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Replacement Materials

Understanding the market for replacement materials across major infrastructure road projects

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Acknowledgements

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Critically, the report would not have been possible without the generous contributions from over 300 individuals representing businesses, industry and governments across the recycled materials and road construction supply chain who participated in the project survey, workshops and oneonone interviews. Infrastructure Australia thanks each for their invaluable contributions.

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Acknowledgement of Country

Infrastructure Australia proudly acknowledges the Traditional Owners and Custodians of Australia, and their continuing connections to the land, waters and communities. We pay our respects to them and to their Elders past, present and emerging. In preparing for the future of our infrastructure, we acknowledge the importance of looking beyond the immediate past to learn from Aboriginal and Torres Strait Islander peoples' unique history of land management and settlement, art, culture and society that began over 65,000 years ago.

As part of Infrastructure Australia's commitment to reconciliation, we will continue to develop strong, mutually beneficial relationships with Aboriginal and Torres Strait Islander partners who can help us to innovate and deliver better outcomes for Aboriginal and Torres Strait Islander communities, recognising their expertise in improving quality of life in their communities.

Note on the artwork

The artwork Moving Along Pathways was created by Kamilaroi/Gamilaraay artist Dennis Golding, specifically for Infrastructure Australia's first Reconciliation Action Plan. The artwork depicts examples of Australia's first infrastructure.

Pathways and river systems are prominent in the artwork and reference the pathways First Nations peoples formed on land and water for transport and communication of knowledge and stories. Images of waterholes, campsites and boomerangs within the artwork acknowledge First Nations cultural practices, technology and places for gathering that continue to be operated today.

Foreword

Australia is on the cusp of a major cultural and economic transformation in the way it values and uses resources previously considered waste. The 2021 Australian Infrastructure Plan identified this transformation as a key reform to meet Australia's future infrastructure needs. As such, I am pleased to present Replacement Materials: Understanding the market for replacement materials across major infrastructure road projects.

This timely piece of work shines a light on current and projected demand for recycled materials in road infrastructure and offers a range of opportunities to boost uptake by addressing market and supply chain constraints. Prefacing this, the key catalysts for the development of this report were:

Unprecedented public infrastructure investment – as explored in Infrastructure Australia's 2022 Infrastructure Market Capacity report, existing materials supply chains face escalating pressures both locally and internationally. At home, Australia's infrastructure ambitions continue to grow to unprecedented levels, while the COVID-19 pandemic and, more recently the war in Ukraine, continue to challenge the supply of imported materials.

The National Waste Policy Action Plan - agreed by all levels of government, this plan emphasises the importance of stimulating demand for recycled materials, including specific action to analyse and report on national infrastructure capacity requirements with a particular focus on plastics, paper, glass and tyres.

In producing this report, Infrastructure Australia worked collaboratively with the Australian Government Department of Energy, the Environment, Climate Change and Water as project sponsor, ecologiQ in Victoria as project advisors, and the Australian Road Research Board and Ernst & Young as project contractors. The collaborative approach and support from government agencies, departments and key individuals was critical to developing this analysis, as was industry support and engagement.

Across Australia, there is already a growing shift towards a more circular economy, and the various government and industry initiatives that explore and facilitate the use of recycled materials are very encouraging. Given this, we look forward to supporting governments and industry on Australia's unfolding journey to reduce waste, improve resource recovery, create demand, and build markets for recycled products.

Infrastructure Australia

Executive summary

At a glance

Infrastructure Australia's milestone 2021 *Infrastructure Market Capacity* report observed that Australia is currently seeing unprecedented levels of investment in public infrastructure. With this will come increased demand for construction materials, which is expected to place greater pressure on already stressed supply chains for virgin materials.

This report examines the potential to unlock new supply chains of recycled materials for use in road infrastructure to meet Australia's growing infrastructure demand. This has the dual benefit of reducing the consumption of virgin materials and diverting considerable volumes of recyclable resources from landfill.

Transforming our economy: the waste action agenda and drivers

Australia is on the cusp of a major cultural and economic transformation in the way we value and use resources, including those previously considered as waste. This transformation has the following agenda and drivers:

- Accelerating Australia's transition to a circular economy to promote greater resource efficiency, maximise the value of the materials used and meet future infrastructure needs.
- Reducing waste, improving resource recovery and building demand and markets for recycled products by using infrastructure projects as a catalyst.
- National and state-based resource management policies setting a pathway towards increased uptake of recovered recycled and replacement materials in infrastructure projects.
- Industry leaders moving to incorporate recycled materials ahead of, and in response to, major market shifts such as the waste export ban, diminishing virgin material supplies and rising material costs.
- Technological developments and emerging new and improved recycled material products and applications driving maturity and value in the market for recycled materials.

Opportunity to use recycled materials

Road infrastructure presents a unique opportunity to make use of recycled materials

Australia has an extensive road network covering over 877,000 km.[1] In 2021, Infrastructure Australia reported that over the next three years the investment in infrastructure will likely – at least – double current spending and around $161 billion (or 4 out of 5 dollars) will be allocated to major transport projects over the next five years.[2]

Road infrastructure building and maintenance use large volumes of construction materials each year. Road infrastructure is also very well suited to the incorporation of recycled materials, providing a major opportunity to reduce landfill and progress towards a more circular economy, where end of life materials are valued resources.

Industry has been gradually developing capacity for recycled material use for decades, now engaging tried and tested technologies, alongside emergent innovative approaches.

The incorporation of recycled materials in the construction, rehabilitation and maintenance of road infrastructure has numerous benefits, including:

- Reducing the amount of waste sent to landfill, illegal dumping and littering
- Reducing the greenhouse gas emissions generated by the production of new materials and the disposal of waste materials
- Reducing our reliance on non-renewable resources and developing a circular economy where materials are continually reused in their highest and best use
- Potentially reducing short and long-term costs
- Potentially improving network performance

In many cases road agencies have been using recycled materials for decades to reduce waste and emissions to deliver safe, sustainable and reliable transport infrastructure.

Estimating the potential

Based on Infrastructure Australia's central case conventional material demand forecast, this report shows that:

- From 2015–31, approximately 200 million tonnes of conventional materials are needed to deliver 998 road projects from across the country. Over 95% of the mass is made up of five key materials: aggregates (29%), asphalt (27%), rock/bluestone (16%), sand (15%) and cement (9%).
- Based on current technology and standards, approximately 27% of the conventional material tonnage could be replaced by using a range of recycled materials. This means replacing approximately 54 million tonnes of conventional materials with approximately 52 million tonnes of recycled materials.
- The largest quantities of conventional materials that could be replaced are asphalt (32% of the replaceable conventional materials tonnage) and concrete (32%).
- The largest quantities of recycled materials that could be used to replace conventional materials are reclaimed asphalt pavement (26% of the recycled materials tonnage to replace conventional materials), followed by recycled crushed glass (24%) and crushed concrete (18%).
- The peak of demand is forecast for 2023–24.
- With advancements in technology and the associated updates to standards, the tonnage of conventional materials replaced could rise from the current 27% to 43%. This could replace nearly 87 million tonnes of conventional materials with nearly 80 million tonnes of recycled materials.
- Based on blue-sky assumptions, the replacement rate could further rise to 59%, replacing nearly 119 million tonnes of conventional materials with 114 million tonnes of recycled materials.

Infrastructure Australia also undertook a low and a high forecast for conventional materials demand. Based on those forecasts, the replacement potential is estimated to be approximately 17% lower than the central case in the low forecast, and approximately 14% higher in the high forecast.

The forecasts generated in this report is based on a pipeline of 998 road projects across the country for 2015–31. Refinement of forecasts and the inclusion of future projects will present different scales of opportunities. Nevertheless, based on the forecast conventional material tonnage, there is significant potential for replacing conventional materials with recycled materials. The scale of the replacement depends on technology, standards as well as market appetite and supply.

Understanding the constraints

- There is a low familiarity of available recycled material products, benefits and market opportunities across the resource recovery and recycling industry.
- Uncertainty, negative perceptions, and a risk aversion culture are key barriers to uptake.
- Environmental regulations are falling behind community and industry expectations and inhibit industry growth.
- Recycling infrastructure and availability of replacement product is not consistent or uniform across the country.
- Supply shortfalls currently exist for fly ash, plastics, crumb rubber, recycled crushed glass, and ground granulated blast furnace slag. Recycled crushed glass and ground granulated blast furnace slag have the greatest risk to future shortages.
- Supply capacity limitations include declining feedstock volumes, geographic mismatch between demand and supply, high capital costs, lack of demand and competing demand from other industries.
- Lack of sustainable and ongoing demand for emerging replacement materials are a key reason for the lack of stable supply.

Key opportunities and actions

Key opportunities and actions to address market constraints impacting the uptake of recycled materials in road infrastructure:

Improving awareness and understanding of recycled materials, specification and opportunities

All levels of government with support from industry groups to:

1. Educate participants along the supply chain on the range of recycled materials available, using databases, educational collateral and case studies.
2. Develop materials to raise awareness and promote the environmental credentials and lifecycle cost benefits of recycled materials compared with products made from virgin materials.

Taking stronger action to enhance confidence in using recycled materials

All levels of government with support from industry groups to:

1. Build awareness and confidence among governments using educational materials, encourage knowledge sharing and generate opportunities for engagement between suppliers and local governments.
2. Develop, update and where beneficial harmonise fit-for-purpose performance-based specifications, standards and guidance to support their application across jurisdictions and to communicate their benefits broadly.
3. Support practical, application-focussed research to translate the latest knowledge to local settings and conditions, and showcase trials and demonstrations to recognise and reward innovation.

Addressing regulatory issues

Environmental regulators should engage with recycling industry representatives to:

1. Shift the negative perception of waste as a hazard and find opportunities to optimise environmental and commercial outcomes.
2. Reform environmental regulation of recovered and recycled materials, including removing or amending regulatory requirements that inhibit efficient business operations, create market uncertainty and lead to adverse outcomes, such as valuable recovered materials being sent to landfills.

The recycling industry should also work with all levels of government to develop product certification rules and processes to manage the quality and consistency of recycled materials for use in road applications.

Improving and modernising recycling infrastructure and workforce capacity and expanding geographic reach

All levels of government with support from industry groups and individual businesses to:

1. Increase the geographic reach of replacement products by using existing material processing infrastructure to accept waste streams and produce replacement products.
2. Increase the attractiveness of the resource recovery and recycling industry to the workforce by modernising facilities and implementing incentives for school-leavers or young people to enter the industry.

Driving demand through sustainable procurements and market signalling

All levels of government with support from industry groups to:

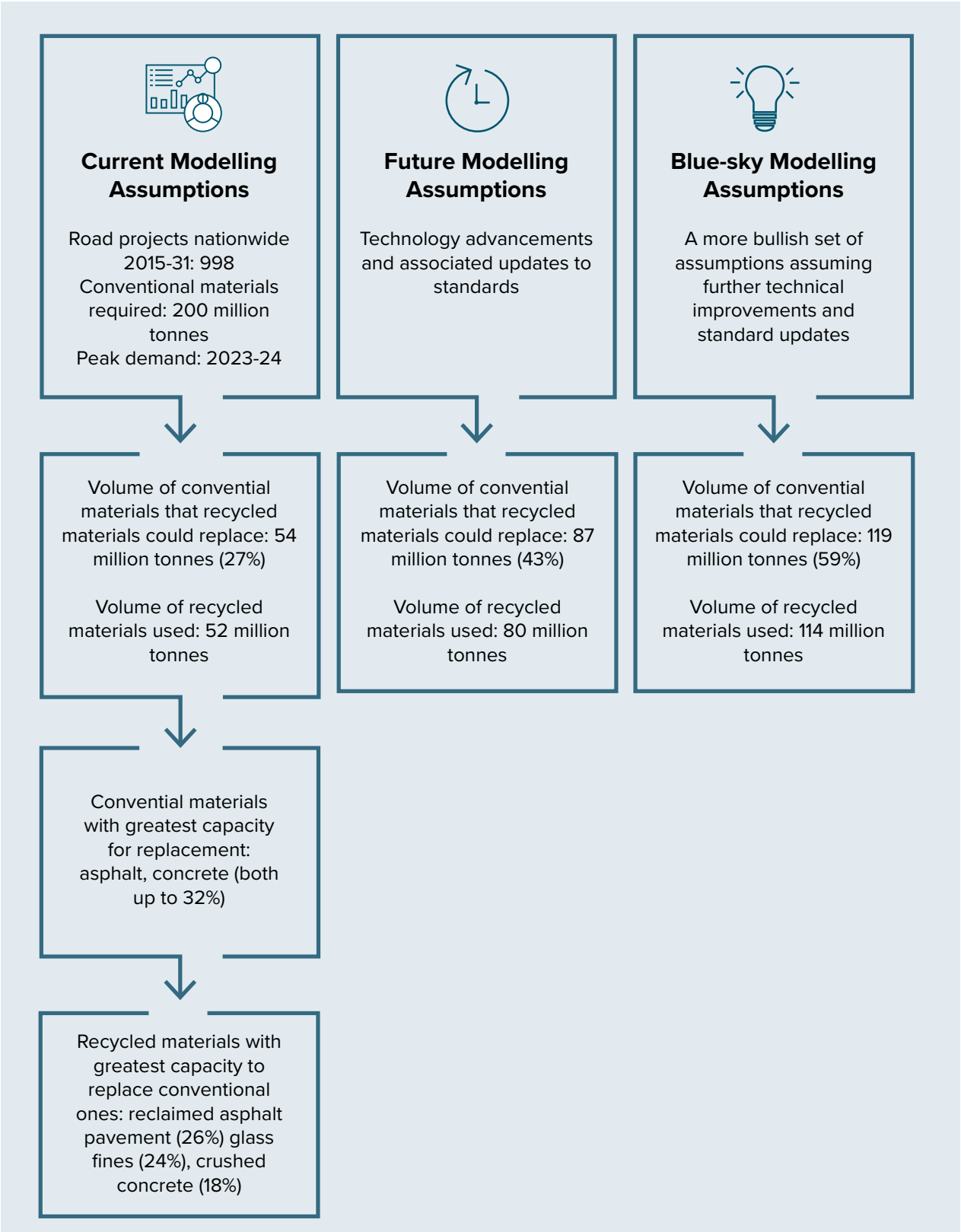
1. Facilitate procurement-driven demand.
2. Provide easy-to-access market and cost information.
3. Provide clear demand signals to support market growth and improve the price competitiveness of recycled materials.

Further opportunities

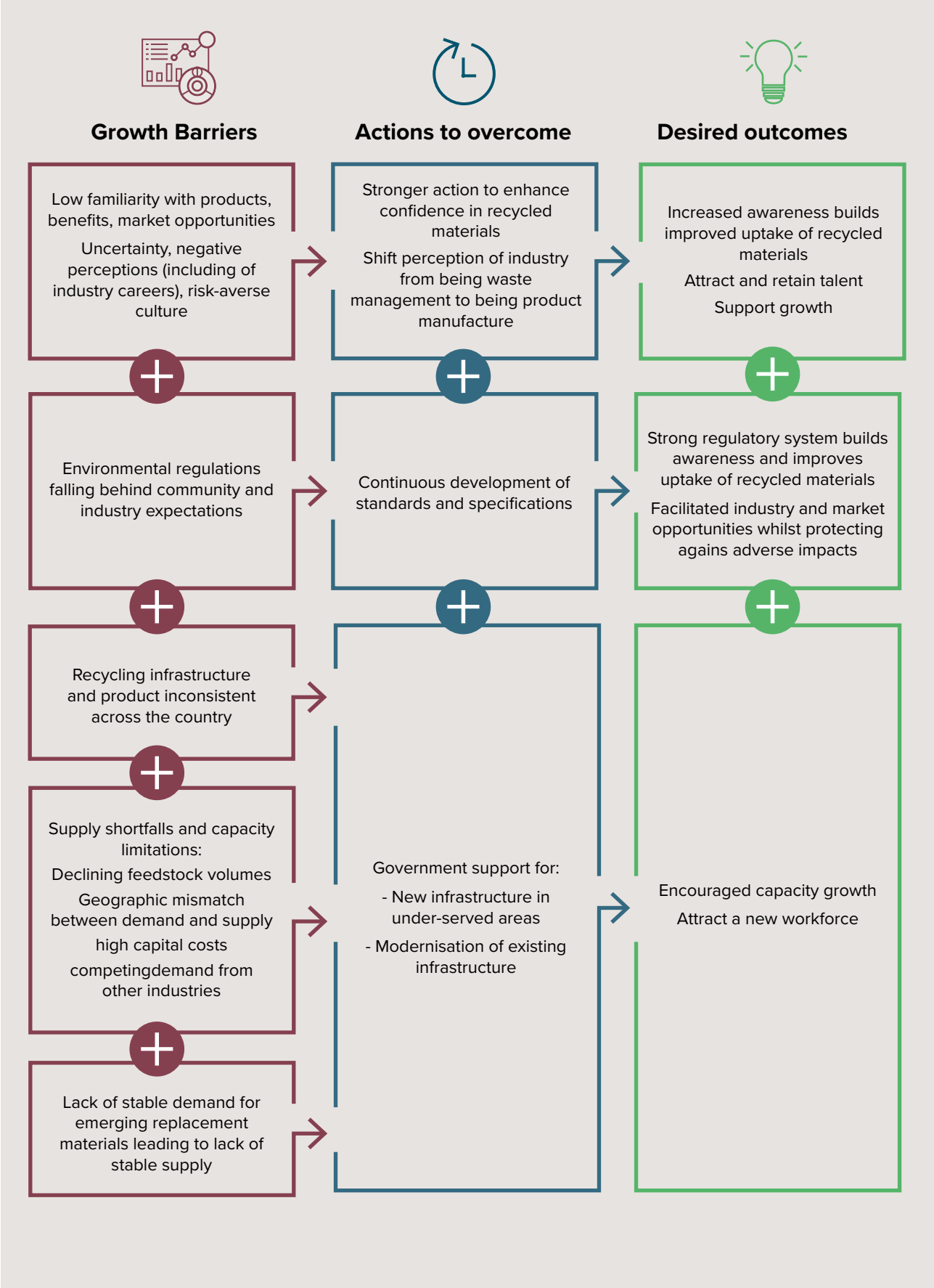
This report focusses on the opportunities and market constraints for using recycled materials in road infrastructure. Momentum is gathering across the infrastructure sectors, including rail and nontransport related infrastructure across various scales to incorporate recycled materials. Future stages of the Market Capacity Program would benefit from expanding the recycled material demand forecasting and market analysis for relevant materials into the rail and other infrastructure sectors. This could build on the *Sustainability Options for Freight Rail* work developed by Australasian Centre for Rail Innovation, Australian Road Research Board and Arup.

Key findings

Key demand modelling findings



Key market analysis findings



Introduction

Overview of the Market Capacity Program

The Market Capacity Program responds to a request from the Prime Minister and First Ministers at the Council of Australian Government meeting on 13 March, 2020, that Infrastructure Australia will work with jurisdictions and relevant industry peak bodies to monitor infrastructure market conditions and capacity at regular intervals, to inform government policies and project pipeline development.

The intent of the Market Capacity Program is to provide governments and industry with world-leading capability that supports investment decisions and industry policy-making.

The Market Capacity Program is underpinned by a data-driven capability designed to comprehensively understand the capacity of the market to deliver the pipeline of major public infrastructure projects. A National Infrastructure Project Database aggregates and organises project data and a Market Capacity Intelligence System applies a comprehensive suite of analytical and system-based tools to interrogate and visualise capacity across sectors, by project type and resource inputs.

In meeting this request, Infrastructure Australia works collaboratively with state and territory governments, and industry across Australia and internationally. These partnerships continue to facilitate our ability to understand and analyse the pipeline of major public infrastructure projects through the Market Capacity Program, first established in 2021.Building on the National Infrastructure Project Database and the Market Capacity Intelligence System developed in the first phase of the Infrastructure Market Capacity Program, the *Infrastructure Market Capacity* report (2021) outlined opportunities to establish new and deeper capability, for example:

- **expanding into more infrastructure sub-sectors** and building a larger and more representative data set
- **deep-dives into materials and opportunities with non-virgin replacements**, embodied carbon, or construction and demolition waste
- greater **understanding about sector-specific constraints and opportunities**, for example in relation to megaproject delivery, or the rail project pipeline.

This second phase of the Market Capacity Program:

- expands the infrastructure sub-sectors to include lower value capital road projects, include local government investment programs as well as road maintenance activities
- focusses on recycled and replacement materials as replacements for virgin materials, including construction and demolition waste (crushed concrete, crushed brick, reclaimed asphalt pavement, ballast), industrial by-products (bottom ash, fly ash, ground granulated blast furnace slag) and commercial and industrial/household domestic waste (recycled crushed glass, recycled plastics, recycled solid organics, crumb rubber)
- provides market insights on the constraints and opportunities from stakeholders across the waste management, recycling and reuse (in road construction) supply chain, including government policies, procurement and operations.

Project aim

Besides uncovering the technical status quo and limitations, and supply chain limitations, this project aims to understand what cultural barriers may exist that act as limiting factors in the uptake of replacement materials, and to showcase best practice in their procurement and application.

Finally, leveraging the capability of the Market Capacity Program, this research presents findings on the potential to use replacement materials, as well as the timing and location of potential demand which will support project planning and investment decisions by government and industry.

Context

The *2021 Infrastructure Market Capacity* report identified that Australia is currently experiencing a record level of investment in infrastructure. With this, demand for materials is projected to grow by an average of 120% over the next three years and material shortages are expected. Demand for quarried material and cement, in particular is likely to produce the most significant challenges due to their reliance on local supply chains. An average annual growth rate for rock/bluestone will approach 60% over the next three years. [2]

These findings, based on virgin materials, point to a critical need to find alternative material sources to meet the infrastructure demand. Recycled and replacement materials offer a potential solution, as well as other benefits such as lower environmental impacts, employment opportunities and cost savings.

This report examines the current and project demand for recycled and replacement materials under different adoption scenarios and investigates opportunities to address market and supply chain constraints.

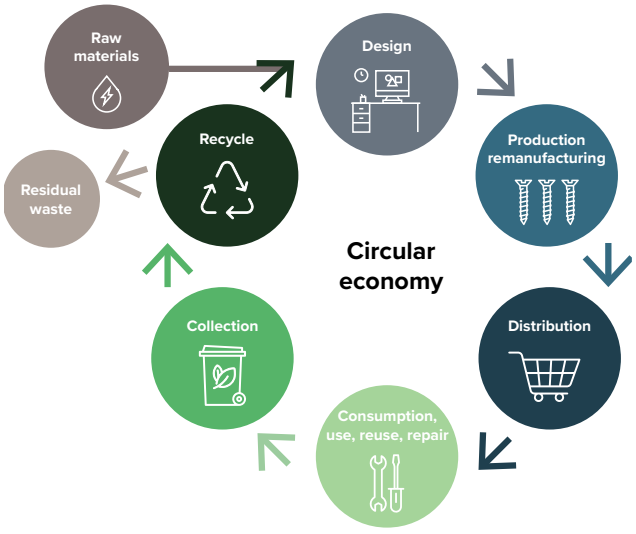
Transforming our economy: the waste action agenda and drivers

Australia is on the cusp of a major cultural and economic transformation in the way we value and use resources previously considered waste.

Across Australia, there is a drive to develop and enhance the circular economy. The *2021 Australian Infrastructure Plan* identified the acceleration of Australia's transition to a circular economy as a key reform to meet Australia's future infrastructure needs.

The circular economy concept (**Figure 1**) treats waste as a resource: from the early stages of design and product manufacturing to building mechanisms of reuse and repair, through to ensuring there is domestic capacity for product recycling and returning waste materials to products of value.

Figure 1: Circular economy



Source: Department of Climate Change, Energy, Environment and Water[3]

To transition to a circular economy, the *2021 Australian Infrastructure Plan* recommends integrating the circular economy in national waste policy and infrastructure projects, including avoiding waste, improving resource recovery and building demand and markets for recycled products.

The *National Waste Policy* and *Action Plan* are key drivers for the incorporation of recycled materials into infrastructure projects.[4] Moreover, policies and regulations are emerging across Australia which drive investment in recycled products. The *Recycled and Waste Reduction Act 2020* seeks to phase out key waste exports and drive investment in Australia's domestic capacity for processing and reusing our waste.[5] The Victorian Government's *Recycled First* policy, led by Major Transport Infrastructure Authority's ecologiQ initiative requires major transport projects in Victoria to optimise the use of recycled materials.[6]

Industry initiatives are also encouraging and facilitating the use of recycled materials. These include project rating and certification schemes such as the IS rating scheme and Green Star which help to benchmark sustainability performance, set priorities and incentivise the use of sustainable products to reduce the environmental impacts of infrastructure projects. Companies such as Downer, Alex Fraser and Fulton Hogan, are seeing these drivers as the way forward: developing markets and creating new products to utilise recycled materials while also driving long-term performance outcomes and economic benefits, such as long-term lower lifecycle costs (Personal communication with Jason Walsh, Petar Lazarus from Alex Fraser and Vince Thai, Laszlo Petho from Fulton Hogan, Workshop 29 March 2022). Environmental benefits, including lowered emissions and landfill reductions, as well as resource security in the face of diminishing natural materials, are all key benefits emerging through the growth of these markets.

The social impacts that may be realised through using recycled materials include employment opportunities, community and civic pride, reduced waste to landfill and the associated environmental and health benefits and intergenerational equity through preservation of natural resources for future generations.

An opportunity: using recycled materials in road infrastructure

In recent times the importance of and interest in using recycled materials has increased significantly. This is due to a number of advancements, including increased levels of research and applications, improved recycling practices, experience, greater allowances for recycled materials in road infrastructure specifications and strong policy drivers such as those tackling emissions reductions and the promoting the circular economy.

Road infrastructure is very well suited to incorporate recycled materials. Large volumes of construction materials are used every year in the industry, presenting a major opportunity to return a significant amount of our nation's waste into productive use.

The incorporation of recycled materials in the construction, rehabilitation and maintenance of road infrastructure has numerous benefits, including:

- reducing the amount of waste sent to landfill, illegal dumping and littering
- reducing the greenhouse gas emissions generated by the production of new materials and the disposal of waste materials
- reducing our reliance on non-renewable resources and developing a circular economy where materials are continually reused in their highest and best use
- potentially reducing short and long-term costs
- potentially improving network performance.

Recycled materials can also deliver performance benefits for roads, such as the use of crumb rubber reducing risk of cracking and improving a roads long-term durability. The road construction industry, including its material suppliers, has progressively developed its capacity for recycled material use over several decades. Now there is increasing demand for tried and tested technologies, alongside emergent innovative materials and approaches.

In many cases road agencies have been using recycled materials for decades to reduce waste and emissions to deliver safe, sustainable and reliable transport infrastructure. Crushed concrete and brick have been used as virgin aggregate replacement for over 40 years, while with reclaimed asphalt pavement (RAP) in asphalt pavements and crumb rubber in spray sealing are also mature technologies. In-situ stabilisation (recycling road pavements/materials in place) has been used to construct Australian roads since the 1950s.

Other recycled materials, such as recycled crushed glass and recycled plastic, and new applications of mature materials, such crumb rubber asphalt, are more recent developments that need both government and industry support to build market maturity.

Road applications often have lower health, safety and environmental requirements compared with competing uses of recycled products, such as those being reused in food packaging. The comparatively lower standards means that recycled materials used in roads do not need to meet the same stringent standards in terms of consistency of product (e.g., colour) and require less processing to be used in roads without compromising performance. A good example is using recycled crushed glass as a natural sand replacement in asphalt or concrete, which can use variable glass colours and sources as well as being either washed or unwashed, compared with recycling the glass into bottles or jars which require consistent colour, quality and thorough washing. These lower requirements allow improved flexibility in the materials that can be safely, effectively and efficiently used in road applications.

Replacement materials, sources and uses

- **Crushed recycled concrete and crushed brick** are recycled products typically recovered from commercial demolition and civil works. Crushed recycled concrete and crushed brick can be used as a subbase under full depth asphalt or as a basecourse under low traffic local roads. Crushed recycled concrete is a well-established recycled material used in road infrastructure.
- **Recycled crushed glass** is mainly sourced from glass food and beverage containers and is processed and crushed to produce a sand-sized material. Recycled crushed glass can be used in the construction of embankments, structural and non-structural fill, retaining wall backfill and drainage, with several specifications in place to support its use. The use of recycled crushed glass in road pavements and concrete are emerging opportunities.
- **Reclaimed asphalt pavement** is obtained from excavating road pavements or from milling existing asphalt surfaces. Reclaimed asphalt pavement comprises high-quality and well-graded aggregates coated in bitumen, making them highly suitable for reuse in new pavements or as a granular material for unbound granular pavements. The use of reclaimed asphalt pavement is widely accepted across Australia as a cost-effective and efficient material.

- **Crumb rubber** is finely ground rubber particles from end-of-life truck and car tyres. Crumb rubber has been used in small volumes in sprayed seal applications for decades and more recently in asphalt pavements. Crumb rubber is known to enhance the durability of binders and is cost effective against other performance-enhancing additives.
- **Fly ash** is a by-product of coal-fired power generation and waste to energy incineration facilities. Fly ash is used as a supplementary cementitious material, a Portland cement replacement, or a filler in asphalt, with strong comparable performance to non-recycled materials.
- **Ground granulated blast furnace slag (slag)** is a by-product of steel and iron manufacturing. When molten blast furnace slag is rapidly quenched with fresh water, the slag becomes granulated. The granulated blast furnace slag, also known as slag aggregate, is then ground to produce ground granulated blast furnace slag. When blended with water, ground granulated blast furnace slag has cementitious properties (binding and strengthening granular materials) that make it a suitable partial replacement for Portland cement. Ground granulated blast furnace slag is mainly used in blended cement to manufacture concrete or as a direct supplementary cementitious material addition in concrete.
- **Bottom ash** is a by-product from coal combustion or waste-to-energy plants that can be used as a bound or unbound aggregate. Widely used in Europe, bottom ash is an emerging road construction material in Australia with an undeveloped market.
- **Recycled solid organics** are sourced from a variety of plant or animal wastes for various uses within the transport industry, predominantly: landscaping; erosion control; and biorientation and biofiltration. Around 50% of solid organic waste presently enters landfill, with large stockpiles nationwide, indicating great potential for the material to be recycled into higher-value uses.
- **Recycled plastics** are sourced from various industrial and household waste stream and can be used in several road applications, including in asphalt, pipes, roadside furniture, supplementary aggregate material, noise walls and bike paths. Australia's recovery rate of waste plastics is around 10%, indicating a significant available supply, yet the market maturity of recycled plastics applications in infrastructure is relatively low.

