).

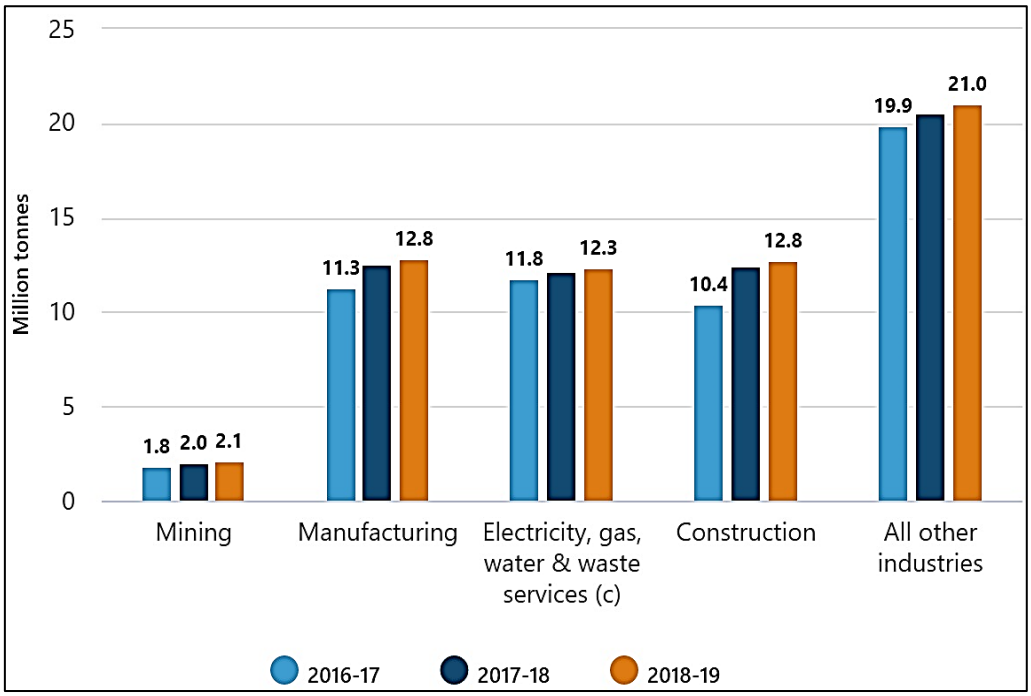

Figure 2. The waste generation by industry in Australia (2016-2019)
Source: ABS (2020)[3]

In terms of waste recovery activities, the C&D waste materials ranked first among other waste streams (Figure 3). In the fiscal year of 2018-19, more than 81% of the C&D waste was recovered throughout Australia, followed by metals, and the paper and cardboard category (66.9%). During the same time, Australia exported 6% of the total waste generated in the country.

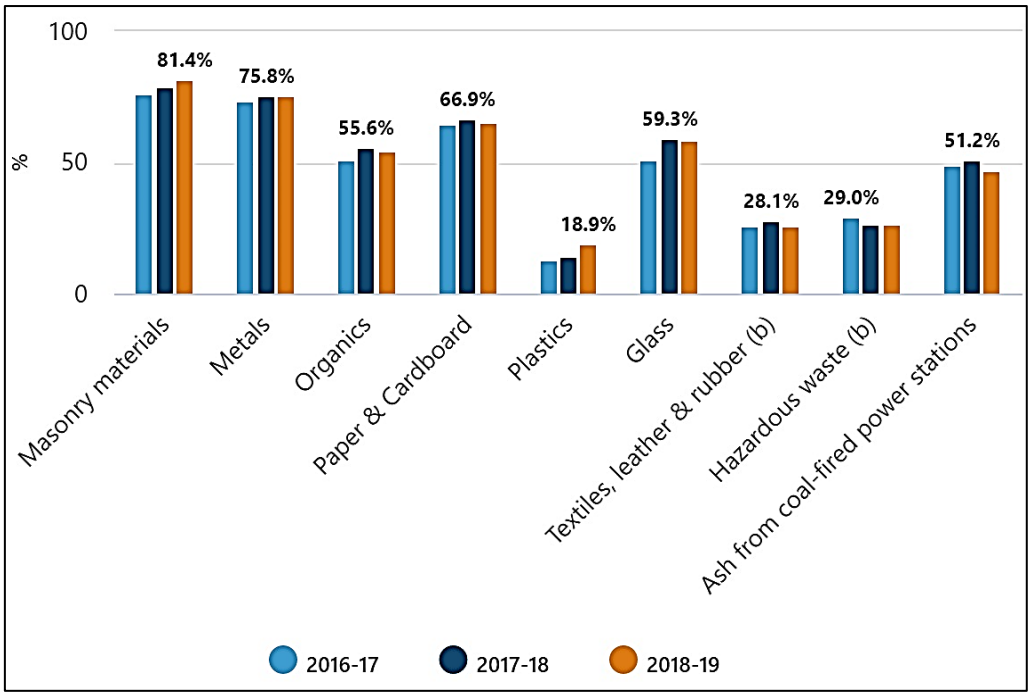

Figure 3. The waste recovery rate for various waste streams
Source: ABS (2020)[3]

[3]Australian Bureau of Statistics. 2020. Waste Account, Australia, Experimental Estimates. Retrieved from https://bit.ly/3ppc7r1

3.3. The economy of C&D waste

The waste management and resource recovery sector contributes to 0.3% of Australia's GDP. In 2019, 36,000 jobs were recorded in this sector, which has increased 16% from 2016. The sector has contributed 4,866 million to the economy. ABS (2020) Reported that among various sectors, the construction industry had spent $2 billion on waste collection, treatment, and disposal services. These expenditures are calculated through the indicator of waste intensity, which quantifies the amount of waste generated per million dollars of value-added to the economy (Figure 4). This indicator for the construction industry is 87 tonnes per million dollars. These figures suggest the large magnitude of the C&D waste economy and the potential for the development of domestic markets.

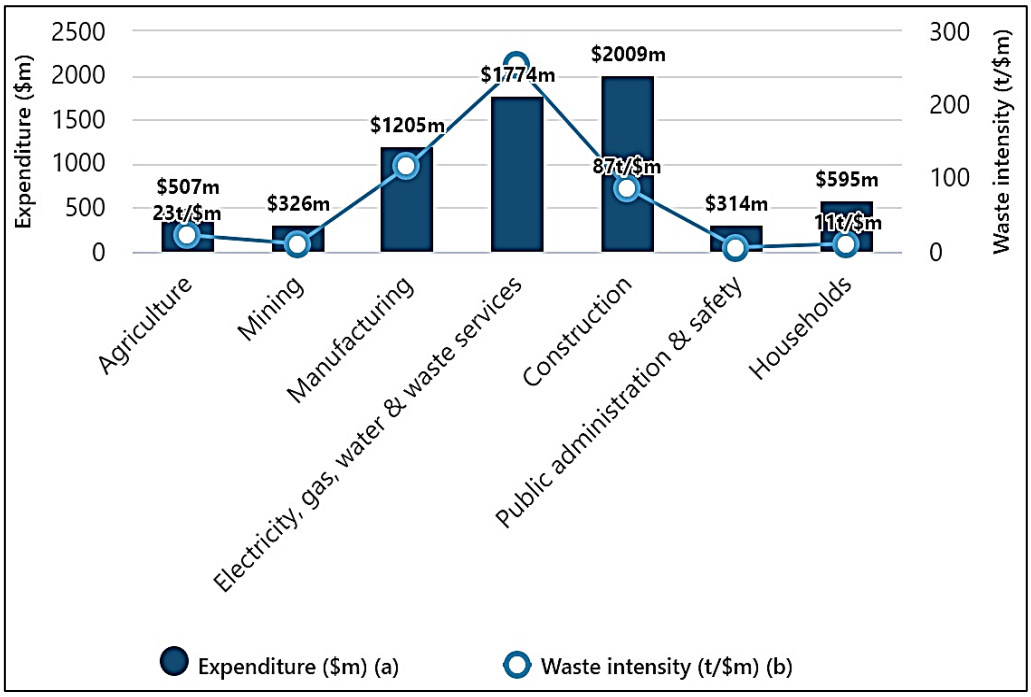

Figure 4. Expenditure on waste services
Source: ABS (2020)[3]

3.4. The market for recycled C&D waste

Market development activities for C&D waste significantly vary across the Australian states and territories. However, most Australian jurisdictions have now acknowledged the significance of a circular economy in the construction industry and sought to transition to non-linear construction material end-of-life management. In some states such as Vic, WA and NSW, large public infrastructure projects have unlocked the potential of using recycled C&D waste in construction projects and present an opportunity to develop sustainable end-markets for these materials. The following review of market conditions in each state and territory will provide an insight into the main factors affecting local market creation and stimulation, and can be used to establish a national platform to facilitate C&D waste trading across Australia.

4. Analysis of Existing C&D waste End markets: Australian Capital Territory

4.1. Overview

The Australian Capital Territory (ACT) has a population of 400,000 residents living in about 145,000 households and is one of the fastest-growing regions in Australia. This territory is one of the leading jurisdictions in waste management, with about 70% of waste being reused and recycled[4]. In 1996, the ACT was the first jurisdiction in the world to employ a 'No Waste' strategy; this important initiative promoted the idea of consideration of waste as a resource between 1996 and 2000. Governance and regulation of C&D waste in the ACT is performed by the Environmental Protection Authority (EPA) and Transport Canberra and the City Services Directorate. In 2018, the ACT government set a 95% target to recover C&D waste in this territory. The rate of waste generation has a linear relationship with construction activities. Since 2014, the value of the construction industry in the ACT has surged, and the total value of work done has reached AUD $766, 681 in 2020[5] (Figure 5), approximating a more than 36% increase from that figure recorded in 2014.

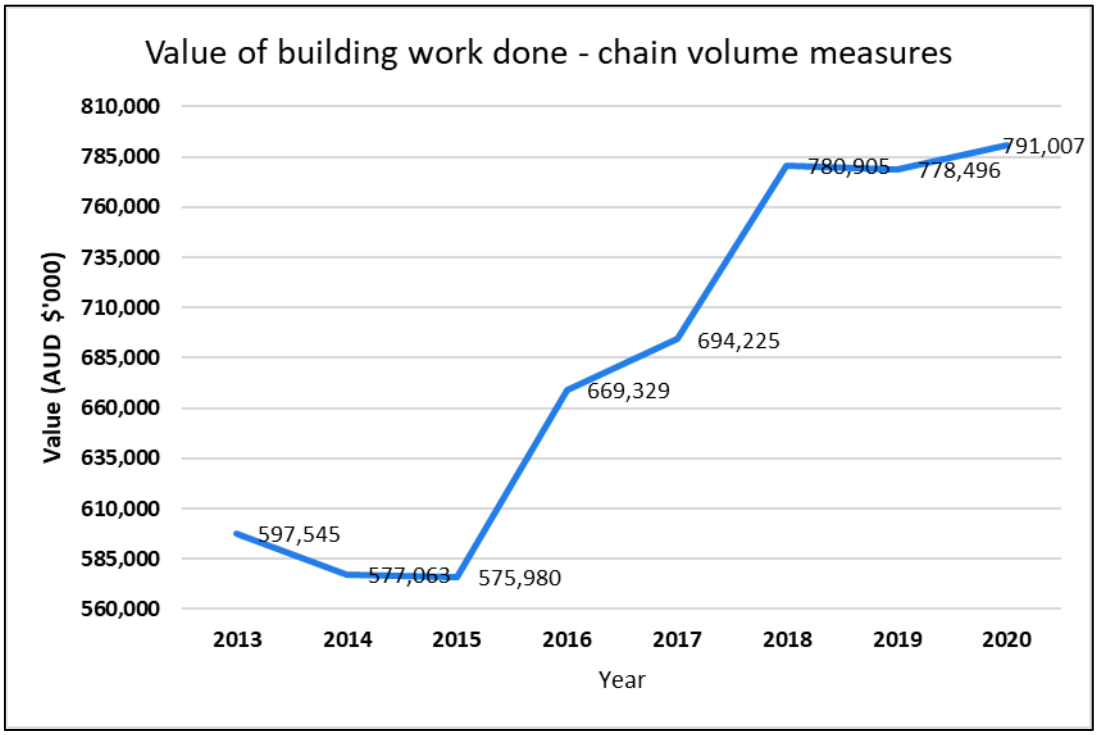

Figure 5. The value of construction activities in the ACT between 2013 and 2020 (until Sep)
Source: ABS (2020)[5]

This section of the report presents data relevant to the waste management of five priority construction materials, an overview of the existing markets, the conditions of material recovery facilities (MRFs), some case studies of using recycled products in construction projects, the extent of government support, and recommendations to enhance market operation across the territory.

[4] Meegan Fitzharris MLA. 2017. Waste and recycling industry in Australia- Submission 20: ACT Government's response
[5]ABS. 2020. Building Activity, Australia. https://bit.ly/3pdAokx

4.2. C&D waste data

The latest report commissioned by the Department of Agriculture, Water and the Environment[2] showed a growth in the overall rate of ACT waste generation, which was less than that in population growth. The territory government had set a target of 90% resource recovery by 2025[6], which later increased to 95%.

Table 1. Priority C&D waste materials statistics in the ACT

Material	Waste generation (t)	Disposal (t)	Recycling (t)
Brick[a]	0	0	25,098
Concrete	116, 646	1,177	115,469
Asphalt	12,009	0	12,009
Steel *	0	0	0
Glass *	8	8	0

Source: 2020 National Waste Database
a recycling figure is for the total waste stream
*numbers are for C&D waste stream only.

It is worth noting that there is a significant waste exchange between ACT and NSW. For instance, about 562 kt of Queanbeyan (NSW) disposable C&D waste was sent to the ACT for re-landfilling; at the same time, C&D waste that was originally generated in the ACT was shipped to NSW because it is a shorter distance than to ACT facilities and offers disposal in non-levy landfills[7]. In 2018, the Waste Management Review[8] reported that the NSW EPA has partnered with police, the ACT Government and local councils to target rogue operators supplying waste soil from construction sites advertised as clean fill to innocent property owners. Compliance and roadside checks were part of the crackdown to ensure fill going to a site had the appropriate council approval to accept it.

4.3. Existing markets

The market for certain C&D waste materials such as concrete, brick, steel and glass are well-established in the ACT. Table 2 provides a summary of the conditions of the market for the case study C&D waste materials in the ACT. The information is sourced from the existing literature and secondary data available publicly. Conversely, the market for EfW recovery (extraction and combustion of methane gas) has been diminished due to the change in the government policy following public concerns about the pollution associated with the operation of EfW facilities, notably West Belconnen Resource Management Centres and Mugga Land Landfills[9]. Currently, the BusinessRecycling platform[10] provides critical information on C&D waste recyclers in the Capital Region.

[6]Australian Government. National waste Policy Action Plan. 2019. https://bit.ly/2TtBTiy
[7] Wu, H., Zuo, J., Yuan, H., Zillante, G. and Wang, J., 2020. Cross-regional mobility of construction and demolition waste in Australia: An exploratory study. *Resources, Conservation and Recycling*, 156, p.104710.
[8] Waste Management Review. 2018.NSW Crackdown Targets Illegal Waste Transporters. https://bit.ly/3vYbB6k
[9] ACT NoWaste. 2018. Waste feasibility study: Discussion paper. Prepared for the ACT Government
[10] Planet ARK. 2020. BusinessRecycling. Retrieved from https://businessrecycling.com.au/>.

Table 2. The market for case study materials

Material	Types/Application	Description	End-users
Brick	Brick dust, crushed brick and whole brick. The whole brick is cleaned and reused; crushed brick is used as a raw material for brick production, generate fill, drainage, road pavement.	The market for this material is quite strong in the ACT. Brick and tiles are the second-highest recycled product in the Capital Region.	The main clients are private builders, civil and infrastructure contractors and landscaping suppliers
Concrete	Major concrete based products include crushed concrete, crushed dust, aggregated, sub-base. Crushed concrete is used as a substitute for virgin aggregates (e.g. limestone, rock and gravel).	Concrete recycling involves the utilisation of crushing machinery that crushes concrete into various sizes. There is a strong market within the Capital Region for recycled concrete for road base and fill and for drainage lines as aggregate. Traditionally, the demand for recycled concrete in civil, commercial and residential activities outweighs its supply generated from construction activities.	The main end-users include private building contractors, civil and infrastructure contractors and wholesale landscape suppliers
Asphalt	Asphalt millings	There is a well-established recycling process and the market for asphalt in the ACT.	
Steel	Steel scrap, rebar, and stainless steel	There is a mature market for ferrous metals, including steel, in the ACT. Builders, skip operators and demolition contractors separate steel from waste mix-loads. Hence, there is a high level of recycling of steel in the Capital Region. The approximate figure for buying steel waste by recyclers is $250; along with the cost-saving associated with avoiding landfill levy fees, this induces strong economic incentive for steel recycling, and hence the market is quite viable for this material. This waste source is the third most recycled product in the Capital Region.	Scrap metal merchants are the main clients for recycled steel

Source: Canberra Business Chamber (2014)[11].

[11] Canberra Business Chamber 2014. Building and construction waste materials: Reduce, Reuse and Recycle-Opportunities and strategies for the Capital region. Canberra Sustainability Special Interest Group

4.4. Material recovery facilities

A 2017 report[4] on the ACT waste management system indicated that the increased waste landfill levy has resulted in a massive diversion of C&D waste materials (>80%) to Material Recovery Facilities (MRFs). Since 2004, the ACT recovered 65-74% of this waste stream. This report also specified that on-site waste separation by construction companies could reduce the cost charged at MRFs from $130/tonne to $20/tonnes.