Appendix A provides further details on each material.

Methodology and assumptions

How we produced this report

As the nation's independent infrastructure adviser, Infrastructure Australia has worked collaboratively with the Australian Government as the project sponsor, with ecologiQ in Victoria as project advisors, and with the Australian Road Research Board and Ernst & Young as the project contractors.

The collaborative approach and support from government agencies, departments and key individuals has been critical to developing this analysis, as has industry support and engagement. In many instances, industry insight has provided the complementary real-world story behind the data. Complementing empirical evidence with real-world insights has been critical in further developing our understanding.

Overview of demand forecasting

Infrastructure Australia's demand forecasting builds on the demand modelling concepts developed for ecologiQ, the Victorian Government agency responsible for implementing its *Recycled First* policy. The ecologiQ model used a bottom-up approach to estimate the project-by-project tonnage of conventional materials based on structure definition and material specification, and the scale of opportunity for replacement based on allowable limits. A broader overview of the ecologiQ demand model is provided below.

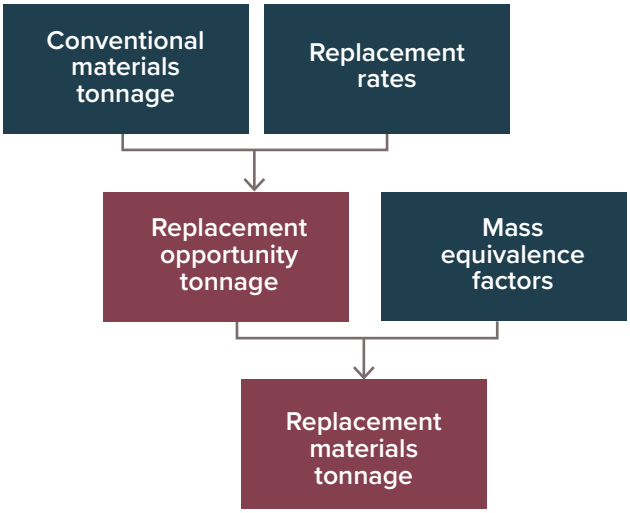
The modelling in this report adopts a top-down approach to estimate the potential for replacement materials on infrastructure projects in Australia. The top-down approach was more suitable given the level of data available and its granularity.

The modelling approach use demand forecasts based on conventional materials as a starting point and applies a range of replacement rates to estimate the size of replacement opportunity in terms of tonnage of recycled materials.

The key output of this model, *Replacement materials tonnage*, measures the tonnage of suitable recycled materials required to meet the demand of the replacement opportunity.

Figure 2 presents the demand forecast model's structure. Dark-blue boxes represent input data and modelling assumptions, while red boxes represent model outputs.

Figure 2: Methodology of forecasting demand for replacement materials



Details of individual components (data, assumption, and logic) of this model are in the technical notes in **Appendix B**.

ecologiQ's demand model

Victoria's ecologiQ has developed an interactive demand model as part of its work to support the transport industry to use recycled and reused materials and build sustainable supply chains.

This demand model identifies opportunities for the use of recycled and reused materials across the pipeline of Victoria's Big Build projects.

The interactive dashboard model helps align supply market development with anticipated material opportunities. It can provide aggregate demand indicators and quantify what is possible based on the maximum allowable limits in current standards and specifications, as well as offer specific project-based insights.

The demand model aligns with the National Waste Policy Action Plan and emphasises the importance of stimulating demand for recycled materials.

It will be enhanced to model emerging product opportunities. This will allow scenario projections, such as extending the recycled content specifications or adding new products or applications (e.g., the impact of demand for recycled plastic composite sleepers in mainline rail tracks).

Accounting for forecast uncertainty

Two sources of future uncertainty may affect the accuracy of the demand forecast for replacement materials: uncertainties about the future demand for conventional materials and the future rates at which recycled materials may replace conventional materials.

Uncertainties about future demand for conventional materials come from the variability in the intensity of resource demand by future projects and the input cost of resources such as labour and raw materials. Drivers of these uncertainties include future changes to operational efficiency and resource market conditions. To account for these variations, three levels of demand forecast scenario for conventional materials – low, central, and high demand – serve as the basis for forecasting demand for recycled materials.

Furthermore, future replacement rates are likely to be higher than current practice as there is extensive ongoing research and development, both overseas and in Australia, in new types of recycled materials and application techniques.

As recycled materials become more accepted by industry practitioners, infrastructure standards and specifications may also be updated to allow for higher replacement rates in the construction and maintenance of their assets. To reflect this, two additional sets of replacement rate scenarios – future and blue-sky – were developed in addition to those reflecting current practice.

- **Current** – existing science and technology, regulation and product allowable limits contained in various Australian state and territory standards and specifications and assumptions used in the ecologiQ model. Conservative assumptions are used reflecting the practical culture of the industry.
- **Future** – assumed advancement in technology and corresponding changes to standards.
- **Blue-sky** – a more bullish set of assumptions assuming further technical improvements and standards updates.

Details of these forecasting scenarios can be found in the technical notes in **Appendix B**.

Limitations

A key limitation of the demand forecast is the lack of visibility of specific material application work breakdowns (e.g., concrete use in foot paths versus structural applications) by project type (e.g., road, rail, structures). To address this, demand modelling was based on assumptions of an averaged replacement capacity across all project types on which the demand forecast of conventional materials was based.

This assumption has important implications for the accuracy of the demand forecast for replacement materials. Specifically, a greater share of actual project types that have higher replacement potentials will underestimate the demand forecast and vice versa. The forecasts of demand herein should therefore be treated as an opportunity indicator model, rather than an absolute market predictor.

Overview of the market analysis

Stakeholder engagement program and other research activities

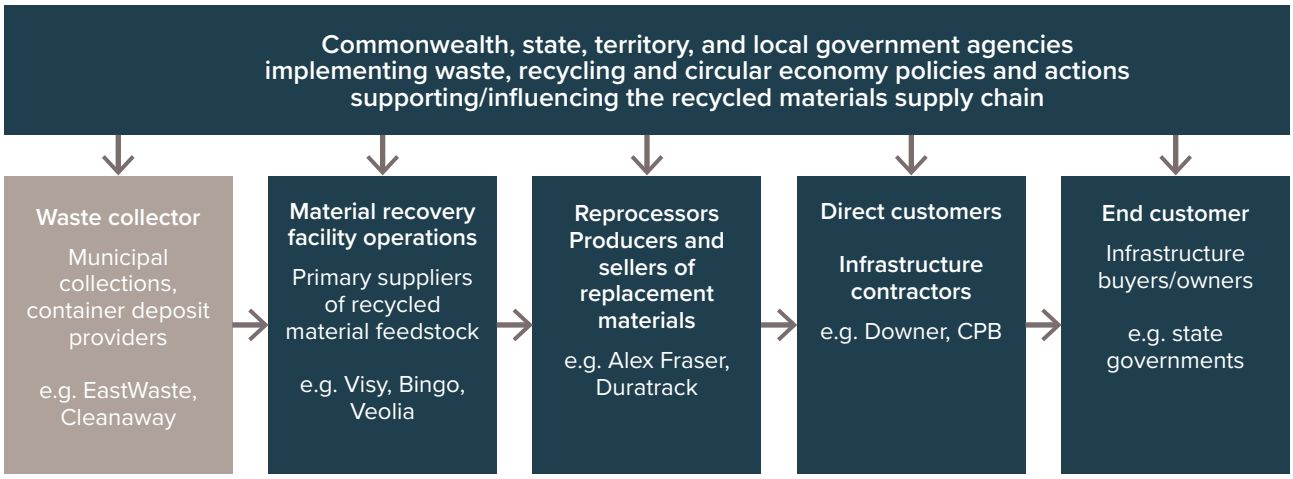
The market analysis in this report presents deep insights from industry and government stakeholders, conveyed through an extensive, collaborative engagement program.

This analysis creates an understanding of the material supply chains and supply chain constraints, including any cultural barriers, showcases best practice in their procurement and application and identifies opportunities to reduce or remove barriers and increase replacement material uptake. Case studies are provided to highlight examples of leading practice and, or where barriers were overcome to facilitate the use recycled materials.

The recycled material supply chain for road infrastructure projects

Figure 3 shows the stakeholder groups which comprise and support the recycled materials supply chain for road infrastructure projects. This includes the suppliers of replacement materials, such as waste collectors and sorters, material processors and customers.

Figure 3: Recycled material supply chain for road infrastructure projects



Stakeholder engagement scope

This analysis considers the recycled materials supply chain from material recovery operations through to direct customers (infrastructure contractors) and ultimate end customers (infrastructure owners). While waste collectors have an important role within the supply chain, the study assumes that they are relatively removed from market constraints and opportunities examined in this report.

The analysis also considers the Australian Government and state, territory and local governments and their agencies who play a critical role influencing, supporting and regulating the supply chain, and who are also major purchasers of infrastructure and drivers of recycled material demand.

Collaborative research program

The collaborative research program involved a quantitative survey, interactive workshops and detailed interviews. Addition information was sourced from documented evidence, as detailed in the reference list.

Quantitative survey

The quantitative survey delivered hard data on the supplier market, including suppliers' capacity, their attitudes to and their experiences with recycled materials.

Target audiences were organisations that currently are or would consider being part of the recycled material supply chain for road infrastructure, namely the material recovery facility operations, reprocessors, producers and sellers of replacement materials as shown above in **Figure 3**.

To be eligible for participation, respondents had to fall into at least one of the following categories:

- supplier of waste/recycled materials – waste/materials sorter, virgin materials supplier
- processor of waste/recycled materials – primary processors of sorted waste/materials; primary processors of virgin materials
- secondary processor of recycled materials, including prospective secondary processors of recycled materials (i.e., is, or would consider becoming, a supplier).

A total of 245 businesses responded to the quantitative survey, which was conducted between 16 March to 8 April 2022. Survey respondents included a mix of businesses across material/product types, business sizes and geographies, including:

- current suppliers of waste/recycled materials (22% of respondents)
- current recycled materials reprocessors (66% of respondents)
- prospective recycled material reprocessors (12% of respondents).

Interactive workshops

The interactive workshops explored the current market conditions, current and forecasted supply capacity, key market constraints and opportunities to increase the adoption of recycled materials in road infrastructure.

A total of 117 invited government and industry stakeholders participated in three interactive videoconference workshops held on 23 to 31 March 2022. Each workshop gained stakeholder insights through a combination of live-polling and structured discussions.

Detailed interviews

Detailed interviews with targeted industry stakeholders provided a deeper dive into the market's capacity for recycled materials and their key constraints. Meanwhile, interviews with state, territory and local governments looked at current and planned roles and actions to support recycled materials' supply chain and market opportunities, including actions to address known barriers to adoption.

A total of 16 detailed interviews were conducted between 23 March and 13 April 2022 – seven with government stakeholders and nine with industry representatives.

An additional two email responses were provided by interview invitees who were unable to participate during the interview period.

Appendix C provides further details of the engagement program and key survey findings.

Limitations

The main limitations of the detailed stakeholder engagement approach were those of possible bias. Interviewees and workshop participants were invited based on project partners' networks and stakeholder recommendations, and as recognised leaders in industry or government, they may present a bias compared to broader industry. The quantitative survey, meanwhile, was sent out to a comprehensive selection of business leaders, meaning there is an inherent bias in those who selected to participate.

While the engagement sample was rigorous in size and coverage, with considerable effort taken to obtain diverse views across jurisdictions, geography, organisation type and size, we cannot guarantee that all voices were captured.

This analysis also acknowledges that quantitative data and detailed insights reflect the point-in-time views of those participants. There is a degree of uncertainty around whether those views represent those of their organisation or the broader industry, so the analysis attempts to corroborate those views with additional sources to ensure they do in fact represent wider industry concerns and issues.

Forecasting potential demand

Major findings

Based on Infrastructure Australia's conventional materials demand forecast, this report shows:

- From 2015–31, approximately 200 million tonnes of conventional materials are needed to deliver 998 road projects across the country. Over 95% of the mass is made up of five key materials: aggregates (29%), asphalt (27%), rock/bluestone (16%), sand (15%) and cement (9%).
- Based on current technology and standards, approximately 27% of the conventional material tonnage could be replaced by using a range of recycled materials. This means replacing approximately 54 million tonnes of conventional materials with approximately 52 million tonnes of recycled materials.
- The largest quantities of conventional materials that could be replaced are asphalt (32% of the replaceable conventional materials tonnage) and concrete (32%).
- The largest quantities of recycled materials that could be used to replace conventional materials are reclaimed asphalt pavement (26% of the recycled materials tonnage to replace conventional materials), followed by recycled crushed glass (24%) and crushed concrete (18%).
- The peak of demand is forecast for 2023–24.
- With advancements in technology and the associated updates to standards, the tonnage of conventional materials replaced could rise from the current 27% to 43%. This could replace nearly 87 million tonnes of conventional materials with nearly 80 million tonnes of recycled materials.
- Based on blue-sky assumptions, the replacement rate could further rise to 59%, replacing nearly 119 million tonnes of conventional materials with 114 million tonnes of recycled materials.

The future demand of replacement materials

Overall demand

This section presents the projected quantity of demand for replacement materials by the pipeline of infrastructure investments in Australia.

Table 1 presents the forecasts for the total tonnage of replacement materials needed for planned infrastructure investments from 2015–31. There are nine forecast results, driven by the combined assumptions on differing levels of resource demand intensity (high, central, and low) and replacement rates (current, future and blue-sky), ranging from a low of 43.3 million tonnes to a high of 129.9 million tonnes.

The range of forecast is narrowed by focusing the central scenario of resource demand intensity, which has a lower bound of 51.9 million tonnes and an upper bound of 114.3 million tonnes.

Table 1: Potential demand for recycled materials by replacement scenario (million tonnes)

	Current	Future	Blue-sky
High	59.0	90.5	129.9
Central	**51.9**	**79.6**	**114.3**
Low	43.3	66.4	95.3

Table 2 provides the corresponding conventional materials that may be saved by the replacement. Forecasts in this table suggest that the total replacement opportunity is between 45.2 million tonnes to 134.9 million tonnes, based on the most conservative assumptions (low and current) and the most optimistic assumption (high and blue-sky) respectively.

The corresponding tonnage forecasts differ slightly between the two tables, due to the difference in material densities between conventional and replacement materials.

Table 2: Opportunity to replace conventional materials by replacement scenario (million tonnes)

	Current	Future	Blue-sky
High	61.7	98.5	134.9
Central	**54.3**	**86.6**	**118.7**
Low	45.2	72.2	98.9

Subsequent analysis in this report will focus on the central scenario as it is the primary assumption made by Infrastructure Australia in forecasting the demand for conventional materials.

Detailed demand by material types

To provide further understanding of the replacement and demand opportunity, the total forecasts presented above are disaggregated from both the perspectives of conventional materials and the replacement materials.

Demand by conventional materials

Table 3 provides a breakdown of the potential savings of conventional materials presented in **Table 2**.

These forecasts are measured by the total tonnage of conventional material in the project pipeline that can be replaced by recycled materials. This view of the demand forecast illustrates the overall size of replacement opportunity and the relative size of the opportunities between material types.

The greatest opportunity for replacing conventional materials by tonnage is likely to come from reducing virgin asphalt, followed by virgin rock and bluestone, and then virgin aggregate components in concrete. However, the combined components of conventional concrete (aggregate and cementitious components) have the joint-highest potential for replacement, along with asphalt. Of all the conventional materials, steel has the least scope for replacement due to the smaller quantities used in infrastructure projects.

Table 3: Opportunity for replacing conventional materials by replacement scenario – central case conventional materials forecast (million tonnes)

	Current	Future	Blue-sky
Asphalt	17.6	29.8	41.7
Concrete (aggregate component)	8.8	17.7	26.5
Concrete (cementitious component)	8.8	12.3	15.9
Steel	3.5	3.5	3.5
Rock/bluestone	15.6	23.4	31.2
Total	**54.3**	**86.6**	**118.7**

Demand by replacement materials

Table 4 presents the contribution of individual replacement materials to the overall demand for them shown in **Table 1**. In this table we have included an additional material known as slag aggregate or granulated blast furnace slag. This is a coarser form of slag than ground granulated blast furnace slag, with typical infrastructure applications as aggregate materials. By contrast, ground granulated blast furnace slag is typically associated with ingredients for cementitious materials.

Under all replacement rate scenarios, the greatest contribution comes from reclaimed asphalt pavement, which accounts for 26–36% of total demand; recycled crushed glass is second-most in demand, accounting for 18–24%; and crushed concrete is third-most in demand, accounting for 10–18%. Other replacement materials make up 1–10% of total demand.

Table 4: Potential demand for recycled materials by replacement scenario – central case conventional materials forecast (million tonnes)

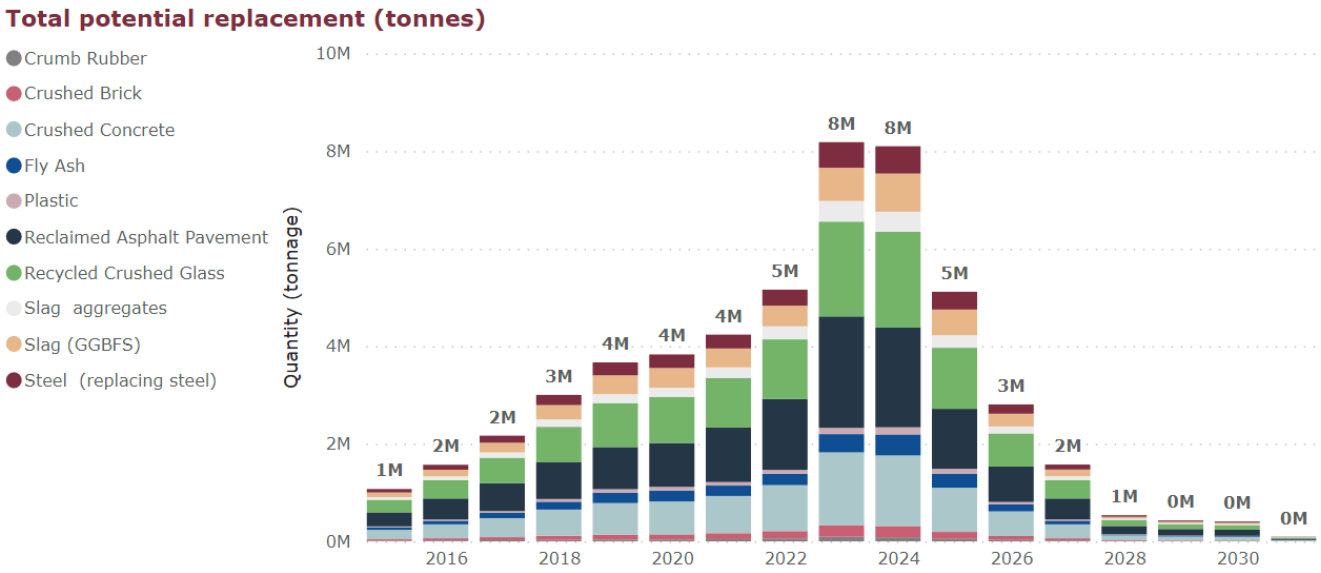
		Current	Future	Blue-sky
Crushed concrete		9.3 (18%)	7.8 (10%)	18.6 (16%)
Crushed bricks		1.5 (3%)	3 (4%)	4.4 (4%)
Reclaimed asphalt pavement		13.5 (26%)	28.7 (36%)	39.3 (34%)
Recycled crushed glass		12.5 (24%)	19.2 (24%)	20.5 (18%)
Crumb rubber		0.6 (1%)	0.6 (1%)	0.6 (1%)
Fly ash		2.6 (5%)	4 (5%)	5.3 (5%)
Slag	Ground granulated blast furnace slag	4.8 (9%)	6.4 (8%)	8 (7%)
	Granulated blast furnace slag (slag aggregate)	2.6 (5%)	5.3 (7%)	12 (10%)
Plastic		0.9 (2%)	1.2 (2%)	2.2 (2%)
Steel		3.5 (7%)	3.5 (4%)	3.5 (3%)
Total		**51.9 (100%)**	**79.6 (100%)**	**114.3 (100%)**

Year-by-year demand forecast

Year-by-year demand forecasts were also produced as a part of this project and can be accessed for individual replacement materials via the Power BI dashboard developed by the consultant team.

Figure 4 shows an example of the year-on-year forecast of replacement materials available to view in the dashboard. A common forecast outcome across different modelling assumptions is that peak demand will occur in 2023–24, underpinned by the peak of planned project activities.

Figure 4: Year-on-year demand forecast for replacement materials – central conventional materials forecast and current replacement rates



Source: Infrastructure Australia Replacement Material Dashboard (2022)

Conclusions

Replacement potentials and demand forecasts in this section are based on the 998 infrastructure road projects across the country with commencement dates from 2015–31, as covered by Infrastructure Australia's demand model. As such, they may need to be updated if the future projects pipeline is revised. Present forecasts suggest that demand for replacement materials over the 16-year period is significant: between 52–114 million tonnes, based on the central scenario of resource demand intensity for conventional materials.

These forecasts have important implications for Australia's public infrastructure investments, in regard to achieving more sustainable outcomes through the circular economy.

For example, there will be opportunities for greater resource efficiency and reducing the resource demand associated with delivering 54 million–118 million tonnes of conventional materials. The production of recycled materials also carries opportunities for innovation, industrial capability and the supply chain. The magnitude of these opportunities and their benefits varies from application to application and is expected to grow as replacement materials become more widely adopted and technically improved in the future.

Utilising replacement materials also stops waste materials from becoming environmental burdens such as landfill and other sources of pollution. Australia generates approximately 2.5 million tonnes of waste plastics annually and the present forecast suggests that nearly half of this waste may be diverted away from landfill at the current replacement rates. Under the future and blue-sky replacement rate scenarios, there is even a real opportunity to substantially mitigate the environmental threat of waste plastics.

However, there are a range of conditions which need to be met before these sustainability benefits can be realised. Critical among these is the availability of a reliable and accessible supply of replacement materials, which is discussed in the **Supply capacity** section of this report.

Other important conditions are implicit in the assumptions of the demand forecast model. These include further research and development to enhance the current performance and cost of recycled materials, thereby expanding their replacement capacity. To achieve this, incentives such as policies and investment are needed to support the acceptance of emerging replacement technologies and the innovation of new replacement techniques – for example, funding for field trials or demonstration projects built with higher contents of replacement materials. Successful trials will both test the upper limit of replacement potential and instill the confidence the industry needs for wider adoption.

Market analysis

Major findings

Australia currently generates just over 62 million tonnes of waste material annually, of which close to 40 million tonnes is recovered through waste/recycled materials suppliers and processors.[7] However, supply capacity is not uniform across material types, with a mix of common and specific issues causing shortages of some types and limiting supply growth.

Current supply capacity

There is currently inadequate supply to meet demand for fly ash, plastics, crumb rubber, recycled crushed glass and slag. The challenges along the supply chains of these materials vary and can overlap.

For example, fly ash suffers from a lack of uniform high-quality supplies and a lack of local availability in some states, the latter also being an issue for crumb rubber. Specialised plastics are both in low demand, due to a lack of industry understanding of their properties, and in short supply because suppliers are accordingly disincentivised to enter the market. Not enough glass is being collected as feedstock for recycling, while the slag shortage is driven by a lack of distribution and storage facilities; both issues are particularly pronounced in regional areas. Compounding those issues are common ones of competing demand from other industries (especially for tyres, glass and bricks), potential future shortages (notably slag and glass) and high investment costs.

Market opportunities

Infrastructure Australia's engagement program revealed the following five key opportunities to address market constraints impacting the uptake of recycled materials in road infrastructure.

Improving awareness and understanding of recycled materials, specification and opportunities

Workshop and survey outcomes indicated a low level of familiarity with available recycled material products, their performance, environmental benefits and their market opportunities. Continued emphasis on the development of standards and specifications, which can support their use, as well as building awareness through education and knowledge sharing are key to overcoming these challenges.

Taking stronger actions to enhance confidence in using recycled materials

Governments and industry can work collaboratively to grow industry confidence in using recycled materials. Uncertainty, negative perceptions and a risk-averse culture are key barriers with decision makers and procurement teams reverting to familiar, business-as-usual practices instead of exploring innovative options. Recycled material standards and specifications are compelling instruments to drive confidence, but specifications currently lack consistency and users are often not aware of the possible allowances. Key actions that will help enhance the confidence of suppliers, engineers, procurement officers and contractors include developing and delivering education and awareness programs, developing and updating specifications and standards and driving cultural changes to reward innovation.

Addressing regulatory issues

Regulations that treat recovered materials as waste needing to be controlled are falling behind community and industry expectations. They must be reviewed to facilitate industry development, advance market opportunities and grow the circular economy, whilst protecting against adverse impacts.

Improving and modernising recycling infrastructure and workforce capacity and expanding geographic reach

Recycling infrastructure and the availability of replacement products was found to be inconsistent across the country, with a concentration of facilities for some materials in metro areas and limited availability in certain markets. The industry is generally considered more akin to waste management than product manufacturing, so attracting and retaining talent is a real challenge to growth.

Government assistance to support the establishment of new infrastructure in under-served areas, as well as supporting the modernisation of existing material processing infrastructure, will encourage growth of capacity and attract a new workforce to the replacement material industry.

Driving demand through sustainable procurements and market signalling

Identified actions that could drive demand include the accommodation of cost impacts of replacement materials in public procurement tenders, the provision of supporting infrastructure standards and specifications in most jurisdictions, the provision of easily accessible supplier and cost information and addressing concerns for the safety and performance impacts of the materials.

Current state of play

Who is in the supply chain?

Table 5 identifies the key operators within the recycled materials supply chain.

Table 5: Recycled materials supply chain

Supply chain category	Stages	Description
Supplier of waste/ recycled materials	Waste/recycled materials collector	Collect and haul waste from sites
	Waste/recycled materials sorter	Identify, classify and sort mixed waste to be sent to recycling plants for further processing
	Virgin materials supplier	Supplier of unused raw materials for processing
Processor of waste/ recycled materials	Primary processor of sorted waste/recycled materials	Take sorted waste/recycled materials for initial processing
	Primary processor of virgin materials	Process virgin materials
	Secondary processor of recycled materials	Process virgin and waste/recycled materials to produce recycled materials to be send to contractor/user
User of finished products	Contractor/user of finished products	Use processed recycled materials to create final products for end market use

How much recovered material is available?

The amount of waste generated and recovered in Australia is summarised in **Table 6**.

Table 6: Waste generated and recovered in Australia

Material	Waste generated	Waste recovered
Crushed concrete and brick	23 million tonnes[a]	19 million tonnes[a]
Glass	1 million tonnes[a]	688 thousand tonnes[a]
Solid organics	14.3 million tonnes[a]	8.58 million tonnes[a]
Reclaimed asphalt pavement	8.2 million tonnes[b]	4.4 million tonnes[b]
End of life tyres	0.4 million tonnes[c]	0.002 million tonnes[c]
Fly ash	11.25 million tonnes[a]	5.3 million tonnes [a]
Granulated blast furnace slag (slag aggregate) and ground granulated blast furnace slag	530 tonnes locally sourced, plus 1,270 tonnes imported (as slag aggregate)[d]	1,660 tonnes (~92% converted to ground granulated blast furnace slag)[d]
Plastic	3 million tonnes[a]	393 thousand tonnes[a]
Bottom ash	1.34 million tonnes[a]	0.63 million tonnes recycled[a]
Total	**~62 million tonnes**	**~39 million tonnes**

Source:
a. Department of Agriculture, Water and the Environment (2018)[8]
b. Hyder Consulting (2009)[9]
c. Bennet (2017)[10]
d. Australasian Slag Association (2020)[11]

Appendix A provides further detail on each of the focused recycled and replacement materials.

Supply capacity

Current supply capacity

Consultations with industry participants show that the current supply capacity of recycled materials is not uniform across material types and that there is a mix of common and specific issues that are causing shortages for some materials.

Identified current shortages

Inadequate supply to meet current demand has been identified for fly ash, plastics, crumb rubber, recycled crushed glass and ground granulated blast furnace slag. The supply challenges experienced along the supply chains of these recycled materials are varied.

Fly ash

The supply of fly ash is being challenged by the gradual phase-out of black coal for power generation. There is also lack of uniform supply of high-quality of fly ash across the country, with abundance found in Queensland and New South Wales and a lack in Victoria and Western Australia. Those states experiencing such shortages rely on interstate and international supplies instead.

Plastics

Recycled (soft) plastic products are generally well supplied. However, there are specialised plastic products that are in short supply, including polyvinyl chloride (PVC) and geosynthetics polymers. PVC plastics are widely used in the piping industry and there is lack of feedstock of recycled PVC to meet the industry demand. Geosynthetic polymers can be used as a stabiliser in the sub-surface layers of pavements but a lack of industry understanding of its performance benefits has led to low demand, which in turn has failed to incentivise suppliers to enter this market.

Crumb rubber

Processed from waste tyres, the supply of crumb rubber is hampered by several factors, including a lack of local availability and restrictions on stockpiling capacity. While waste tyres are abundant in Australia, the facilities to transform them into crumb rubber are limited to specific locations in Sydney, Melbourne, Brisbane and Perth (forthcoming next year). This localised nature of supply means that haulage costs are sometimes prohibitive to a stable supply of crumb rubber in other, especially remote, locations. On the other hand, the seasonal nature of construction and maintenance activities mean that stockpiling may be necessary to achieve availability of materials on demand. However, restrictions on the stockpiling crumb rubber imposed by environment protection agencies have limited the effectiveness of this solution to overcome seasonal supply issues of crumb rubber.

Recycled crushed glass

Supply challenges for recycled crushed glass are found mostly upstream, with not enough of waste glass being collected as feedstock for recycling. This is a prevalent issue and most pronounced in regional areas. A possible cause is the introduction of container deposit schemes, which have diverted a major source of waste glass back to its original use as containers for consumer food and beverages.

Ground granulated blast furnace slag

The slag shortage is driven by the lack of distribution and storage facilities. Its unavailability is primarily an issue for regional areas, which lack a dedicated silo infrastructure for its storage (which has to compete for space from storing fly ash).

Common issues affecting supply growth

In addition to specific material shortage, our consultations uncovered a range of issues and challenges common to all recycled infrastructure materials under consideration. All are expected to affect the future supply capacity of replacement materials.

Geographic barriers

The accessibility of recycled materials is a common issue and raised by industry participants. With recycled material supplies often concentrated in metropolitan areas, access to materials can be limited in more remote areas. Material haulage over longer distances can add significant costs, compared with locally sourced materials. Haulage of recycled materials may also negate the sustainability benefits due to the haulage emissions generated. Such geographic barriers are found to be dividing the supply capacity between states, and between metropolitan and regional areas within the same state.

Competing demand from other industries

Competing uses of recycled materials can limit supply growth in road infrastructure. The main alternative use of recycled glass is in food and beverage containers. Tyre-derived products, such as granulated and crumb rubber can be used for sports surfaces, applications in the automotive industry (bumpers, floor mats etc.), adhesives and sealants. Finally, bricks can also be recycled if they are whole and in reasonable condition for other infrastructure applications.

Turning-off the tap

Replacement materials are predominately sourced from by-products or end-products of other industrial or consumer processes, so their ongoing supply depends on the continuity of the upstream process. For some replacement materials such as fly ash and glass, upstream processing is already creating supply challenges. Attention on this issue should be directed to material types whose upstream feedstock may be phased out by future sustainability regulation and policies – or, taps being turned off. A likely candidate for this is soft plastics, which is subject to increasingly stringent policies for its use in the country, such as plastic bag bans.

High cost to add supply capacity

There is a significant investment cost for suppliers to introduce new facilities to keep up with the future demand of replacement materials. Such investments are often in need of finance, which has become increasingly costly due to recent interest rate rises to combat post-pandemic inflation. Uncertainty around higher rates in the coming decade may deter suppliers from adding capacity, unless there is bona fide evidence of potential demand to make their investment worthwhile.

Low demand and low supply

Supply issues have been so far considered independently from demand-side factors. However, the economic theory suggests that supply is often a response to the demand in the market. The outcome of this response is that future supply of a material is probably directly dependent on its expected demand over the same time horizon. As evidenced by comments from one of the industry participants, in the case of geosynthetic polymers (a form of recycled plastic), poor understanding and awareness of the performance benefits of this material have resulted in low demand and, subsequently, in low to no supply in the marketplace.

Potential future shortage

The analysis of future supply shortages considers recycled material demand forecasts against supply capacity findings. Materials forecasted for high demand but are currently experiencing supply issues are most likely to experience future shortages. **Table 7** presents potential future supply gaps for individual replacement materials.

Table 7: Potential supply concerns – central case conventional materials forecast

Replacement materials		Future demand level	Current supply issues	Potential supply concern
Crushed concrete		Medium	No	Low
Reclaimed asphalt pavement		High	No	Moderate
Recycled crushed glass		High	Yes	High
Crushed bricks		Low	No	Negligible
Crumb rubber		Low	Yes	Moderate
Slag	**Ground granulated blast furnace slag**	Medium	Yes	High
	Granulated blast furnace slag (slag aggregate)	Low	Yes	Moderate
Fly ash		Low	Yes	Moderate
Plastic		Low	Yes	Moderate
Steel		Low	No	Negligible

The **future demand level** in **Table 7** is based on the demand forecasts shown in the **future** column of **Table 4**. The future demand level is rated high if demand forecast for that material is above 15 million tonnes; medium for between 5–15 million tonnes; and low for other quantities. **Current supply issues** are based on those identified through the industry engagement process. The assessment of the **potential supply concern** is based on the size of demand and the presence of supply issues. Specifically, a supply concern is considered heightened by a higher level of demand and the existence of supply issues. Following this rule, a material with medium level of demand is considered as high in supply concern if there are known current supply issues, but as low if there are no known current supply issues.

Of the materials assessed, recycled crushed glass and ground granulated blast furnace slag are expected to experience major supply gaps in forecast period due to their relatively high demand and current supply constraints. In comparison, reclaimed asphalt pavement, crumb rubber, slag aggregate, fly ash and plastic are causing lower concern, driven either by their high forecast demand or known issues in their supply chain, but not both at the same time. Other materials were found to have low to minimal future-supply concerns, as there would be low demand or a lack of ongoing concern in their supply chain.

Policies or investments aimed at addressing future supply gaps of replacement materials should do so strategically, focussing on materials with a higher likelihood to experience shortages in the future.

Market opportunities

How can the market increase the uptake of recycled materials in road infrastructure?

The value chain of recycled materials is long and complex, with unique challenges at every step. Infrastructure Australia's engagement program revealed five key opportunities to address market constraints impacting the uptake of recycled materials in road infrastructure:

- Improving awareness and understanding of recycled materials, specification and opportunities.
- Taking stronger actions to enhance confidence in using recycled materials.
- Addressing regulatory issues.
- Improving and modernising recycling infrastructure and workforce capacity and expanding geographic reach.
- Driving demand through sustainable procurements and market signalling. Improve awareness and understanding of recycled materials, specifications, opportunities

There is an opportunity to improve the awareness and understanding of recycled material applications in road infrastructure and allowable uses as defined by industry standards and specifications. This section highlights the issues surrounding awareness along the supply chain, leveraging findings of the survey, interviews and workshops, and outlining actions and opportunities for progress.

Key issues associated with awareness and understanding across the supply chain include:

- Key participants across the supply chain are unfamiliar with recycled products, their potential uses, markets and value.
- There is low-level knowledge of material quality/ performance.

Survey results indicated that participants along the supply chain are unfamiliar with recycled products or the potential benefits from these materials. Respectively, 28% and 27% of participants are not certain of the quality or performance of recycled materials in comparison to their virgin counterparts.

The survey showed an interest in expanding material production, though there is a lack of definitive awareness of how this might function. Around half (54%) of recycled materials reprocessors would consider producing other recycled materials in future, though a third (33%) are unsure what materials these would be. Small businesses were more uncertain about future production types.

Additional feedback from workshop and interviews supports the survey findings, defining key challenges as a lack of knowledge of the current allowable uses and performance of recycled materials and a lack of knowledge sharing of existing use and trials across the industry.

The workshops highlighted a lack of experience with recycled materials overall, especially with crushed brick, bottom ash and solid organics. **Table 8** shows the industry's level of experience with recycled materials as an average of workshop participant response ratings (on a scale of 1–10 with 1 being no experience).

Table 8: Average response ratings from workshop respondents for experience

Recycled material	Level of experience (scale 1 to 10)
Crushed concrete	2.4
Crushed brick	1.6
Recycled crushed glass	2.7
Reclaimed asphalt pavement	2.5
Crumb rubber	2.5
Fly ash	2.1
Ground granulated blast furnace slag	1.9
Bottom ash	1.5
Solid organics	1.3
Plastics	2.1

A lack of awareness around product options, inconsistency from trials and lack of knowledge sharing were noted as barriers to adoption by workshop respondents. Limited awareness of the triple-bottom line benefits of using recycled materials was also noted, as well as a lack of awareness around other key benefits, including improved performance, regulatory compliance and lower lifecycle costs.

One example given was the lack of understanding around using recycled materials in plastic pipes to support critical infrastructure performance.

Participants also lamented a general lack of desire to learn. The key consequence of this lack of awareness and understanding is the lost economic and environmental opportunity. There are many opportunities not being leveraged along the supply chain, reducing the valuable economic and environment benefits that recycled materials present.

Actions

These findings point to a need to improve the awareness and understanding of recycled materials, specifications, and opportunities for their application. Recommended actions for delivery by all levels of government with support from industry groups include:

- Educate participants along the supply chain on the range of recycled materials available, using databases, educational collateral (see ***Recycled content in use video series***) and case studies.
- Build awareness and confidence among governments using educational materials, encourage knowledge sharing and generate opportunities for engagement between suppliers and local governments.
- Develop materials to raise awareness and promote the environmental credentials and lifecycle cost benefits of recycled materials compared with products made from virgin materials.

Recycled content in use video series

The Commonwealth Sustainable Procurement Advocacy and Resource Centre (C-SPARC) supports the shift to sustainable procurement. C-SPARC works between government and industry to facilitate opportunities to significantly increase the use of recycled content in line with target four of the *National Waste Policy Action Plan*.

Through recent interactions with stakeholders, it became apparent that there is a general lack of knowledge of recycled content products which limits their inclusion in procurement activities, both for government and industry.

This led C-SPARC to produce a series of short videos to raise awareness of Australian made recycled content products that are currently on the market. The videos cover a range of recycled materials including glass, plastic, paper and tyres and showcase innovative Australian businesses using recycled content for products purchased by all levels of government.

In total 19 businesses are showcased in the videos which are available at 'Recycled content in use' (**Figure 5**). The videos are accessible for use by all levels of government as well as industry for supporting the uptake of recycled content.

Figure 5: *Recycled content in use* video series

Source: Department of Climate Change, Energy, the Environment and Water (2022)[12]

Stronger actions to enhance confidence of using recycled materials

Infrastructure Australia advocates for stronger coordinated actions to enhance the confidence of using recycled materials in road infrastructure.

Engineers, designers, and asset managers demand confidence in the performance, durability and safety of the materials they use or maintain. Likewise, contractors and infrastructure buyers have a responsibility to ensure a safe working environment for those handling materials, as well as infrastructure users and adjacent populations. Concerns over new and emerging recycled material products are valid and an important part of safety and reliability assessments for high-value infrastructure.

While genuine concerns due to well-founded evidence or experience, or a lack of experience with new products exists, there is an observable over-correction and tendency towards risk aversion that inhibits the use of new and emerging materials. This aversion can be fuelled by misconceptions and misinformation around proven materials that stagnates innovation and market development.

The lack of confidence in suppliers, road agencies and asset owners is a major inhibitor in the uptake of recycled materials and a potential lost opportunity to explore recycled materials and realise numerous benefits. This lack of confidence is particularly relevant for innovative and emerging materials, such as those based on recycled plastics. Performance and quality assurance processes will facilitate acceptance and demand from practitioners.

Key findings

Uncertainty and negative perceptions

Despite growing confidence in the use of recycled materials overall, the widescale construction of roads and pavements with recycled materials does present challenges in the minds of material recovery and recycling businesses. More than a quarter of survey participants are uncertain about the quality or performance of recycled materials in comparison to virgin material substitutes.

Around one in two (48%) of current reprocessors believe that recycled materials are of a similar quality to virgin materials. A similar number (54%) think they perform the same as virgin materials. A relatively high proportion are not certain about the relative quality and performance of recycled materials over virgin materials, even among current reprocessors (28% for quality and 27% for performance), indicating further education is needed.

Perceptions of low-quality recycled materials act as a barrier for almost one in five (18%) participants of the quantitative survey, with 38% of recycling and waste processing businesses reporting that they have customers who perceive recycled materials to be of a lower quality.

Of those survey participants who currently do not process recycled materials, nearly half (49%) would not consider the possibility of processing/producing recycled materials in the future at all. These respondents tend to have a higher degree of confidence and trust in virgin materials, identifying that they are cheaper to use and that there is a more consistent supply of raw materials. These perceptions are exacerbated by a poor understanding of the benefits of recycled materials, as well as a lack of conviction about the real impact they have on the reduction of emissions.

Around one in five (18%) businesses also noted unfavourable legislative and regulatory conditions as factors affecting confidence in recycled materials, creating doubts in the minds of businesses and users on the quality and durability of such materials.

Past experience and misconceptions

According to some respondents, entrenched views regarding replacement materials could be traced back to past experiences and perceptions drawn from outdated technologies and processes, coupled with misconceptions. Misleading information based on the misuse of products that have delivered bad results through inappropriate substitution further threatens confidence and the adoption of recycled products.

While there was broad acknowledgement of consolidating market maturity for various materials, industry is filled with examples where even products that have been used for decades and have shown good performance outcomes are consciously avoided. One workshop participant observed a key barrier to uptake was “poor understanding by project engineers of materials as well as making cost-based decisions and choosing familiar brands, rather than recycled materials from specialist providers, even when backed with 10 years of evidence of success”.

Some participants also noted how research and development had led to positive outcomes, with an asphalt supplier noting “plastics, toner, glass and reclaimed asphalt pavement, which have all worked well after years of research”.

A representative of the recycled plastics industry explained: “post-industrial, or pre-consumer, plastics have worked well in infrastructure. However, post-consumer plastics need further development and broader acceptance to secure consistent feedstock to supply infrastructure”.

Conversely, another stakeholder observed that "multi-year trials do not necessarily lead to wholesale standardised adoption", indicating that there are cultural aspects at play.

Risk aversion and a comfort with the status quo

In the workshops, industry participants noted that a culture of risk aversion was a major constraint to using recycled materials with decision makers and procurement teams reverting to familiar, business-as-usual practices instead of exploring innovative options. One participant noted a "disconnect between policy at the executive levels of government and a complete lack of willingness to do anything different at the specifier level (that controls the tendering process)". It was also noted that there are "conflicting views within client companies... some are for it. But the technical team won't allow it".

In an interview, one contractor explained that "risk aversion [in their customer base] is the major barrier to using more and higher percentages of recycled materials". A number of road contractors observed that local government engineers were often suspicious of, and reluctant to try, new materials or approaches for fear of damage to their own professional reputations and career prospects. External observers noted that there is a stigma towards failure in the engineering community that heightens risk aversion and inhibits departures from tried and proven approaches.

A lack of fit-for-purpose specifications, standards, guidance and education

Specifications and standards provide a low-risk pathway to support the production and adoption of proven materials, technologies and processes in prescribed applications. These technical documents should be supported by guidance and education to assist understandings and interpretations in locally specific applications.

Specifications that stipulate the use of different recycled materials in road projects can provide greater clarity and guidance around optimal performing products, which in return, helps producers deliver product performance guarantees to their customers.

Survey participants acknowledge that there is a need for common safety and performance standards to drive the production and use of recycled materials. Most (88%) survey respondents valued how standards and specifications enable the use of recycled materials and 92% of respondents positively regarded the development of national standards and specifications for the use of recycled materials to support their business' decision to produce recycled materials for road projects.

Industry feedback highlighted the lack of standards and specifications to guide practitioners to adopt replacement materials. Such guidance is made available by some agencies but not others. In those instances, the lack of specific guidance on the use of replacement materials will hinder their uptake.

The lack of up-to-date specifications, standards, guidance and education on the use of recycled materials in road infrastructure was, however, a repeated concern of industry. The issue of **standards not being up to date with all current waste streams and waste uses in construction materials** was commonly discussed as a barrier, as was the need for performance-based specifications and standards. One road contractor suggested "the development of performance specifications, guidelines to material use, and the development of technical specifications for materials are key steps needed in ensuring material consistency, quality and reuse".

While all states and territories have developed or adopted specifications for recycled materials, specifications differ by jurisdiction, degree of maturity and allowances, creating uncertainty in local applications and regulatory burdens in conforming to different requirements.

In our workshops, one industry practitioner commended the "success of alternative material specs and standards being developed and applied (with respect to fly ash and slag)".

However, another stated that "standards give mixed impressions to clients because they often have a lack of interest in going beyond the standard".

Acceptance of standards is also variable. Government and industry insiders observed a reluctance to adopt recycled materials even when they are prescribed and permitted in specifications. One contractor reported: "a big barrier currently seems to be the road owner hesitation, even with specifications that allow use of the recycled materials, engineers at local government organisations refuse to utilise them". Another identified aversion embedded in the procurement: "client specifications do not allow certain waste streams and products".

Industry feedback suggests that a cultural change within road authorities and with road asset owners is still needed to support the use of existing and future specifications that allow recycled materials.

Actions

Recommended actions to help enhance the confidence of suppliers, engineers, procurement officers and contractors using recycled materials in road infrastructure include:

1. Build awareness and confidence among governments using educational materials, encourage knowledge sharing and generate opportunities for engagement between suppliers and local governments.
2. Develop, update and where beneficial harmonise fit-for-purpose performance-based specifications, standards and guidance to support their application across jurisdictions and to communicate their benefits broadly.
3. Support practical, application-focussed research to translate the latest knowledge to local settings and conditions, and showcase trials and demonstrations to recognise and reward innovation.

These actions are recommended for delivery by all levels of government with support from industry groups .

Many of these actions are already occurring at various scales in different locations and markets and will benefit from increased support and coordination. Current activities include operating education and awareness programs, developing and updating specifications and standards and driving cultural changes to reward innovation.

Education and awareness programs

There is a need to continue building the capability of government engineers, purchasers and their contractors to understand and evaluate the quality, durability and cost effectiveness of products containing recycled materials. This can be done through targeted training, education and awareness programs as well as practical demonstrations of recycled material use in a variety of real-world applications.

In Victoria, ecologiQ addresses misconceptions and lack of awareness about recycled materials by providing guidance to contractors on opportunities to increase recycled content within the allowable limits or through new materials and applications. The agency also challenges perceptions by educating and elevating technical knowledge, as well as providing technical advice to suppliers and contractors on testing and validating materials and performance.

Greater attention could be directed towards delivering a coordinated education package to material suppliers focussing on the benefits and value of recycled materials to the road construction sector. This would embolden suppliers to speak positively with their customers about the materials and develop maturity in emerging supply chains. Nine in 10 (88%) survey participants recognise the attractiveness of actions to improve the capacity and capability of members across the recycled materials supply chain and how it will support them in their ability to produce recycled materials for road projects.

Developing and updating specifications and standards

Addressing limitations for the use of replacement materials within specifications is a critical enabler to enhancing user confidence and consumer demand. Where new and updated standards are developed, they should aim for national consistency by lifting, not lowering, the bar, enabling optimal usage across state boundaries. Furthermore, specifications and standards must be supported by guidance and education to aid understanding, provide guidance on their correct application and build wider acceptance.

Up-to-date and fit-for-purpose standards and specifications in all jurisdictions is a necessary catalyst for cultural change, especially in less familiar materials such as plastics.

Queensland's Department of Transport and Main Roads is a recognised leader in developing a suite of research-backed specifications to allow the use of recycled materials in road projects. The Department however has noted "a lack of awareness of the potential uses permitted in Transport and Main Roads specifications" as a continuing barrier to increasing quantities of recycled materials used on Transport and Main Roads projects.

Department of Transport and Main Roads' recycled materials specification program

Queensland's Department of Transport and Main Roads is committed to developing a circular economy where waste is avoided, reused and recycled to the greatest extent possible.

The Department has a long history of using recycled materials to reduce waste and emissions to deliver safe, sustainable and reliable transport infrastructure. In recent times the importance of and interest in using recycled materials has increased significantly. The Department's approach to using recycled materials is summarised in **Figure 6**.

Figure 6: Queensland Department of Transport and Main Roads' recycled material application specifications

Application	Recycled material								TMR Specification
	Crushed concrete	Crushed brick	Crushed glass	RAP	Crumb rubber	Fly Ash and Slag	Insitu material	Recycled plastic	
Unbound pavements	✓	✓	✓	✓	-	-	-	-	MRTS05, MRTS36
Sprayed sealing	-	-	-	-	✓	-	-	R	MRTS11, MRTS18,
Asphalt	-	-	✓	✓	R/D	✓ (As filler)	-	R	MRTS30, MRTS32, MRTS36, MRTS101, MRTS102, MRTS103, MRTS18, PSTS112
Concrete	R	-	R	-	-	✓	-	✓ (As fibre)	MRTS70*
Concrete Pavements	-	-	-	-	-	✓	-	-	MRTS39, MRTS40
Stabilisation	✓	✓	✓	✓	-	✓	✓	-	MRTS07B, MRTS07C, MRTS08, MRTS09, MRTS10
Earthworks, drainage and backfill	R	R	✓	R	-	-	✓	-	MRTS03, MRTS04
Geosynthetics	-	-	-	-	-	-	-	✓ R	MRTS27 MRTS58 MRTS100 MRTS104
Crack & Seat/Rubblisation (Concrete pavements)	-	-	-	-	-	-	R/D	-	
Other (including road furniture)	-	-	-	-	-	-	-	R	

✓ = currently permitted within specified limits/uses R = Research underway D = Demonstration projects underway

Source: Queensland Department of Transport and Main Roads (2020)[13]

The Department's approach to specifying recycled materials is to facilitate their use as an alternative to conventional materials. This means that contractors have 'as of right' permission to use these materials, where they comply with specifications.

The Department does not mandate the use of recycled materials as this may lead to undesirable or unintended outcomes, such as them being transported significant distances, leading to an increase in both costs and greenhouse gas emissions.

While the Department has enabled the use of many recycled materials in its business-as-usual practices, the uptake of some of these materials has been limited. The lack of awareness of the permitted uses has been identified as one of the key barriers to increasing the quantities of recycled materials used on projects.

To address this and other identified barriers, the Department's approach is shifting from facilitating the use of recycled materials to optimising their use on projects. An example of this shift is in its contractor tender schedules, where the Department lists all permissible recycled materials and maximum allowable percentages and states its preference for recycled materials over conventional materials where they are:

- permitted in accordance with the Department's technical specifications and the contract
- cost competitive with conventional materials
- available in quantities applicable to the specific project.

They also require contractors to document any reasons for not using the maximum allowable recycled materials content.

To support this change in focus, Queensland's Department of Transport and Main Roads' is working to raise awareness of the potential uses of recycled materials with stakeholders, which in turn has the potential to increase their use.

In Victoria, ecologiQ addresses challenges in industry standards and specifications that limit the use of innovative applications and materials by working closely with industry to review standards and specifications and updating them to allow for more recycled materials. This includes a new specification for recycled plastic noise walls and 30% reclaimed asphalt pavement in the intermediate asphalt layer (see **Mordialloc Freeway project**). They have also developed reference guides for recycled materials in rail, road and ancillary infrastructure, including thousands of industry standards and specifications, as well as details on approval pathways for emerging materials.

Mordialloc Freeway project

Major Road Projects Victoria, ecologiQ and the Australian Road Research Board helped develop a new technical specification to support the installation of recycled plastic in noise walls on Victorian road projects.

The newly opened Mordialloc Freeway – known as Australia's greenest freeway – is a standout example of sustainable materials in action, with the project using around 800 thousand tonnes of recycled and reused materials.

Major Road Projects Victoria and ecologiQ engaged Australian Road Research Board in 2020 to develop a new technical specification to support the installation of the revolutionary noise walls, which allows for up to 100% recycled plastic in noise walls on Victorian road projects. This has paved the way for future projects to use waste plastic in a way that would have been unimaginable just a few years ago.

This includes the world's first 75% recycled plastic noise walls. The wall panels were made using 570 tonnes of plastic waste – around the same amount collected kerbside from 25,000 Victorian households in a year. They used a mix of hard plastics such as milk and shampoo bottles, and soft plastics including food packaging.

The Mordialloc Freeway also used recycled plastic in drainage pipes and to reinforce concrete on shared paths, recycled glass in asphalt, recycled concrete in road base, reclaimed asphalt pavement and landscaping mulch made of pine pallets.

More than 10 suppliers from Victoria's growing market for recycled materials helped deliver the vision for Australia's greenest freeway. Major transport projects such as the Mordialloc Freeway provide a huge boost for these suppliers in Victoria, generating business and ongoing employment.

Innovation, research and knowledge

Continued investment in innovation, research and knowledge sharing is critical to building and maintaining the confidence of government and industry stakeholders in the recycled materials supply chain. Practical, application-focussed research can translate the latest knowledge to local settings and conditions, while trials and demonstrations can showcase real-world applications. Demonstration trials are recognised by industry practitioners as reliable for verifying the safety impact and performance of new materials under Australian conditions. Effective demonstrations must be well designed to avoid duplication, redundant trials on the same material and wasting valuable resources that could be used for separate research and development.

Supported by strong and targeted communications, research outcomes and knowledge sharing can help shift existing mindsets and reservations around the cost and performance of recycled materials.

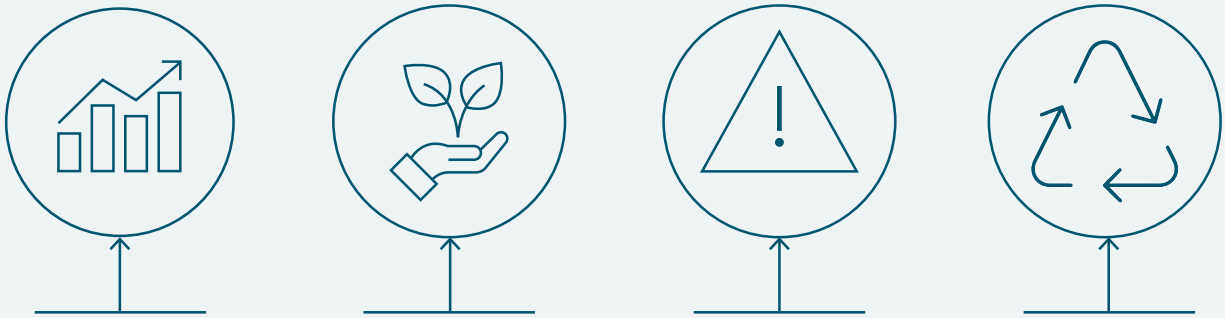
The National Asset Centre of Excellence is one example of practical, applied research being put into action within Queensland's Department of Transport and Main Roads.

National Asset Centre of Excellence

The National Asset Centre of Excellence is a joint R&D initiative between Queensland's Department of Transport and Main Roads and the Australian Road Research Board, which has undertaken extensive research into the potential use of recycled materials in the Queensland roads. It is a key enabler of this type of research, along with Austroads and other initiatives such as the Western Australian Road Research and Innovation Program.

The Queensland Department of Transport and Main Roads has adopted principles developed by the National Asset Centre of Excellence program to consider the use of new or expanding the use of recycled materials (Figure 7).

Figure 7: Principles for using recycled materials



The end result provides as good, if not better, performance than conventional materials

They do not harm the environment, the community or workers

They do not cause operational issues in the longer term (such as contaminated land)

They are recyclable at the end of life

The program's focus on delivering research to facilitate the incorporation of recycled materials in the construction, rehabilitation and maintenance of Queensland's roads, has delivered numerous benefits, including:

- reducing the amount of waste sent to landfill, illegal dumping and littering
- reducing the greenhouse gas emissions generated by the production of new materials and the disposal of waste materials
- reducing our reliance on non-renewable resources and developing a circular economy where materials are continually reused in their highest and best use
- potentially reducing short- and long-term costs
- potentially improving network performance.

Address regulatory issues

Regulations that treat recovered materials as waste needing to be controlled are falling behind community and industry expectations and need to be reviewed to facilitate industry growth and circular economy goals.

Key findings

Regulation that facilitates industry development whilst protecting against adverse impacts

Infrastructure Australia advocates for a strong regulatory system that facilitates industry development and advancement of market opportunities whilst protecting against adverse impacts.

Some replacement materials, such as plastics, may cause environmental, health and safety concerns, including micro-leeching and fuming during construction. Supply chain confidence and product demand is linked to assurances that recycled materials will not breach product quality, safety and environmental protection requirements set by relevant authorities, such as state Environmental Protection Agencies.

Environmental protection regulations set out operating conditions and penalties to prevent harmful impacts to the environment and communities. The recycled material supply chain (i.e. the resource recovery sector, recovered material reprocessors and recycled product suppliers) and its customers have, however, expressed strong concerns about inappropriate and excessively burdensome environmental regulations that impact processing costs, the ability to store and stockpile materials, and the capability of the industry to meet market demand.

Nearly a quarter (22%) of businesses selling products and services for use in road projects identified unfavourable regulatory conditions as a top concern in producing recycled materials. Large businesses (200+ employees) are particularly negative about regulatory conditions, with 3 in 10 (30%) citing regulatory conditions as a major concern that lessen the confidence of using these materials.

The Australian Council of Recycling argues that the current regulatory environment is the most significant burden on the operation and growth of the recycling industry. Current environmental protection regulations do not distinguish from one form of end-of-life material to another, even if it has been separated as waste or been through a manufacturing process. Additionally, many recovered materials are considered as volatile, hazardous waste products due to the possibility of contaminants. Regulations do not sufficiently recognise current resource recovery capabilities and processes that identify and remove such contaminants.

A noted consequence of classifying recovered and recyclable materials as waste is the regulatory limits placed on the storage of used products. Processed and baled recycled plastic, for example, can only be stored on site for eight days. This restriction appears to have little basis and significantly limits production rates and the ability of suppliers to meet customer demand. This is particularly true for products used in road construction, which is seasonal. Compliance with the regulations can also lead to adverse environmental and economic outcomes. This includes valuable recovered materials being disposed of in landfill, along with transport and disposal fees being accrued by the supplier.

Other industry stakeholders also raised regulatory inconsistencies as barriers to the uptake of recovered material use in construction products. Such inconsistencies are found in environmental regulator requirements and approvals, waste codes, beneficial use codes, resource recovery codes or similar required to manage environmental issues and control areas of use. That is, the differing ‘green tape’ requirements of the various jurisdictions.

One industry participant identified Victoria’s new financial assurance requirements for construction and demolition waste as a major concern for the industry. However, there is evidence that environmental regulators are beginning to take greater notice of the recycling industry. Australian Council of Recycling, the peak body for the resource recovery industryhas welcomed a recent reversal of New South Wales’ Environmental Protection Agency’s recovered fines order and exemptions that would have unnecessarily diverted recoverable materials to landfill.