The ACT government has ruled out energy from waste (EfW) from the available waste management options for this territory in favour of the territory's climate change direction objectives. In the ACT, from 2020, the new MRFs that intend to engage in EfW extraction activities are prohibited from incineration, gasification, pyrolysis or variations of these for energy recovery[12]. This policy limits the market availability for combustible C&D waste such as timber. It also includes:

- Evaluation of the operation of existing recycling facilities
- Evaluation of issues impacting recycling facilities
- Identifying strategies to overcome these issues.

Canberra Concrete Recyclers Pty Ltd[13] is an active recycler that accepts a wide range of C&D waste in the Capital Region. This company structures its operation costs based on the mix of the load it receives at the weighbridge. Table 2 exemplifies the charges associated with C&D waste acceptance at a recycling facility based in the ACT and provides cost information for a range of recycled products. The figures in the table show that gate fees at recycling facilities are way cheaper than landfilling fees, which are currently sitting at $199.2 and $146.2 in metropolitan and regional areas, respectively.

Table 3. An example of the tipping fees and price list in a recycling facility in the ACT

Waste material	Tip fee ($)/t	Waste material	Tip fee ($)/t
Brick/Terracotta tiles/pipes clean	23	Concrete oversize (+600- +800), including blocks, piers, poles, beams	16-100
Clean concrete (± 400 mm)	12-14	Coloured Tiles (excl. White tiles)	23
Brick and Concrete Mix	30	Asphalt	6
Virgin excavated natural material (VNEM)	41	Demolition waste all categories	160
Products			
Asphalt subbase (20 mm)	20	Compactable fill	8
Asphalt oversize (40 mm)	18	Top soil (unspecified)	16
Road-base / sub-base -20mm DGS	16	Bricks unclean	35
Aggregate (5, 14, 20 mm)	16-29	Uncrushed screened concrete	27
Crushed concrete dust (7, 14, 20 mm)	12.5-16	Landscaping rocks	25

Source: https://www.canberraconcreterecyclers.com.au/- extracted in December 2020

[12] ACT Government. 2020. ACT Waste-to-Energy Policy 2020-25.
[13] Canberra Concrete Recyclers. 2020. Retrieved from https://www.canberraconcreterecyclers.com.au/

Table 4. An example of the tipping fees and price list in a recycling facility in the ACT

Waste material	Tip fee ($)/t	Waste material	Tip fee ($)/t
Drilling fluid	60.50	Rock	7.70
Non-clean fill	66	Clean concrete	9.90
		Contaminated concrete	110
VNEM	24.75	All metals	Nil
Asphalt	7.70	Clean brick	7.70
Mixed masonry-Terra/Ceramics/Coloured Brick (not Clean Red Brick) / Concrete / Natural Marble / Natural Granite)	22	C&D waste "A" Grade (primarily recyclable materials, i.e. timber, brick, asphalt)	132
		C&D waste "B" Grade (primarily non-recyclable materials, i.e. plastics, plywood, cardboard, fence palings)	154
Products			
Top soil (screened)	15.40	Aggregates 10-60 mm	15.40
Top soil (unscreened)	3.30		
Scalps (brick)	Free	Asphalt millings	17.60
Scalps (Dark)	11	Crushed brick: 5-7 mm 10-20 mm	 17.60 33
Concrete backing	15.40	Recycled golden mulch (m^3)	15.40
Brick dust/crusher dust	3.30	Rock	44

Source: ACT recycling. Source: https://actrecycling.com.au/ - extracted in December 2020

The full list of MRFs operating in this territory that recovers the study materials is provided in appendices.

4.5. Use of C&D waste recycled in construction projects

Below are examples of using recycled materials in construction projects in the ACT. These case studies are representative of market operation in the Capital Region.

Case study 1 - In March 2019, the ACT laid around 1,000 tonnes of asphalt containing recycled products during an ACT roads trial. The asphalt contains several waste materials including 250 kilograms of reclaimed asphalt. The ACT Government has planned to use this product in other road infrastructures. The cost of using this product is equivalent 22to that of traditional asphalt. The impact on local government budgets of not using recycled product could also contribute to higher waste disposal costs.

Case study 2- In November 2018, a recycled product called Plastiphalt, which is composed of recycled glass and soft plastics, was trialled on existing sections of Horse Park Drive and Gundaroo Drive under the 2018-19 road resurfacing program. The project was completed in April 2019.

4.6. Government

In 2020, an agreement between the federal government and ACT government was reached to deliver a major upgrade to MRF through financial support under the Government's $190m Recycling Modernisation Fund[14]. The Government committed to providing $21m to the ACT MRF. The objective

[14]Australian Government. 2020. *Joint Media Release: $21 million for better recycling for the ACT*. https://bit.ly/3ieOelg

of this fund is to better separate and process recycling streams. This fund will enhance market development and stimulation for waste materials, including C&D waste sources.

The government—in pursuit of its 95% target for C&D waste recovery—plans to deliver exemplars of waste resource recovery in the construction and operation phases of Canberran projects[8].

4.7. Recommendations

The report prepared for Canberra Business Chamber has made some recommendations to improve the C&D waste management system in the ACT; some of the recommendations are relevant to the scope of this report. Furthermore, in the National Waste Data and Reporting (cycle 2017-19) report,[15] some suggestions to improve the C&D waste market are provided. Below are the selected recommendations from these two reports:

1. Establish a website or mobile application to develop a market for exchange in the soil (the most relevant to the scope of this report).
2. Establish a regional website or mobile application to provide information about the location, opening hours and restrictions of all landfill sites.
3. Require tenders for government contractors to have criteria that favour the recycling of materials.
4. Determine and fix a standard and protocol for the collection of C&D waste data.
5. Revisiting the ACT's EfW policy to reinstate the government support for EfW activities for combustible C&D waste materials.
6. The responsible organisation should account for solar panels as an emerging issue.

[15]Blue Environment. 2019. National waste data and reporting cycle 2017-19. State and territory feedback and suggested improvements https://bit.ly/2S4cbAZ

5. Analysis of Existing C&D waste End markets: New South Wales

5.1. Overview

New South Wales is a south-eastern Australian state, distinguished by its coastal cities and national parks. It has a total area of 800,642 km² and covers 10.4% of Australia. NSW is also known to have the largest population in Australia. Based on predictions, NSW's population will reach 8.196 million by the end of June 2021[16]. The construction industry is required to provide residential builds and infrastructure to accommodate and provide urban amenities for the growing population. The construction industry, therefore, plays an important role in the state's economic profile. The industry is the fourth contributor to NSW's gross state product (GSP). Except for 2019, the value of building work done (all construction sectors and building types) in NSW (Figure 6) has steadily grown over the last few years[5] reaching $10.68 billion. NSW has commenced work on the largest infrastructure upgrade program in Australia. The state government has committed to spending $80 billion on new economic infrastructure over the next four years from 2020[17].

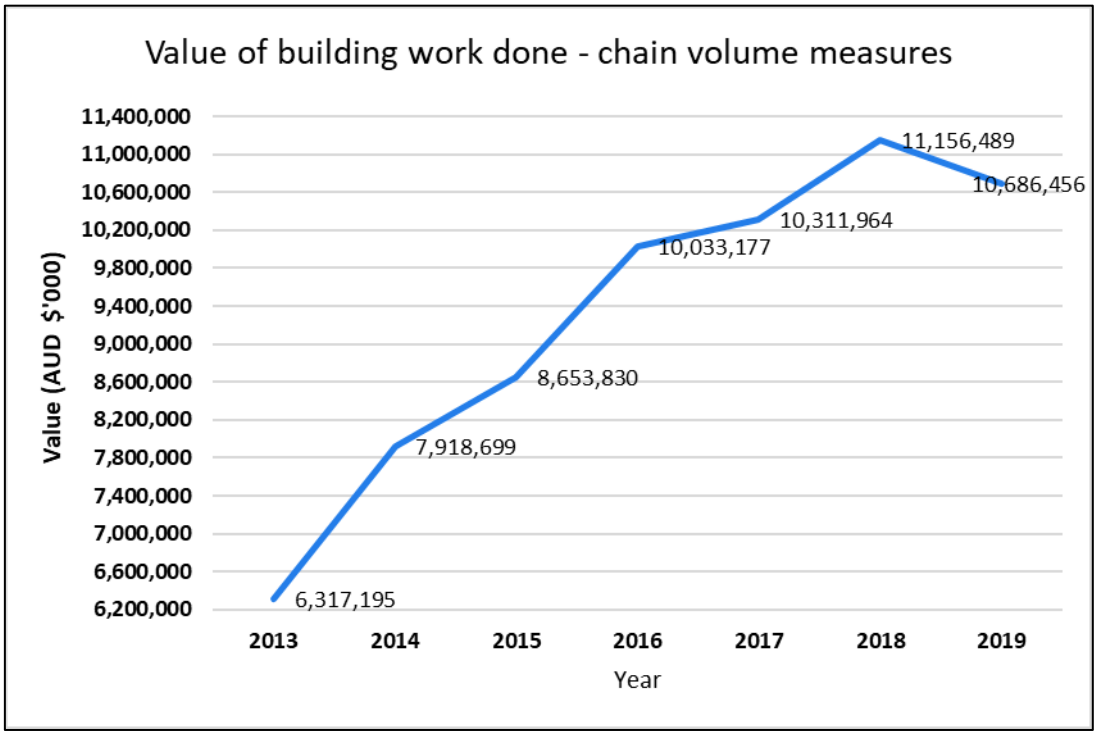

Figure 6. The value of construction activities in NSW between 2013 and 2020 (until Sep)

5.2. C&D waste data

The latest report commissioned by the Department of Agriculture, Water and the Environment shows that the five priority materials in this report were recycled in significant quantities in 2018-19 (Table 5). Brick and concrete are the primary waste materials that were recycled in almost equivalent amount. In a recent report, there is no waste disposal data recorded for the fiscal year 2018-19. However, the collective trend in C&D waste generation shows an increase in the quantity; it is likely that NSW's significant infrastructure program and its spill over into private sector investment has contributed to this growth[18].

In NSW, about 7,752 kt of C&D waste was recycled in 2018-19, which is 3% down from 2016-17. Similarly, the C&D waste disposal quantities witnessed a 3% decrease compared to 2016-17, reaching

[16]Population Australia. 2020. Population of New South Wales 2021. Retrieved from https://bit.ly/3irLnDB
[17] NSW Industry Report. 2020. Infrastructure and construction. Retrieved from https://bit.ly/3sHEGC4
[18] PWC. 2019. NSW Waste Sector Volume II: Situational Analysis. Retrieved from https://bit.ly/3bRy0eF

1, 905 kt. In 2018, C&D waste was the largest source of waste, accounting for 60% of waste generation volume[18]. In contrast, EfW records show a significant increase in energy recovery between 2016-17 and 2018-19; the state recovered energy from 40 kt of C&D waste, which is a 288% increase compared to the previous data reporting period[15]. Since 2007, the resource recovery rate in the state has followed a growing trend. The latest estimated waste recovery rates for NSW are 68% and 77%[2]. The recycling target rate for the C&D waste stream is 80%.

Table 5. Priority C&D waste materials statistics NSW

Material	Waste generation (t)	Disposal (t)	Recycling (t)
Brick[a]	1,291,546	0	1,291,546
Concrete	1,291,339	0	1,291,339
Asphalt	85,275	0	85,275
Steel *	0	0	547,471
Glass *	995	0	995

Source: 2020 National Waste Database
a recycling figure is for the total waste stream
*numbers are for C&D waste stream only.

Table 5 indicates that asphalt has found its way to market; indeed, the government's support—focused on using recycled products in road constructions—has unlocked the potential of application of reclaimed asphalt in NSW road infrastructure[19].

5.3. Existing markets

The state's focus on the development of the market tends to have prioritised municipal waste materials. However, in recent years, with changes in policies and the introduction of the circular economy concept, coupled with increased construction activities and elevation of its quantity[2], addressing the C&D waste stream is gaining traction among policymakers. The government, in collaboration with the private sector, intends to increase resource efficiency in the construction industry through market development and stimulation.

In partnership with the NSW Government (Department of Planning, Industry and Environment), Plant Ark launched Australia's most comprehensive online database that helps small to medium businesses find recycling collection and support services for the workplace. This platform[20], which was established in 2019, invites providers of recycling and waste disposal services to list their details for free.

The market operation heavily hinges on private businesses and recycling facilities that individually contribute to C&D waste trading; online versions of these have become popular recently. The volume of construction activities and the quantity of C&D waste generated and recycled in the state has been a convincing motive for recycling businesses to create and stimulate markets for such products. For instance, the Recycled Building Centre, which is a Sydney-based recycler, sell reclaimed building waste materials from the demolition of houses, factories and warehouses. The major share of their materials belongs to bricks, timber, sandstone and steel. The company has an online shopping platform to sell

[19]Local Government NSW. 2020 Recycled materials in roads and pavements a technical review. Retrieved from https://bit.ly/35VCZXW
[20]Plant ARK. Business Recycling. 2020. Retrieved from https://businessrecycling.com.au/

these products. Another recycler, the Building Recyclers Depot PTY Ltd (https://www.therecyclers.com.au/), sorts and sells C&D waste based on their previous/future application and function i.e., kitchen, bathroom, windows and doors, and landscaping. In addition to their webpage, these recyclers also use other popular trading platforms such as Gumtree and Facebook Marketplace to trade their products. Table 6 shows a (live at the time of writing) price list of recycled products that are supplied in the NSW metropolitan area.

Table 6. Recycled product price list in NSW

Item	**Turtle Nursery and landscape supplies Price (A$/t)**		**Gumtree Price (A$/t)**
Recycled Roadbase	46	Recycled Roadbase	35
RCA (10, 20mm)	55	10mm recycled brick Aggregate	44
Recycled asphalt	46	10mm recycled brick aggregate (bulk bag)	55
Recycled concrete dust	45	Recycled concrete dust	10
RCA 40/70	55	RCA 40/70	20

The prices are current in January 2021.

Concrete—To roughly estimate the potential market for recycled concrete products in NSW, the following calculations are made. Assuming all recycled concrete is to be converted to 10mm (concrete), which is priced at $55/t (Table 6), and accounting for 10% residual waste during recycling (Table 5), the total potential market for recycled concrete is $63.9 million per year.

Total potential market size = the state's concrete recycling quantity - 10% residual waste allowance × the retail price of recycled product
Total market worth = $1,291,339 – $129,133 × $55 = $63,921, 330

Brick—Using the above equation and considering 10% residual waste for 10mm brick aggregate and recycled asphalt, the total potential markets are $51.1 million and $3.5 million, respectively. The potential market for steel and glass is $690 m and $7.96 m, respectively, based on a retail price of 1.26 per kg[21] and 8 per kg[22].

[21] Current scrap metal prices Australia, 2021. Scrap metal prices Sydney. Retrieved from https://bit.ly/2MnsEx2
[22] Shop crushed glass aggregate. Retrieved from https://bit.ly/2Mhpyul

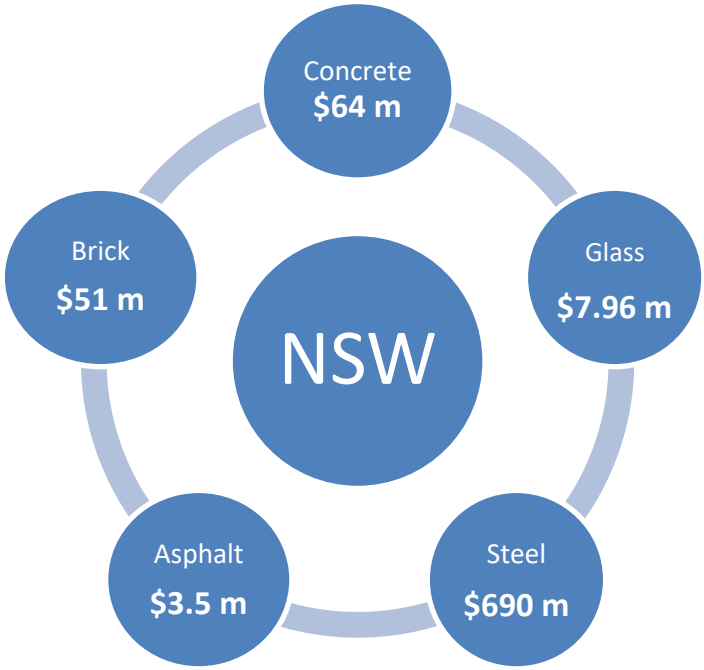

Figure 7. The potential market for priority materials in NSW

5.4. Material recovery facilities

Despite the C&D waste recycling industry in NSW being considered to be mature and the state's overall strategy to support diverting waste from landfills, MRFs lag behind the state's ambitious waste recycling target, set at 80%[23]. A report by the NSW EPA shows that many licensed C&D recycling facilities are diverting from landfill well under 50% of the waste they receive, representing a significant loss of valuable resources from the productive economy[23].

A recent report by PWC[18] has shown that the C&D waste recycling rate in 2018 throughout the state varied between metropolitan levy areas (81%), non-levied areas (34%) and regional levy areas (64%). The low recycling rate in non-levied areas indicates the need for imposing a landfill levy that will eventually result in further recycling and market development. The full list of MRFs operating in this state which recovers the study materials is provided in appendices.