New South Wales EPA’s reversal of recovered fines order and exemptions

NSW EPA consults with industry on recovered fines orders and exemptions

In May 2022, the NSW EPA issued a decision not to change rules governing recovered fines, following consultation over the course of six months with the waste and resource recovery industry and small businesses.

Recovered fines are residues left at the bottom of waste skip bins after all large recyclable materials have been removed. The EPA has found this material can contain contaminants like asbestos and microplastics, which can pose potential health risks and cause environmental harm.

The EPA had proposed changes to rules governing how recovered fines are processed and used, following a compliance review.

However, the extensive engagement which followed uncovered a number of specific concerns, which led to EPA's decision to maintain existing rules.

Additionally, the EPA has also confirmed that it will focus on waste industry education, monitoring and compliance, as well as industry collaboration to improve the quality of recovered fines.

The outcome of the consultation reflects the EPA's commitment to balance the need for environmental regulation that is fit for purpose whilst providing adequate protections for human health and the environment.

The collaborative approach undertaken to environmental regulation was welcomed by industry, with the Australian Council of Recycling (ACOR) reinforcing the importance of a constructive relationship between industry and regulators.

ACOR CEO, Suzanne Toumborou said: "The NSW EPA decision to retain the existing rules and instead focus on education and compliance is the appropriate approach to support progress towards the NSW resource recovery targets."

Source: NSW EPA (2022), ACOR (2022)[14]

Ensuring quality is upheld

Accompanying the growth of recycled material markets and the waste export bans, some established recycled material product producers have observed an influx of new low-cost market entrants who are producing lower-quality product. From a customer perspective, it can be difficult to differentiate product quality, so the emergence of lower-quality product is undermining the industry's efforts to supply quality product. Established industry practitioners are calling for regulatory support to make sure illegitimate suppliers are controlled and that processed waste products meet performance standards (e.g. low levels of contamination). One supplier said: "Access to raw feedstock can be challenging due to lack of stringent application of regulation allowing unscrupulous/ illegitimate operations to flourish. This results in an under-capitalised market due to lower than required financial returns".

A related issue that needs addressing is illegal and unreported dumping sites, and poor on-site storage of waste practices.

Supporting the domestic market

Additionally, the end-of-life tyre industry is calling for a ban on imported rubber to support the export ban on tyres and ensure the growth of the domestic market and support while it is still developing.

Actions

These findings and stakeholder feedback point to the need for greater engagement between environmental regulators and recycling industry representatives to shift the negative perception of waste as a hazard and find opportunities to optimise environmental and commercial outcomes.

Areas of focus for environmental regulators engaging with recycling industry representatives shouldinclude:

- Shifting the negative perception of waste as a hazard and finding opportunities to optimise environmental and commercial outcomes.
- Reforming regulation of recovered and recycled materials to remove or amend those which have unintended effects such as inhibiting efficient business operations, creating market uncertainty and leading to adverse outcomes, such as valuable recovered materials being sent to landfills.

In reforming environmental regulations, consideration should be given to regulatory harmonisation to minimise the previously referenced 'green tape' for business operating in multiple states and territories.

The survey of the recycling industry identified that public policy and regulation development are some of the most attractive measures to support the continuation or uptake of recycled materials production.

A key recommended action for the recycling industry working with all levels of government is the development of product certification rules and processes to manage the quality and consistency of recycled materials for use in road applications.

Improving recycling infrastructure and workforce capacity and expanding geographic reach

End-user access to replacement products can be hindered by the location of a project in relation to the location of supply. The market survey indicated that replacement products are not always readily available throughout the country. Within jurisdictions that do have mature replacement product suppliers, there were noted limitations in regional and rural areas.

Production capacity of replacement product manufacturers varies. Larger producers produce end products with both virgin and recycled materials to maintain sustainable production volumes, however there are production costs and downtime in switching between products, impacting producer flexibility and market responsiveness.

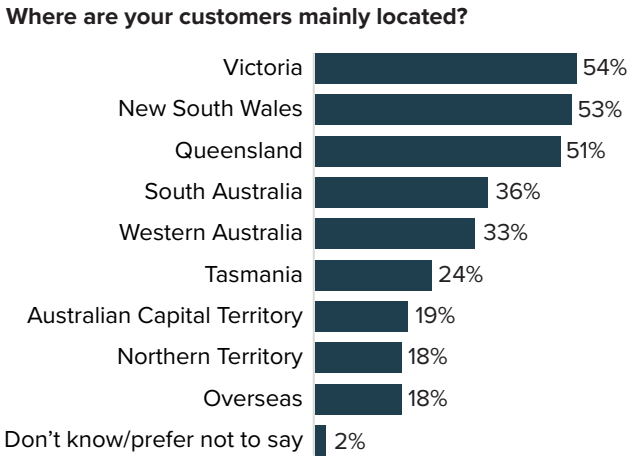
The producer market is in its growth period and is therefore fragmented, with many small players focussing on limited products or geographies. Producers are dabbling rather than solidifying themselves in the recycled materials market and investing in capital or workforce capability. Most of the inputs are considered waste materials and the sector is seen mostly as waste management rather than product manufacturing. This somewhat pejorative view limits the attractiveness of the resource recovery and recycling industry as a career when compared to other infrastructure and manufacturing jobs.

Key findings

Geographic concentration in certain markets

Figure 8 shows that most replacement product users are based in Victoria, New South Wales and Queensland, with more than 50% of the businesses surveyed serving these markets. One in three (33%) users of replacement materials users are based in Western Australia and South Australia and just under one in five users of replacement materials are based in Tasmania and Northern Territory.

Figure 8: Location of replacement project users



The demand model (discussed in the section on the future demand) estimated approximately 82% of projected demand would come from Victoria, New South Wales and Queensland, which aligns with total value of road projects in those states. This means that smaller jurisdictions such as Northern Territory, with lower replacement material demand, are under-served and might not be able to convert the theoretical demand to actual usage.

Range of materials are limited

Certain replacement materials, including recycled crushed glass, fly ash and crumb rubber, are not widely available across the country. For example, there currently is no glass crushing facility in Western Australia, so this is not used as a replacement product in road infrastructure (interview conducted with Main Roads WA 25 April 2022). However, should this facility become available, and were it economically feasible to do so, recycled crushed glass could replace up 2 million tonnes of virgin material in Western Australia.

Facilities are not always available where needed or scalable.

Even in states with good penetration of users of replacement products, such as Victoria and Queensland, facilities tend to be in metro areas. In Queensland, there are glass recyclers in Brisbane, Rockhampton, Mackay, Townsville and Cairns that can produce replacement products to the required standards (interview conducted with Queensland Department Transport and Main Roads 29 March 2022). However, they are not large enough to supply large projects, hence the limited consumption of replacement materials. This is especially true if designers and engineers need a hybrid material composition that takes advantage of replacement product but still needs virgin product. Haulage costs, a key outlay for building materials, makes transporting replacement products uneconomical in such scenarios. This has been exacerbated by the

price of fuel price increasing by 12.5% from January to May 2022, as well as nationwide heavy-vehicle driver shortages.

A barrier to improving the availability of facilities, specifically in regional and rural Australia, is economies of scale (interview conducted with ALGA Central 23 March 2022). Economies of scale are often achieved when the scale of operation is larger, which is difficult for regional and rural operations, making manufacturing costs higher and limiting throughput. On top of this, license applications for new facilities can take over seven months to get approval, making these recycling facilities slower to start up (interview conducted with Tyrecycle/Resource Co 23 March 2022).

Workforce issues

Workforce issues in the recycling and waste industries that also impede the use of recycled materials in road infrastructure are people and skill shortages, limiting business' ability to collect, sort and process materials. Major reasons for these shortages are falling commodity prices, government levies and an uncertain regulatory environment.[15] Currently, waste and recycling are bundled into one sector but there is a push for them to combat the perception that a career in the waste industry is not attractive. It can be challenging to entice new workers into the sector due to unappealing conditions related to wages, noise, smell and cleanliness.

Moving from world-leading research to world-leading production

Australia is regarded as having world-class research capabilities in the infrastructure space by both government and industry stakeholders, with approximately $210 million invested by governments in recycling infrastructure and technology, according to a new analysis by the Australian Council of Recycling. However, aside from reclaimed asphalt pavement and fly ash, which are considered standard replacement products, most other replacement materials are still emerging, with trials, pilots or small-scale adoption. This lack of certainty around future demand does not encourage investment in new or improved capacity or recruitment of a more professional workforce, leaving the industry highly fragmented, with most companies producing replacement products either being small enterprises (fewer than 20 employees) or producing both virgin and replacement products.

Actions

Most replacement product businesses surveyed have not received government assistance, including funding, grants and tax incentives. Survey participants indicated that access to grants for technology improvements will support their ability to increase throughput or invest in production capacity, with 98% of participants ranking this as a key measure to support the industry. Over half of the organisations plan to, or already have, invested in new technologies, upgrading machinery or plants, for producing recycled materials, indicating they foresee growth in this area and have identified revenue streams that meet return-on-investment thresholds. Industry views financial incentives, such as grants, very positively as strong drivers to support building and upgrading plants and equipment that increase the processing capacity and capability for different waste streams (interview conducted with BINGO Industries 11 April 2022).

One potential way to increase the geographic reach of replacement products is to utilise existing material processing infrastructure to accept waste streams, such as existing quarries that accept construction waste and produce crushed recycled concrete. Leveraging current infrastructure to produce replacement products would also reduce the cost of entry. Alternatively, building new infrastructure would increase the capacity to process recycled materials. Both solutions could improve regional collection and processing, a key action in improving geographic reach and accessibility. Reaching regional and rural Australia was a consistent concern raised in workshops and interviews. Main Roads Western Australia have a desire to establish crushed recycled concrete facilities in Bunbury then in Geraldton, reinforcing that the desire to expand this market does exist (interview conducted with Main Roads WA 25 April 2022).

Modernising facilities and implementing incentives for school-leavers or young people to enter the industry could increase the attractiveness of the resource recovery and recycling industry to the workforce. The current perception of replacement product manufacturing being tied to waste management does not appeal to younger workers. The ability to reframe the industry as being part of the circular economy and recycling will make it more attractive and tie more closely to values that younger worker align with in organisations such as sustainability and social responsibility. Modernising these recycling facilities will enable it to meet contemporary work environment standards (see **Recycling Modernisation Fund**). Finally, establishing free (or low-fee) apprenticeship incentives and training can attract new talent, or upskill existing talent.

Recommended action for delivery by all levels of government with support from industry groups and individual businesses include:

- Increase the geographic reach of replacement products by using existing material processing infrastructure to accept waste streams and produce replacement products.
- Increase the attractiveness of the resource recovery and recycling industry to the workforce by modernising facilities and implementing incentives for school-leavers or young people to enter the industry.

Recycling Modernisation Fund

The Australian Government has been investing in recycling infrastructure that can boost our recycling capacities and capabilities as we move towards a circular economy. Through the Recycling Modernisation Fund (RMF), industry will be receiving funds from the Australian, state and territory governments, topping up their investment to build or expand their facilities.

To date, the RMF has funded 14 projects which recycle waste glass and tyres into materials that can be used as road base aggregates in accordance with state and territory related standards. Several projects are looking at innovative solutions that will remove sugars, yeast and organic traces from glass improving the quality of the feedstock. Eliminating such contamination is the first step in ensuring the feedstock can be used as road base and in civil construction.

Other projects are minimising the transport burden and related emissions by creating opportunities within the same facility footprint, such as building glass recycling facilities at existing material recovery facilities. Waste glass separated from kerbside collection at the material recovery facility will then be absorbed by the onsite glass recycling facility, rather than being baled and sent away for further processing. Some regional projects are using this model to process the glass and regrade it onsite for supply to local end-users for use in road base, asphalt and concrete. Councils are also minimising handling costs associated with waste haulage (e.g. same fee per truck, whether the volume is big or small) and overcoming large distances by producing their own recycled crushed glass at their material recovery facilities for use on their own road projects. Upgraded facilities will be able to blend such glass with recycled asphalt pavement, maximising the amount of recycled product incorporated into the end product.

A successful tyre project will be processing tyres and waste rubber materials into crumbed rubber and mesh powder for local use in civil infrastructure projects as a commercial polymer replacement in asphalt and bitumen. Another one will be separating the steel from the tyres at the shredding stage, which will then be available for re-use by the steel industry, with the remaining rubber being crumbed and made available to the asphalt industry, soft sporting surfaces and playgrounds, and as a tile adhesive.

As industry and governments come together to find solutions to minimise waste and promote sustainable procurement in construction projects, we see innovation working at its best, with big construction projects reusing crushed glass to make up to two-thirds and three-quarters of the sand used in the structural asphalt layers on the projects.

As RMF funded trials are being completed, such as the one looking at a low-carbon geopolymer concrete containing recycled crushed glass, and as new projects are announced, it is expected that industry will have the tools to promote sustainable projects in the construction and road industries.

Source: Department of Climate Change, Energy, the Environment and Water (2021)[16]

Driving demand through sustainable procurements and market signalling

In a competitive market, the market supply of a product or service is an outcome of the collective decisions made by businesses to enter or leave that market. Businesses will only enter the market if they can expect to turn a profit. A necessary condition for a profitable business is the presence of, or the potential for, demand for their products and services. On the other hand, businesses will exit the market when the level of demand needed to sustain profit disappears.

This basic premise was echoed in the feedback received from industry members during consultation. For example, one participant pointed out that the low demand for geosynthetic polymers made from recycled plastics is the primary reason why there has not been greater market availability of this product. Indeed, the low-demand, low-supply outcome is especially common among novel or emerging products that have yet to obtain confidence within industry that they are reliable or worth trying.

Lack of consistent and ongoing demand, or the likelihood of such demand in the future, means that new suppliers will be reluctant to enter the market, as there will be no surplus of demand to make the business viable. The lack of stable supply further deters the uptake of affected materials, as potential buyers may become concerned about the future serviceability of their asset. A vicious cycle is hence born, stymieing the growth of replacement materials that fail to generate adequate demand over the long term.

In addition to the feedback on recycled plastic, other consultation feedback directly supports the need to induce demand and maintain supply on an ongoing basis.

Key findings

The need for pull factors in procurement contracts

One participant's feedback linked the low demand of replacement materials to the requirement of cost effectiveness in the procurement contracts of most infrastructure projects. They argued that focussing on minimising the upfront and financial components of procurement costs often makes replacement materials less attractive than conventional materials. Such focus is potentially biased, as replacement materials may offer superior lifecycle cost benefits from economic and environmental perspectives.

Another respondent pointed out that contractors often are the ones recommending replacement materials in their proposals, which can translate to to ad hoc and spotty demand. Instead of pushing replacement materials for the client to consider, the industry prefers the client (public asset owners) to include the pull factor in their procurement tenders by explicitly requesting the inclusion of replacement materials in project requirements.

The need for cost information and assistance

Lack of transparency around price and understanding of lifecycle cost information have also been cited as the reasons why some local governments are hesitant to choose replacement materials over their conventional counterparts. Local governments are keen to support sustainable procurement for their projects but are also budget-constrained and therefore unwilling to switch from conventional materials without fully understanding the cost implications, both upfront and over the asset's lifecycle.

Actions

According to consultation feedback, established demand is a necessary condition for sustained and consistent supply of recycled materials. Governments therefore have a role to provide policies and actions that provide certainty and strengthen demand for replacement infrastructure materials. Recommended actions for delivery by all levels of government with support from industry groups include:

- facilitating procurement-driven demand
- providing easy-to-access market and cost information
- providing clear demand signals to support market growth and improve the price competitiveness of recycled materials.

A consensus from the industry engagement is the view that procurement contracts for infrastructure projects should not penalise proposals with higher usage of replacement materials on the basis of cost. Public procurement policies in particular should be willing to support environmentally sustainable practices that may be at a cost-disadvantage to conventional alternatives.

On the other hand, industry feedback also noted that procurement contracts which aim to promote sustainability should also refrain from overly specific mandates or targets, as such conditions may prevent contractors from proposing innovative and creative approaches to achieve sustainable outcomes.

Another comment supporting procurement-driven demand suggests that the evaluation criteria of procurement contracts that value sustainability should give weight to the lifecycle impacts of proposed materials in terms of economic, environmental and social outcomes. This would shift the focus on any upfront cost disadvantages to long-term benefits.

Finally, public procurement could also lead direct demand for specific replacement materials. An example of this in action can be seen in the Paving the Way initiative undertaken by the Southern Sydney Regional Organisation of Councils.

Paving the Way (Southern Sydney Regional Organisation of Councils)

A total of 16 Sydney metropolitan councils joined forces to recycle nearly 100 million glass containers per year into local roads through the largest, local government-led procurement of recycled road-making materials in New South Wales history.

A request for tender released in September 2020 by the Southern Sydney Regional Organisation of Councils, on behalf of 16 councils representing over 2.1 million people, aimed to initiate a new age of road-making by using recycled crushed glass as a substitute for natural sand in roads in line with Transport for New South Wales and AUS-SPEC specifications.

The initiative, Paving the Way, is expected to create a local, closed-loop market for over 20,000 tonnes of glass per year, or approximately one-third of these councils' household glass recycling collections, without compromising existing recycling of glass into beverage containers. By signalling ongoing aggregated demand to the market, the Southern Sydney Regional Organisation of Councils has stimulated end markets for recycled glass, as well as supported local jobs and the development of essential recycling infrastructure.

A triple bottom line cost-benefit analysis, conducted in 2022 in collaboration with the New South Wales Department of Planning, Industry and Environment, identified a 1.19 benefit cost ratio of the initiative. It found that using 20,000 tonnes of glass per year would reduce 1,660 tonnes of greenhouse gas emissions by avoiding the transport of virgin sand from distant quarries and interstate transport of glass without a local market. The procurement's innovative contract model will track emissions and volumes of recycled materials to help councils report on sustainability targets.

Paving the Way, which has received coordination and technical support funding from the New South Wales Environment Protection Authority, is the first project under the Procure Recycled memorandum of understanding, signed by the Southern Sydney Regional Organisation of Councils in November 2019, to prioritise recycled materials in procurement in response to China's National Sword policy, which barred imports of Australia's recyclable materials, and the Council of Australian Governments' decision to ban exports of unprocessed recyclable materials. Since then, the Southern Sydney Regional Organisation of Councils has worked closely with Transport for New South Wales, the Department of Planning and Environment, the Environmental Protection Authority and the National Building Specification to refine specifications and align policies on recycled civil works materials.

Phase Two of the initiative will launch a 12-council demonstration project of crumb rubber asphalt in partnership with Tyre Stewardship Australia by the end of 2022. This project will identify climate-resilient asphalt mixes that are expected to extend road asset life by up to 50% and create a market for over 100,000 locally recycled end-of-life truck tyres and 56,000 car tyres.

Provide easy-to-access market and cost information

Feedback from industry consultation suggested that reliable and easy-to-access sources of product information will drive the demand for replacement materials. Specifically, such information is needed to cover the location, supplier background, availability and price information of the replacement materials.

Buy Recycled Directory is one such source of information provided by Sustainability Victoria.

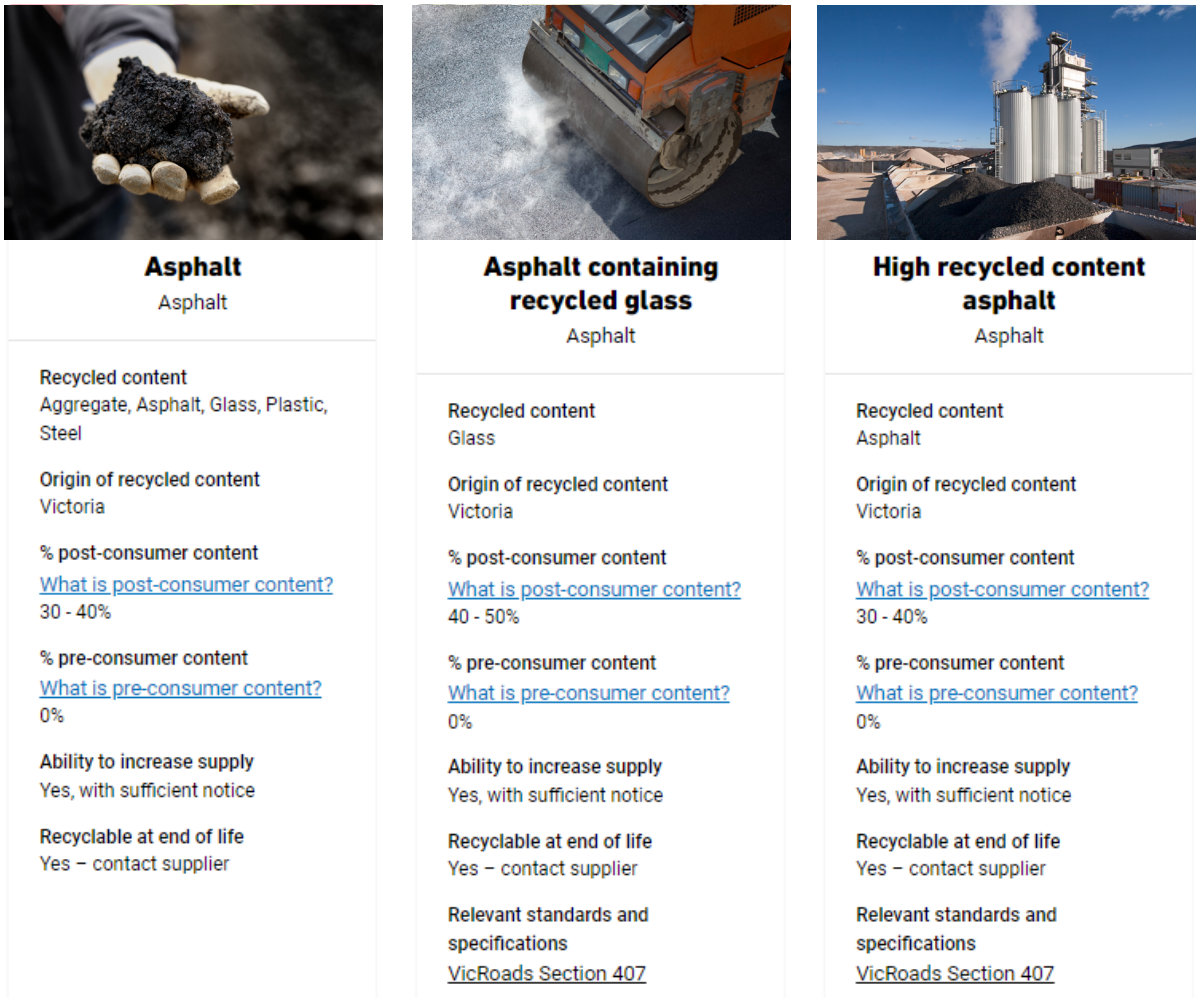
Buy Recycled Directory (Sustainability Victoria)

Sustainability Victoria's *Buy Recycled Directory* lists products containing recycled content and provides buyers with easy access to suppliers and product options. The directory was launched in July 2020 and is a key tool within Sustainability Victoria's Buy Recycled service, which supports councils to use more recycled materials and products in infrastructure, landscaping, parks and gardens.

To be listed on *Buy Recycled Directory* as a product provider, the supplier must adhere to the Code of Practice of the directory. The Code of Practice includes the product compliance criteria that must be met for listing including relevant legislative and regulatory requirements. Interestingly, the Code of Practice does not have a minimum requirement for recycled content in the material product, as long as the recycled content is greater than 0%.

The image below shows sample search results for asphalt product, including information on the recycled material applied, the content level, the supplier information and supply capacity.

Figure 9: Buy Recycled Directory



Source: Adapted from the Buy Recycled Directory website

In addition to product information, industry has also called for tools to understand an asset's lifecycle assessment, including sustainability impacts of replacement materials in terms of emissions and other environmental impacts. There may be opportunities for the Australian Government or state agencies to develop tools for industry practitioners to do this.

Provide clear demand signals to support market growth and improve the price competitiveness of recycled materials

Several suppliers suggested that they could easily increase their supply capacity if major materials purchasers provided clear, longer-term demand signals, or commitments, to the market. Longerterm purchasing commitments allow suppliers to optimise production and manage fluctuations in feedstock and stockpiling, allowing for more cost-effective options and cheaper, more competitive material prices.

Asphalt manufacturers indicated that there are significant costs and downtime involved in transitioning material processing operations from those including recycled content to those that exclude them (as is the preference of some buyers). Some manufacturers have begun incorporating recycled content in their mixes as standard practice and only revert to virgin-only mixes at the explicit instruction of customers. This practice allows manufacturers to benefit from recycled materials' natural cost advantages and improves operational efficiencies.

Conclusions

Recycled and replacement materials are well suited for road infrastructure uses but there is general lack of awareness of their uses and benefits. This can lead to low market confidence and risk aversion that inhibits market opportunities, including improving the cost-effectiveness of emerging materials and markets. Government and industry stakeholders are calling for improved education and awareness to help participants along the supply chain to understand recycled materials and their opportunities in road infrastructure.

To support awareness a strong, contemporary regulatory system, including product and application specifications and standards is needed to facilitate industry development and advancement of market opportunities whilst protecting against adverse impacts.

Industry engagement also revealed strong themes of risk-aversion, misinformation and a negative perception towards recycled materials. While education and practical demonstrations are a key action, there is a broader cultural issue at play affecting the implementation of government policies aimed at increasing the use of recycled materials. A targeted program to recognise and reward innovation and incentivise behavioural changes should also be considered.

The recycled material supply chain is a diverse and the market is fragmented, servicing a mix of customers and locations across Australia. As such, recycled and replacement products are not always readily available where they are needed resulting in large transportation costs which can offset cost or environmental benefits. Governments should consider ways to support the development of recycled material markets in under-served areas.

The supply of recycled materials is varied and many recycled materials have competing uses that limit their availability. This is the case for recycled plastics and glass, which can be diverted away from infrastructure toward other competing uses unlike materials such as ground granulated blast furnace slag, reclaimed asphalt pavement and fly which are mostly used for infrastructure applications.

Considering future demand scenarios, recycled crushed glass and ground granulated blast furnace slag are expected to experience major supply gaps in forecast period due to their relatively high demand and current supply constraints. In comparison, reclaimed asphalt pavement, crumb rubber, slag aggregate, fly ash and plastics face relatively more moderate yet still significant challenges for meeting future demand.

Next steps

Responding to market capacity opportunities

Key opportunities and actions to address market constraints impacting the uptake of recycled materials in road infrastructure include the following:

Improving awareness and understanding of recycled materials, specification and opportunities

All levels of government with support from industry groups to:

1. Educate participants along the supply chain on the range of recycled materials available, using databases, educational collateral and case studies.
2. Develop supplier-focussed communications materials and knowledge that promotes the environmental credentials and lifecycle cost benefits of recycled materials compared with products made from virgin materials.

Taking stronger action to enhance confidence in using recycled materials

All levels of government with support from industry groups to:

1. Build awareness and confidence among governments through educational materials, encourage knowledge sharing and generate opportunities for engagement between suppliers and governments.
2. Develop, update and where beneficial harmonise fit-for-purpose performance based specifications, standards and guidance to support their application across jurisdictions and to communicate benefits more broadly.
3. Support practical, application-focussed research to translate the latest knowledge to local settings and conditions, as well as showcasing trials and demonstrations to recognise and reward innovation.

Addressing regulatory issues

Environmental regulators to engage with the recycling industry, in order to:

1. Shift the negative perception of waste as a hazard and find opportunities to optimise environmental and commercial outcomes.
2. Reform environmental regulation of recovered and recycled materials, including removing or amending regulatory requirements that inhibit efficient business operations, create market uncertainty and lead to adverse outcomes, such as valuable recovered materials being sent to landfill.

The recycling industry should also work with all levels of government to develop product certification rules and processes to manage the quality and consistency of recycled materials for use in road applications.

Improving and modernising recycling infrastructure and workforce capacity and expanding geographic reach

All levels of government with support from industry groups and individual businesses to:

1. Increase the geographic reach of replacement products by using existing material processing infrastructure to accept waste streams and produce replacement products.
2. Increase the attractiveness of the resource recovery and recycling industry to the workforce by modernising facilities and implementing incentives for school-leavers or young people to enter the industry.

Driving demand through sustainable procurements and market signalling

All levels of government with support from industry groups to:

1. facilitate procurement-driven demand
2. provide easy-to-access market and cost information
3. provide clear demand signals to support market growth and improve the price competitiveness of recycled materials.

Further opportunities

This report focusses on the opportunities and market constraints for using recycled materials in road infrastructure. Momentum is gathering across the infrastructure sectors, including rail and nontransport related infrastructure across various scales, to incorporate recycled materials. Next stages of the Market Capacity Program would benefit from expanding the recycled material demand forecasting and market analysis for relevant materials into the rail and other infrastructure sectors. This next stage could build on the *Sustainability Options for Freight Rail* work developed by Australasian Centre for Rail Innovation, Australian Road Research Board and Arup[17].

Appendix A
Detailed material supply chain overviews

A–1 Crushed recycled concrete and brick

Concrete is a structural material typically recovered from commercial demolition and civil works. Crushed recycled concrete can be used as a subbase under full depth asphalt or as a basecourse under low traffic local roads. Crushed recycled concrete may contain sand, brick, tile, asphalt, and recycled crushed glass. It is a high-strength and durable material that can reduce landfill volumes when used instead of limestone.

End of life bricks are mostly recovered from domestic demolitions works and typically contain hardened clay bricks and some crushed concrete and cement/lime mortar. Recycled crushed bricks are most commonly used in unbound and bound pavements
as an alternative to natural and quarried aggregates and sand.[18]

In 2013, 8.7 million tonnes of demolition concrete was produced in Australia.[19]

A case study from the *National Waste Report* (2020) showed that crushed recycled concrete can offer superior performance compared to virgin aggregate when used in a hardstand application, as well as being cheaper and more environmentally friendly.[20] The carbon footprint of crushed recycled concrete is 65% less than that of the equivalent quarried material because it is softer and requires less energy to crush.

Figure 10 summarises the crushed recycled concrete material flow which begins with the recovery of end-of-life concrete from a demolition site. The recovered concrete is then sorted, separated and then reprocessed and crushed. The final product is then suitable for use in road infrastructure application and is sold to road construction companies. The process for recycled crushed brick is similar.

Figure 10: Material flow of crushed recycled concrete

Of the $70 per tonne required to collect, transport, and recover the materials, $40 is attributed to collection, with labour costs being a major component (interview conducted with BINGO Industries 11 April 2022). As the materials are low value, transport costs are a significant part of this pricing, making proximity to the supply point important. Where there are shortages of virgin quarry materials, such as in and around Melbourne, crushed recycled concrete will be cost competitive with virgin materials.

A–2 Reclaimed asphalt pavement

Reclaimed asphalt pavement is asphalt that was previously used as an engineering material and is itself fully recyclable as a construction material. Reclaimed asphalt pavement can be used as a structural layer of asphalt pavement. End-of-life asphalt is removed from the pavement by milling and reprocessed for recycling

by crushing and screening. Reclaimed asphalt pavement has strict specifications that can limit its use. For example, in some states, reclaimed asphalt pavement is not permitted in asphalt surfacing due to increased risk of cracking and lower skid resistance.

In 2005, almost 4 million tonnes of asphalt were disposed of in Australia.[21] If this total volume were commercially recycled, the energy savings would equate to 5 million households' energy requirements for a month. RAP can also reduce costs by reducing the need for virgin materials and transportation requirements and divert waste from landfill.

A–3 Recycled crushed glass

Australia's annual glass consumption is approximately 1.21 million tonnes with 90% being packaging (i.e. bottles and jars)[22]. Eighty-four per cent of glass is recovered, however around 20 million tonnes still ends up in landfill.[24]

Glass collected for recycling is primarily sourced from food and drink bottles and jars, and can be clear, green, or amber (brown). Glass sourced from drinking glasses and window glass are often unsuitable for recycling back into bottles or jars but may be suitable for use road applications.

Recycled crushed glass can be used as a natural sand replacement for many road applications including fill, drainage and retaining walls.

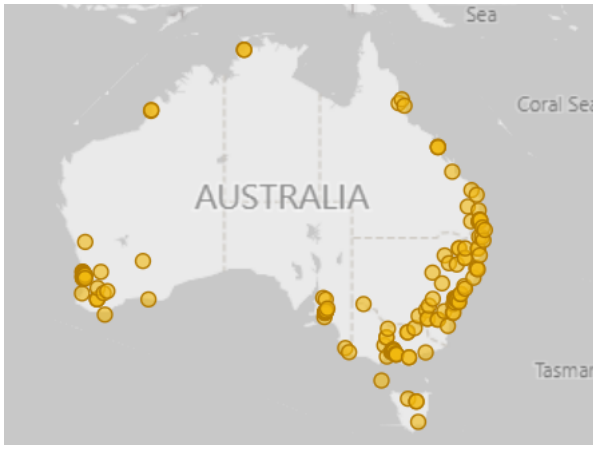
Every tonne of recycled crushed glass used in road applications can save approximated 560 kg of natural sand, 176 kg of soda ash, 176 kg of limestone and 64 kg of feldspar.[23]

The material flow of crushed glass in asphalt is shown in **Figure 11**, and the locations of glass recovery and processing facilities around Australia can be seen in **Figure 12**.

Figure 11: Material flow of recycled crushed glass (RCG) in asphalt

Source: Transport for NSW (2020) [24]

Figure 12: Locations of glass recovery and processing facilities in Australia



Source: Department of Agriculture, Water and the Environment 2018[25]

The economic sustainability of crushed recycled glass and glass cullet need to be improved with a focus on reducing costs associated with milling the glass and washing it to remove contaminants (where required). A significant amount of energy is required to process the glass, so the cost of using this material is higher compared to raw materials.

The market value of recycled glass products (the end product) is estimated to be $100–149 per tonne delivered. When glass is used in roads, it can replace limestone, limestone costs are estimated at $30–38 per tonne, which is significantly cheaper.

A–4 Crumb rubber

Crumb rubber is sourced from the recycling of end-of-life vehicle tyres, and can be used in road infrastructure, especially in sprayed seals and asphalt. End-of-life tyres contain valuable polymers and carbon black that result in more durable roads when combined with bitumen. It also improves skid resistance, drainage performance, service life, resistance to crack reflection, and aggregate adhesion.

In Western Australia, 600–700 tonnes of crumb rubber are used annually for sprayed bituminous seals[26]. Western Australia imports its crumb rubber predominantly from Victoria, but suppliers are currently being established within the state.

In Australia, 51 million used tyres reach their end-of-life each year[27]. Only 5% of these are domestically recycled with the others being put in landfill, stockpiled or illegally dumped.

The most common sources of crumb rubber are truck tyres and off-the-road (OTR) tyres, as they have a higher concentration of natural rubber[28]. Processed crumb rubber has an estimated market value of around $700 per tonne. **Figure 13** outlines the processing steps for crumb rubber.

Figure 13: Supply chain of rubber crumb

A–5 Fly ash

Fly ash is a by-product of coal-burning, electricity-generating power stations[29] that is commonly used as a supplementary cementitious material. It can be used in cementitious materials, concrete and as a binder component in geopolymer concrete, which is concrete utilising alternative binders to ordinary Portland cement. Fly ash can also be used as a lightweight aggregate in concrete and for the stabilisation of fine-grained soils. The average amount of fly ash in cementitious material is 15–30%[30].

Using fly ash in concrete has many benefits including reducing costs, reducing greenhouse gas emissions, improving durability, and reduction in the heat of hydration[31].

Queensland recorded a reduction in up to 70% of greenhouse gas emissions from the use of fly ash[32]. Up to 35% of cement used in structural concrete can be replaced with fly ash and Queensland specifications require a minimum of 25% fly ash must be used.

Fly ash production is concentrated in black coal power-generating states of Queensland and New South Wales. In 2018–19, Australia's coal combustion generated 12.5 million tonnes of ash of which 90% (11.25 million tonnes) was fly ash[33]. Only 47% of the total ash generated was recycled.

Around 216 million tonnes of coal ash is stored or stockpiled in New South Wales. These stockpiles contribute up to 100 tonnes of leachate containing heavy metals and metalloids entering the waterways each year.

When used as a lightweight aggregate, fly ash is first collected from coal-fired power stations. The fly ash is then mixed with a binder and then formed into pellets using a pelletiser. After reaching the appropriate size, they are dried. The pellets are then sintered (compacting and forming a solid mass using heat or pressure) and finally cooled. The product is then ready to be used as a lightweight aggregate in the production of structural lightweight aggregate concrete. **Figure 14** shows the production and supply steps for fly ash as a lightweight aggregate.

Figure 14: Production and supply of fly ash

When high levels of fly ash are used in concrete it can lead to extended set times and slow strength development, which can delay rate of construction.[32] Extended set times can be advantageous in the case of cement stabilisation, where longer working times can allow more time to rectify construction issues or defects.

In addition, fly ash properties can largely depend on the composition of the coal. The variability of the unburnt carbon in fly ash in the market has a direct impact on concrete or cementitious materials' performance.

The leading supplier of fly ash in Australia is Flyash Australia Pty Ltd. The two major cement and concrete manufacturers, Boral Ltd and Cement Australia Pty Ltd, share ownership of this company. There is little incentive for power stations to facilitate users of fly ash to increase uptake as it is free for them to deposit fly ash in dams. Cement companies also have little incentive to use a large amount of fly ash as companies do not have significant competitors using large amounts of fly ash.[34]

A–6 Ground granulated blast furnace slag (slag)

Blast furnace slag is a by-product from iron and steel production in a blast furnace.[35] Iron ore, coke, and limestone are fed into the furnace. The iron ore is reduced to iron and the remaining materials form slag. The molten slag and is then quickly cooled with fresh water to produce a granular product. This product is then crushed or milled to a fine particle size which has cementitious (pozzolanic) properties.

Ground granulated blast furnace slag's cementitious properties make it a suitable partial replacement for Portland cement. Ground granulated blast furnace slag is mainly blended with cement to manufacture concrete or as a direct supplementary cementitious material addition in concrete. Up to 60–70% of cement used in structural concrete can be replaced with ground granulated blast furnace slag[34]. **Figure 15** shows the processing and supply of ground granulated blast furnace slag.

Figure 15: Processing and supply of ground granulated blast furnace slag

A–7 Bottom ash

Bottom ash is another industrial by-product from coal power plants.[36] These coarse particles fall to the bottom of the furnace during combustion. Bottom ash can also be generated from wastetoenergy incineration facilities.

Bottom ash can be used for several road infrastructure applications such as unbound and bound aggregate in the embankment fill, subbase layer, the capping layer of pavements or as a replacement for aggregate in structural concrete.[37]

When compared to sand and gravel, bottom ash has a higher shear strength and is a suitable material for road base but due to its lower abrasion resistance, it is not recommended for full replacement of natural aggregates in base layers.[38]

Of the total generated ash, 10% is bottom ash.[35] In 2018, ~1.34 million tonnes of bottom ash was generated in Australia, with only 47.6% being recycled[39].

A–8 Plastic

The most commonly found polymers in applications of plastics are high-density polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP), polyethylene terephthalate (PET), poly vinyl chloride (PVC) and polystyrene (PS).

Applications of recycled plastics in road infrastructure include the manufacture of plastic ancillary components, including roadside furniture, road cones, safety barriers, boardwalks, drainage covers. Higher percentages of recycled plastics can be used in this application compared to when used within a bituminous binder.

Using recycled plastics in asphalt has become a potential use of the waste product. Research is currently being conducted through a joint National Asset Centre of Excellence–Western Australian Road Research and Innovation Program project and a project done by the Royal Melbourne Institute of Technology on behalf of Austroads.[40]

Soft plastics can be used as an additive that melt to form part of the bituminous binder which bonds and waterproofs the aggregate. This means there would be no issue with microplastics. Asphalt commonly comprises of 95% aggregate and 5% bitumen binder.[41]

It has been found that the use of recycled plastics in roads may have limited impact on the current plastic waste stream so should be developed alongside other applications. If 6% by mass of waste plastic was added to the 800,000 tonnes of bitumen used in Australia annually, it would remove only 2% of the waste plastic generated in Australia per year. [42]

In 2018 the Downer Group partnered with Hume City Council, Close the Loop and REDcycle to develop Australia's first road using soft plastic and glass asphalt.[43] The plastics used in this application were soft plastics with 200,000 recycled plastics bags being used every 1 km of the twolane road. In Victoria, around 170,000 tonnes of soft plastic waste is created each year and only about 10% of that is recovered. In comparison to regular asphalt, the modified glass and plastic asphalt has superior deformation resistance for withstanding heavy vehicle traffic. This research led to the commercialisation of the product and soft-plastic asphalt is now available across Australia. It is used by seven local governments in Victoria and councils in New South Wales and South Australia.

REDcycle collect plastic bags and other soft plastics with drop-off points in all major cities around Australia.[44] They collaborate with three Australian owned recycling and manufacturing partners who use these materials: Replas, Close the Loop and Plastic Forests. Replas and Close the Loop have been involved in projects that utilise recycled plastic in road infrastructure in Australia.

In 2018–19, 2.54 megatonne of plastic waste was generated in Australia.[45] Of this volume, just under 13% was recycled and the remainder was sent to landfill. **Figure 16** shows the flow of waste plastic through the supply chain.

Figure 16: Supply of plastics

Table 9 shows the number of plastic reprocessing facilities in Australia.[46]

Table 9: Plastic waste reprocessing facilities in Australia 2016–17

State/Territory	Number of processing facilities
Australian Capital Territory	0
New South Wales	20
Northern Territory	2
Queensland	12
South Australia	12
Tasmania	2
Victoria	24
Western Australia	4
Total	**76**

Source: Locock (2017)[47]

Victoria and New South Wales have the largest reprocessing capabilities. These states reprocess ~30% of the recycled plastic that is recovered from each jurisdiction.

An issue with post-consumer plastics is they are often contaminated making them more complex to recycle. The recycled plastic must be carefully sorted to ensure it is not mixed with hard plastics and they must be cleaned to remove contaminants. This makes the process quite labour intensive. Plastic consumption has seen an increase of 10% while the recycling rates have decreased by 2%.[48]

A–9 Recycled solid organics

Recycled solid organics are products recycled from organic waste. Solid organics are sourced from plant or animal waste and can be used in road infrastructure, mainly in landscaping, erosion control, and biorientation and biofiltration applications.

Recycled organics can add nutrients, act as a soil conditioner, improve water retention, and act as a seed suppressant.

Emissions largely consist of methane which is generated by the anaerobic decay of organic matter.[49] In 2020–21, waste accounted for 2.7% of the total emissions in Australia.

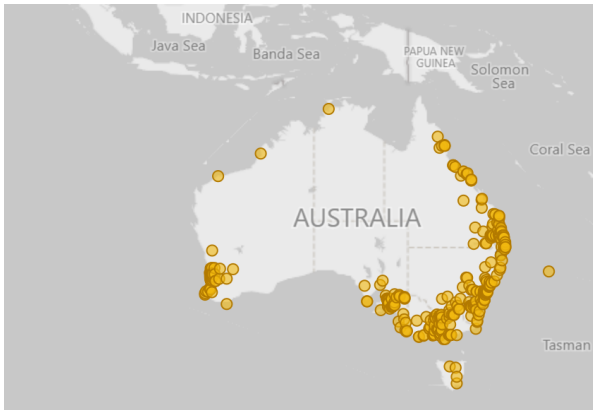
In 2018–19, 14.3 megatonnes of organic waste were generated in Australia of which around 7.4 megatonnes (51.5%) was recycled. According to the Australian Organics Recycling Industry Capacity Assessment 2020–21, the industry is capable of processing 82% of organic materials. This indicates there is untapped physical capacity of existing operations that can be utilised to achieve the National Waste Policy's target of halving the amount of organic waste sent to landfill for disposal by 2030.[55] **Figure 17** shows the recycling process of solid organics.

Figure 17: Solid organic waste recycling process

Source: Adapted from Suez (2017)[50]

Figure 18 shows the locations of organic recycling facilities across Australia.

Figure 18: The organics recycling facilities in Australia



Source: Department of Agriculture, Water and the Environment (2018)[51]

There are some key challenges related to recycled organics composting. The supply is directly related to the green waste collection and processing market. A sudden increase in supply due to rainfall or seasonality can be unmatched by demand as demand is controlled by economic growth, housing development timings and demand for gardening products. In addition, changes to supply can impact processing time which limits maturation time. This is directly related to quality so can cause greater variations between processors. Stockpiling is also limited by odour management regulations.

Contamination of recycled organics is also difficult to manage. It can be contaminated with plastic, glass, and other materials. In addition, products in this market can be very inconsistent with a varying price and volume making it challenging to pursue. Often most of the supply is in metropolitan cities, but the demand is in regional areas which can raise transportations costs.

There are future opportunities to address these challenges including fostering agricultural use, developing an overflow arrangement, and promoting urban amenity demand.

Food organics and garden organics is a kerbside collection service that enables food scraps and garden waste to be recycled into a top-quality compost.

Appendix B
Technical notes for demand modelling

B–1 Overview

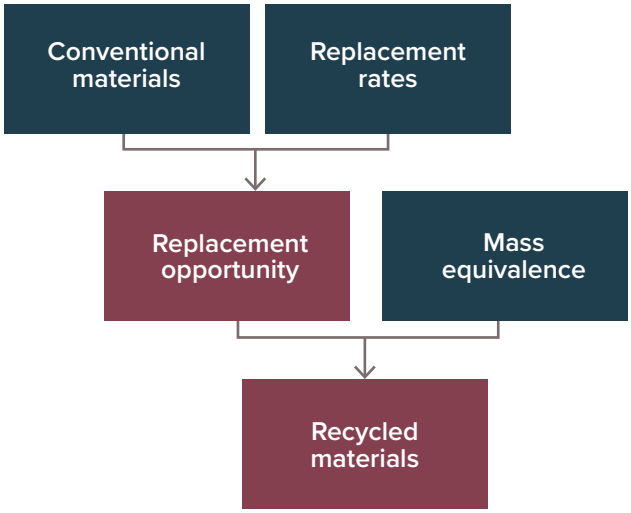
Background

Infrastructure Australia commissioned Australia Road Research Board and Ernst & Young to estimate the opportunity for replacing conventional materials and the potential demand for recycled materials for delivering major projects across the country. This report details the methodology, input and findings of the analysis.

Methodology

The modelling uses Infrastructure Australia's forecast conventional materials quantities (2015–31) and applies with analysis-derived estimates of replacement rates to estimate the quantity of conventional materials that could be replaced. It then applies mass and volume relativities between conventional and recycled materials to estimate the demand for replacement materials. The methodology of forecasting demand for replacement materials is depicted in **Figure 19**.

Figure 19: Model map



Findings

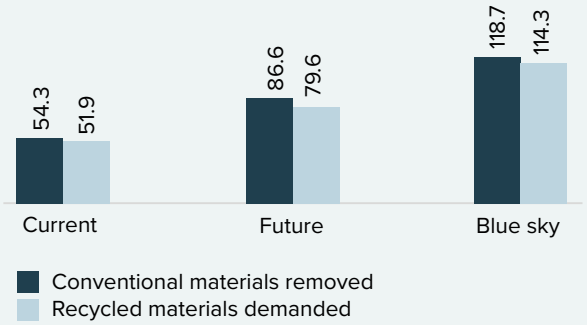
This report presents the findings for each of Infrastructure Australia's central case, low and high forecasts for conventional materials (**Figure 20**), based on the replacement scenarios of:

Current – existing science and technology, regulations and product allowable limits

Future – assumed advancement in technology and corresponding changes to standards

Blue-sky – a more bullish set of assumptions assuming further technical improvements and standards updates.

Figure 20: Central case forecast (million tonnes)



Compared to central case forecast above:

Low forecast: –17%

High forecast: +14%

Limitations

The accuracy of the conventional material demand forecast, quantities and type, underpins the robustness of the findings.

The broad aggregation of conventional material types and lack of information on the structures means generic assumptions are used when formulating replacement rates and mass equivalence factors.

Implications

There is significant potential for replacing conventional materials with recycled materials, with advancements in technology and the associated updates of standards presenting further opportunities. The scale of replacement realised will be affected by market appetite and supply.

B–1—1 Central case forecasts on the potential demand for recycled materials

Based on Infrastructure Australia's central case forecast for conventional materials demand.

- y-axis; groups of conventional materials that could be replaced
- x-axis: amount of recycled materials that could be used to replace each group of conventional materials.

Figure 21, Figure 22 and Figure 23 have been generated using a dashboard developed for this estimation project.

Figure 21: Forecast demand for recycled materials (tonnage) – current scenario

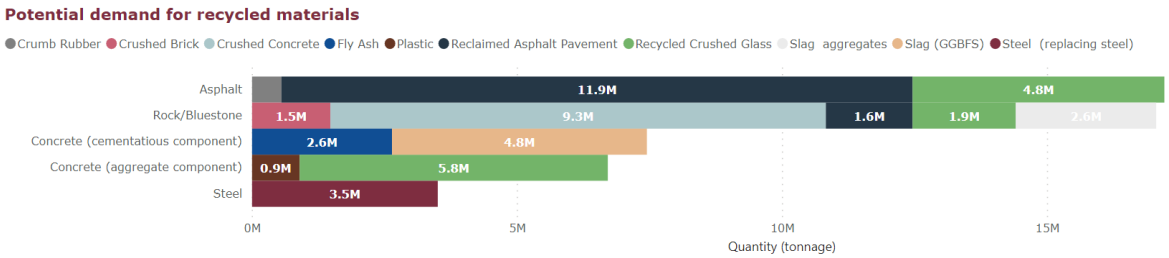


Figure 22: Forecast demand for recycled materials (tonnage) - future scenario

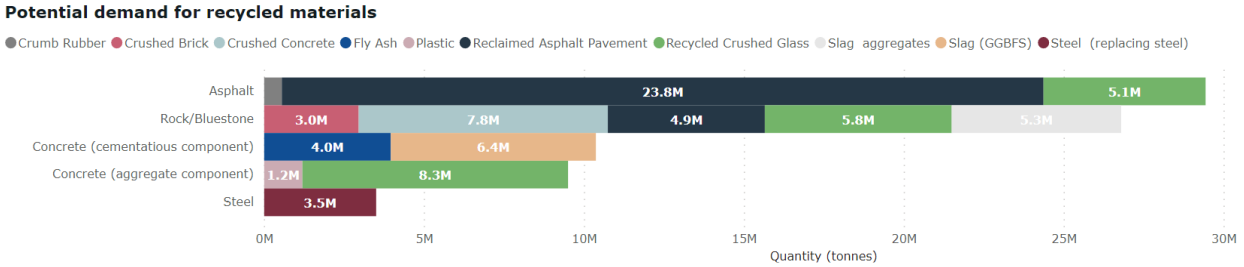
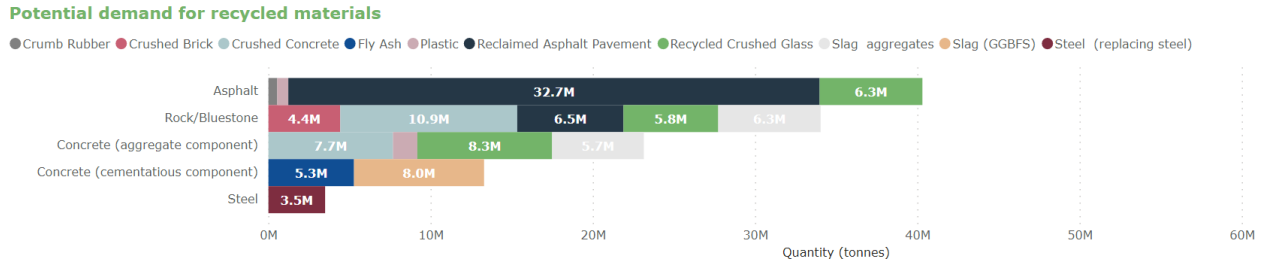


Figure 23: Forecast demand for recycled materials (tonnage) - blue sky scenario



B–2 Background

B–2—1 Purpose of this appendix

Infrastructure Australia commissioned Australia Road Research Board and Ernst & Young to estimate the opportunity for replacing conventional materials and the potential demand for recycled materials for delivering major projects across the country.

This appendix supports Section 3 Forecasting Potential Demand.

B–2—2 Contributors to the analysis

This report is the product of collaboration between Infrastructure Australia, Australia Road Research Board and Ernst & Young, with:

- Infrastructure Australia commissioning the technical work, providing the input data and overall steer on the analysis
- Australia Road Research Board managing the overall consulting engagement, providing input to the assumptions using its technical expertise in materials science, design and standards
- Ernst & Young providing the modelling support, using its experience in quantitative analysis including in the recycled materials sector.

The remainder of the appendix uses 'the consultant team' for noting actions undertaken by the joint Australia Road Research board and Ernst & Young team.

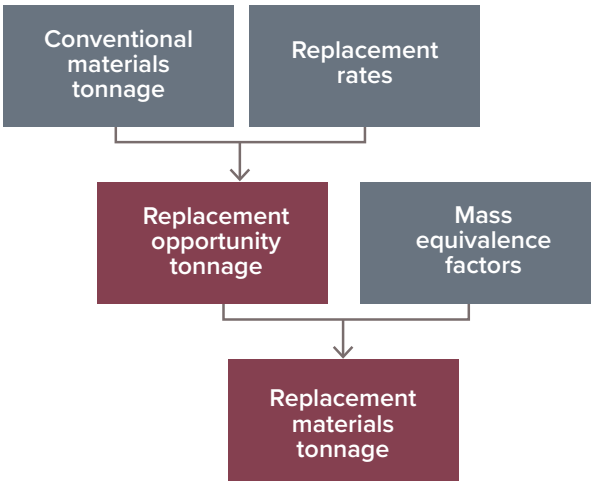
B–3 Methodology

B–3—1 Overview of approach and limitations

The approach

The following calculation steps have been developed for delivering the forecasts:

- Infrastructure Australia provided the quantities of conventional materials that are forecast to be required to deliver the range of projects under its analysis from across Australia.
- The consultant team formulated a set of replacement rates to estimate the opportunity for replacing each type of conventional materials with recycled materials.
- To account for the density differences between conventional and replacement materials, the consultant team applied a set of mass equivalence factors to estimate the mass (tonnage) of recycled materials needed to satisfy the requirements of infrastructure projects based on conventional materials.



The scenarios

Infrastructure Australia developed demand forecasts of conventional materials using a methodology based on assumptions on the resource demand intensity by project type (e.g., total labour and material demand per road tunnel project) and unit cost rates for labour and materials (e.g. $/FTE steel worker and $/tonne of steel). To account for the uncertainties within these assumptions, Infrastructure Australia developed a set of forecasts under three scenarios that correspond to variations in these assumptions:

- **Central case** – demand forecasts under this scenario reflect the level of resource demand and unit cost rate based on the industry norm observed by Infrastructure Australia
- **Low forecast** – demand forecasts under this scenario are approximately 17% lower than the central case as it assumes a 25% lower resource demand intensity and 10% lower unit cost rate compared to the central case
- **High forecast** – demand forecasts under this scenario are approximately 14% higher than the central case as it assumes a 25% higher resource demand intensity and 10% higher unit cost rate compared to the central case.

The conventional materials forecasts were undertaken separately/outside this replacement materials analysis; they are external inputs to this analysis.

The replacement rates formulated consist of three scenarios:

- **Current** – replacement potential based on existing conditions in science and technology, regulations and standards
- **Future** – assuming a degree of technological and regulatory progress
- **Blue-sky** – providing an upper-limit set of potentials, with bullish assumptions for advancements.

The above scenarios are discussed further in the subsequent sub-sections.

Limitations

As with any model, the output is underpinned by the input. The forecast conventional materials in terms of the overall quantity, definition of material types and split between types, underpins the forecast replacement opportunities, what type of recycled materials are likely to be demanded and how much. The lack of structural details of projects in the input data provided means all conventional materials data are used 'as given', without understanding what the quantities of different types of materials are used for and how they are used. Therefore, general assumptions are made on the potential opportunities for replacement, and how much of recycled materials are likely to be required to replace the corresponding conventional materials. Overall, the accuracy and granularity of the input data underpins the robustness of the analysis.

B–3—2 Input – conventional materials forecasts and scenarios

Data

Infrastructure Australia provided forecasts of conventional material demand from projects across the country (summarised in **Table 10** below).

Table 10: Projects included in the analysis (2015–31)

State and territory	Number of Projects
Victoria	131
South Australia	48
New South Wales	191
Australian Capital Territory	11
Tasmania	80
Northern Territory	35
Queensland	362
Western Australia	140
Total	**998**

Infrastructure Australia provided three sets of forecasts of coneventional materials used on the projects – a central case set of figures, a low forecast and a high forecast. The quantities are shown in **Table 11** below.

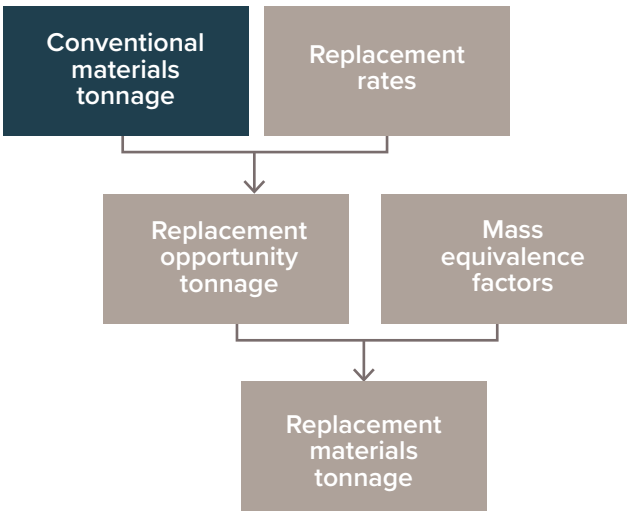


Table 11: Forecast conventional materials quantities (million tonnes)

	Low	Central case	High
Aggregate	48.8	58.6	66.6
Cement	14.7	17.6	20.0
Sand	24.8	29.8	33.8
Asphalt	45.5	54.6	62.0
Bitumen binders	4.2	5.0	5.7
Rock/Bluestone	26.0	31.2	35.4
Steel – structural elements	0.7	0.9	1.0
Steel reinforcement	2.2	2.6	3.0
Total	166.9	200.2	227.5
% vs Central case	–17%	–	+14%

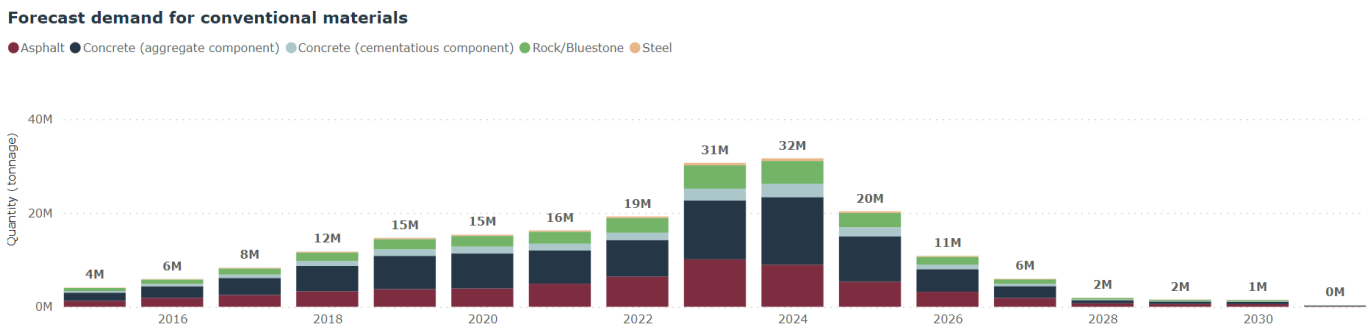
Grouping and profile

The above conventional materials are grouped according to the table below, with this analysis splitting out concrete into aggregate and cementitious components to enable separate assumptions for replacement rates (discussed in the next section). This study-specific set of grouping is to achieve a reasonable balance between detail and ease of formulating assumptions. Profile of conventional material demand is shown in **Figure 24**, with grouping outlined in **Table 12**.