5.5. Use of recycled products

NSW is a pioneer in the testing and application of recycled products in pavements and road constructions. Since 2008, the state has invested heavily in trials demonstrating the suitability and performance of recycled waste materials in infrastructure projects[24]. Below are two case studies in which multiple organisations cooperated to encourage market development for MRF products.

Crushed glass in pavement construction[25]- In 2010, Waverley Council, in partnership with NSW Department of Planning, Industry and Environment, NSW Roads and Traffic Authority, Institute of Public Works Engineering Australia and the Packaging Stewardship Forum, provided the first site within NSW to demonstrate alternate use of crushed glass in pavement construction as an accepted

[23] NSW EPA. 2016. New minimum standards for managing construction and demolition waste in NSW. Retrieved from https://bit.ly/39LELMq
[24]GHD. 2009. Packaging Stewardship Forum, Australian Food and Grocery Council. Retrieved from https://bit.ly/35UZcp5
[25]Edge Environment Pty Ltd. 2012. Construction and demolition waste guide recycling and re-use across the supply chain. Retrieved from https://bit.ly/2Kuruz4 f

product in NSW roads. Waverley Council substituted 15 tonnes of glass cullet into the road projects, 7.5 tonnes into the asphalt and 7.5 tonnes into concrete.

Asphalt construction for heavy vehicle load[19]**-** in 2018, Downer Pty Ltd, in collaboration with two councils (i.e., Hume City Council and Randwick Council) and some other organisations, used asphalt in some NSW roads with heavy vehicle load traffic. The project objectives were to minimise reliance on natural resources and virgin materials and reduce carbon emissions and the amount of waste being landfilled. From the C&D waste stream, reclaimed asphalt pavement and coarse aggregate were used. The produced asphalt contained 20 to 30% reclaimed asphalt pavement. The performance testing of the product shows that it improves fatigue, has superior deformation resistance for heavy vehicle loads, last 15% longer than standard asphalt and is capable of withstanding 20% increase traffic loading.

5.6. Government

The government sector in NSW has a pivotal role in creating and stimulating the market for using recycled products. The government, through various initiative and grants, has provided support for market development. As indicated earlier, the government support of the Business Recycling platform is a practical facilitating approach that directly impacts market development. Another initiative is the EPA's Circulate Industrial Ecology Program that supports the transition to a circular economy in NSW by funding innovative commercial industrial ecology projects that recover materials. An initiative that is more specific to the C&D waste market is the Civil Construction Market Program, which provides grants to organisations to divert C&D waste from landfill and produce post-consumer recyclate such as glass, paper and plastic through reuse, recycling and industrial ecology projects in the NSW civil construction sector[26]. The grant objectives are to reduce the amount of C&D material sent to landfill, create new markets and opportunities for C&D waste material within NSW civil construction projects, create new markets and opportunities for post-consumer recyclate within NSW civil construction projects and remove the risk associated with trialling innovative resource recovery methods[27].

Furthermore, the government sector provides guidelines that aim to stimulate the market for recycled C&D waste materials in construction projects. For instance, in 2020, Local Government NSW, in partnership with the University of Sydney, prepared and released a guideline[28] to drive the use of recycled products on roads and pavements in local councils. address the concerns preventing the use of recycled materials by local councils and thus promote national uniformity and good practice in the specification and application of material reuse in roads and pavements by local council engineers. In addition to Local Government NSW, other organisations have supported case studies of using recycled products in construction projects; these include the Institute of Public Works Engineering Australasia IPWEA (NSW), the Roads &Transport Directorate, Transport for NSW, EPA, Environment, Energy and Science (EES) and the NSW Environmental Trust.

[26] Laclette, A. 2021. Circular economy projects eligible for grants. Planet Ark. Retrieved from https://bit.ly/3bRaBtL
[27]NSW EPA. 2021. Civil construction market program grants. Retrieved from https://bit.ly/38WHdjV
[28]Local Government NSW. 2020. Recycled materials in roads and pavements. Retrieved from https://bit.ly/2NkzB2m

5.7. Recommendations

Below are some recommendations to create and stimulate markets for recycled C&D waste products in NSW. These recommendations are extracted from experts' views published in different sources[19, 18,29].

- Deliver creative incentives such as fee waiver programs for local governments and businesses that use recycled content/process recyclables,
- Provide support via the waste levy for recycling, such as transport subsidies for regional areas, until market failures are addressed, rather than leaving everything to the market,
- Mandate minimum recycling content in all large-scale construction projects,
- Share recycling market information,
- Create markets for recycled content at the design and tender stages of state significant developments,
- Give priority access to government markets if companies can demonstrate above target resource recovery levels,
- Phase in NSW Government recycled content procurement targets and associated baselines, monitoring and reporting systems,
- Provide support to Local Government Procurement to enhance the Sustainable Choice Database to include recycled materials and more products containing recycled content and provide the functionality to track and report on local government expenditure on recycled materials and products containing recycled content,
- Take a staged, individual approach towards introducing recycled content targets for local government procurement to enable supporting tools and databases to be developed and for regional and local variations to be taken into account,
- Fund further research, development and delivery of recycling technologies and products generated from recyclables, particularly by local or regional councils,
- Establish clearing house/brokering service (virtual) matching waste/resource materials to potential users/manufacturers of recycled products would address some of the uptake barriers,
- Develop and financially support a mechanism to facilitate the generation/bulking up of volumes at an appropriate geographic distribution through cooperative arrangements across suppliers including support for infrastructure. This may be needed both at state and regional levels,
- Work with stakeholders across supply chains to find opportunities to not only reduce waste but also ensure recycled content is valued and used over and over as a renewable resource through new clean technologies, and
- Improve on-site separating and processing will support improved diversion rates and reduced contamination.

[29]Local Government NSW. 2020. Submission to the NSW 20 year waste strategy issues paper. Retrieved from https://bit.ly/3o6L6qY

6. Analysis of Existing C&D waste End markets: Northern Territory

6.1. Overview

The Northern Territory (NT) is a vast federal territory in Australia located in the arid Red Centre. This territory has a tropical monsoonal climate, which features a dry and a wet season. The NT's economy is mainly concentrated around a few industries. These include construction, government and community services, and the mining sectors, which account for half of the NT's total economic output. In 2020, the construction industry employed 11, 158 people, 23% down from the previous year[30]. The latest report by ABS shows that the value of building work done in NT has been on a sharp decline since 2014. Unlike most jurisdictions, this value has steadily shrunk from AUD $418 million in 2014 to about AUD $183 million in 2020, a 128% decrease (Figure 8). This figure contributed 6.3% 32to the total NT GDP in 2018-19.

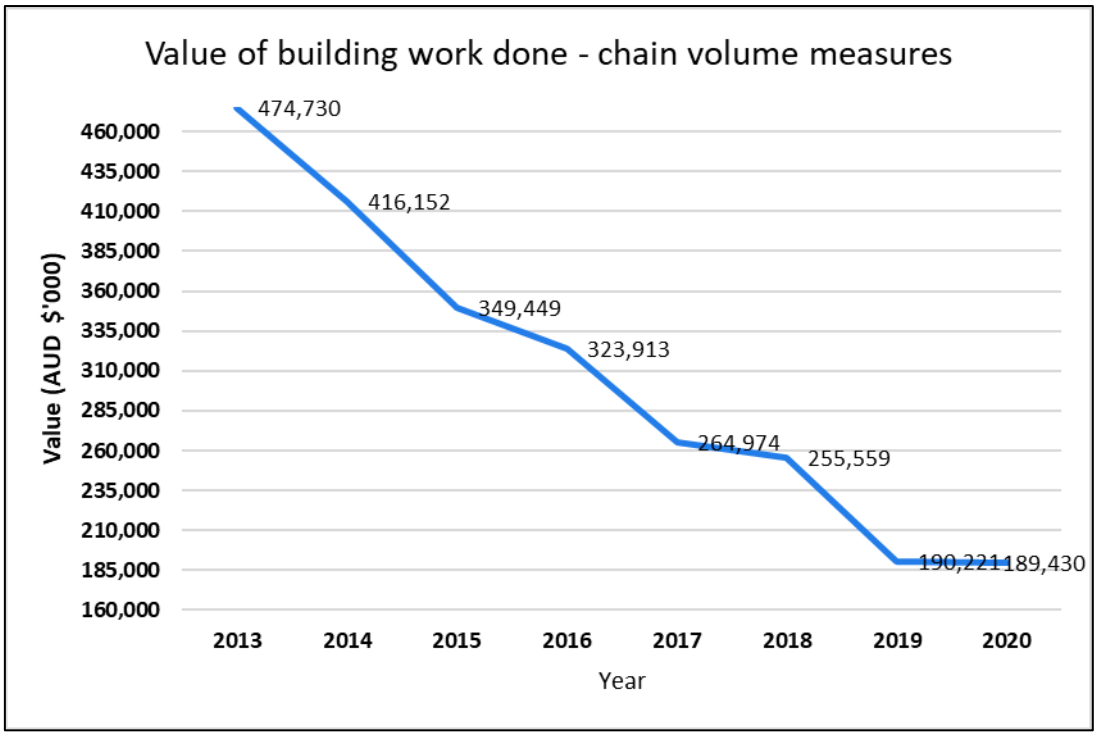

Figure 8. The value of construction activities in NT between 2013 and 2020 (until Sep)
Source: ABS (2020)[5]

[30] Department of Treasury and Finance. 2020. Northern Territory economy. Retrieved from https://bit.ly/3bRa0Z3

6.2. C&D waste data

According 33to the latest report (2018-19)[2] provided by the Department of Agriculture, Water and the Environment, except for steel, which is largely disposed of at landfills, none of the studied waste materials are recycled in NT. This could be related to an integrated data reporting system and reduced construction activities across the state.

Table 7. Priority C&D waste materials statistics in NT

Material	Waste generation (t)	Disposal (t)	Recycling (t)
Brick	0	0	0
Concrete	0	0	0
Asphalt	0	0	0
Steel	119,811	119,811	0
Glass	94	94	0

Source: 2020 National Waste Database

[a] recycling figure is for the total waste stream

*numbers are for C&D waste stream only.

6.3. Existing markets

Currently, there is no functional market for recycled C&D waste across the NT, and much of what is generated at the construction and demolition sites is destined for landfills. The lack of information on C&D waste management makes it difficult to examine the capacity for market development and stimulation in this territory[31].

6.4. Material recovery facilities

Shoal Bay Waste Management Facility[32] is one of the very few centres in the City of Darwin that accepts a range of C&D recyclables. One division in this centre, Recycle Shop, which became operative in August 2020, sells second-hand construction materials. In Recycle Shop, which is operated by Helping People Achieve (HPA), a community-based organisation, the construction industry practitioners can exchange C&D waste resources. The full list of MRFs operating in this territory that recovers the study materials is provided in appendices.

6.5. Use of recycled products

In NT, there is a limited number of projects in which the use of C&D waste recycled products has been documented. In 2020, for the first time in NT, a collaboration between the City of Darwin and Downer Group resulted in the use of recycled asphalt to upgrade seven major roads in Darwin. The recycled material used in road projects is estimated to save 12 tonnes of CO2 emission[33].

[31] Mathur, D., O'Leary, R. and Gerritsen, R., 2016. Reducing building waste in Alice Springs. Charles Darwin University.

[32] City of Darwin. 2020. Overview - Shoal Bay Waste Management Facility. Retrieved from https://bit.ly/38XYzwB

[33] Mirage. 2020. Recycled asphalt used for first time in NT. Retrieved from https://bit.ly/3j7lb1d

6.6. Government

The territory government has a pivotal role in establishing a market for recycled products. The government has begun to transition to a circular economy and it is expected that the territory will increase market capacity to maximise resource efficiency of construction materials.

6.7. Recommendations

The following are the main recommendations made to boost C&D waste market development in NT:

- Mandate minimum recycling content in all large-scale construction projects,
- Share recycling market information,
- Create markets for recycled content at the design and tender stages of state significant developments,
- Distribute the levy revenue to increase the capacity of recycling facilities across the state.

7. Analysis of Existing C&D waste End markets: Queensland

7.1. Overview

Queensland is an Australian state covering the continent's northeast, with a coastline stretching nearly 7,000 km. Queensland is Australia's second-largest state following WA, with a total area of 1,730,648 km². The state is the third most populated state in Australia, and the population is increasing at one of the fastest rates in the country. Based on Population Australia estimation[34], Qld's population will reach 5.188 million by the end of June of 2021. The second-largest employer in the state is the construction sector, with 245,100 people employed in the industry in 2019-20. The construction industry contributed $27.3 billion (8.1% of total output) to Qld's economy in 2019-20, making it the state's third-largest sector[35]. Since 2016, the value of building work done (all construction sectors and building types) in Qld has consistently decreased when it had reached its historical peak (Figure 9). A fall in major projects and reduction in the waste received from interstate are the main contributors to such low figures. Reduced construction activities have resulted in a lower amount of C&D waste generated annually. Furthermore, the state has one of the lowest waste recovery rates in Australia[36].

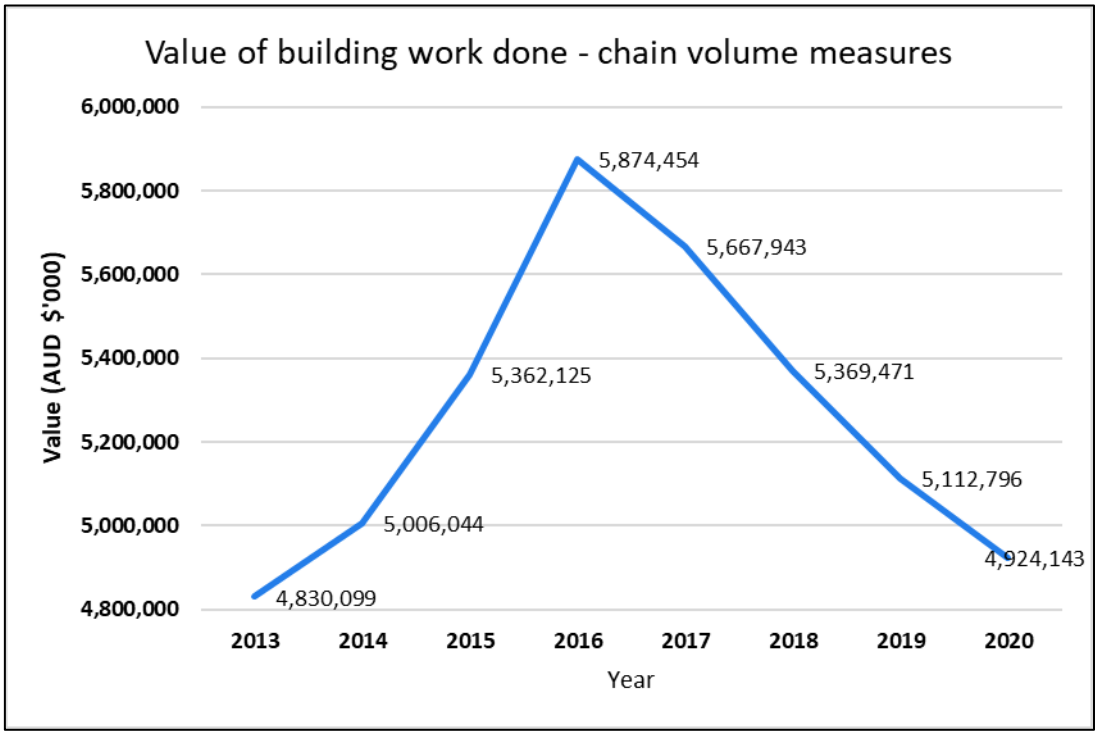

Figure 9. The value of construction activities in Qld between 2013 and 2020 (until Sep)

7.2. C&D waste data

As outlined above, the decline in construction works and interstate waste in recent years contributed to a fall in the C&D waste volume. In 2018-19, the total state C&D waste recovery and disposal were 3.09 mt and 2.2 mt, respectively. However, the total amount of C&D waste reported decreased by 37 kt[36] and the interstate C&D waste volume in 2018-19 declined by 19% compared to 2017-18 (1.03 mt to 864 kt). Historically, Qld's C&D waste disposal and recovery were rising until 2018-19. In the same year (2018-19), about 3 mt (or 58. %) of the 5.2 million tonnes of C&D waste reported was recovered, a rate that is far behind the national average rate[36]. Among the five priority materials listed in Table 8,

[34] Population Australia. 2021. Population of Queensland 2021. Retrieved from https://bit.ly/39LqxLj
[35]Queensland Treasury. 2020. About the Queensland Economy. Retrieved from https://bit.ly/2Kw4QGH
[36]Queensland Government. 2019. Recycling and waste in Queensland. Retrieved from https://bit.ly/38Zhojl

concrete has the largest volume of waste generation and recycling. The available data[2] shows no disposal records for brick, concrete, asphalt and steel.

Table 8. Priority C&D waste materials statistics in Qld

Material	Waste generation (t)	Disposal (t)	Recycling (t)
Brick	73,278	0	73,278
Concrete	1,868,779	0	1,868,779
Asphalt	438,221	0	438,221
Steel*	410,401	0	410,401
Glass*	7, 502	957	6,545

Source: 2020 National Waste Database
*numbers are for C&D waste stream only.

The state's recycling target rate is set at 80% by 2024[37], which is considered to be an ambitious aim that might not have been achieved in three years.