Table 12: Conventional materials grouping

Resource group	Grouping used in this estimation project
Cement	Concrete (cementitious component)
Sand	Concrete (aggregate component)
Asphalt	Asphalt
Bitumen binders	Asphalt
Rock/Bluestone	Rock/Bluestone
Steel – structural elements	Steel
Steel reinforcement	Steel

Figure 24: Conventional materials usage profile – central case forecast



B–3—3 Assumption rates and scenarios

Concept and methodology

A replacement rate is a percentage figure applied to a type of conventional material, to estimate the tonnage of that material which could be replaced by a recycled material.

The consultant team reviewed the following materials when developing the replacement assumptions:

- **Replacement rates in the ecologiQ model**. Major Road Project Victoria's ecologiQ team has developed replacement rates as a part of the material demand forecasting method for Victoria's Big Build projects. The replacement rates applied in the ecologiQ model are project-specific: they are developed based on the purpose, design, location, size, material availability and standards of specific infrastructure projects. These replacement rates are aggregated by material type to inform the demand forecast of recycled materials.
- **Standards and specifications of public road agencies**. A number of state, territorial and local road agencies regulate the extent to which recycled materials can be applied in road projects. Specifically, standards and specifications from the following agencies have been considered:
  - Department of Transport Victoria
  - Main Roads Western Australia
  - Queensland Department of Transport and Main Roads
  - Department of Infrastructure and Transport South Australia
  - Transport for New South Wales
  - Australian Local Government Association.
- **Australian and international research**. The developments of new recycled infrastructure materials and incorporation methods are an active area of research both in Australia and internationally. Related research produced by the following sources have been considered by the consultant team:
  - Guidance and findings in Austroads publications.
  - Specifications developed by the Institute of Public Works Engineering Australasia.
  - Experience and knowledge collated from projects undertaken by Australia Road Research Board.

Through the above review, a set of rates were formulated to best reflect the current situation. Further, the consultant team developed assumptions to capture the potential effects from increasingly advanced technologies and corresponding standards updates. The scenarios are:

- **Current** – replacement rates in this scenario reflect the current usage of recycled materials by major projects in Australia
- **Future** – replacement rates in this scenario reflect the expected usage of recycled materials in a future when requisite infrastructure standards have been updated to accommodate the higher replacement potential supported by current research
- **Blue-sky** – replacement rates in this scenario reflect the highest replacement potential by recycled materials that may be achieved indicated by the latest research and Australia Road Research Board's professional opinion.

While current standards and research provide references of replacement rates for individual recycled materials, there is a lack of knowledge on how multiple recycled materials may be applied as a composite replacement material. However, a composite replacement rate is needed to estimate the total demand of recycled material as a share of conventional material.

To address the lack of this knowledge, the consultant team has made assumptions for the total replacement rates under the three scenarios based on their knowledge of the properties of recycled materials in

typical infrastructure applications. For example, collectively recycled materials will not replace more than 70% of the cementitious component in concrete application even when their individual replacement rates may sum up to more than 70%. Assumed total replacement rates are presented in **Table 13** below.

Table 13: Total replacement rate by scenario

	Current	Future	Blue-sky
Asphalt	30%	50%	70%
Concrete (aggregate component)	10%	20%	30%
Concrete (cementitious component)	50%	70%	90%
Steel	100%	100%	100%
Rock/Bluestone	50%	75%	100%

Summing to the total replacement rates for each conventional material group, **Table 14**, **Table 15** and **Table 16** present more detailed breakdowns of what each conventional material group could be replaced with, and the percentage replacement.

Replacement rates used

The replacement rates are presented below.

Table 14: Percentage of conventional materials that can be replaced by recycled materials – current replacement scenario

	Crushed concrete	Reclaimed asphalt pavement	Recycled crushed glass	Crushed brick	Crumb rubber	Ground granulated blast furnace slag	Granulated blast furnace slag	Fly ash	Plastic	Steel (concrete)	Steel (replacing steel)
Asphalt	0%	20%	8%	0%	2%	0%	0%	0%	0%	N/A	N/A
Concrete (aggregate)	0%	0%	7%	0%	0%	0%	0%	0%	3%	N/A	N/A
Concrete (cementitious)	0%	0%	0%	0%	0%	30%	0%	20%	0%	N/A	N/A
Steel	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	100%
Rock/Bluestone	30%	5%	5%	5%	0%	0%	5%	0%	0%	N/A	N/A

Table 15: Percentage of conventional materials that can be replaced by recycled materials – future replacement scenario

	Crushed concrete	Reclaimed asphalt pavement	Recycled crushed glass	Crushed brick	Crumb rubber	Ground granulated blast furnace slag	Granulated blast furnace slag	Fly ash	Plastic	Steel (concrete)	Steel (replacing steel)
Asphalt	0%	40%	8%	0%	2%	0%	0%	0%	0%	N/A	N/A
Concrete (aggregate)	6%	0%	10%	0%	0%	0%	0%	0%	4%	N/A	N/A
Concrete (cementitious)	0%	0%	0%	0%	0%	40%	0%	30%	0%	N/A	N/A
Steel	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	100%
Rock/Bluestone	25%	15%	15%	10%	0%	0%	10%	0%	0%	N/A	0%

Table 16: Percentage of conventional materials that can be replaced by recycled materials – blue-sky replacement scenario

	Crushed concrete	Reclaimed asphalt pavement	Recycled crushed glass	Crushed brick	Crumb rubber	Ground granulated blast furnace slag	Granulated blast furnace slag	Fly ash	Plastic	Steel (concrete)	Steel (replacing steel)
Asphalt	0%	55%	10%	N/A	2%	0%	0%	0%	3%	N/A	N/A
Concrete (aggregate)	10%	0%	10%	0%	0%	0%	5%	0%	5%	N/A	N/A
Concrete (cementitious)	0%	0%	0%	0%	0%	50%	0%	40%	0	N/A	N/A
Steel	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	100%
Rock/Bluestone	35%	20%	15%	15%	0%	0%	15%	0%	0%	0%	0%

B–3—4 Assumption – mass equivalent factors

Concept and methodology

Bringing input conventional materials forecast and replacement rates together generates the estimated mass of conventional materials that could be replaced. The next step is to estimate the corresponding mass of recycled materials that are required to replace them.

Doing so requires adjustments to account for the fact that recycled materials do not necessarily have the same density as the conventional material they replace which may result in more or less mass for the same volume of infrastructure material.

Mass of recycled materials are calculated by multiplying the mass of conventional materials with a mass equivalence factor which is the ratio of the density of recycled material over the density of the conventional material it replaces.

This method of calculating the mass of recycled materials assumes that conventional materials and the recycled materials occupy the same volume of space within each infrastructure application. For example, a pavement wearing course is assumed to have the same design dimensions – width, length, and thickness – with either virgin asphalt or reclaimed asphalt pavement.

Mass equivalence factors used

The factors used to 'convert' a tonne of conventional material to a tonne of replacement material are presented in **Table 17** below.

Table 17: Mass equivalence factors

	Crushed concrete	Reclaimed asphalt pavement	Recycled crushed glass	Crushed brick	Crumb rubber	Ground granulated blast furnace slag	Granulated blast furnace slag	Fly ash	Plastic	Steel (concrete)	Steel (replacing steel)
Asphalt	–	1.00	1.06	–	0.47	–	–	–	0.38	–	–
Concrete (aggregate)	0.87	–	0.94	–	–	–	1.28	–	0.34	–	–
Concrete (cementitious)	–	–	–	–	–	0.91	–	0.75	–	–	–
Steel	–	–	–	–	–	–	–	–	–	1.00	1.00
Rock/Bluestone	1.00	1.05	1.25	0.95	–	–	1.35	–	–	–	–

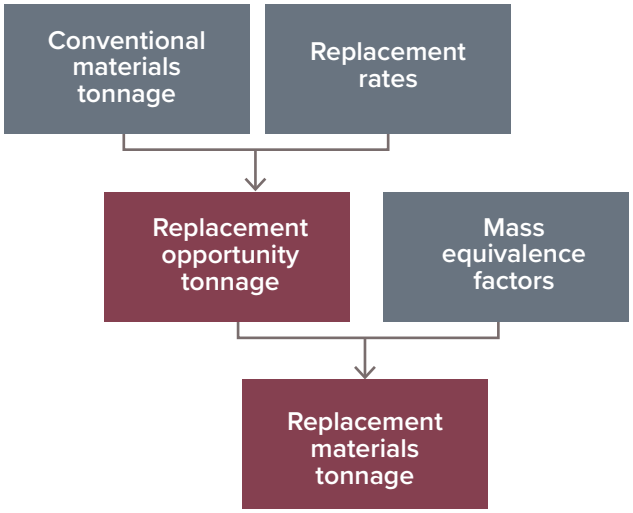
B–4 Outputs

B–4—1 Headline results

Overview

Based on the range of conventional materials forecast provided by Infrastructure Australia, using different replacement rates under each technology and standards scenarios, the consultant team forecasted a range of opportunities for replacing conventional materials. Then, based on the relativities between conventional materials and recycled materials, the consultant team forecasts the range of potential demand for recycled materials.

This section presents the forecasts for conventional materials replacement opportunities, and the corresponding demand for recycled materials. It first presents the aggregate forecasts, then breaking down into further detail, presenting results from each of the conventional materials scenarios – central, low, high, and the forecast demand for recycled materials under each of the replacement scenarios – current, future, blue-sky.



Opportunity for replacing conventional materials

The forecast opportunity for replacing conventional is aggregated in **Table 18** below, for all projects across the data period. Compared to the differences between conventional material demand levels (high, central, low), the assumptions for replacement extent make the greater difference. More advanced technology and the associated updated standards are forecast to lead to considerable increases to replacement potential, with the blue-sky scenario circa doubling the tonnage compared to current replacement assumptions.

Table 18: Total opportunity for replacing conventional materials (million tonnes)

	Current	Future	Blue-sky
High	61.7	98.5	134.9
Central	**54.3**	**86.6**	**118.7**
Low	45.2	72.2	98.9

Of the opportunities to replace conventional materials, the greatest tonnage opportunity is forecast to be from reducing asphalt quantities, followed by rock/bluestone. **Table 19** below presents the tonnes of conventional that could be replaced, for the central case under the three replacement scenarios.

Table 19: Opportunity for replacing conventional materials by replacement scenario – central case conventional materials forecast (million tonnes)

	Current	Future	Blue-sky
Asphalt	17.6	29.8	41.7
Concrete (aggregate)	8.8	17.7	26.5
Concrete (cementitious)	8.8	12.3	15.9
Steel	3.5	3.5	3.5
Rock/Bluestone	15.6	23.4	31.2
Total	**54.3**	**86.6**	**118.7**

Potential demand for recycled materials

Given the volume-mass relationship between conventional and recycled materials are not onetoone, the forecast tonnage of recycled materials required is different from the tonnage of conventional materials removable. **Table 20** below presents the tonnage of replacement materials that are potentially needed to replace the forecast removal of conventional materials.

Table 20: Potential total demand for recycled materials by replacement scenario (million tonnes)

	Current	Future	Blue-sky
High	59.0	90.5	129.9
Central	**51.9**	**79.6**	**114.3**
Low	43.3	66.4	95.3

Table 21 below presents a breakdown of the total tonnage by replacement material type for the central case conventional material demand forecast. Most of the demand are forecast to be for reclaimed asphalt pavement and recycled crushed glass, followed by crushed concrete.

Table 21: Potential demand for recycled materials by replacement scenario – central case conventional materials forecast (million tonnes)

	Current	Future	Blue-sky
Crushed concrete	9.3	7.8	18.6
Crushed brick	1.5	3.0	4.4
Reclaimed asphalt pavement	13.5	28.7	39.3
Recycled crushed glass	12.5	19.2	20.5
Crumb rubber	0.6	0.6	0.6
Fly ash	2.6	4.0	5.3
Ground granulated blast furnace slag	4.8	6.4	8.0
Granulated blast furnace slag (slag aggregate)	2.6	5.3	12.0
Plastic	0.9	1.2	2.2
Steel	3.5	3.5	3.5
Total	**51.9**	**79.6**	**114.3**

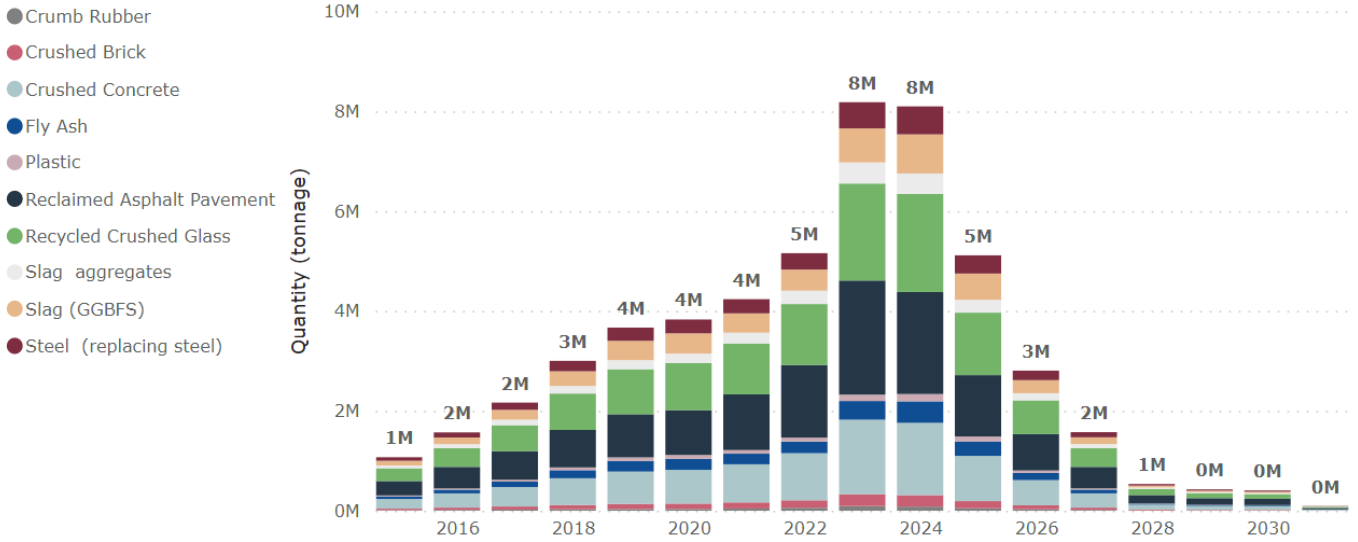
The remainder of this section (**Figure 25** to **Figure 33**) presents the results using dashboard generated outputs for the three conventional materials forecast scenarios, each with the three replacement rate scenarios.

B–4—2 Central case

Figure 25: Central case based on current replacement rates

Total potential re-use opportunity: current state
> current replacement rate based upon: existing science and technology; regulation; product allowable limits within state and territory standards and specifications, and; modelling assumptions from Victorian Government's ecologiQ initiative which seeks to integrate recycled and reused content across Victoria's transport infrastructure projects

Total potential replacement (tonnes)



Select Forecast Type

High | Low | Medium

Select Recycled Material Type

Crumb Rubber | Plastic | Slag (GGBFS)
Crushed Brick | Reclaimed Asphalt Paveme... | Steel (replacing steel)
Crushed Concrete | Recycled Crushed Glass
Fly Ash | Slag aggregates

Select State

ACT | NSW | NZ | SA | VIC
AUS | NT | QLD | TAS | WA

Potential demand for recycled materials

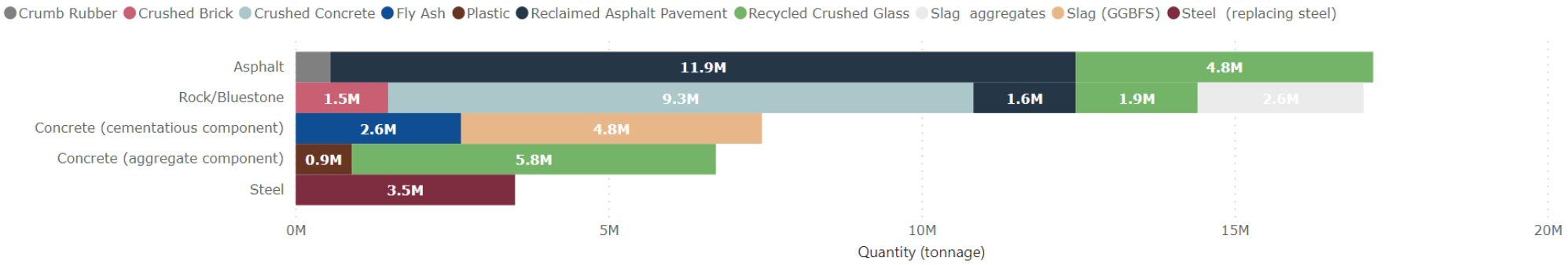


Figure 26: Central case based on future replacement opportunities

Total potential re-use opportunity: future state
> with respect to future replacement rates assuming advancement in technology and corresponding changes to standards

Select Forecast Type

High	Low	Medium

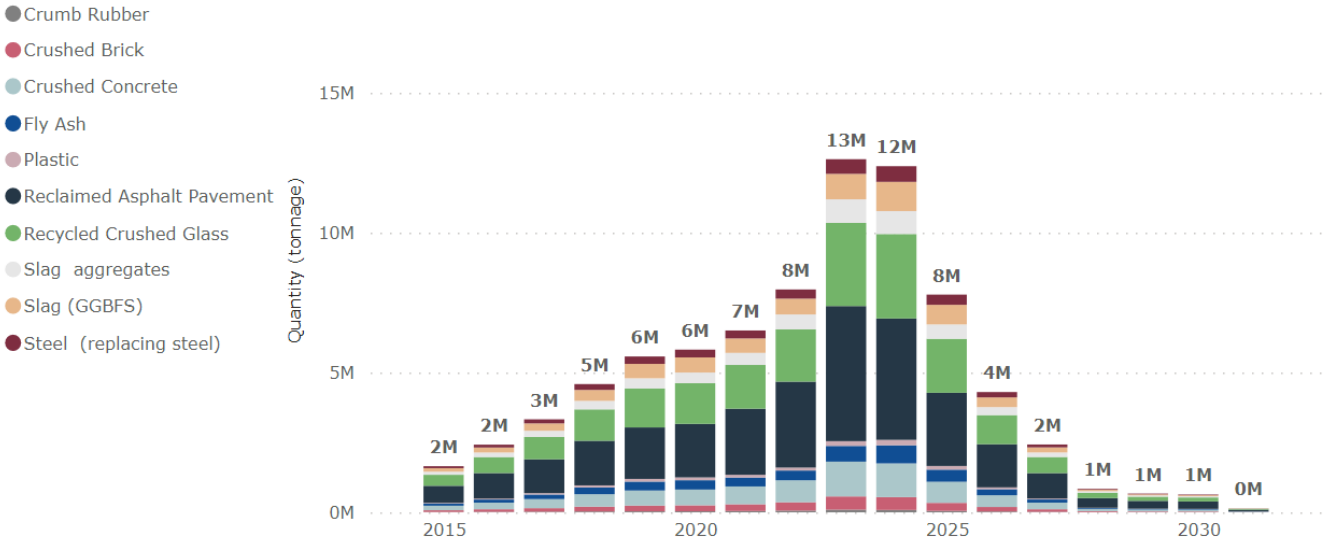
Select Recycled Material Type

Crumb Rubber	Plastic	Slag (GGBFS)
Crushed Brick	Reclaimed Asphalt Pavement	Steel (replacing steel)
Crushed Concrete	Recycled Crushed Glass	
Fly Ash	Slag aggregates	

Select State

ACT	NSW	NZ	SA	VIC
AUS	NT	QLD	TAS	WA

Total potential replacement (tonnes)



Potential demand for recycled materials

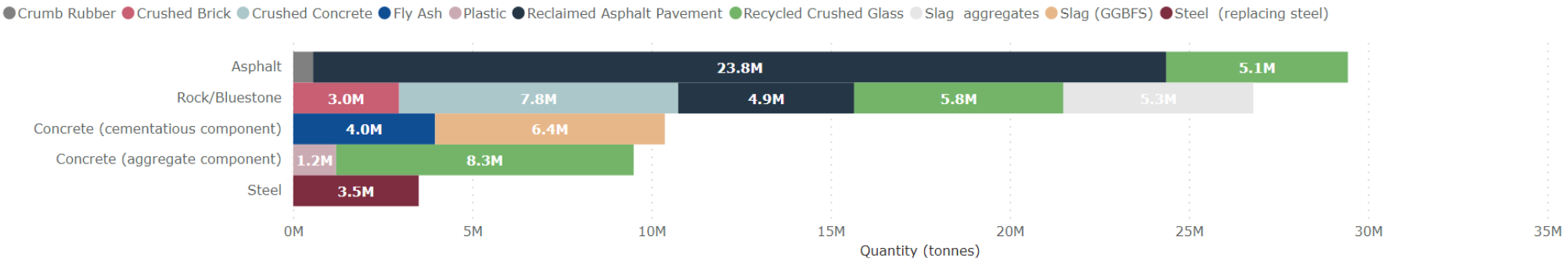
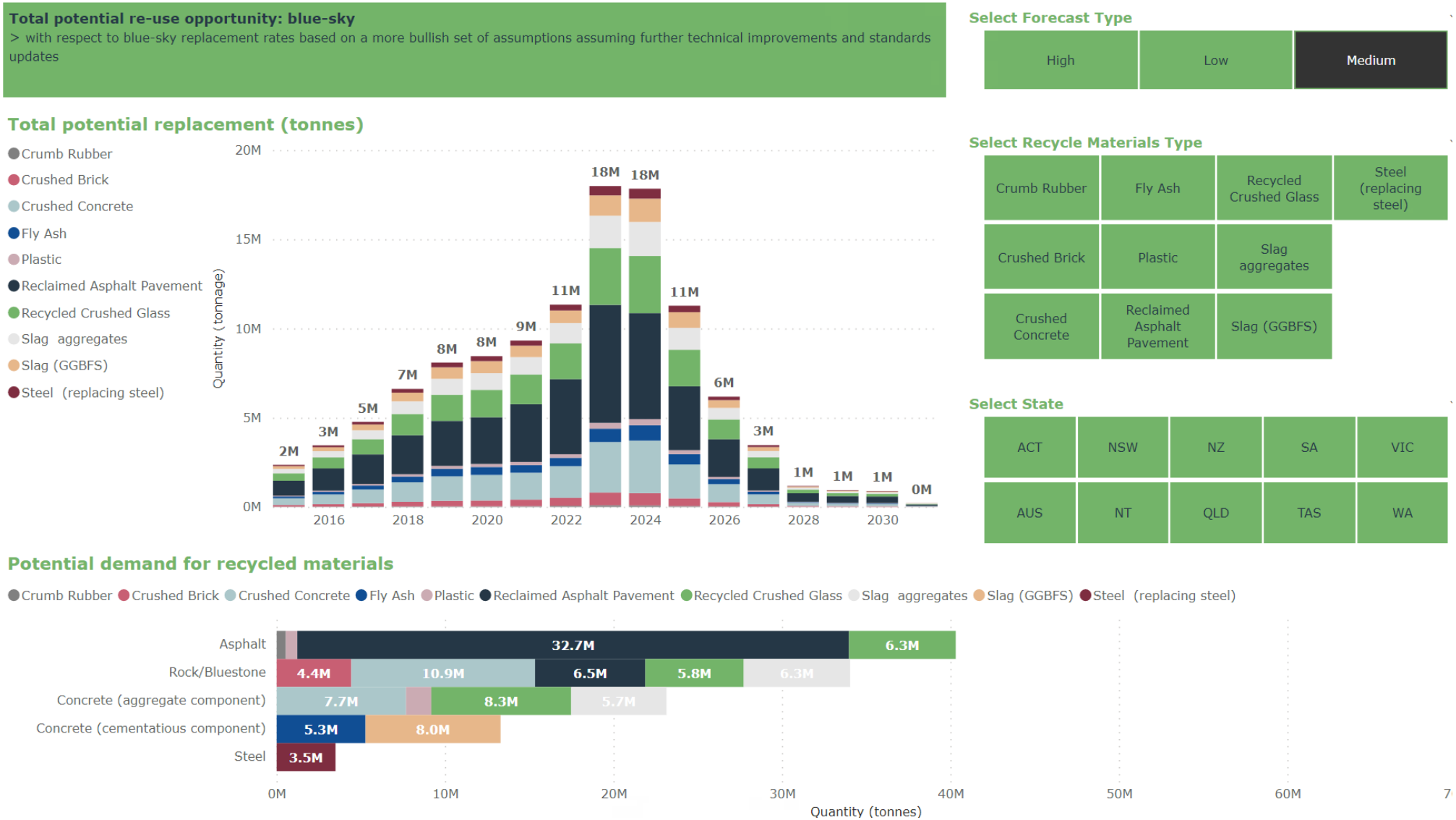


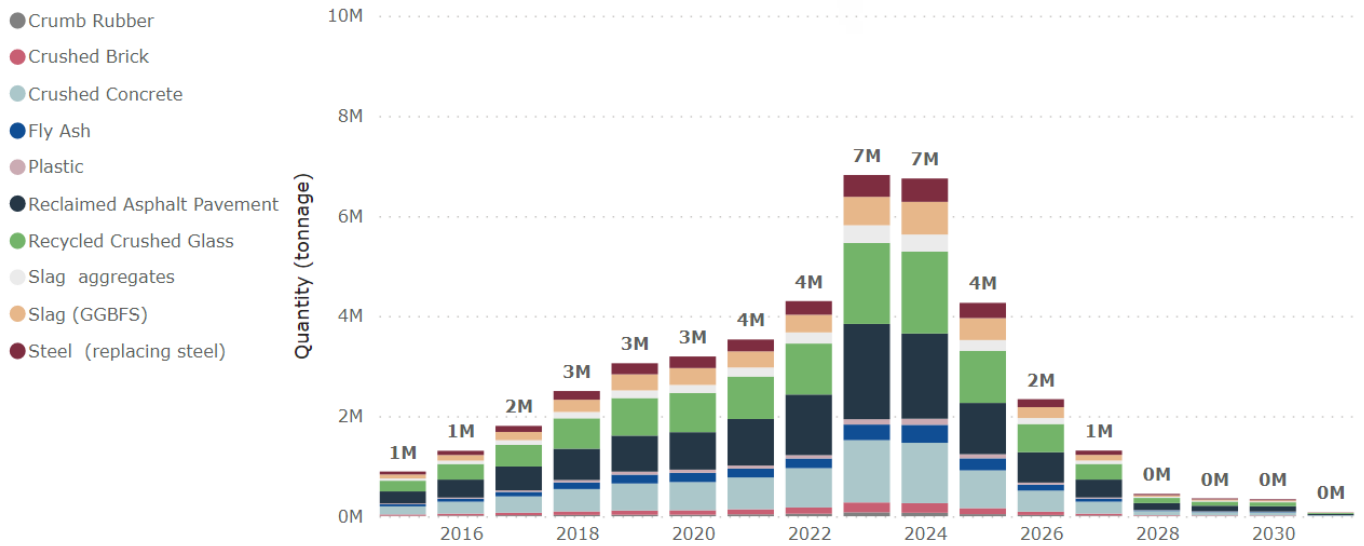
Figure 27: Central case based on blue-sky potential

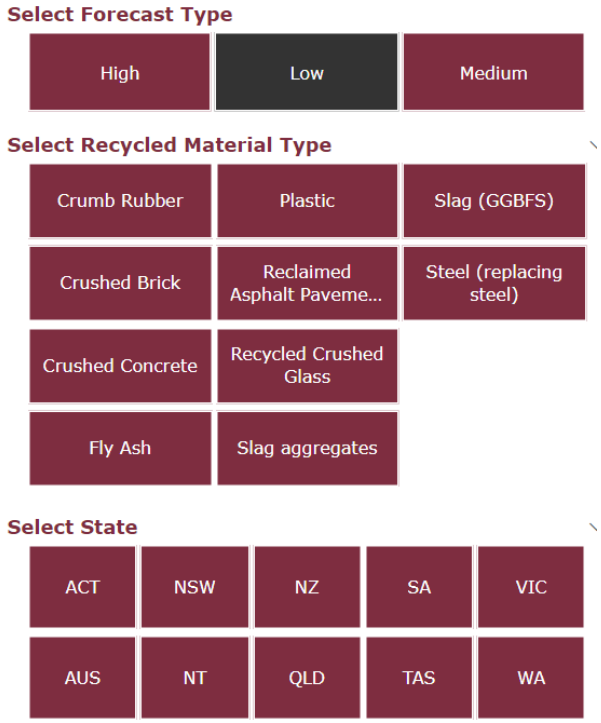


B–4—3 Low forecast

Figure 28: Low forecast based on current replacement rates

Total potential re-use opportunity: current state
> current replacement rate based upon: existing science and technology; regulation; product allowable limits within state and territory standards and specifications, and; modelling assumptions from Victorian Government's ecologiQ initiative which seeks to integrate recycled and reused content across Victoria's transport infrastructure projects