7.3. Existing markets

The market for C&D waste is not fully developed in Qld due to several reasons including lack of incentive, insufficient recycling facilities, geographically spread cities and towns, and low landfill levy. However, it is believed that a newly introduced landfill levy, currently set at $75 per tonne, will have a positive impact on developing end-markets for C&D waste resources[38]. It should be noted that reinstating a waste levy might shock the waste management and resource recovery sector as they are still dealing with the consequences of the imposition of the new landfill levy[39].

Currently, there is no viable market for recycled products, and the main application of recycled products are in public projects and local recycling facilities and retailers. However, with the recent government shift in waste management focus, the utilisation of C&D waste materials in major public projects has become trendy and will eventually result in C&D waste end-market development throughout the state. Like other states, second-hand and recycled C&D waste resources are being traded at a large scale on different platforms such as Gumtree and Facebook Marketplace.

From the priority items tabulated in Table 8, there is a potentially strong market for concrete, given the current volume of recycling. There are several facilities in Qld such as BMI Group, Alex Fraser Group and Moreton Bay Recycling that supply concrete recycled products including RCA, drainage recycled concrete and crusher dust. The local recycling facilities do not charge waste producers for dumping concrete if they dispose of clean concrete; however, if waste producers choose to dispose of their concrete waste in a waste tip, then the charges include a $75/t landfill levy plus about $26/t for commercial waste fees[40]. Such a cost disparity—i.e. $101—is a notable financial incentive for those who are involved in concrete waste generation.

[37]Queensland Government. 2018. Discussion paper: Transforming Queensland's Recycling and Waste Industry. Retrieved from https://bit.ly/3oWflBY
[38] Baird, L. 2020. Cleanaway can negotiate rocky regulatory road. Financial Review. Retrieved from https://bit.ly/3sEbImu
[39] Australian Landfill Owners Association. 2018. Landfill levy for Queensland, A submission to the Department of Environment and Science. Retrieved from https://bit.ly/2Nn30sL
[40]Moreton Bay Recycling. 2019. Concrete recycling in Brisbane: Tip vs specialist recycling centre. Retrieved from https://bit.ly/2M9yJNb

The result of the desktop review shows that different types of recycled concrete products are being sold at various prices depending on the location, quality and pricing mechanism. Table 9 presents some price examples illustrating the conditions of end-market for recycled products derived from the end-of-life of this important construction material (Table 9).

Table 9. Price example of C&D waste recycled products in Qld

Item	**Bulk Landscaping Supplies* Price (A$/t)**	**Moreton Bay Recycling[40] Price (A$/t)**
Crusher Dust	22- 26	11
5mm (Concrete)	35-40	N/A
10mm (Concrete)	33-38.5	28.6
20mm (Concrete)	28-34	17.60
40 & 70mm (Concrete)	27-32	24.2
Road base (CBR15)	22-28	N/A

*The supplier sets a minimum of 12 t order for such prices
The prices are current in January 2021

To better understand the viability of the market of a recycled product in Qld, Moreton Bay Recycling[41] 38compared the cost of recycled concrete versus virgin products. The comparison shows that the percentage of cost-saving can range from 3.3% (in the case of 40mm drainage aggregate) up to 53.3% (in the case of 70-100mm drainage aggregate). That said, in some cases (e.g. 7mm drainage aggregate), quarry products are slightly cheaper than their recycled alternatives.

Concrete—To roughly estimate the potential market for recycled concrete products in Qld, the following calculations are made. Assuming all recycled concrete is to be converted to 10mm (concrete), which is priced at $28.6/t (Table 9), and accounting for 10% residual waste during recycling (Table 8), the total potential market for recycled concrete is $48.1 million per year.

Total market worth = the state's concrete recycling quantity - 10% residual waste allowance × the retail price of recycled product
Total market worth = $1,868,779 – 186,877 × $28.6 = $48,102, 397

7.4. Use of recycled products

The history of utilisation of recycled products in construction project dates to a decade ago, though it has not flourished until recently. With the growing popularity of the circular economy concept in the waste management context, the state's policymaking has transitioned towards initiatives that include maximising resource efficiency. Currently, the Qld Department of Transport and MainRoads (TMR) is exploring new opportunities for the use of recycled materials in earthworks, drainage and concrete, focusing on diverting unwanted resources including C&D waste materials from landfill. TMR's trial goal is to increase the utilisation of RAP up to 40% in new asphalt and divert 8 kt of C&D waste materials from landfill. In doing so, in a collaborative construction project, Alex Fraser pilot-tested the application of more than 17 kt of recycled materials on Brisbane's National Freight Terminal[42]. Redland City Council

[41]Moreton Bay Recycling. 2019. Comparing recycled concrete aggregate prices with quarry aggregates. Retrieved from https://bit.ly/3iuBsgi
[42]Jones, L. 2019. Roads Online: Queensland achieves first recycled plastic road. Retrieved from https://bit.ly/39K0jJm

is working with Alex Fraser and Suncoast Asphalt to resurface one kilometre of road comprising significant amounts of hard plastics and reclaimed asphalt pavement while cutting council costs and carbon emissions. However, the results of this trial project and their performance are yet to be publicised. Below are two case studies in which C&D waste recycled products are used in Qld:

Bruce Highway (Pine River to Anzac Avenue)[43]- Bruce Highway is one of Australia's major highways and links to Brisbane and Cairns. The $3.5 million Pine River to Anzac Avenue upgrade is being undertaken to improve road user safety at the most southern section of the Bruce Highway, around North Lakes, north of Brisbane. The road is heavily trafficked, carrying 1,500 vehicles per hour. Alex Fraser supplied 5,500 tonnes of Recycled Concrete Pavement Material (RM001) for the project through civil constructors ALL ROADS. Choosing recycled materials is expected to result in approximately 47 tonnes of carbon savings, 1,335 tonnes less material compared to nonrecycled materials and 45 fewer truck movements in this project.

Clem Jones (CLEM7) Tunnel[44]- In 2010, the construction of the Clem Jones Tunnel (CLEM7) provided a critical river crossing that bypasses the CBD to link Brisbane's growing northern and southern suburbs, with direct connections at Bowen Hills, Kangaroo Point and Woolloongabba. Alex Fraser developed a recycled concrete roadbase to engineers' specification specifically for the project. The material was stabilised to meet the demands of the application. Recycled roadbase is approximately 15-20% lighter compared to materials produced from Queensland quarried rock, which means less material is required. For the CLEM7 project, the benefit of using recycled materials was a cost-saving of an estimated $570 k, and 725 fewer truck movements. The use of recycled materials also prevented the extraction of 120 kt of natural resources, saved more than 100 kt of waste from going to landfill and reduced carbon emissions by around 1kt.

7.5. Government

In addition to the legislative responsibility of the government sector, the state authorities need to encourage market development through funding infrastructure expansion, such as a $100 M funding program for waste and recycling (the Resource Recovery Industry Development Program)[45], to meet the demands that are forceable to be created due to a growth in landfill levy rates and diversion of waste materials. In addition to the state's latest initiatives to demonstrate the suitability of recycled C&D waste, the ongoing research to showcase the performance of infrastructure with recycled content can provide confidence in the market. Government sustainable procurement is another necessary step towards the transition to a circular economy in the construction industry.

7.6. Recommendations

Below are some state-specific recommendations that drive the creation and stimulation of end markets for C&D waste resources. The recommendations are based on expert views provided in different sources[39, 46, 47]:

- Ensure the waste and resource recovery infrastructure planning is aligned with the waste strategy, market development strategy and any other upcoming regulatory decisions,
- Develop standards for materials, as well as specifications for particular products and end-markets,

[43] Alex Fraser. 2020. Bruce Highway (Pine River to Anzac Avenue). Retrieved from https://bit.ly/3p38Flx
[44] Alex Fraser.2015. Clem Jones (CLEM7) Tunnel Retrieved from https://bit.ly/2NoeNXJ
[45]Waste Management Review. 2018. Queensland opens $100M funding program for waste and recycling. Retrieved from https://bit.ly/39M2jki
[46] Qld Treasury corporation. 2018. Economic opportunities for the Queensland waste industry: final report. Retrieved from https://bit.ly/2LNmMx2
[47] Waste Management Review. 2018. Levy Loopholes. Retrieved from https://bit.ly/2XTd92p

- Change procurement practices to incentivise and encourage (or mandate, as appropriate) the use of recycled content where it is available,
- Review landfill levy rate annually to ensure its functionality is able to obstruct all loopholes and will be in favour of end-market development and stimulation,
- Take advantage of interstate waste transfer to provide sustainable feedstock for recycling facilities
- Guarantee a full levy exemption will apply to residual waste materials created producing trade-exposed recycled materials, and
- Distribute the levy revenue to increase the capacity of recycling facilities across the state.

8. Analysis of Existing C&D waste End markets: South Australia

8.1. Overview

SA, with a total land area of 983,482 Km^2, is the fourth largest of Australia's states and territories by area, and fifth largest by population. It has a total of 1.77 million people[48]. It occupies one of the driest, most barren parts of the continent, but its southern fringe consists of well-watered and fertile lands and is where most of the population is located[49]. The construction industry in SA is not among the top industries, however, in terms of "industry share of output" and "gross value added (GVA)", it is ranked third among other industries in 2018-19[50]. The value of building work done (all construction sector and types) in SA has fluctuated between 2013 and 2020 (Figure 10). Despite this, figures recorded in 2020 increased 18% from figures estimated in 2013. Defence projects are expected to make up a large percentage of the work for the Adelaide construction industry in the foreseeable future. Projects underway include the Future Frigates and Future Submarine program with the next phases of Air 7000 and Air 555 at Edinburgh in the pipeline[51]. Recently, the $25,000 HomeBuilder Grant program to recover the effects on the industry caused by COVID-19 conditions has increased construction activities and as a result, construction jobs have grown 4%, which is above the national average figures[52].

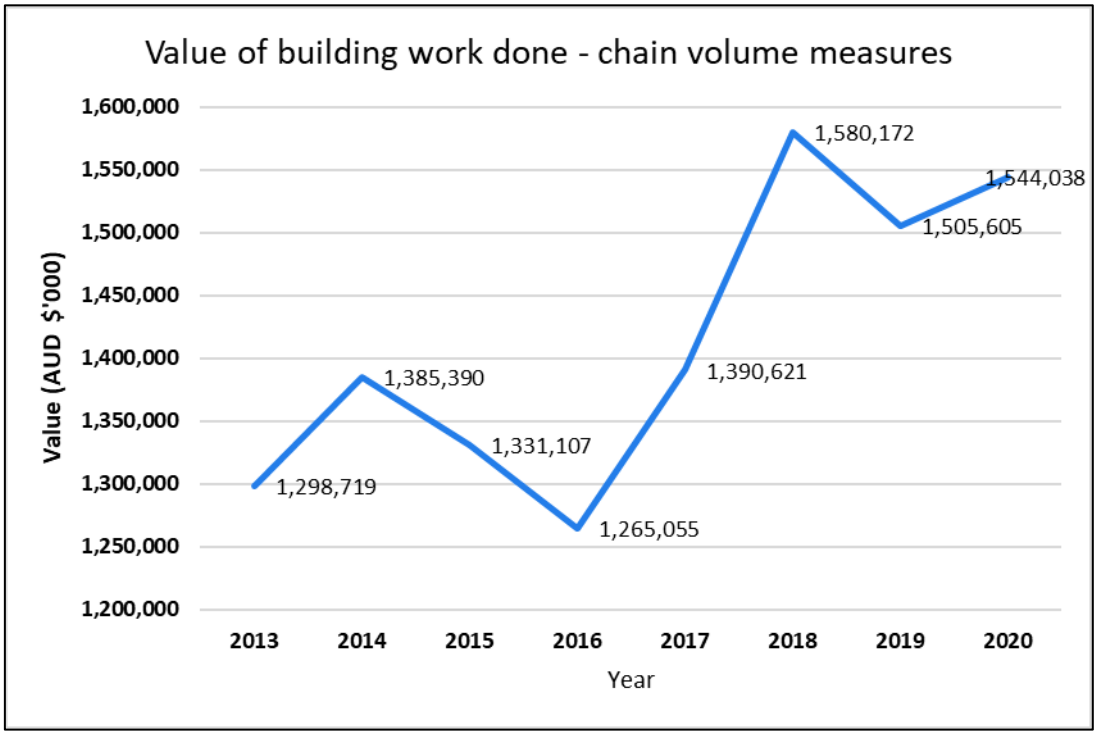

Figure 10. The value of construction activities in SA between 2013 and 2020 (until Sep)
Source: ABS (2020)[5]

SA holds a special national and international position in the management of waste, including C&D waste materials. Its waste management and resource recovery industry has been successful in collaborating with the waste management responsible organisation in achieving the SA waste management strategy document[53] and a circular economy.

[48] ABS. 2020. National, state and territory population. Retrieved from https://bit.ly/3o1599S
[49] McCaskill, M. 2020. Britannica: South Australia. Retrieved from https://bit.ly/3p7hF9y
[50] Ai Group. 2020. Economic outlook: South Australia. Retrieved from https://bit.ly/38WdwPT
[51] WT Partnership. 2019. Australian construction market conditions report. Retrieved from https://bit.ly/2M4maTu
[52] Government of SA. SA leads nation in building and construction jobs growth. Retrieved from https://bit.ly/3bPKgMG
[53] Green Industries SA. 2015. South Australia's waste strategy 2015-2020. Retrieved from https://bit.ly/3qFRt6f.

8.2. C&D waste data

SA continues to perform well in its efforts to recycle material and reduce landfill disposal[2]. The 2020 National Waste Report indicated that the generation of C&D waste increased by 32% from 1,231 kt in 2017 to 1,64 kt in 2019. With the increase in the C&D waste quantity, waste landfilling, energy recovery and recycling activities were also expanded. The growth rate was recorded to be 12%, 33% and 101%, respectively, reflecting the state's successful efforts to recover C&D waste materials. As presented in Table 10, for the five case study materials (i.e. brick, concrete, asphalt, steel and glass), the annual quantity of recycling outperformed disposal in 2018-19. For instance, in the same year, more than five times the amount of brick waste was recovered as was landfilled. In this state, the resource recovery rate is 85%, which ranks first in Australia. This rate consists of 80% of recycling and 4.4% energy recovery.

Table 10. Priority C&D waste materials statistics in SA

Material	Waste generation (t)	Disposal (t)	Recycling (t)
Brick	122,717	20,638	102,079
Concrete	988,757	27,355	961,402
Asphalt	285,895	69.12	285,826
Steel*	54,929	4,046	50,883
Glass*	331	331	0

Source: 2020 National Waste Database
*numbers are for C&D waste stream only.

8.3. Existing markets

The waste management and resource recovery sector is an important industry in SA. Leading the country in terms of waste recovery rate, SA has great potential for creating new and stimulating existing markets for certain C&D waste materials, notably brick and asphalt (Table 10). SA is at the centre of waste interstate transport for recycling in Australia. Several states and territories (e.g. NT, NSW, Vic, WA) transport their waste to this state to recycle and repurpose. For example, it receives metal and glass from NT and NSW[54]. The latest reports show that this state also exports some C&D waste (i.e. 1,954 t plastic recovered from C&D waste) to interstate for recycling. The University of Adelaide researchers[54] has argued that the reason for such a business pattern is the financial benefit gains through waste trading, which highlights the significance of an efficient domestic market in this state. A newly published report by the state government[55] indicated that in 2017-18 about 86% of all waste streams were recovered in the state, and the remaining were sent overseas (7%) and interstate (7%). The exported materials included mainly metals, cardboard and paper, and to a lesser extent, plastic.

A recent report by GISA[55] displays the conditions of the existing market for some C&D waste materials across this state. In SA, the resource recovery industry is a significant sector of the state's economy, with an annual turnover of about $1 billion, a contribution of more than $500 million to Gross State

[54] Wu, H., Zuo, J., Yuan, H., Zillante, G. and Wang, J., 2020. Cross-regional mobility of construction and demolition waste in Australia: An exploratory study. *Resources, Conservation and Recycling*, 156, p.104710.
[55]Green Industries SA.2020. South Australia's Recycling activity survey 2018-19 report. Retrieved from https://bit.ly/3qBQQdP

Product (directly and indirectly) and employing about 4,800 people. The value of the resources recovered is each year is also significant: in 2017-18, this was estimated at $356 million[61].

8.4. Material recovery facilities

Pre-cycle is an initiative that kicked off in SA in 2016[56]. The aim of this initiative is to help builders remove C&D waste materials from construction sites. The initiative outlines a six-stage process during construction. First, pre-cycle sorts recyclable materials at their source before removing them to be recycled and contribute to a circular economy in the construction industry. The operating company, Premier Insulation, recycles and repurposes the offcuts from new home construction sites, saving construction companies waste removal bills and keeping unused building materials from ending up in a landfill. 80% of what is collected from construction sites get used[57]; the calculations of benefits of this initiative shows that, in a typical house, construction builders would only use one-sixths of bins and pay one-third of waste management expenses compared to conventional waste management practices. The initiative is also able to divert 30m^3 of waste that would otherwise have been landfilled. A report by Green Industries SA[56] showed that this business model could increase landfill diversion to 76%, up from the 10% seen in the business-as-usual approach. The full list of MRFs operating in this state which recovers the study materials is provided in appendices.