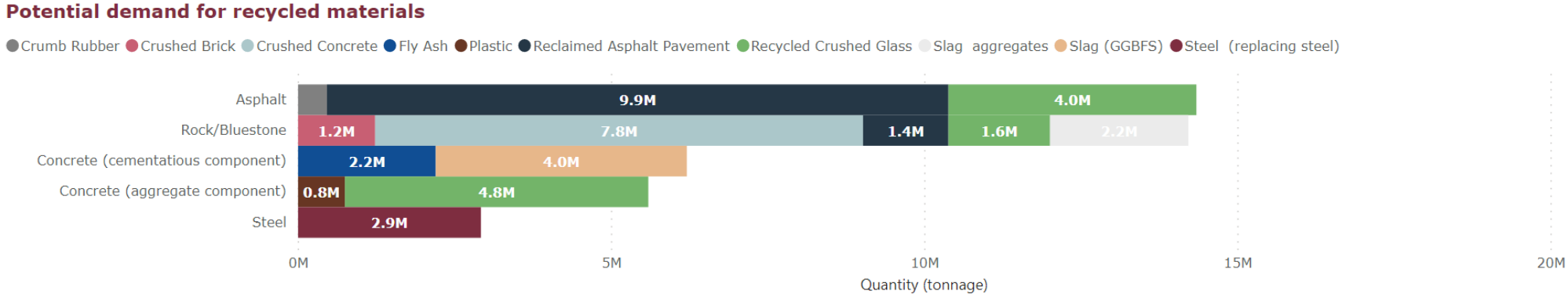


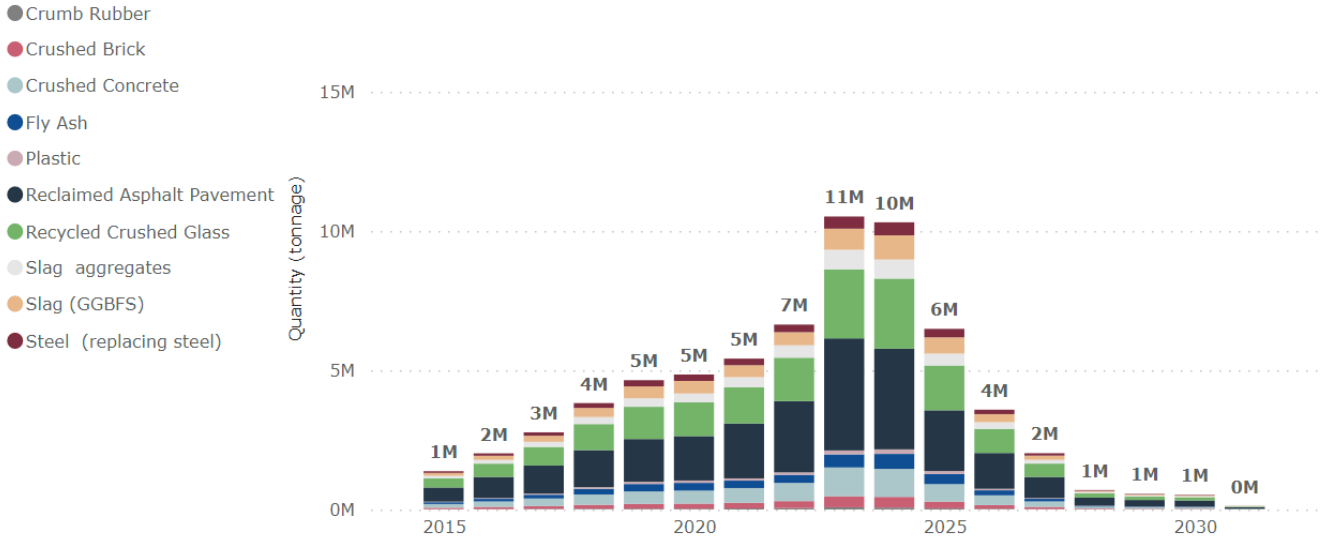
Figure 29: Low forecast based on future replacement opportunities

Total potential re-use opportunity: future state
> with respect to future replacement rates assuming advancement in technology and corresponding changes to standards

Select Forecast Type

High	Low	Medium

Total potential replacement (tonnes)



Select Recycled Material Type

Crumb Rubber	Plastic	Slag (GGBFS)
Crushed Brick	Reclaimed Asphalt Pavement	Steel (replacing steel)
Crushed Concrete	Recycled Crushed Glass	
Fly Ash	Slag aggregates	

Select State

ACT	NSW	NZ	SA	VIC
AUS	NT	QLD	TAS	WA

Potential demand for recycled materials

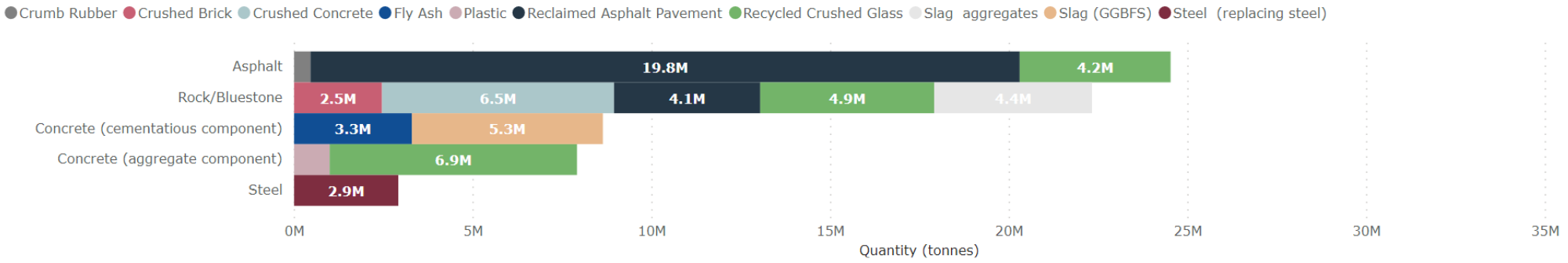


Figure 30: Low forecast based on blue-sky potential

Total potential re-use opportunity: blue-sky
> with respect to blue-sky replacement rates based on a more bullish set of assumptions assuming further technical improvements and standards updates

Select Forecast Type

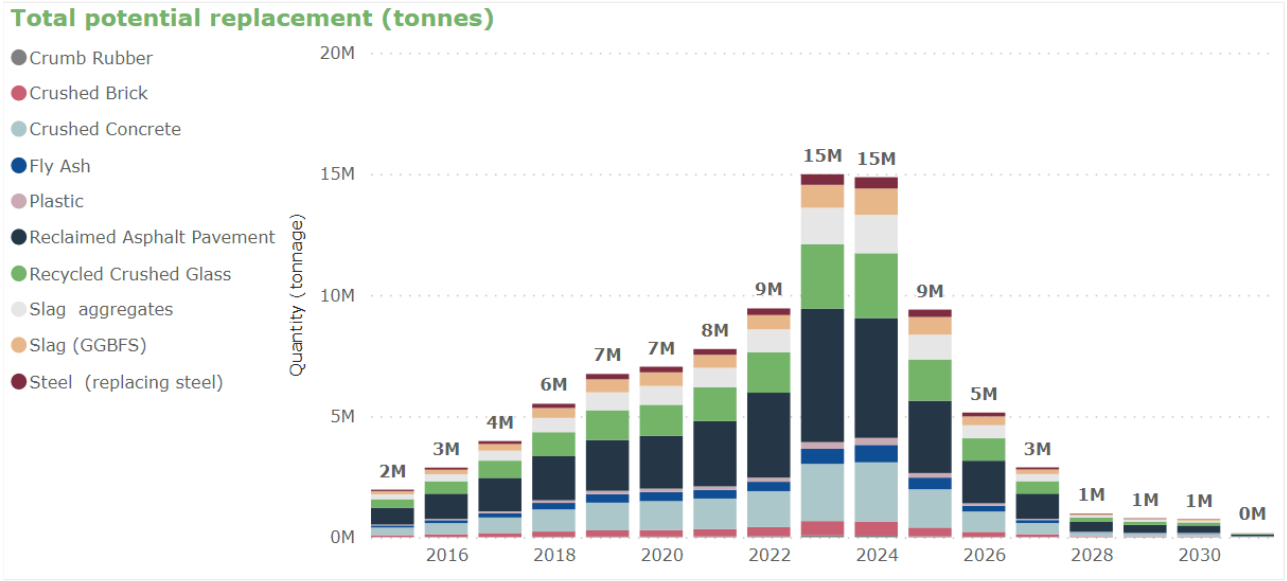
High	Low	Medium

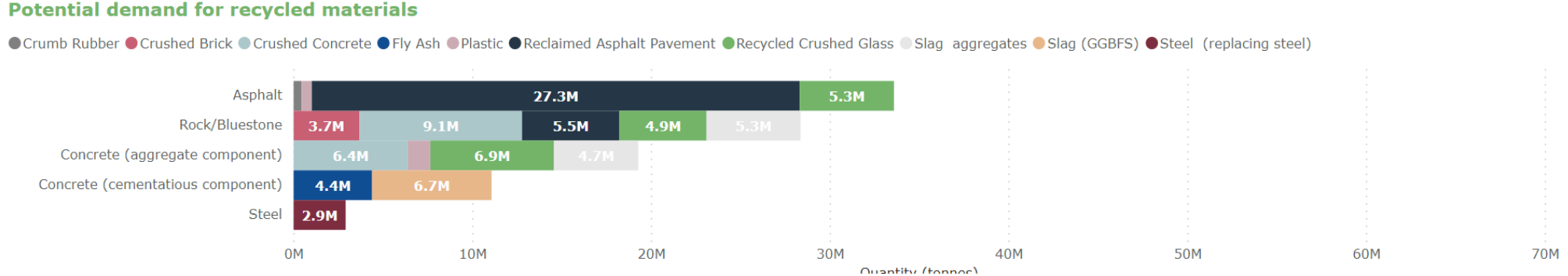
Select Recycle Materials Type

Crumb Rubber	Plastic	Slag (GGBFS)
Crushed Brick	Reclaimed Asphalt Pavement	Steel (replacing steel)
Crushed Concrete	Recycled Crushed Glass	
Fly Ash	Slag aggregates	

Select State

ACT	NSW	NZ	SA	VIC
AUS	NT	QLD	TAS	WA



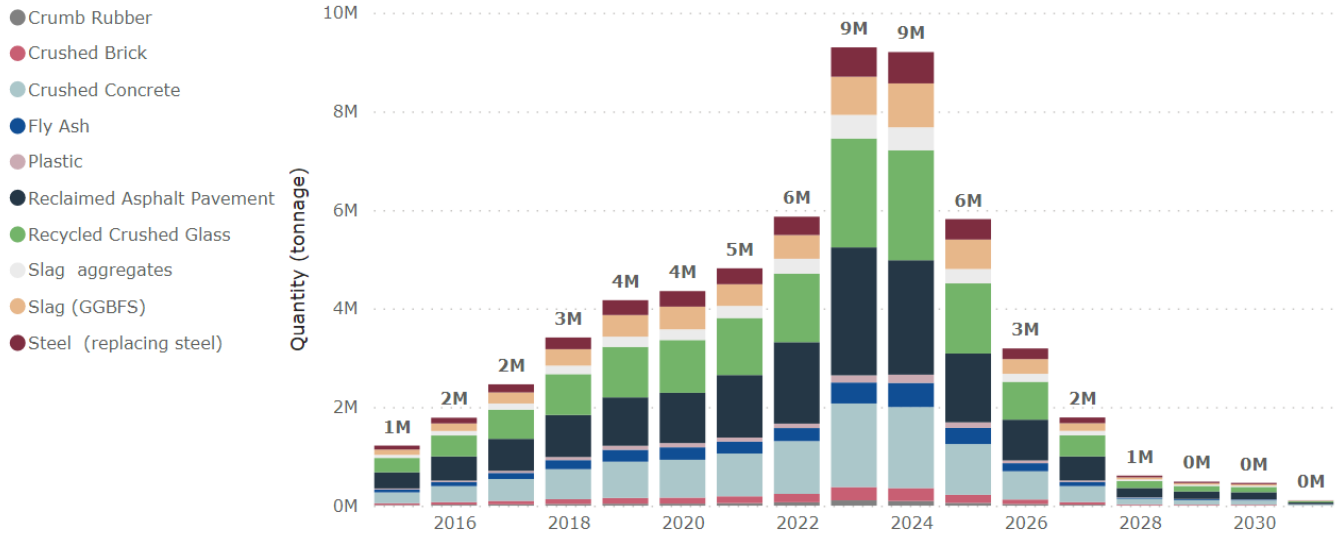


B–4—4 High forecast

Figure 31: High forecast based on current replacement rates

Total potential re-use opportunity: current state
> current replacement rate based upon: existing science and technology; regulation; product allowable limits within state and territory standards and specifications, and; modelling assumptions from Victorian Government's ecologiQ initiative which seeks to integrate recycled and reused content across Victoria's transport infrastructure projects

Total potential replacement (tonnes)



Select Forecast Type

High	Low	Medium

Select Recycled Material Type

Crumb Rubber	Plastic	Slag (GGBFS)
Crushed Brick	Reclaimed Asphalt Paveme...	Steel (replacing steel)
Crushed Concrete	Recycled Crushed Glass	
Fly Ash	Slag aggregates	

Select State

ACT	NSW	NZ	SA	VIC
AUS	NT	QLD	TAS	WA

Potential demand for recycled materials

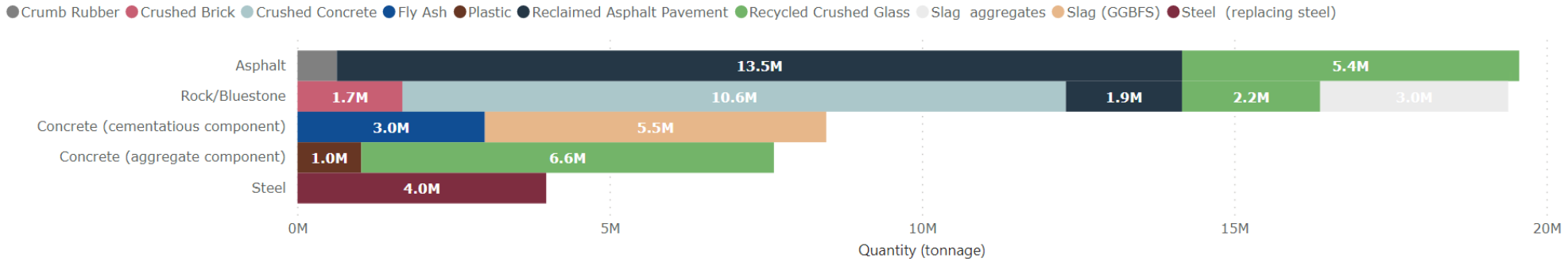


Figure 32: High forecast based on future replacement opportunities

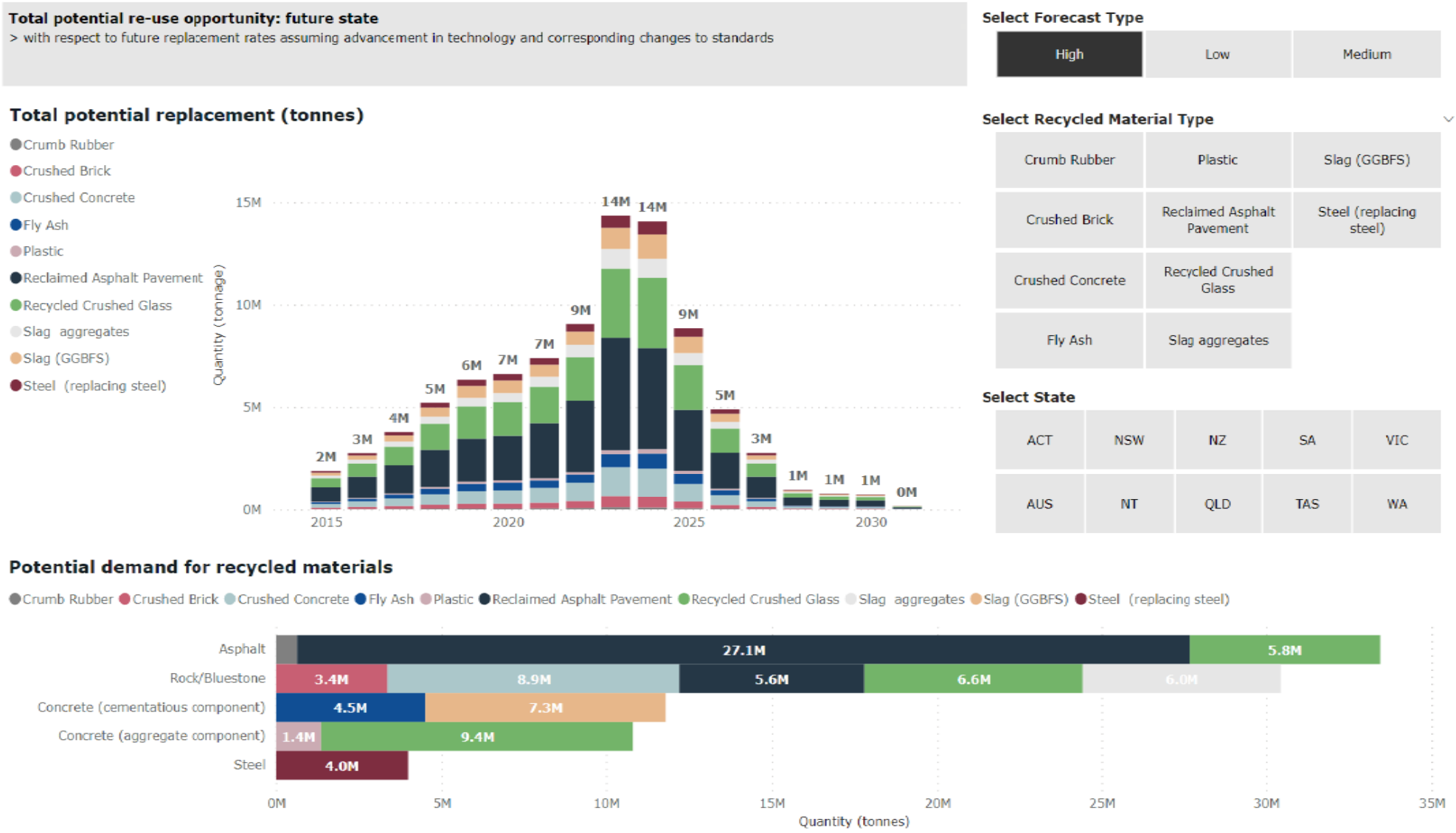
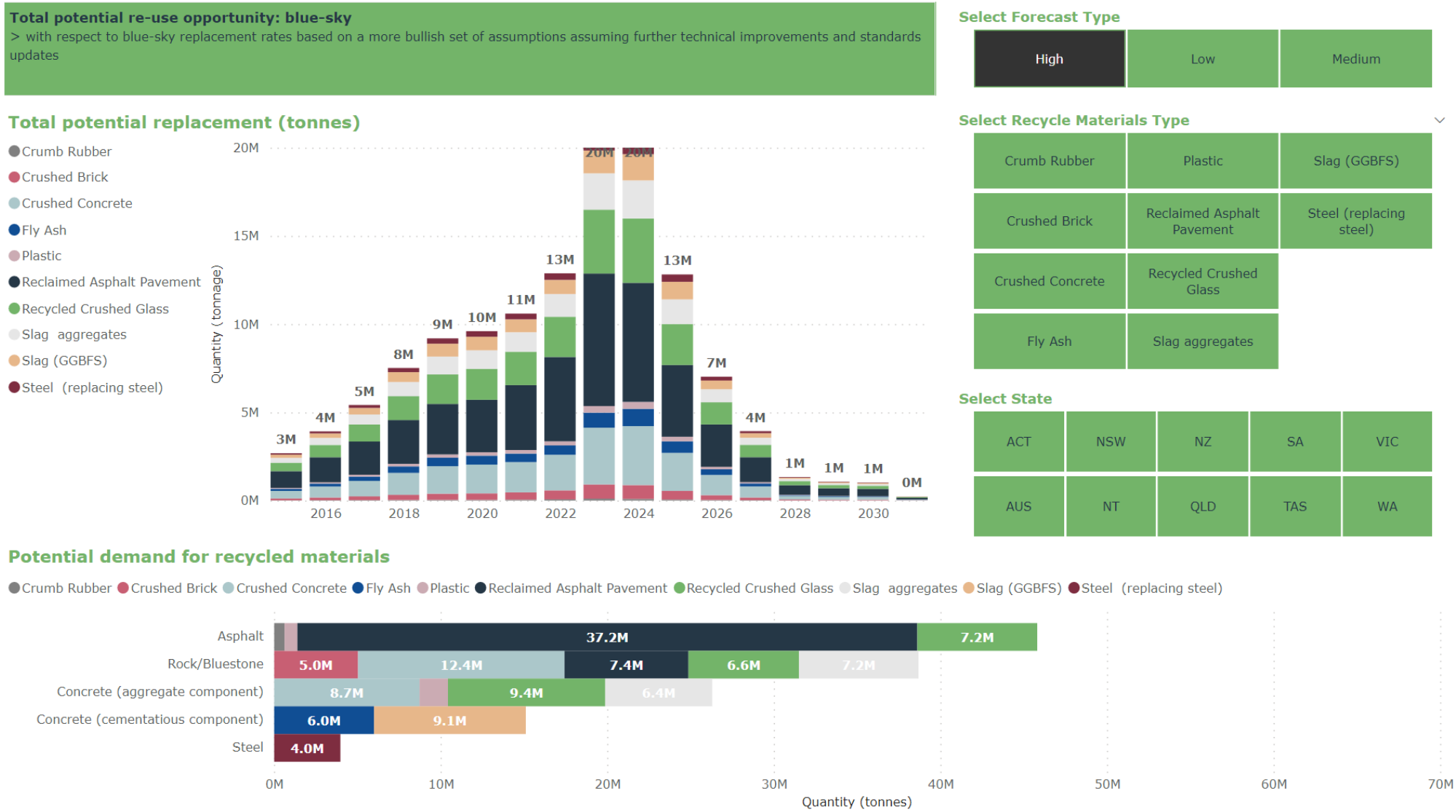


Figure 33: High forecast based on blue-sky potential



B–5 Findings and implications

B–5—1 Summary of findings

Based on Infrastructure Australia's central case conventional material demand forecast, this report shows:

- From 2015–31, approximately 200 million tonnes of conventional materials are needed to deliver 998 road projects from across the country. Over 95% of the mass is made up of five key materials: aggregates (29%), asphalt (27%), rock/bluestone (16%), sand (15%) and cement (9%).
- Based on current technology and standards, approximately 27% of the conventional material tonnage could be replaced by using a range of recycled materials. This means replacing approximately 54 million tonnes of conventional materials with approximately 52 million tonnes of recycled materials.
- The largest quantities of conventional materials that could be replaced are asphalt (32% of the replaceable conventional materials tonnage) and concrete (32%).
- The largest quantities of recycled materials that could be used to replace conventional materials are reclaimed asphalt pavement (26% of the recycled materials tonnage to replace conventional materials), followed by recycled crushed glass (24%) and crushed concrete (18%).
- The peak of demand is forecast for 2023–24.
- With advancements in technology and the associated updates to standards, the tonnage of conventional materials replaced could rise from the current 27% to 43%. This could replace nearly 87 million tonnes of conventional materials with nearly 80 million tonnes of recycled materials.
- Based on blue-sky assumptions, the replacement rate could further rise to 59%, replacing nearly 119 million tonnes of conventional materials with 114 million tonnes of recycled materials.

Infrastructure Australia also undertook a low and a high forecast for conventional materials demand. Based on those forecasts, the replacement potential is estimated to be approximately 17% lower than the central case in the low forecast, and approximately 14% more in the high forecast.

B–5—2 Implications from the demand forecast

The forecasts generated in this report is based on Infrastructure Australia's 998 projects across the country for between 2015 and 2031. Refinement of forecasts and the inclusion of future projects will present different scales of opportunities. Nevertheless, based on the forecast conventional material tonnage, there is significant potential for replacing conventional materials with recycled materials. The scale of the replacement depends on technology, standards as well as market appetite and supply.

Appendic C
Market analysis engagement program

The market analysis was informed by engagement program consisting of:

- a quantitative survey of the resource recovery and recycling industry
- facilitated workshops with the recycled materials supply chain and its customers
- one-on-one interviews with industry and government leaders.

C–Quantitative survey

C–1—1 Survey objective

The overall objective of the market survey was to understand material supply and supply chain constraints for recycled materials. In particular, the survey aimed to deliver hard data on the supplier market, including suppliers' capacity, their attitudes to and their experiences with recycled materials.

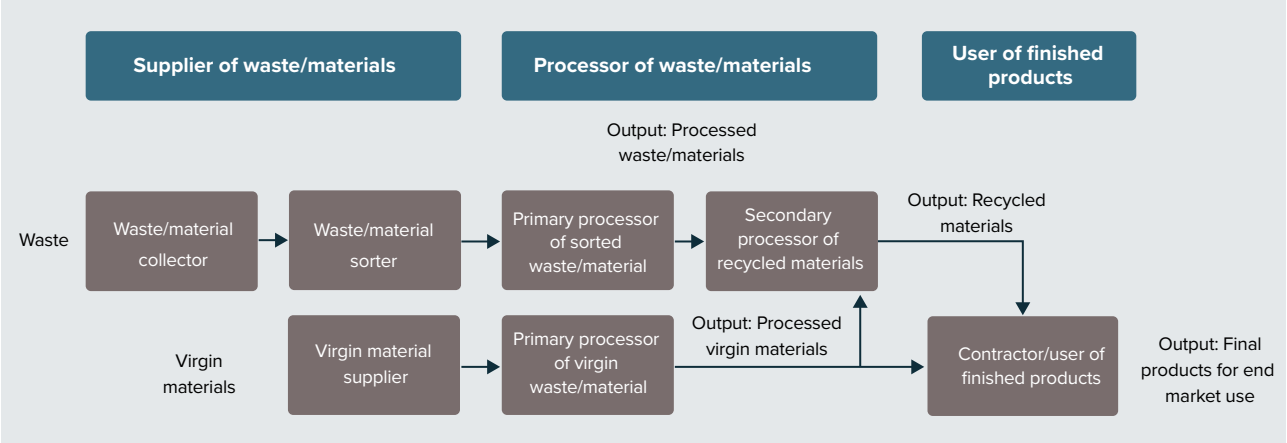
C–1—2 Methodology

The target audiences included a mix of organisations that currently are or would consider being part of the recycled material supply chain. To be eligible for participation, all respondents had to fall into at least one of these categories:

- supplier of waste/materials:
  - waste/materials sorter
  - virgin materials supplier
- current processor of waste/materials:
  - primary processors of sorted waste/materials
  - primary processors of virgin materials
- current secondary processors of recycled materials, including prospective secondary processors of recycled materials (i.e., considerers/non-rejectors).

This included a mix of businesses across material/product types, business sizes and geographies as illustrated in **Figure 34** and **Figure 35**.

Figure 34: Quantitative survey industry participants



The survey was conducted from 16 March to 8 April 2022. It was administered as an online survey (main method) and via computer assisted telephone interviewing (supplementary method).

It took participants approximately 15–20 minutes to complete the survey. Participants were recruited via multiple sources, including:

- a purchased list of contacts from one of Ernst & Young's approved list brokers. A list of senior decision makers within the business was shortlisted based on their associated Australian and New Zealand Standard Industrial Classification codes
- a secondary list from Ernst & Young and Australian Road Research Board databases
- via Infrastructure Australia network affiliates/partners
- via Australian Road Research Board's website
- via the Infrastructure Australia social media platforms.

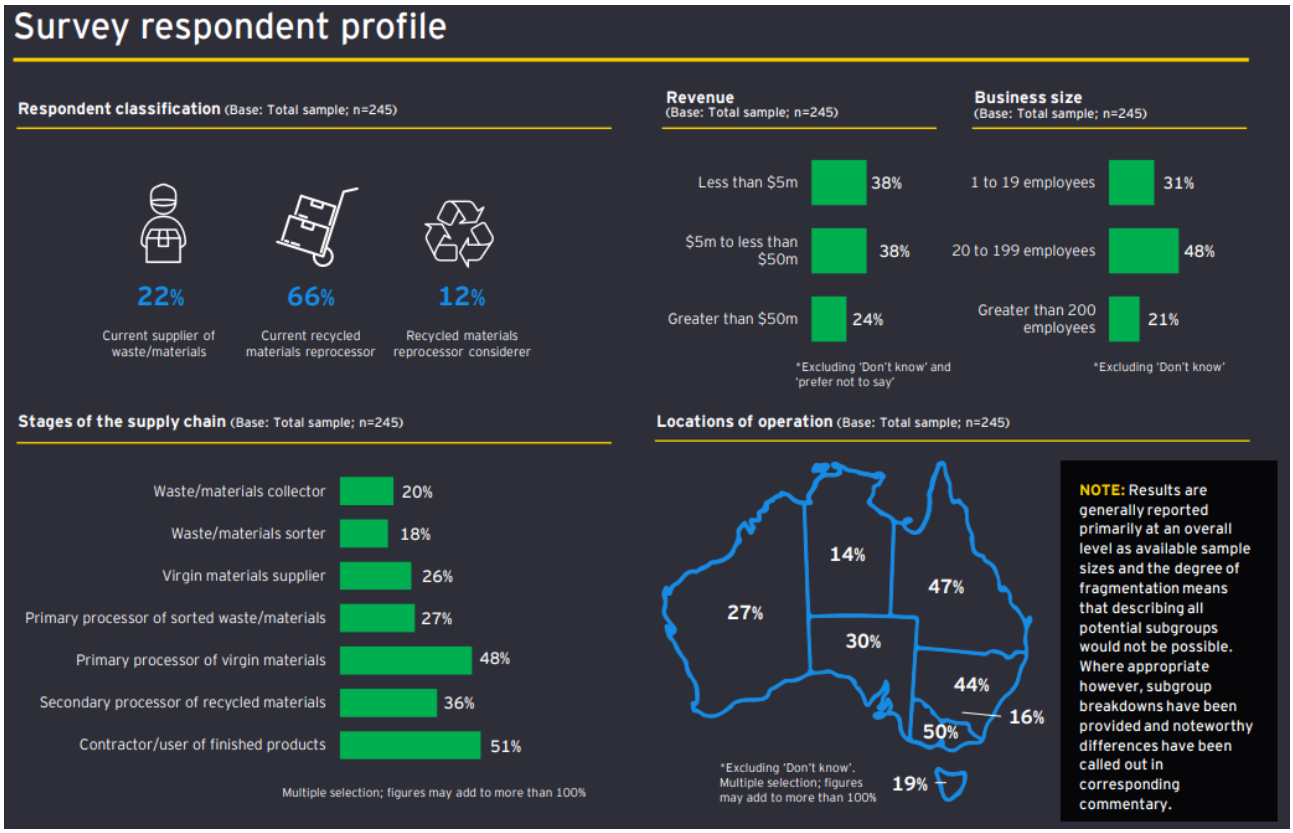
Where a list of contact names was available, EY Sweeney either emailed each contact a unique link to complete the survey online or completed the survey with them via computer assisted telephone interviewing. All other contacts were invited via a generic link, published by respective partners, websites and/or platforms (as described above).