8.5. Use of recycled C&D waste products

SA is a pioneer state in using recycled C&D waste products in public infrastructure projects. Below are two examples of such an application:

Built Environs: 100 Hutt Street, Adelaide (South Australia)[25]- 100 Hutt Street is a commercial office building and the head office of Built Environs, the national building brand of McConnell Dowell. 100 Hutt Street was refurbished between 2007 and 2008 using the GBCA's Green Star building rating tool to demonstrate leading practice. The refurbishment achieved an overall rating of five green stars. During the construction, 100 Hutt Street implemented a waste management plan and recycled or re-used 95.1% of construction waste (by weight) from the construction activities, far exceeding the Green Star credit criterion.

Reclaimed asphalt as unsealed residential pavement in Regional South Australia[58]- The reconstruction of Cooper Street Kudla was undertaken by the City of Gawler works engineering department, which chose Bitumate as the appropriate material for an unsealed surface. Cooper Street is a regional access road to five residential properties. Reconstruction of the road pavement in addition to the installation of side drainage was required due to regular flooding. As an unsealed surface, patrol grading is minimal, and with some residual bitumen, it provides some cohesion to reduce ravelling (particularly at the intersection) and some "re-healing" of the surface under traffic in hot weather occurs. Reclaimed asphalt is received at C&D recycling facilities predominantly in the form of slab asphalt removed from old pavements. The raw feed material is processed through crushing and screening to grading with little or no plasticity. The product is produced by Resource under the brand name "BitumateTM".

[56] Green Industries SA. 2020. Circular Economy in Action in South Australia: Pre-cycle – making building sites cleaner, greener, and more efficient.
[57] The Lead. 2018. Pre-cycling in construction industry saves money and environment. Retrieved from https://bit.ly/3p0ieBX
[58] Sustainable Aggregates SA. 2018. Cooper Street Kudla. Retrieved from https://bit.ly/3pykT5W

8.6. Government

The state government through GISA provides a range of funding to unlock the potential of the Circular Economy, develop infrastructure to process and create new products from waste, seed funding for new technologies and commercialise research in SA. Notably, the Circular Economy Market Development grant[59] aims to encourage councils, not-for-profit organisations, research institutes and businesses that produce, manufacture, sell or promote SA-recycled materials and recycled products. Furthermore, the government's $190 million Recycling Modernisation Fund[60] is set to improve recycling outcomes and address critical gaps in the state recycling infrastructure. To further support efforts in developing the market at the state level, the new waste strategy document has an extensive focus on the circular economy. This is reflected in the fact that the waste strategy is entitled 'A Vision for a Circular Economy[61]. The government support has progressively increased with recent changes to the accessibility of overseas end markets. For instance, the South Australian Sustainable Procurement Working Group has been formed to maximise collaboration between all levels of government, the business community and the waste sector to develop a framework to drive end-market development for post-consumer recyclables. Such initiatives can underpin viable and sustainable markets for the state's C&D waste stream.

8.7. Recommendations

The following recommendations are made to increase the capacity of existing markets for recycled C&D waste products and develop new end markets across the state. The recommendations are extracted from various sources[61] in which experts' views are considered:

- Build stable markets for remanufacturing and secondary materials,
- Increase market confidence for investments in the circular economy, resource recovery and waste management,
- Increase use of recycled material and build demand and markets for recycled products,
- Promote manufacturing of products and components that replace virgin materials with sustainably produced materials,
- Develop successful procurement case studies demonstrating benefits of using recycled-content products to government and industry, and
- Support the development of accredited testing for product standards and performance to increase confidence in the quality of remanufactured products.

[59] GISA. 2021. Circular Economy Market Development Grants. Retrieved from https://bit.ly/36uviln
[60] GISA. 2021. Recycling Modernisation Grant Program. Retrieved from https://bit.ly/2MJxMLO
[61] GISA. 2020. A Vision for a Circular Economy: Waste Strategy 2020-2025. Retrieved from https://bit.ly/3j7e6xF

9. Analysis of Existing C&D waste End markets: Tasmania

9.1. Overview

Tasmania (Tas) lies about 240 km south of the state of Victoria, from which it is separated by the shallow Bass Strait. The state comprises a main island called Tasmania; Bruny Island, nestling close to the south-eastern coast of the main island; King and Flinders islands in the Bass Strait; numerous smaller islands off the coast of the main island; and subantarctic Macquarie Island, about 1,450 km to the southeast. The main island is roughly heart-shaped, with a maximum length and width of 320 km. The state also produces a major portion of Australia's hydroelectric power and possesses a great diversity of natural resources[62]. Tasmania has long maintained a higher birth rate than most other states. Birth rates have generally been lower in the cities than in the smaller towns and rural areas.

Tas has mineral, forest, water and tourist resources. It has a diversity of economic activity and relatively stable labour relations. Its economy, however, suffers markedly from the small scale of much of its resource base, from restricted local markets, and problems with transport to external markets. Production and processing of minerals and metals furnish nearly half of the total value of Tasmania's exports. Another one-third of export value is split about equally between food and beverage products (especially meat and dairy), and wood and paper products.

The construction industry has demonstrated a steadily uprising trend since 2014[5]. In 2020, the value of building work done in this state reached AUD $417 million, a 36% increase from the 2014 figure. A recent report by Inside Construction[63] estimated that the total worth of the construction projects in 2020-21 in the state will amount to AUD $2.8 billion a year. Figure 11 illustrates the value of building work done in Tas from 2014 to 2020.

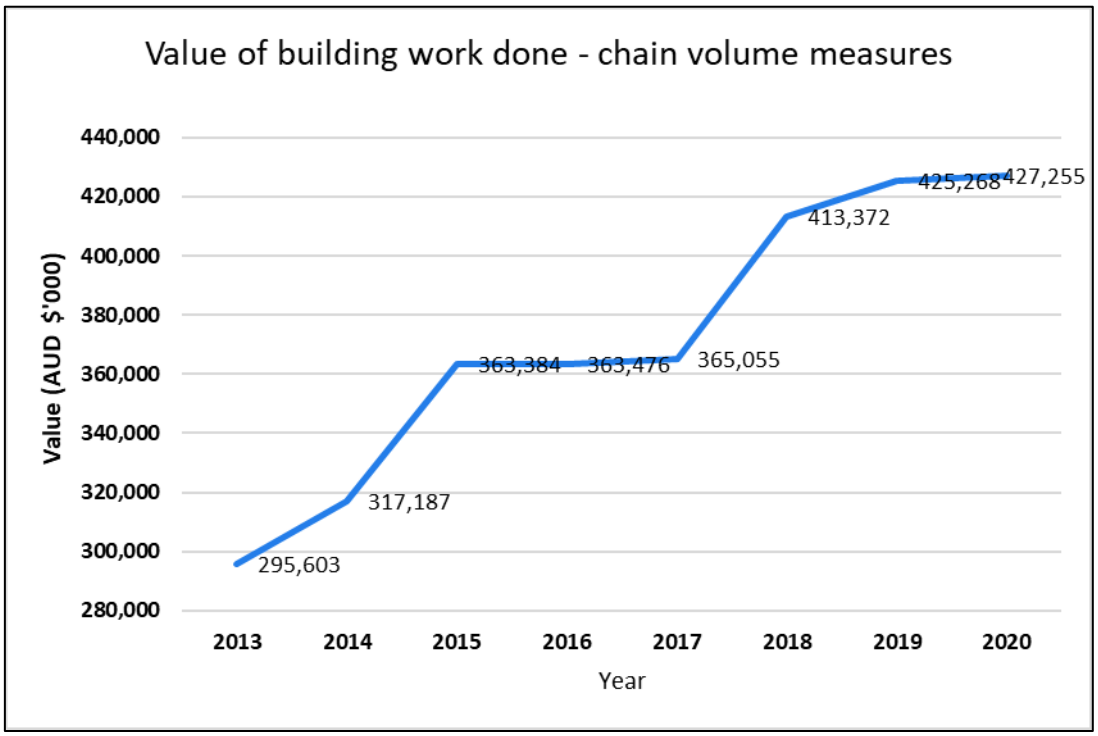

Figure 11. The value of construction activities in Tas between 2014 and 2020 (until Sep)
Source: ABS (2020)[5]

[62] Scott. P. 2017. Britannica: Tasmania island and state, Australia. Retrieved from https://bit.ly/3sQg0Ya
[63]Inside Construction. 2019. Skills and construction boom in Tasmania. Retrieved from https://bit.ly/3qvTIss

The state has the lowest C&D waste recovery rate in Australia, with about 1% of C&D waste recovered each year. The state does not have a current waste strategy, and hence there is no official waste minimisation or recovery target; the 2019 Draft Waste Action Plan[64] targets a 40% average recovery rate for all waste streams by 2020. This section of the report presents data relevant to the waste management of five priority construction materials, an overview of the existing markets, the conditions of material recovery facilities (MRFs), some case studies of using recycled products in construction projects, the extent of government support and recommendations to enhance market operation across the state.

9.2. C&D waste data

The Tas construction industry generates about 44 kt of waste annually, of which only 1% is recovered, making it the lowest rate in Australia[2] and well below the national resource recovery average. According to the latest report (2017-18)[65] provided by the Department of Agriculture, Water and the Environment, none of the studied C&D waste materials is recycled across the state. It is most likely that these materials are landfilled as the state does not impose a landfill levy on materials to be disposed of.

Table 11. Priority C&D waste materials statistics in Tas

Material	Waste generation (t)	Disposal (t)	Recycling (t)
Brick	0	0	0
Concrete	0	0	0
Asphalt	0	0	0
Steel	0	0	0
Glass	0	24	0

Source: 2020 National Waste Database
*numbers are for C&D waste stream only.

9.3. Existing markets

In a report prepared by Urban EP[66], issues were identified by waste management and resource recovery stakeholders as impediments to the creation and stimulation of the market for recycled products. Among the four problem areas indicated by the three regions, the state government and the resource recovery centre is the insecure market for investing. To tackle these issues, the report suggests that there is a need to implement coordinated education, engagement, and marketing and market development measures. These two solutions involve fostering acceptance and uptake of new recovery services, stimulating demand for recovered resources, and guiding consumer and purchasing behaviour and decisions; as well as the implementation of sustainable procurement. In turn, this will stimulate markets for resources recovered locally and encourage the replacement of non-recyclable and single-use items with reusable content items.

While the current conditions in the market and the nature of the construction industry—in which time is money—do not favour deconstruction as opposed to demolition, Tas has shown the capacity for

[64]Department of Primary Industries, Parks, Water and Environment. 2019. Draft Waste Action Plan. Retrieved from https://bit.ly/39LLjKN
[65]Blue Environment. 2018. National Waste Report. Retrieved from https://bit.ly/3o1IBWy
[66]Urban EP. 2019. Feasibility Study into a Statewide Waste Management Arrangement. Retrieved from https://bit.ly/3bVp9Zq

market development measures through private sector efforts. For instance, Hobart's Resource Work Cooperative [67] (HRWC) based in Tas and founded in 1993, carries out deconstruction that generally maximises the value of resources used in construction projects. HRWC[68] is Australia's largest not-for-profit, self-funded, workers' cooperative that aims to create employment through waste minimisation activities. The cooperative provides two services, namely urban salvage and deconstruction. Through urban salvage services, HRWC removes reusable waste directly from the demolition site. Currently, HRWC is seeking to trial this service on a larger scale. Through deconstruction, their team deconstruct buildings by hand to recover up to 95% of materials to recover resources. HRWC partners with registered builders and a team of qualified resource workers to provide a low impact alternative with competitive rates.

9.4. Material recovery facilities

Tasmania's waste management system operates in three waste management group regions: the South region, Northern Tasmanian region and The Cradle Coast. Observations indicate that in each region, while there are multiple landfills, one landfill centre dominates the market for disposal services[66]. For instance, Dulverton Waste Management operates the biggest landfill in the Cradle Coast, Copping Landfill takes the majority of waste in the South Region, and Launceston Waste Centre receives 84% of the waste generated in the Northern Tasmanian Region. In some of these landfills, C&D waste is marginally recovered. The full list of MRFs operating in this territory that recovers the study materials is provided in appendices.

9.5. Use of recycled C&D waste products

The use of recycled C&D waste products in Tas is minimum and limited to one project that documents its overall information.

Kingstone roadworks[69]- Kingborough Council's application of an aggregate consists of recycled materials in roadworks in partnership with RED Group, Close the Loop and Downer Group. About 78 tonnes of recycled asphalt, along with other waste streams (e.g. glass, toner, plastic bags), were used. The project's aim is to reseal Baynton Street, Harris Court, Lucas Street and Cleburne Street.

9.6. Government

While there are some attempts to use recycled products in construction projects at the local government level, the state government support to boost the C&D waste market is not sufficient. The Northern Tasmanian Waste Management Group (NTWMG) region has planned to provide funding to create a regional C&D recovery facility at the Launceston Waste Centre[70]. The three waste management groups have collaborated to publish two reference guides to help improve resource recovery in the construction and demolition, and commercial and industrial sectors.

9.7. Recommendations

There are several recommendations that can improve the operation of the limited existing market for C&D waste across Tasmania. Some of these were extracted from the Feasibility Study into a Statewide Waste Management Agreement Report[66]:

[67] Crerar, C. 2019. Renew: Inside the war on construction waste. Retrieved from https://bit.ly/3sBkaTH
[68] Resource Work Cooperative. Retrieved from https://bit.ly/2M5SkOq
[69] Kingborough Council. 2020. Recycled Roads in Kingston Retrieved from https://bit.ly/39l5RuE
[70] Northern Tasmanian Waste Management Group (NTWMG). 2018. Five-year strategy: 2017–2022.

- Consider circular economy principles as being core to its operations and a natural fit for Tasmania's circumstances,
- Develop strategies for priority materials,
- Implement and improve statewide data collection, analytics and reporting,
- Establish coordinated education, engagement and marketing,
- Local governments engagement and procurement support to lock in demand for new services and facilitate efficient use of assets,
- Market development measures including sustainable procurement,
- Coordinate advocacy and policy input,
- Infrastructure funding to simulate investment in recovery assets,
- Devise a market and/or statutory instrument to address gate fee differentials,
- Introduce a statewide waste levy to encourage waste recovery and market development.

10. Analysis of Existing C&D waste End markets: Victoria

10.1. Overview

Vic is the second most populated state in Australia. Victoria has a total area of 227,416 km2, which accounts for 3% of Australia's total landmass and makes it the smallest mainland state. Victoria's coastline is 1800 km long and borders the Bass Strait, the body of water that separates the mainland from Tasmania. Based on the latest estimations, Victoria's population will reach 6.6 million by the end of June 2021[71]. Victoria's construction industry employs almost 240,000 people and contributes $21.6 billion to the Victorian economy. The industry is driven by a continuing increase in Victoria's population and the need to provide housing and related infrastructure[72]. The value of building work done (all construction sectors and building types) in Vic is in Figure 12. The Victorian construction industry has continued to grow over the last decade, reaching $9.92 billion in 2020. As a result, C&D waste is the largest contributor to the state's total annual solid quantity. In 2018, compared to C&I and MSW, more C&D waste was recovered than was landfilled.

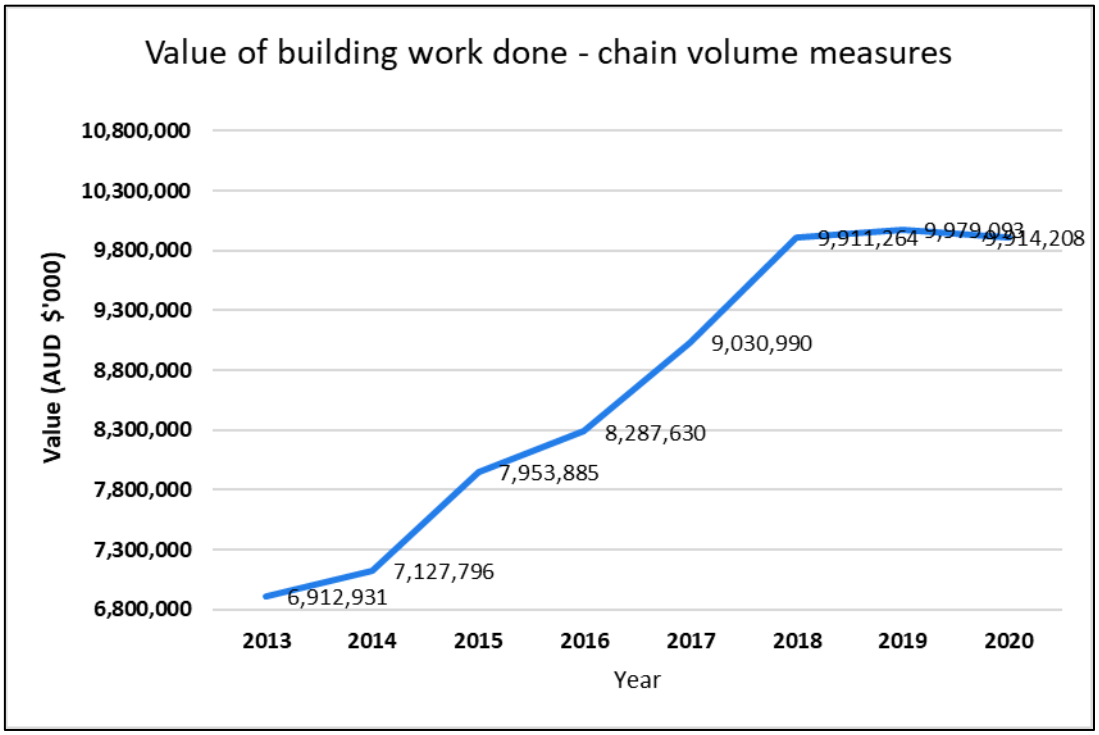

Figure 12. The value of construction activities in Vic between 2013 and 2020 (until Sep).

10.2. C&D waste data

Due to massive residential, commercial and public construction across the state, Vic's annual C&D waste generation rate is among the highest in Australia. Currently, the state's C&D waste recovery is 87%. The waste generation in the state has increased by 47% since 2017, reaching 8,133 kt in 2019. Likewise, there was a surge in C&D waste recycling and disposal, by 56% and 15%, respectively. The government's commissioned report[2] has shown that concrete and brick are the major C&D waste materials in Vic. Table 12 summarises waste data related to the five case study materials in Vic.

[71] Population of Australia. 2021. Population of Victoria 2021. Retrieved from https://bit.ly/3ojnLCt
[72]Live in Melbourne. 2021 Transport, defence and construction technologies Retrieved from https://bit.ly/3pnYPej

Table 12. Priority C&D waste materials statistics in Vic

Material	Waste generation (t)	Disposal (t)	Recycling (t)
Brick	804,650	0	804,650
Concrete	2,710,460	0	2,710,460
Asphalt	231,560	0	231,560
Steel *	147,838	0	147,838
Glass*	3,331	2,339	972

Source: 2020 National Waste Database
*numbers are for C&D waste stream only.

Concrete comprises the largest end-markets across the state, due to its massive application in infrastructure projects and huge waste generation annually. A report prepared by SV[73] indicates that the end product market for this material in 2013-14 was about $40 m. This report estimated that the end product market for brick was $10 m in the same period.

Vic transports 32,985 t of metals (25%), 2, 374 tons of paper & cardboard (46%), 2074 t of plastic (74%), 445 t of TLR (45%), 75 t of glass (7%) and 656 t of organics (1%) of recovered C&D waste to interstate or overseas for reprocessing/recycling[74]. The analysis of multiple reports showed that the major destination of this waste was probably SA[7]. It is expected that the state's waste recycling sectors will need to adjust to meet the policy objectives announced by the Council of Australian Governments (COAG) in March 2020, which will progressively ban export waste from July 2020 onwards[75].

10.3. Existing markets

Compared to other states, Victoria has a strong market for recycled products. Hence, recycling facilities such as Bingo Industries and Re-purpose offer lower base prices. Furthermore, massive infrastructure projects being executed across the state provides a great opportunity for stakeholders to use recycled products in construction projects. For instance, in 2019, the City of Bayside[76] used recycled asphalt in roadworks in four suburbs, in the form of 12,000 tonnes of sustainable asphalt that contained waste materials. It is estimated that the state's waste recovery sector transition to a circular economy will help to create more than 3,900 new jobs and establish new skills in design, repair, efficiency and material usage across Victoria[77]. Below are estimated markets for the five study materials in this study:

Concrete, assuming all recycled concrete is to be converted to 10mm (concrete), which is typically priced at $22/t, and accounting for 10% residual waste during recycling, the total potential market for recycled concrete is $53.67 million per year.

Total market size = quantity of recycled concrete - 10% residual waste allowance × the retail price of 10mm RCA[78]

[73] Sustainability Victoria. 2014. Market summary – recycled brick, stone and concrete. Retrieved from https://bit.ly/3poOSNL
[74] Sustainability Victoria, SV, 2018a. State-wide Waste and Resource Recovery Infrastructure Plan (Victoria 2017), retrieved from https://bit.ly/3ae0iNI
[75] Infrastructure Victoria. 2020. Advice on recycling and resource recovery infrastructure. Retrieved from https://bit.ly/3an2OBB
[76] Waste Management Review. 2019. Alex Fraser opens high recycled technology asphalt plant. Retrieved from https://bit.ly/2NLV2JS
[77] Department of Environment, Land, Water and Planning. 2020. Recycling Victoria A new economy. Retrieved from https://bit.ly/3j4pEBV
[78] Bingo Industries. 2021. Aggregate, retrieved from https://bit.ly/3iRXI4f

Total market size = 2,710,460 t – 271,046t × $22 = $53.67 million

Brick—In Vic, recycled brick is priced at $1.32[79], and each brick weighs around 3.75 kg. Given the annual recycling rate (Table 12), it can be inferred that the potential market size for brick is $7.28 million. The associated calculations are provided below:

Number of recycled bricks: 804,650 t (quantity of recycled brick in WA) / 3.75 kg (average weight of a brick) = 214.57 million bricks
Potential market size: 214.57 m (number of recycled bricks) - 10% residual waste allowance × $1.1 (average price of a brick) = $212.5 million

Asphalt—Recycled asphalt in Vic is worth $20 per tonne[80] and given the state's concrete recycling quantity, which is 231,560t (Table 12), the potential market size for this resource is $4,168,080. The calculations are as below:
Total market size = quantity of recycled asphalt - 10% residual waste allowance × the retail price of recycled product
Total market size = 231,560 t –23,156 t × $20 = $4. 17 million

Steel—The potential market for steel is the largest among the study materials in Vic. Recycled stainless steel is approximately $1.26 per kg[81]. Given the state's recycled steel amount (Table 12), 147,838 t, the potential market is worth $175 million.
Total market size = quantity of recycled steel × the retail price of recycled product
Total market size = 147,838,000 kg × $1.26 per kg = $186,275,880

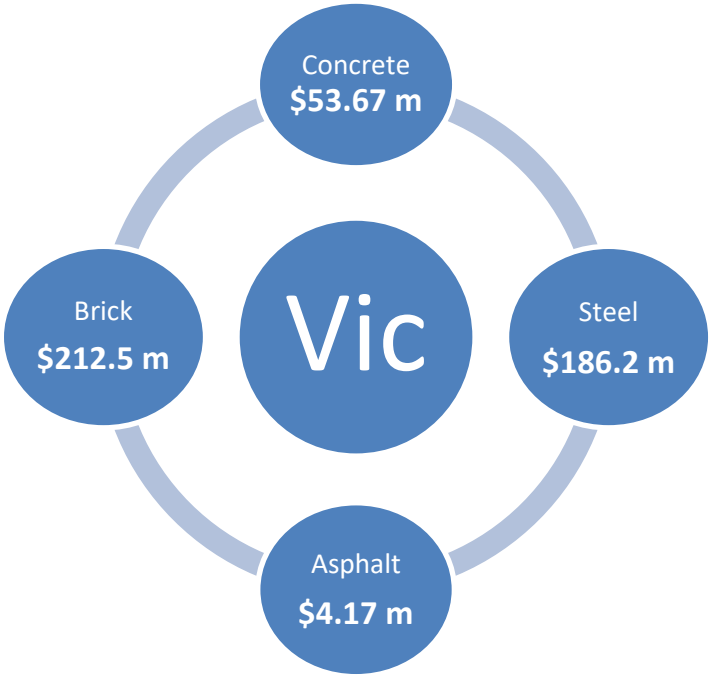

Figure 13. The potential market for priority materials in Vic.

[79]Recycled brick centre. 2020. retrieved from https://bit.ly/3abqj07
[80]Newcomb. 2021. Recycled asphalt. Retrieved from https://bit.ly/3oslDbx
[81]Current scrap metal prices Australia. 2021.Scrap metal prices Perth. Retrieved from https://bit.ly/3678WMU

10.4. Material recovery facilities

By developing guidelines, the state government supports the knowledge enhancement of resource recovery best practice management. For instance, in 2019, SV published a document to guide the development, management and operation of MRFs across Victoria[82]. Victoria's MRFs are under continuous inspection by a task force to ensure safety measures are observed. In 2014- 15, Melbourne featured 20 waste transfer stations, 23 resource recovery centres and 25 drops off facilities[83]. It is estimated that through improving material efficiency and recycling under a circular economy, the state's economy would be boosted by $6.7 billion[77]. The full list of MRFs operating in this state which recovers the study materials is provided in appendices.

10.5. Use of recycled C&D waste in construction projects

Victoria continues to improve the application of recycled waste products in large infrastructure projects. Below are some case studies demonstrating its track record of success in using recycled waste projects across the state.

Manufacturing with recycled materials in regional Victoria[84]- Integrated Recycling, located in Mildura, Victoria, uses recycled plastic primarily from local agricultural sources to create durable products such as grapevine posts, landscaping products, boardwalks and railway sleepers. It also manufactures Duratrack, a recycled plastic railway sleeper that lasts more than three times longer than timber sleepers and requires less energy to manufacture than concrete or steel sleepers. This keeps waste plastic that would otherwise go to landfill at a higher value in use for longer—a key principle of the circular economy. Integrated Recycling received support from rounds 2 and 3 of the Victorian Government's Resource Recovery Infrastructure Fund to increase its production capacity.

Dingley Bypass, South East Melbourne[85]- The 6.4km, $156 million Dingley Bypass has been completed with Alex Fraser materials. The bypass was opened by Minister for Roads and Road Safety Luke Donnellan in mid-March 2019, a full five months ahead of schedule. The new road makes the Alex Fraser Clarinda site, where 96% of crushed pavement materials for the project were sourced, even easier for customers to access. Throughout the two-year project, 269,000t of Class 4 Crushed Concrete, Class 2 and 3 Crushed Concrete and Recycled Sand was supplied. Alex Fraser products resulted in 23,000 fewer tonnes used due to the density savings compared to quarried rock and 770 fewer truck movements. In addition, 1.7kt of CO_2 have been prevented from entering the atmosphere.

10.6. Government

The Victorian state government's financial support for the recycling and waste management industry is wide-ranging. In 2019, the government announced a plan titled 'Recycling Victoria: A new economy', in which it will invest $300 million to transform the recycling sector[86]. The fund aims to drive investment in world-class infrastructure and technology, make the state's future recycling system more sustainable, create cutting-edge local industries and support thousands of new local job. The state government also provides funding for projects that use recycled materials[87]. The Victorian Government has released $2.6 million in grants from the Sustainable Infrastructure Fund to help roll

[82] Sustainability Victoria. 2019. Guide to better practice at resource recovery centres. Retrieved from https://bit.ly/3pvyv1Q
[83]Victorian Government. 2016. Resource recovery infrastructure and landfills in Melbourne. Retrieved from https://bit.ly/2MK1YH2
[84]A circular economy for Victoria 2019- Sustainability Victoria. Retrieved from https://bit.ly/3t3KyFE
[85]Alex Fraser. 2018. Dingley Bypass. Retrieved from https://bit.ly/3a7s7r1
[86]Service Victoria. 2019. Recycling Victoria A new economy Retrieved from https://bit.ly/3pt5l3t
[87]InsideConstruction. 2020. Grants available for construction projects using recycled materials. Retrieved from https://bit.ly/38WcFyF

out recycled materials for local construction projects. Infrastructure projects across 79 local councils are expected to cost $8 billion over the next three years. The government intends to leverage this funding to encourage the use of recycled products.

The other market development initiative has come through Recycling Victoria, the Government's 10-year action plan for waste and recycling. It will invest more than $300 million to transform the state's recycling sector, reduce waste and create thousands of jobs. In 2020, Sustainability Victoria launched an online directory that will feature local, Victorian products containing recycled content. The directory will help the Victorian government source recycled materials. It will be used by state and local government procurers and buyers to help them easily research, review and access recycled content products. Lastly, the government initiative to encourage localised waste management through several waste and resource recovery groups across Victoria sets an example of how integrating contextual conditions in the broader context of a state's waste management strategy can if properly coordinated with other organisations (e.g., EPA, SV, industry and businesses), drive a vital market for recycled C&D waste products. It is also noteworthy that Victoria was the first Australian jurisdiction to develop a comprehensive framework that plans for waste and resource recovery infrastructure[77].

10.7. Recommendations

The following are some recommendations to improve the operation of Vic's existing market for recycled products. The recommendations are made according to experts' views published in different sources[82] and should emerge from collaboration between key stakeholders including the government, the construction industry and the resource recovery sector:

- Work with local and other relevant stakeholders to develop sustainable end-markets for recovered recyclables to reduce exposure to price volatility of international commodity markets,
- Recommend the use of recycled and recovered material in infrastructure design and build and the purchase of products that are made from or contain recycled or recovered material,
- Establish a framework for monitoring progress towards the circular economy, including the identification of indicators and metrics.

11. Analysis of Existing C&D waste End markets: Western Australia

11.1. Overview

Western Australia (WA), the largest state in Australia, covers the entire western third of the country, WA is made up mostly of the arid Outback and its total area is 2,529,875 km², which accounts for 33% of Australia's total landmass[88]. Its population is concentrated in its fertile southwest corner, home to the Margaret River wine region and the riverside capital, Perth. Based on the latest estimations, WA's population will reach 2.81 million by the end of June of 2021[88]. WA's gross state product (GSP) of $285.6 billion in 19-2018 was 15% of Australia's gross domestic product (GDP). Construction is the third major contributor to the state GSP following mining, business and property services[89]. However, the latest data shows that construction activities in WA have consistently weakened since the start of 2015 in all construction sectors. In 2020, the value of building work done (all construction sectors and building types) dropped to about $2 billion (Figure 14), a 72% decrease from that of 2015, making it the largest detractor from GSP growth[88]. Unsurprisingly, this resulted in a significant decrease in the amount of C&D waste generated in the state. In WA, C&D waste materials are considered as priority waste management resources.

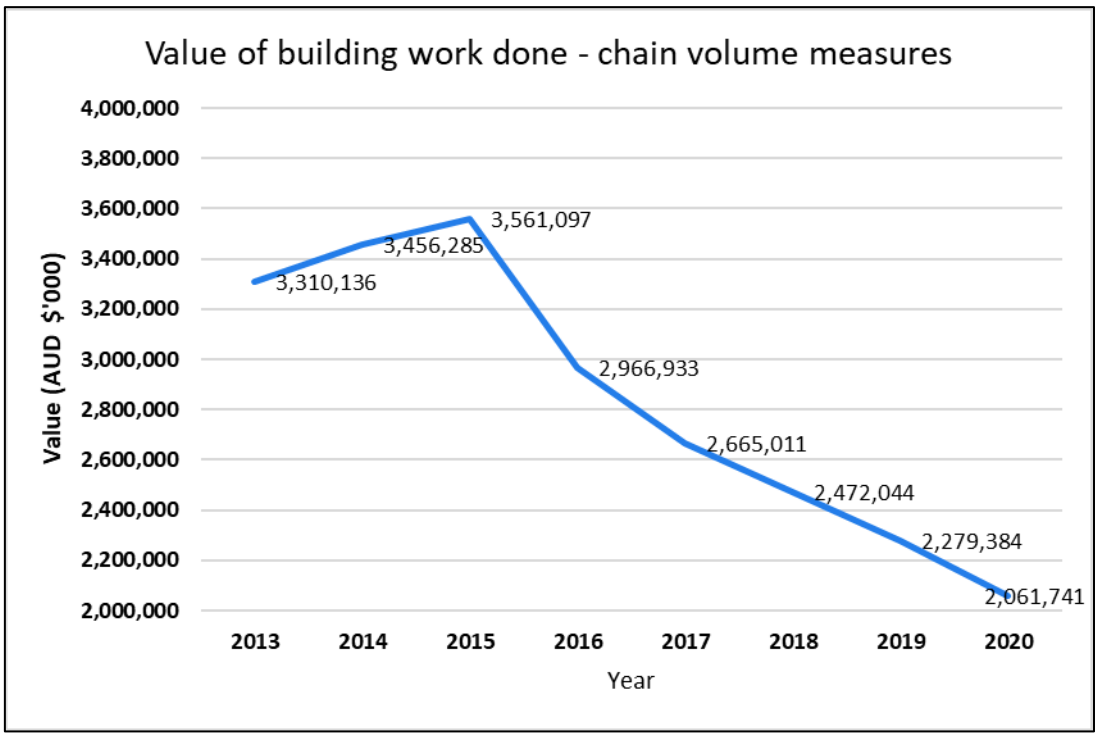

Figure 14. The value of construction activities in WA between 2013 and 2020 (until Sep).

11.2. C&D waste data

The C&D waste sector is the largest volume of waste resources diverted from landfill. It is also the largest volume of waste generated of any material type; it accounts for 90% of total solid waste in the state[90]. Compared to other major states, WA features a smaller C&D waste flow[2]. In 2018-19, the state produced 1.9 mt C&D waste. The low generation of C&D waste and recycling and disposal is directly related to the state's declining trend in construction activities. According to the National Waste Report[2], the state's C&D waste recycling in 2019 increased by 26% compared to that in 2017, while the

[88] Population Australia. 2020. Population of Western Australia 2021. Retrieved from https://bit.ly/36e0dZB

[89] WA Department of Jobs, Tourism, Science and Innovation. 2020. Western Australia economic profile. Retrieved from https://bit.ly/39Rwvdx

[90] Waste Authority. 2020. Roads to Reuse. Retrieved from https://bit.ly/391jhvz

C&D waste disposal saw a comparatively slight decrease (3%). The C&D waste-based EfW was recorded at 2 kt. The most recent data reported by the Waste Authority[90] shows an 80% resource recovery rate for the C&D waste stream, which is 24% more than average resource recovery in the state. Among the priority materials, concrete had the greatest recycling rate. The data for waste disposal for brick, concrete, asphalt and steel are non-existent (Table 13).

Table 13. Priority C&D waste materials statistics in WA

Material	Waste generation (t)	Disposal (t)	Recycling (t)
Brick	19,213	0	19,213
Concrete	217,994	0	217,994
Asphalt	136,816	0	136,816
Steel*	138,870	0	138,870
Glass*	230	230	0

Source: 2020 National Waste Database
*numbers are for C&D waste stream only.

There are overseas markets for scrap steel and—according to the Waste Authority report[92]—in 2018-19, more than 597 kt of non-packaging steel was destined for overseas markets (Asia), in addition to 20.5 kt that was sent interstate. The state has embarked on a few major infrastructure projects that will change the waste flow landscape. In early 2020, WA had $27.2 billion of major resource projects under construction or committed and $91.1 billion under consideration[89]. It is foreseen that these projects will also be opportunities to divert C&D waste resources from landfills by utilisation of recycled products in constructions; albeit, the pandemic situation might present some challenges.

11.3. Existing markets

With over 1.5 million tonnes of C&D materials processed annually in WA, there is a large supply of usable materials, and recently there have been some successes in developing new markets for these recycled materials[91]. Currently, the largest end-market for C&D waste materials is public projects. These projects have unlocked the potential of a domestic market for extensive application of recycled products. Particularly, the Waste Authority's initiative called 'Roads to Reuse' (RtR)[90], established in 2020, outlines the state's effort in the use of recycled C&D waste. The organisation's vision is to encourage State Government organisations, local governments, regional councils and the private sector to use recycled C&D products in civil applications, such as road construction. The reduced construction activities, however, are estimated to cause a decline in supplying feedstock for recycling facilities and thus affect the market development in future[92]. To better understand the potential of existing markets, the following calculations for concrete, brick and asphalt are made. These are based on local prices of recycled products and the quantity of waste recycled across the state annually.

Concrete—Assuming all recycled concrete is to be converted to 10mm (concrete), which is typically priced at $55/t, and accounting for 10% residual waste during recycling, the total potential market for recycled concrete is $63.9 million per year.
Total market size = quantity of recycled concrete – 10% residual waste allowance × the retail price of recycled product

[91]Active Sustainability. 2020. WA Construction Resources - Recovered Construction and Demolition Materials Resource Guide. https://bit.ly/36a9Po1
[92]Waste Authority. 2020. Recycling Activity in Western Australia 2018-19. https://bit.ly/2MrxMQE

Total market size = 217,994t – 21,800 t × $55= $10. 79 million

Brick—In WA, recycled wire-cut red clay and recycled pressed red clay cost $1.31 and $1.53, respectively[93]. Each brick weighs 3.75 kg and given the annual recycling rate in WA (Table 13), it can be inferred that the potential market size for brick is $7.28 million. The associated calculations are provided below:

Number of recycled bricks: 19,213,000 kg (quantity of recycled brick in WA) / 3.75 kg (average weight of a brick) = 5.13 million bricks
Potential market size: 5.13 m (number of recycled bricks × $1.42 (average price of a brick) = $7.28 million

Asphalt—Recycled asphalt in WA is worth $9.50 per tonne[94] and given the state's concrete recycling quantity which is 136,816 t (Table 13), the potential market size for this resource is $63,921, 330. The calculations are as below:
Total market size = quantity of recycled asphalt – 10% residual waste allowance × the retail price of recycled product
Total market size = 136,816 t – 13, 681 t × $9.5 = $1. 17 million

Steel—The steel potential market is the largest among the study materials. The recycled stainless steel is approximately $1.26 per kg[95]. Given the state's recycled steel (Table 13), the potential market is worth $175 million.
Total market size = quantity of recycled steel × the retail price of recycled product
Total market size = 138,870,000 kg × $1.26 per kg = $174, 976,200

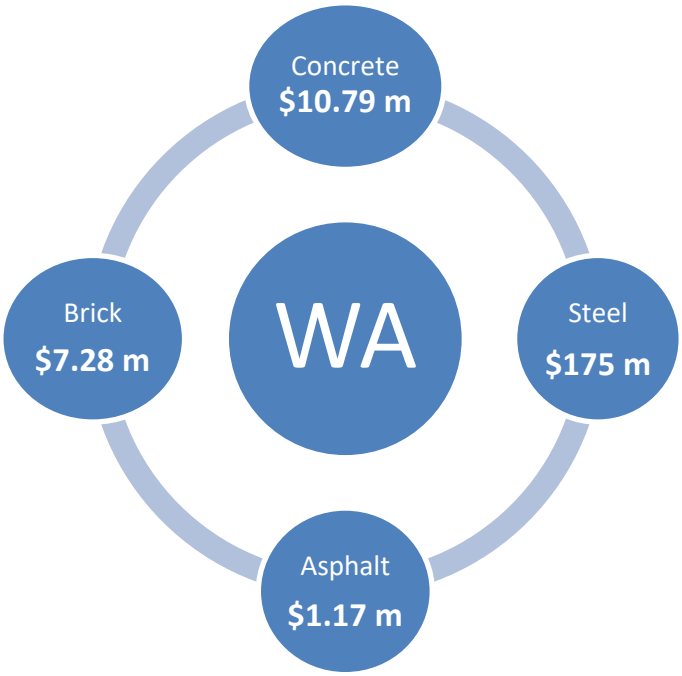

Figure 15. The potential market for priority materials in WA.

[93]REDe Recycled Bricks. 2021 products. Retrieved from https://bit.ly/36cvNXz
[94] Reece Aggregates and Recycling. 2021. Products price list. Retrieved from https://bit.ly/368f7QO
[95] Current scrap metal prices Australia. 2021. Scrap metal prices Perth. Retrieved from https://bit.ly/3678WMU

According to a recent report[91], currently, the state does not have the ideal market capacity for timber (structural and packaging), gyprock, metal (roofing, gutters, lintels) and plastics (strapping, packaging).

11.4. Material recovery facilities

The WA has the biggest material recovery facilities across Australia. The new Cleanway's South Guildford plant is the biggest recycling plant in the southern hemisphere[96]. Before a very recent fire incident forced it to shut down, this facility accepted recyclables from 20 local governments. The public authorities such as the Waste Authority and EPA attempt to increase customers' awareness of the benefits of recycling and actively support recycling businesses. For instance, a public entity, the Southern Metropolitan Regional Council (SMRC), launched a directory of recycling facilities under a program called Recycle Right[97]. The program aims to encourage and assist residents and businesses in WA to recycle, reduce their waste and live more sustainably.

A survey study[91] on the operation of major C&D waste recyclers in Perth indicated that:

- All materials processed for recycling and reuse comply with environmental regulations, and well and specific standards and specifications for end-use applications.
- All undertake National Association of Testing Authorities (NATA) testing.
- They recover, recycle or make available for reuse a range of materials and also produce a range of products.
- All have some form of in-take quality control procedures to monitoring inbound loads, including:
  o Only receiving own-loads, or known and trusted customers;
  o Visual and photo/x-ray imaging of in-bound loads;
  o Pricing to match the quality of separated/sorted materials vs. co-mingled loads; and
  o Rejecting contaminated loads (to be sent to landfill).
- All have on-site processing facilities—i.e. primary sorting and crushing, screening and handpicked sorting, secondary crushing and then stock-piled for testing as required.

The differences in their operation include a focus on a particular market and product, varying approaches to separating and sorting materials, and detecting asbestos in their feedstock. This report also illustrates the main processed materials and their end-markets identified in the study WA's recycling facilities:

Table 14. Product received, processed and relevant main end-markets**.**

Products Received	% of total product processed	Main end-market(s)
Fill sand	High – 65% Average – 35% Low – 20%	- Civil developments and building construction - construction blocks
Crushed recycled concrete	High – 80% Average – 35% Low – 5%	- Roads and road shoulder work - Carparks and truck parking - Driveways - Construction site and ground development -Rammed earth walls and construction blocks - Concrete batch aggregate substitute

[96]Smithers, 2019. Biggest recycling plant in southern hemisphere opens in WA. The West Australian. Retrieved from https://bit.ly/2YdUxKE

[97] WA Government. Recycle Right. Retrieved from https://bit.ly/39g5Ic1

Mixed masonry material (blended rubble - concrete, bricks, tiles, pavers)	High – 20% Average – 35% Low – 90%	- Road base - Track material - Subgrade works - Hardstands - Construction site and ground development
Recycled asphalt / Bitumen	Average ~10%	- Roads - Hard stands - Car parks
Drainage stone (crushed aggregates)	Average ~3%	- Subsoil drainage for car park runoff - Garden bed drainage
Concrete dust / fines	~2%	- Concrete batch substitute - Compacted pavements
Crushed bricks – red, cream, blended	~1%	- Ground cover for courtyard settings - Garden landscaping and placement around plants - Rockeries and around pathway stepping-stones
Brick fines – red, cream, blended	~1%	-Walkways - Verge parking areas, and driveways - Inside shade houses, and horse arenas

Source: Active Sustainability (2020)[91]

The full list of MRFs operating in this state which recovers the study materials is provided in appendices.

11.5. Use of recycled products in construction projects

According to industry and government reports, it makes economic sense to apply current certified recycled C&D waste materials in large infrastructure projects. In a research report[91] commissioned by the Waste Authority, C&D recyclers reported that their certified road-base products are valued at $5-6 per tonne, while virgin quarried materials are valued at up to $20 per tonne. Furthermore, the report indicated the figures for certified clean-fill products and their virgin alternative are $3 and $10 per tonne. Below are some case studies in which recycled C&D waste were used.

Kwinana Freeway Northbound Widening[98]- This project was completed in 2019 and used approximately 25,000 tonnes of recycled construction and demolition (C&D) waste or crushed recycled concrete as sub-base under full-depth asphalt. Further, the project team has provided surplus site material to smaller local projects and overall, sold 56,783 tonnes of waste sand suitable for reuse.

Street Pavement in Willetton, WA [99]- Boral, a major Australian construction and building materials supplier, in partnership with the City of Canning council, has constructed a suburban street in Perth using four recycled materials. The street materials include waste tyres, plastic, glass and old road pavement, all of which were originally bound for landfilling. The recycled materials were combined with crushed rock and bitumen to pave a street in Willetton, WA.

Port Coogee recycled asphalt trial[100]- the City of Cockburn, in partnership with real estate agency Frasers Property, has also paved 750m² of the road in the waterfront community of Port Coogee, southwest of the Perth CBD, with a recycled product known as Reconophalt. Reconophalt comprises a variety of recycled waste materials, including recycled plastic bags, waste toner from printer cartridges, crumb rubber from car tyres and recycled asphalt pavement. Densford Civil poured the Reconophalt,

[98] Waste Authority. 2019. Roads to reuse pilot project case study. Retrieved from https://bit.ly/2M5IWun

[99] Jones, L. 2019. Boral uses for recycled materials in Perth Street. Roads and Infrastructure Australia. Retrieved from https://bit.ly/3ooeCbw

[100] Quary.2020. Suburban roads paved with sustainable asphalt Retrieved from https://bit.ly/3iSiAYM

while the Downer Group supplied the materials. Reconophalt potentially lasts longer than standard asphalt—it has a 65% greater fatigue life.

11.6. Government

Public authorities are in the process of transiting to circular economy and energy efficiency. Therefore, the government is strongly supporting the use of recycled products, particularly in public projects. This has resulted in notable market stimulation for certain C&D waste resources such as concrete and brick. That said, the problem of large proportions of recycled C&D waste failing to find suitable markets persists, and hence, stockpiles continue to grow[91]—currently at about 1 mm^3. Indeed, stockpiling is a major issue in WA that requires immediate state government's attention[101].

11.7. Recommendations

Some recommendations for improving the existing end-market and creating potential markets for C&D waste materials are provided below. These recommendations are extracted from waste management and resource recovery experts' opinions published in different sources[91,102]:

- Implement uniform waste levies across the state, and ideally applying them in a manner that minimises 'border' market distortions,
- Monitor and prevent illegal waste dumping activities to encourage more material recovery,
- Develop technologies that assist authorities to identify and control illegal dumping across the state,
- Facilitate the process of obtaining licences and approvals necessary for the establishment of new facilities,
- Remedy contamination of raw materials and poor source separation,
- Increase customers' awareness of recycled products and their safety.

[101] Department of Water and Environmental Regulation. 2018. Submission: Waste levy and waste management: proposed approaches for legislative reform. https://bit.ly/2Nq3Che

[102] WRIWA.2019. Waste and recycling industry association of Western Australia. Retrieved from https://bit.ly/3iuZwzO

12. Barriers to Creation and Stimulation of End-Markets

12.1. Overview

The uptake of practices related to using recycling C&D products are still limited and continue to have detrimental impacts on the environment[103]. The main barriers to using recycled products in the construction industry have been identified from previous studies (Table 15). The following section provides an explanation of how these factors have hindered the application of recycled products in construction projects.

Table 15. The main barriers to the use of recycled materials

No	Barrier	Short Description
1	Increased costs of energy and transport	Sometimes recycled products are costlier than raw materials.
2	Lack of knowledge on recycled products	Unfamiliarity with recycled products limited their application in construction projects.
3	Limited technologies for waste recovery	Limited technologies in the waste recovery industry resulted in poor quality and expensive recycled products.
4	Low quality, contamination and reduced performance	Less than expected quality hinders the wide application of recycled products in the industry.
5	Lack of market availability of the products	Uncertainty about the market discourages the production of quality second-hand materials.
6	Limitations caused by specifications, standards and permits	Specifications and standards have both positive and negative impact on the recycled product's market.
7	Limited acceptability and negative perceptions (public and the industry)	Negative perceptions towards recycled products limited their usage in the industry.

12.2. Increase in energy and transport costs

Cost is considered to be one of the main barriers to using recycled C&D waste materials in the construction industry. Several studies indicate that recycled products are costlier than conventional materials[104, 105, 106]. A few reasons contribute to higher costs in recycled C&D waste materials including longer transport distance[107], industrial waste sorting procedures[104], increased energy requirements for recycling, landfill levy for residual waste and high capital costs for recycling facilities[108] and equipment[109, 110]. In some circumstances, the use of recycled materials is reported to be less expensive

[103]Umar, U.A.; Shafiq, N.; Malakahmad, A.; Nuruddin, M.F.; Khamidi, M.F. 201. A review on adoption of novel techniques in construction waste management and policy. *Journal of Material Cycles and Waste Management.* 2017, 19, 1361–1373.

[104] Tam, V.W. Comparing the implementation of concrete recycling in the Australian and Japanese construction industries. *Journal of Cleaner Production*. 2009, 17, 688–702

[105] Colin, R. Systems for Reuse, Repurposing and Upcycling of Existing Building Components. Ph.D. Thesis, University College London, London, UK, 2019.

[106] Dunant, C.F.; Drewniok, M.P.; Sansom, M.; Corbey, S.; Allwood, J.M.; Cullen, J.M. Real and perceived barriers to steel reuse across the UK construction value chain. *Resources Conservation and Recycling*. 2017, 126, 118–131.

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[108] Wang, J.; Li, Z.; Tam, V.W. Critical factors in effective construction waste minimization at the design stage: A Shenzhen case study, China. *Resources Conservation and Recycling*. 2014, 82, 1–7

[109]Begum, R.A.; Satari, S.K.; Pereira, J.J. Waste generation and recycling: comparison of conventional and industrialized building systems. *American Journal of Environmental Science*. 2010, 6, 383–388.

[110]Denyer, D.; Tranfield, D. Producing a Systematic Review. The Sage Handbook of Organizational Research Methods; Buchanan, D.A., Bryman, A., Eds.; Sage Publications: Thousand Oaks, CA, USA, 2009.

than fresh materials[25, 73]. However, if waste producers and recyclers are willing to work collaboratively, it can lead to a win-win situation for both parties[111].

12.3. Limited knowledge of recycled products

There is solid evidence that a lack of knowledge of the various characteristics of recycled waste is a factor that diminishes the willingness to use them in the construction industry. A lack of awareness and knowledge leads to negative market demand for recycled products. This could also lead to a negative perception of used materials, final product quality and price in recycled products from the end-users[112,25]. Marketplaces for re-used and recycled material are yet to be mainstream and there is still limited development of knowledge and practical impacts[105]. The limited communication between key stakeholders such as contractors and recyclers and a "wait and see" attitude is also other factors affecting the limited knowledge on recycled products[104].

12.4. Limited technologies for waste recovery

Technologies play an important role in safe and effective waste recovery. Limited technological advances and associated high capital costs in the waste recovery sector have historically hindered manufacturing commercially competitive products[112]. Limited education on emerging waste recovery technologies, lack of investment in waste management technologies[104] and limited incentives for private investment in technology are key reasons affecting the uptake of recycled C&D product use.

12.5. Low quality and reduced performance

Previous research studies indicate that construction industry stakeholders face issues such as quality, contamination and unacceptable performance when choosing recycled products over conventional materials[25, 112]. Lack of technological support, such as resources, training, limited competent staff and expertise, and the lack of a benchmarking tool[104] and systematic decontamination procedures[113] are key reasons affecting the quality and reducing the performance of recycled C&D waste products. As there is no assurance of maintaining the same quality and performance as virgin resources in the recycled product, there is a critical need for defining standards, resourcing producers and training staff members[104].

12.6. Lack of market availability of the products

The viable market has a direct mutual relationship with further using recycled products. When there is an established market for recycled products, the economy of scale assists with further investment in recycling facilities, resulting in lower total cost, higher quality and less contamination. The imbalance of supply and demand for recycled products creates a narrow window of opportunity to trade recycled C&D products. A study in Australia on recycled PVC products application reports that the cost of recycled material is the same as virgin material and recommended that the industry needs greater scale or a higher value for PVC to incentivise more PVC recycling[25]. Once these results are achieved, more industry stakeholders will be persuaded to buy and use recycled materials in construction projects. Market availability is underpinned by several factors including effective supply chain, properly

[111] Liu, J.; Nie, J.; Yuan, H. 2020. Interactive decisions of the waste producer and the recycler in construction waste recycling. *Journal of Cleaner Production*.,256, 120403

[112] Bolden, J.; Abu-Lebdeh, T.; Fini, E. Utilization of recycled and waste materials in various construction applications. *American Journal of Environmental Science*. 2013,9, 14–24

[113] Sánchez, I.G.; Lauritzen, E.K. Integrated decontamination and rehabilitation of buildings, structures and materials in urban renewal-a european project for a sustainable city concept. In Proceedings of the International RILEM Conference on the Use of Recycled Materials in Buildings and Structures, Barcelona, Spain, 8–11 November 2004.

designed landfill levy, government incentives and subsidies, and finding new applications outside of the construction industry[105].

12.7. Limitations caused by specifications, standards and permits

There is an ongoing debate within the waste management and resource recovery industry about the role of specifications, standards and permits in promoting the application of recycled products in the construction industry. If the organisations need to provide indemnities, operate trials or accept risk, these also create an additional layer of complexity that may become an impediment for recycling C&D waste products[105]. On the one hand, specifications and standards determine the quality of materials recycled, giving peace of mind to stakeholders to use these materials. On the other hand, many recyclers indicate that complicated and difficult-to-meet specifications and standards are a significant hindrance in selling recycled products to the market.

12.8. Limited acceptability and negative perceptions (Public and the Industry)

Due to various factors, such as a lack of knowledge and a view of the products as unconventional, there is a negative perception among construction industry stakeholders towards using recycled products[105]. Different stakeholder groups may have different perceptions[114]. These perceptions are changing as field trials show how to use these materials to their optimum performance and as virgin resources become scarcer[25]. This highlights the critical need for prototyping during design stages to test acceptability[105].

[114] Henry, M.; Kato, Y. Perspectives on Sustainable Practice and Materials in the Japanese Concrete Industry. *Journal of Material Civil Engineering*. 2012, 24, 275–288.

13. Strategies to Create and Stimulate End-Markets

13.1. Overview

There are a number of strategies that can be used to stimulate existing markets and develop new applications for recycled C&D waste products. In this review, five major clusters of enablers have been identified that can assist key stakeholders to advocate the use of recycled materials in the construction industry.

13.2. Increase community awareness and education on recycled products

Access to information and the education of construction experts are the two points of leverage for increasing the application of recycled products. Therefore, bolstering efforts to inform stakeholders about the technical properties and environmental performance (primarily awarding authorities), and existing law and standards, is required. Furthermore, the distribution of more data, better documentation and reports about reference buildings assist with increasing engineers' experience with recycled products. In addition, the scientific community needs to make a more significant effort to convey the acquired knowledge to the professionals.

13.3. Develop supportive regulations, policies and specifications

The government should prioritise the task of improving specific legislation and regulations, with a focus on establishing the mandatory degree of normative standards. Notably, design codes should highlight the environmental aspects of the construction and give designers more flexibility in material sourcing, leading to an increased usage of recycled products. Detailed specifications should also be developed in the form of application-specific quality standards for different recycled products as another option to increase the demand for such products. The introduction of mandatory policies (unified, stakeholder-oriented policies)[104]—such as sustainable procurement to meet specific reuse/recycling targets, more purchasing power and grants that are offered to companies to help initiate recycling locally—would encourage both recyclers and builders to invest in waste management solutions[115].

13.4. Facilitate sustainability programs

Another promising route is the implementation of sustainability programs that suggest the use of recycled products in construction projects. Some reports[116] [117] have demonstrated that running these programs leads to further adoption of recycled products in the construction industry. However, there is evidence proving otherwise[118]. Among others, it seems that the design of rating systems, developers' biases and lack of incentives to motive end-users are the most influential reasons for their ineffectiveness. Furthermore, scholarly and political engagement with business practice are urgently needed to facilitate sustainability programs[119].

[115] Ghaffar, S.H.; Burman, M.; Braimah, N. Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery. *Journal of Cleaner Production*. 2020, 244, 118710.

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[119] Leipold, S.; Petit-Boix, A. The circular economy and the bio-based sector—Perspectives of European and German stakeholders. *Journal of Cleaner Production*. 2018, 201, 1125–1137.

13.5. Promote product certification

A product certification that is awarded following material testing, plus quality control, can increase the adoption of recycled materials in the construction industry. As different supply sources will cause variation in quality, stricter quality controls for recycled materials are required[120]. A government agency should be established to control the quality and production of these materials. Guidance on clear technical specifications or standards on the use of recycled aggregate for structural applications will enable recyclers and producers to adhere to industry standards[104].

13.6. Advocate targeted technologies and innovative practice

The waste management and resource recovery industry should embrace new technologies and innovation. Technological advances help recycled materials producers meet market demands through products having reasonable price and quality. Notably, governments, as the main stakeholder responsible for protecting the environment, should support the industry by providing a fund to invest in technologies and innovation.

[120] Tam, V.W.; Kotrayothar, D.; Loo, Y.-C. On the prevailing construction waste recycling practices: A South East Queensland study. Waste Management and Resourch. 2009, 27, 167–174.

14. Concluding Remarks

14.1. Conclusions

This review demonstrates differences and similarities in the existing end markets operation for C&D waste resources across Australian states and territories. For each state and territory, several recommendations are provided that can assist policymakers, researchers, and practitioners to contribute to the creation and stimulation of end markets. Furthermore, this report identified major barriers to the operation of existing C&D waste end markets which included an increase in energy and transport costs, limited knowledge of recycled products, limited technologies for waste recovery, low quality and reduced performance, lack of market availability of the recycled products, limitations caused by complex specifications and standards, limited acceptability and negative perceptions. To overcome these barriers, several strategies are put forward, namely, increase community awareness, develop supportive regulations, promote sustainability programs, promote product certifications, and advocate targeted technologies and innovations. These barriers and strategies can form a management framework that informs decisions, policies and best management practices in the AEC industry to move towards a circular economy.

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16. Appendices

List of C&D waste recylers in different states and territories

State	Material	Recycler	
ACT	Concrete	Canberra Concrete Recyclers P/L Tiger Waste Collection	REMONDIS Australia Pty Ltd ACT Recycling Pty Ltd Capital Waste Skips
	Brick	Canberra Concrete Recyclers P/L Tiger Waste Collection	REMONDIS Australia Pty Ltd ACT Recycling Pty Ltd Capital Waste Skips
	Steel	Canberra Concrete Recyclers P/L Tiger Waste Collection REMONDIS Australia Pty Ltd Capital Waste Skips Access Recycling	Sims Metal Management Act Nowaste - Mugga Lane Resource Management Centre Metal Mart WV Technologies
	Asphalt	Canberra Concrete Recyclers P/L Tiger Waste Collection	REMONDIS Australia Pty Ltd ACT Recycling Pty Ltd
	Glass	Australian Paper Recovery	
NT	Concrete	A Rescue Bin Hire Cleanaway Shoal Bay Waste Management Facility	Secure waste solutions Jim's Skip Bins
	Brick	A Rescue Bin Hire Berrimah Second-hand Building Supplies Cleanaway	Jim's Skip Bins Secure waste solutions Shoal Bay Waste Management Facility
	Steel	Berrimah Second-hand Building Supplies	
	Asphalt	Shoal Bay Waste Management Facility	
	Glass	Envirobank Recycling Pty Ltd Territory Can Man	
NSW	Concrete	24/7 Rubbish Removal AE Biggs AKA Civil Benedict Recycling BINGO Industries Recycling Ecology Park (& landfill) Bingo Recycling Centre Blaxland Resource Recovery and Waste Management Facility Breen Resources Pty Ltd Concrete Recyclers (Group) Pty Ltd Concrush Pty Ltd Concut NSW Eco Resource Recovery Pty Ltd - ECORR Economy Waste Group Enviro Recycling	Genesis Alexandria Get Fast Waste Bins Kimbriki Resource Recovery Centre Kincumber Quarry Metropolitan Demolitions & Recycling Recycled Concrete Products Remondis Australia (Taren Point) PTY Rock & Dirt Recycling SUEZ Ryde Resource Recovery Centre Sustainable Resource Centre Sydney Transwaste Industries Woy Woy Transfer Station
	Brick	24/7 Rubbish Removal AE Biggs AE Biggs AKA Civil Benedict Recycling	Genesis Alexandria Get Fast Waste Bins Kimbriki Resource Recovery Centre Kincumber Quarry Recycled Building Centre

		BINGO Industries Recycling Ecology Park (& landfill) Bingo Recycling Centre Breen Resources Pty Ltd Concrete Recyclers (Group) Pty Ltd Eco Resource Recovery Pty Ltd - ECORR Economy Waste Group Enviro Recycling	Recycled Concrete Products Remondis Australia (Taren Point) PTY Rock & Dirt Recycling SUEZ Ryde Resource Recovery Centre Sustainable Resource Centre Sydney Transwaste Industries The Brick Pit
	Steel	24/7 Rubbish Removal AE Biggs Associated Scrap Metals PTY Ltd. Australian Metal Co Pty Ltd Bingo Recycling Centre Breen Resources Pty Ltd Clevedon Salvage Cooke's Metal Recyclers P/L E-Planet Pty. Ltd. Get Fast Waste Bins InfraBuild Recycling Loumbos Pty Ltd	Mr Metal Recycling Remondis Australia (Taren Point) PTY Renewable Energy Corp Renewable Energycorp Aust Sell and Parker Metal Recycling Sims Metal Management Southern Cross Metals Pty Ltd St George Metal Recovery SUEZ Artarmon Resource Recovery Centre Wolverton Scrap Metals
	Asphalt	24/7 Rubbish Removal AE Biggs AKA Civil Benedict Recycling BINGO Industries Recycling Ecology Park Bingo Recycling Centre Breen Resources Pty Ltd Concrete Recyclers (Group) Pty Ltd Eco Resource Recovery Pty Ltd - ECORR Economy Waste Group	Enviro Recycling Genesis Alexandria Get Fast Waste Bins Kimbriki Resource Recovery Centre Kincumber Quarry Recycled Concrete Products SUEZ Ryde Resource Recovery Centre Sustainable Resource Centre
	Glass	Blaxland Resource Recovery and Waste Management Facility Glass Genie Hoxton Lane Cove Return and Earn	TOMRA Recycling Centre Wastefree (Aus) Pty Ltd Wetherill Park SUEZ Recycling centre Woy Woy Transfer Station
Qld	Concrete	Alex Fraser Queensland BMI Group Jim's Skip Bins	Morten Bay Recycling Resource Recoveries & Recycling
	Brick	Alex Fraser Queensland BMI Group Jim's Skip Bins	Morten Bay Recycling Resource Recoveries & Recycling
	Steel	Action Metal Recyclers Brisbane Scrap Metal Recycling PTY LTD J.J. Richards & Sons Pty Ltd	Scott Metals Resource Recoveries & Recycling United Scrap Metal Traders
	Asphalt	Alex Fraser Queensland Resource Recoveries & Recycling	Wholesale Sands and & Recycling BMI Group
	Glass	J.J. Richards & Sons Pty Ltd Resource Recoveries & Recycling	
SA	Concrete	Adelaide Eco Bins Adelaide Resource Recovery Adelaide Waste and Recycling Centre	Integrated Waste Services Kartaway Campbelltown Transfer Station

		City of Salisbury Waste Transfer Station Dialabin Eco Waste Solutions - CBS Bins	OZ Mini Bins ResourceCo S.A. Waste Management Pty Ltd SUEZ ResourceCo
	Brick	Adelaide Eco Bins Adelaide Resource Recovery City of Salisbury Waste Transfer Station Dialabin Eco Waste Solutions - CBS Bins	Kartaway Campbelltown Transfer Station OZ Mini Bins ResourceCo SUEZ ResourceCo
	Steel	Adelaide Eco Bins Adelaide Resource Recovery Adelaide Waste and Recycling Centre Advanced Recycling Technologies City of Salisbury Waste Transfer Station Dialabin Ferris Metal Recyclers Hackham Recyclers Hampshire Recycling Heathfield Resource Recovery Centre Integrated Waste Services Kartaway Campbelltown Transfer Station	Metrowaste OZ Mini Bins REMONDIS Australia Pty Ltd ResourceCo S.A. Waste Management Pty Ltd Scout Recycling Centre Southern Region Waste & Recycling Centre Trading Metals Wastek Pty Ltd YCA recycling
	Asphalt	Adelaide Resource Recovery OZ Mini Bins ResourceCo	
	Glass	Aldinga Recycle Centre OZ Mini Bins Pooraka Transfer Station	S.A. Waste Management Pty Ltd Scout Recycling Centre
Tas	Concrete	Mornington Park Waste Transfer Station Break O'Day Cleanaway	Secure waste solutions A Rescue Bin Hire Jim's Skip Bins
	Brick	Mornington Park Waste Transfer Station The Glenorchy Tipshop	Jackson Street Waste Management Centre
	Steel	Barretta Waste Management Facility Jackson Street Waste Management Centre Mornington Park Waste Transfer Station	Sims Metal Management The Glenorchy Tipshop
	Asphalt	Burnie City Council Waste Management and Resource Recovery Centre	
	Glass	Mornington Park Waste Transfer Station Wizz Away	
Vic	Concrete	A Rescue Bin Hire Alex Fraser Recycling Industries Atlas Waste Management Bayside Waste and Recycling Centre Bingo Recycling Centre Cleanaway Color Skip Bins Control Bin Hire (Aust.) Pty. Ltd. Frankston Regional Recycling and Recovery Centre Future Recycling Transfer Station Icon Walls	Kartaway East Brunswick Public Transfer Station Knox Transfer Station Melbourne Junk Removal Monash Waste Transfer and Recycling Station Rubbish Removal Melbourne S.M.A.R.T Recycling Pty Ltd Secure waste solutions SUEZ Hampton Park Resource Recovery Precinct

	Brick	A Rescue Bin Hire Alex Fraser Recycling Industries Atlas Waste Management Bayside Waste and Recycling Centre Beaver Bricks P/L Bingo Recycling Centre Cleanaway Color Skip Bins Frankston Regional Recycling and Recovery Centre Future Recycling Transfer Station	Kartaway East Brunswick Public Transfer Station Knox Transfer Station Melbourne Junk Removal Metropolitan Bin Hire Monash Waste Transfer and Recycling Station Rubbish Removal Melbourne S.M.A.R.T Recycling Pty Ltd Secure waste solutions SUEZ Hampton Park Resource Recovery Precinct
	Steel	A1 Cheapest Rubbish Removals Alex Fraser Recycling Industries All Metal Recyclers (Aust) Pty Ltd Atlas Waste Management Auss Metals Pty Ltd Bolinda Road Resource Recovery Centre Cleanaway Deer Park Metals Pty Ltd Hart Metals Inner City Metal Recycling JK Recycling Pty Ltd Kartaway East Brunswick Public Transfer Station Manhari Metals	Melbourne Junk Removal Metal Scrap Australia Moonee Valley Transfer Station Norstar Steel Recyclers Pacific Metal Group PF Metals Platinum Recycling Port Melbourne Metals Port Phillip Resource Recovery Centre Scrap Metal Yard Sims Metal Management Southern Cross Metal Recyclers SRS Recycling Pty Ltd
	Asphalt	Alex Fraser Recycling Industries Atlas Waste Management Bingo Recycling Centre Cleanaway	Kartaway East Brunswick Public Transfer Station Knox Transfer Station Rubbish Removal Melbourne S.M.A.R.T Recycling Pty Ltd
	Glass	Bayside Waste and Recycling Centre Bellfield Waste Recovery Centre Bolinda Road Resource Recovery Centre Cleanaway Control Bin Hire (Aust.) Pty. Ltd. Frankston Regional Recycling and Recovery Centre Future Recycling Transfer Station Glass Recovery Services Kartaway East Brunswick Public Transfer Station Knox Transfer Station	Monash Waste Transfer and Recycling Station Moonee Valley Transfer Station Moreland City Council Mornington Resource Recovery Centre Nillumbik Recycling and Recovery centre Recycal SUEZ Hampton Park Resource Recovery Precinct Visy Recycling
WA	Concrete	All Earth Group Backyard Bins Balcatta Recycling Centre Capital Recycling City of Rockingham - Millar Road Landfill Facility	Eclipse Resources Pty Ltd Instant Waste Management WA Recycling Pty Ltd West Tip Waste Control Wizz Binz
	Brick	Balcatta Recycling Centre Capital Recycling Instant Waste Management West Tip Waste Control	WA Recycling Pty Ltd Wizz Binz Backyard Bins Eclipse Resources Pty Ltd

	Steel	Big Dog Transport and Recycling Collins Recycling Ingot Metals Instant Waste Management P Zissis & Son Sims Metal Management Welshpool West Metro Recycling Centre Auscon Metals & Machinery	Balcatta Recycling Centre Go Recycle Runabout Metals Sims Metal Management Kwinana Beach Sims Metal Management Malaga Wanneroo Metal Recycling West Tip Waste Control Wizz Binz
	Asphalt	Backyard Bins Instant Waste Management	WA Recycling Pty Ltd West Tip Waste Control
	Glass	Balcatta Recycling Centre Waste Wise Environmental West Metro Recycling Centre	

Source: Business Recycling (here)
Just drop off locations listed