A soft launch was conducted in the first instance on 16 March 2022, when 50 invitations were sent. A review of the soft launch data was undertaken before proceeding to the full launch, with the remaining invitations sent on 17 March 2022.

C–1—3 Survey respondent profile

A total of 245 businesses responded to the survey as shown in **Figure 35**.

Figure 35: Survey respondent profile



C–1—4 Key findings

The recyclable material supply chain is a diverse and fragmented market, which serves a mix of customers and locations across Australia

Participating businesses in the survey represent a mix of businesses within the waste and material supply chain ecosystem, who currently service a range of markets and customers.

- For-profit businesses in the private sector represent the largest customer base, with 87% of businesses surveyed selling products and services to these audiences. Government customers are the second-highest reported customer cohort (60%), followed by consumers/ residential markets (52%).
- Businesses have multiple locations of operation, with 73% reporting that they have operations based on the eastern seaboard (86% compared to 42% non-east coast), across a mix of metropolitan (73%) and regional (67%) areas
  - government makes up a larger proportion of the customer base for businesses operating in regional areas, where 7 in 10 (69%) businesses sell products and services to government
  - this figure is slightly lower for those operating in metro areas (57%).
- The geographic reach of where their customers are based is diverse, although at least half tend to service customers on the eastern seaboard.
- Over three-quarters (77%) of participating businesses currently service road sector customers. Current reprocessors of recycled materials are more likely to sell products or services for road projects, with 7 in 10 (72%) indicating they do so.
- Businesses that participated in the survey are typically small (31% with 1 to 19 employees) to medium (48% with 20–199 employees) in size, with an annual turnover of < $5 million (38%) and $5–50 million (38%). High turnover businesses ($50 million+) are more likely to have customers in Victoria (77%).

A sizeable proportion of businesses within the supply chain sell recycled materials for road projects, although opportunities exist to expand production and revenues

The use of recycled materials for road projects readily exists in and around Australia, with 62% of survey participants saying they process recycled material into road project materials. This tends to be a more common occurrence among large businesses and those operating in regional areas. Crushed concrete, in particular, has the highest reported production for use in road projects.

Revenues from these projects are however relatively low, with two in five (41%) current reprocessors reporting a revenue of 1 to 20% through such projects. This may partly explain why a large proportion (72%) of current reprocessors of recycled materials are also in the business of processing/producing virgin materials.

Consideration of expanding materials produced for road projects is mixed, and opportunities exist to make recycled materials a more attractive supplementary option. Just over half (54%) of current recycled materials reprocessors surveyed would consider producing other recycled materials in the future, although a sizeable proportion (33%) of participants do not know what new materials they would produce. One in five (20%) would never consider producing other recycled materials, a more common trend among small businesses. Small businesses are also more likely to indicate they are uncertain about future production types, with around one in two (46%) businesses with less than 20 employees indicating this.

Implications

Support key stakeholders along the supply chain by educating them about the range of recycled materials through databases, educational collateral and case studies. Policy development that improves the price competitiveness of recycled materials, and which provides clear demand signals to support profitability and production would be beneficial.

Recycled materials are viewed positively largely due to the environmental and practical advantages offered

There is a sense of willingness within industry to produce and use recycled materials, which is largely driven by a host of environmental and practical benefits.

Most commonly, recycled materials are viewed positively as they help reduce waste sent to landfill which is the most common driver to produce recycled materials (43%). Primary suppliers of waste/materials are most likely to cite reducing waste sent to landfill as a driver (61%), followed by current producers of recycled materials (50%). Seventeen per cent also acknowledge that there is increasing technology/ innovation, which supports the production of replacement materials.

There is also a sense of responsibility among businesses to do their part for the environment by reducing emissions, with a higher proportion of current reprocessors of recycled materials mentioning this (24%).

While current producers of virgin materials reported similar patterns in relation to drivers as current reprocessors, proportions within each driver are lower, possibly suggesting a lower overall resonance with recycled materials.

Notwithstanding, survey participants also acknowledge the practical sides, with the supply of traditional quarry materials becoming increasingly constrained due to a depletion of natural resources. Using recycled materials reduces the reliance upon and use of non-renewable materials (16%), and encourages more efficient use of natural resources (11%). Similar proportions also recognise that virgin materials are becoming increasing costly to use (10%), which is likely dampening the market demand for raw materials, vis-à-vis recycled materials, with a growing trend noted both currently and in the future.

Implications

Build up the momentum for the production and use of recyclable materials by focussing on the environmental credentials and the lifecycle cost of such materials compared with virgin materials.

Perceived performance, cost and compliance issues are leading barriers to businesses producing recycled materials

Despite growing confidence in the use of recycled materials overall, the widescale construction of roads and pavements with recycled materials do present challenges in the minds of businesses, some of which are more nuanced among different cohorts.

Primary suppliers of waste/materials are most commonly concerned with the economic barriers acknowledging that virgin materials are cheaper to use (28%). It is also perceived to be unhelpful with low demand in the market (28%), and subsequently low uptake of the products and low returns on investment.

In contrast, current reprocessors of recycled materials are more likely to cite misperceptions and predispositions among industry towards recycled materials. This includes perceptions around the poorer quality of recycled materials (23%), which is largely a sentiment noted among their customers

(44% having come across this always/most of the time/sometimes compared to a 38% average). Those who service customers in the road sector are more likely to have customers believing that products made from recycled materials for road projects perform worse than products from virgin materials (50% always/most of the time/sometimes compared to a 36% average). It appears that a fear of the unknown and a lack of confidence among customers is likely to influence business inertia to produce more recycled materials. These concerns are further compounded by unfavourable regulatory conditions (21%) that do not necessarily support the demand and supply for replacement materials, as well as a lack of government incentives/grants (19%).

Current producers of virgin materials are more similar to primary suppliers of waste/materials, where there is a greater focus on economic concerns. Some 31% feel that it is cheaper to use virgin materials than recycled materials, offering quicker returns on investment. While 50% of survey participants who currently do not process recycled materials (n=83) would not reject the idea of processing/producing recycled materials in the future, a similar proportion say they would not consider the possibility at all (n=41).

Of these future considerers, both suppliers of waste/materials and producers of virgin materials appear to have a higher degree of confidence and trust in virgin materials. This confidence is primarily based around the belief that virgin materials are cheaper to use raw materials in locations where their supply is consistent. This belief exacerbated by a poor understanding of the benefits of recycled materials as well as a lack of conviction about the real impact they have on the reduction of emissions.

Overall, the survey identifies various concerns, including:

- misperceptions and predispositions, particularly around the quality and performance of products made with recycled materials, as perceived by customers and businesses not currently reprocessing these materials, as well as a lack of interest among customers
- regulatory barriers associated with a lack of regulatory policies to support the transition toward the use and production of replacement materials, as well as an unfavourable financial/incentive system
- market barriers, which appears to be influenced by the lower price of virgin materials, high(er) upfront investment costs which can reduce profitability, and limited standardisation for the use and production of recycled materials.

Encouragingly, there is some acknowledgement of the increasing technology/innovation that supports the supply of remanufactured products, as noted previously. Further activities are necessary to ensure that recovered materials meet the quality requirements demanded by customers, which will likely require the review of activities and processes, and the development of new technologies.

Implications

Educate the sector as well as customers to ensure adequate knowledge about recovered materials and their characteristics, which is fundamental for overcoming the misperceptions about the quality and durability of products that potentially raise such barriers.

Establishing standards and regulatory conditions that support the optimal performance of recycled materials would be valued

Prioritisation of the development of national standards and specifications is called for... of which 92% would find this to be a very/somewhat attractive measure to supporting their business' decision to continue, or consider, producing recycled materials for road projects.

The survey suggests there is still a degree of ambiguity around the perceived quality and performance of recycled materials, which are generally viewed to be on par with virgin materials. This belief is evident even among existing reprocessors of recycled materials, with one in two (48%) of these businesses believing that recycled materials is similar 'quality', and 54% thinking they 'perform' the same as virgin materials. A relatively high proportion are vague about the relative quality and performance of recycled materials, even among current reprocessors (28% for quality and 27% for performance), indicating further education is needed.

Developing specifications that stipulate the use of different recycled materials in road projects can provide producers greater clarity and guidance in producing optimal performing products. This can provide product performance guarantees to customers, which help address some of the cultural barriers towards products made with replacement materials.

As part of this process, early engagement with stakeholders and decision makers who have responsibility for standards and certifications needs to be fostered to ensure that recycled materials are fit-for-purpose and accurately reflect both policy objectives and technical needs.

Implications

The development of a common standard for the production of recycled materials provides businesses greater assurance of the production of high-quality recycled materials for road projects. This in return can help shift existing mindsets and reservations around the quality and performance of recycled materials among customers and stakeholders across the supply chain.

A call to review government specifications in procurement processes and practices is noted

An opportunity exists to review government specifications in procurement processes and practices, with 88% of participating businesses in the survey recognising the attractiveness of this measure.

Exploring this possibility further may be valuable, as businesses acknowledge that current procurement conditions relating to recycled products do not necessarily drive current procurement of products containing recycled materials, with 13% of current reprocessors identifying this factor to be a barrier to greater production.

Including recycled content specifications in tenders and contracts may help drive the demand and subsequently supply for replacement materials. Business case examples may also be helpful in educating procurement stakeholders to see how recycled content products can be adapted to their needs, including information on performance, cost and reliability in specific applications.

This in part may involve increasing the technical skills and expertise of procurement stakeholders such as government members, so they are informed buyers in the process, are conscious of the material choices, cost and wider benefits, and are in a position to challenge standards to enable innovation and drive efficiencies. Training may need to be introduced to enable procurement stakeholders to understand how best to integrate recycled content into their procurement planning and strategy, including sourcing suppliers and product availability.

Implications

Reviewing procurement guidelines, including educating procurement stakeholders about recycled material choices, helps ensure buyers are informed purchasers. This in return could promote end markets for recyclable materials in building demand and uptake of such materials.

Opportunity exists to provide businesses with financial assistance to make recycled materials a more attractive proposition

Initiatives to help make the production of replacement materials more price competitive and financially sustainable for businesses are appreciated… with survey findings revealing that concerns are present around the costs and profitability associated with the production of replacement materials.

While drivers for businesses' willingness to produce recycled materials largely centre around the environmental impacts that they can bring, uncompetitive pricing conditions and low market demand for recycled materials can also hinder businesses from transitioning to the production of replacement materials.

Businesses require assurances that the operating cash flows from producing recyclable materials will be sufficient to repay their initial investments. External drivers such as financial incentives can help promote its uptake by helping businesses address expenditure needs, such as upfront capital costs (with 98% valuing financial assistance to help reduce costs associated with infrastructure setup), talent sourcing (83%), and staff training (80%). Some have explicitly mentioned the value of marketing support and development grants to help them expand their customer base and markets.

Coincidentally, about half (52%) of businesses surveyed have invested in, or are planning to invest in, new technologies; 40% have not. Larger businesses are more likely to be new technology adopters, which is likely influenced by the availability of financial support.

Implications

Interventions that are focussed on intrinsic motivations, as well external drivers such as measures using financial stimuli can both support each other and together, may increase positive impact of businesses uptake of replacement material production.

C–2 Workshops

Infrastructure Australia hosted three workshops facilitated by Australian Road Research Board and Ernst & young. Over 100 individuals representing the following government agencies and industry organisations participated in the workshops.

C–2—1 Government

- Australian Local Government Association
- Austroads
- Department for Infrastructure and Transport, South Australia
- Department of Agriculture, Water and the Environment, Australian Government
- Department of Environment and Science, Australian Government
- Department of Environment, Land, Water and Planning, Victoria
- Department of Infrastructure, Transport, Regional Development and Communications, Australian Government
- Department of Jobs, Precincts and Regions, Victoria
- Department of State Growth, Tasmania
- Department of Transport, Victoria
- Department of Transport, Western Australia
- ecologiQ, Major Transport Infrastructure Authority, Victoria
- Environment NSW
- Environmental Protection Authority, New South Wales
- Green Industries South Australia
- Infrastructure NSW
- Infrastructure SA
- Infrastructure WA
- Local Government Association of South Australia
- Main Roads Western Australian
- Major Road Projects Victoria
- Mitcham Council
- Northern Territory Government
- Office of Projects Victoria
- Queensland Transport and Main Roads
- Southern Sydney Regional Organisation of Councils Standards Australia
- Sustainability Victoria
- Transport for New South Wales
- Wyndham Council

C–2—2 Industry

- AECOM
- AI Group
- Alex Fraser
- Arcadis
- Australian Packaging Covenant Organisation
- Australian Society for Concrete Pavements
- Boral
- Cement Concrete & Aggregates Australia
- Cleanaway
- Close The Loop
- Construction Material Processors Association
- Downer
- EcoDynamics
- Fibrecon (Enviromesh Pty Ltd)
- Fulton Hogan
- Hanson Downer Group
- Hyder Consulting
- Infrastructure Sustainability Council
- Institute of Public Works Engineering Australasia
- Pact
- Pipa
- Repurpose IT
- ResourceCo-Tyrecycle
- Roads Australia
- Smartlite
- Tyre Stewardship Australia
- Waste Management & Resource Recovery Association

C–3 Interviews

The following organisations participated in the one-on-one interviews:

C–3—1 Government

- Australian Local Government Association
- Infrastructure Tasmania
- Main Roads Western Australia

- Major Projects Canberra
- Queensland Transport and Main Roads
- Sustainability Victoria

C–3—2 Industry

- Alex Fraser
- Australian Council of Recycling
- Australian Society for Concrete Pavements
- BINGO Industries
- Boral
- Cement Concrete & Aggregates Australia
- Fulton Hogan
- Pact
- ResourceCo-Tyrecycle
- Veolia

AustStab and IPWEA Australasia also provided written responses.

C–4 Workshop and interview commentary

The workshops and interviews provided invaluable insights from many, diverse government and industry stakeholder organisations to inform the report. Recorded comments were consolidated and categorized into four key topics and many sub-topics. The following figures (**Figure 36**, **Figure 37**, **Figure 38**, **Figure 39** and **Figure 40**) and tables (**Table 22**, **Table 23**, **Table 24**, **Table 25** and **Table 26**) show the breakdown of comments by category and sub-category. This analysis gives an indication of the relative level of interest or concern for each category and sub-category.

Figure 36: Share of engagement comments by topic

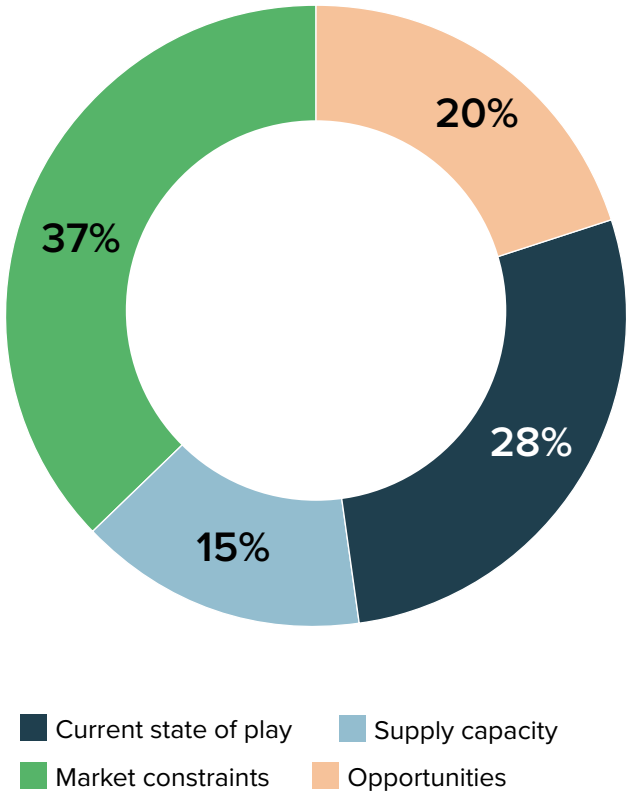


Table 22: Number and share of engagement comments by topic

	Number of recorded comments	Share of comments
Current state of play	82	28%
Supply capacity	43	15%
Market constraints	109	37%
Opportunities	52	20%
Total	**286**	**100%**

Figure 37: Share of current state comments by sub-topic

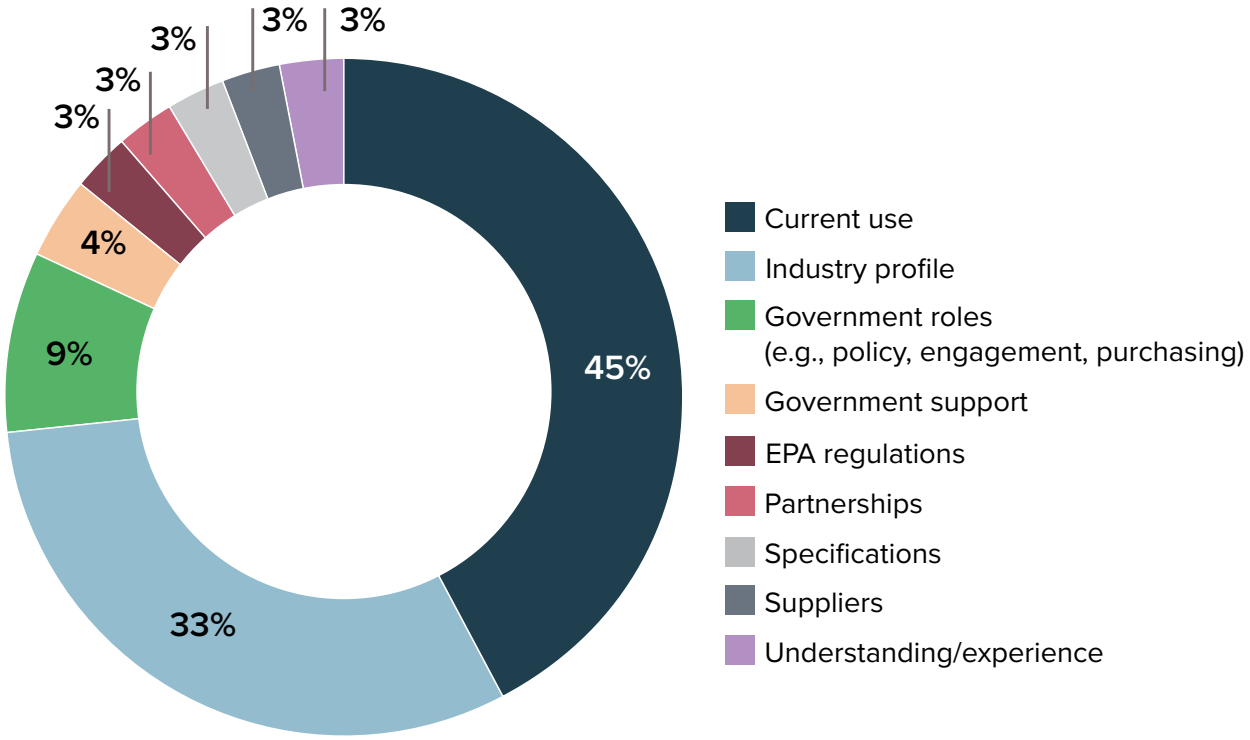


Table 23: Number and share of current state comments by sub-topic

	Number of recorded comments	Share of comments
Current use	36	45%
Industry profile	26	33%
Govt roles (e.g., policy, engagement, purchasing)	7	9%
Government support	3	4%
EPA regulations	2	3%
Partnerships	2	3%
Specifications	2	3%
Suppliers	2	3%
Understanding/experience	2	3%
Total	**82**	**100%**

Figure 38: Share of supply capacity comments by sub-topic

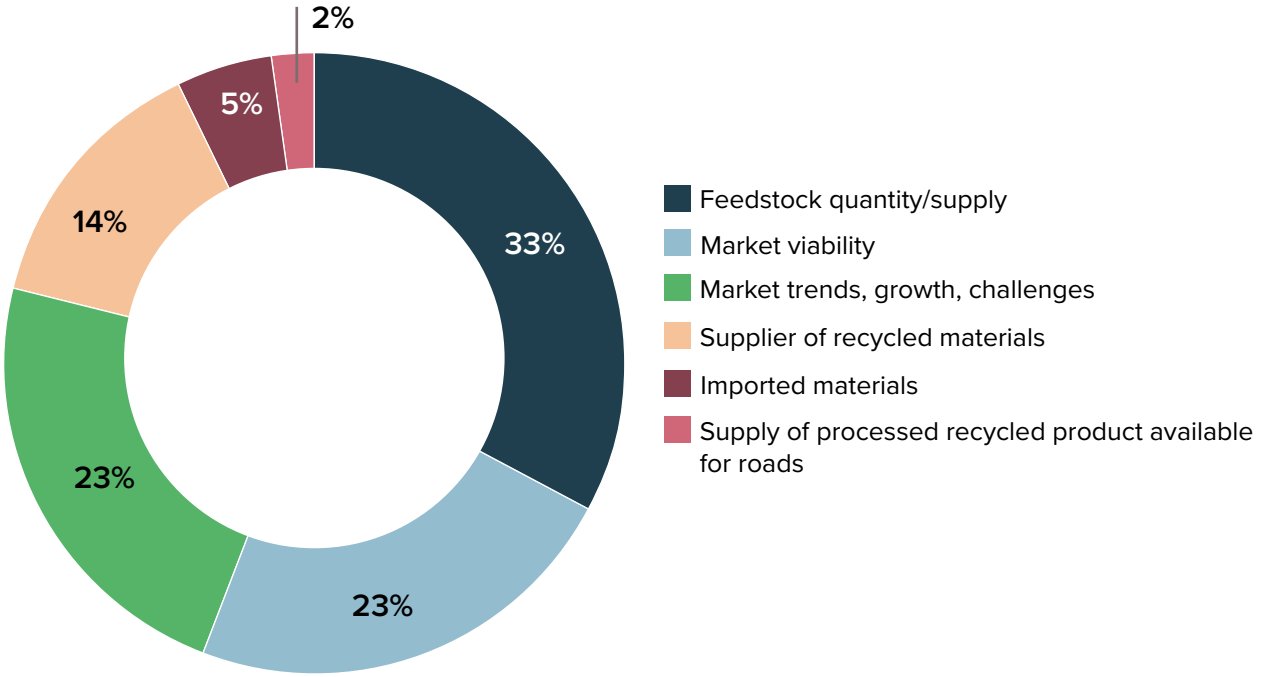


Table 24: Number and share of supply capacity comments by sub-topic

	Number of recorded comments	Share of comments
Feedstock quantity/supply	14	33%
Market viability	10	23%
Market trends, growth, challenges	10	23%
Supplier of recycled materials	6	14%
Imported materials	2	5%
Supply of processed recycled product available for roads	1	2%
Total	**43**	**100%**

Figure 39: Share of market constraints comments by sub-topic

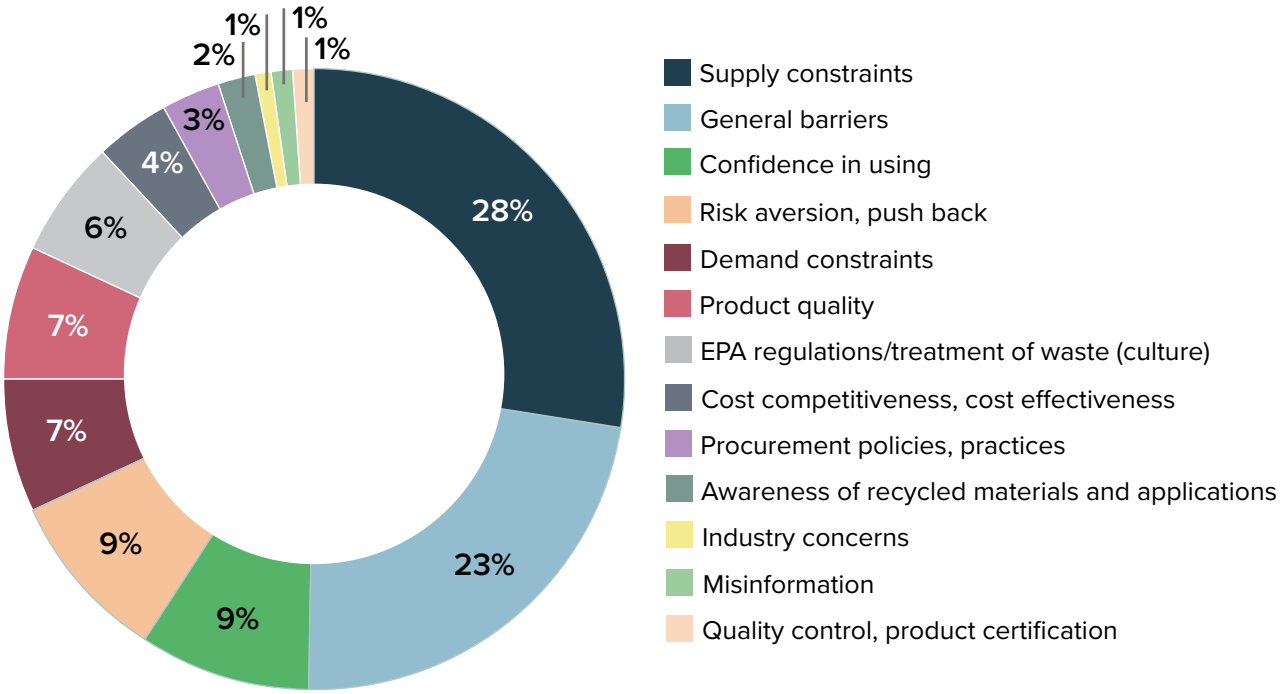


Table 25: Number and share of market constraints comments by sub-topic

	Number of recorded comments	Share of comments
Supply constraints	30	28%
General barriers	25	23%
Confidence in using	10	9%
Risk aversion, push back	10	9%
Demand constraints	8	7%
Product quality	8	7%
EPA regulations/treatment of waste (culture)	6	6%
Cost competitiveness, costeffectiveness	4	4%
Procurement policies, practices	3	3%
Awareness of recycled materials and applications	2	2%
Industry concerns	1	1%
Misinformation	1	1%
Quality control, product certification	1	1%
Total	**109**	**100%**

Figure 40: Share of opportunities comments by sub-topic

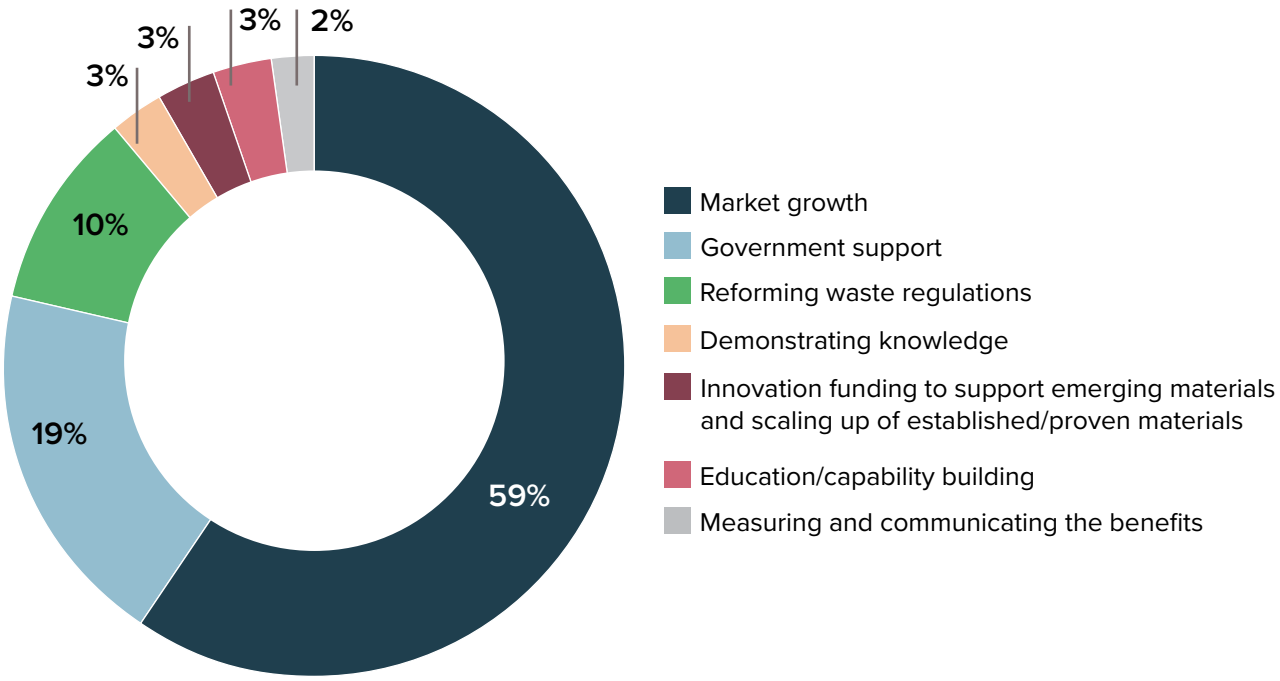


Table 26: Number and share of opportunities comments by sub-topic

	Number of recorded comments	Share of comments
Market growth	34	59%
Government support	11	19%
Reforming waste regulations	6	10%
Demonstrating knowledge	2	3%
Innovation funding to support emerging materials and scaling up of established/ proven materials	2	3%
Education/capability building	2	3%
Measuring and communicating the benefits	1	2%
Total	**58**	**100%**

Glossary

Term	Definition
Organic waste	The component of soil that is composed of organic compounds that have come from the remains of organisms, such as plants and animals, including their waste products.
Recycled crushed glass	A processed materials sourced from waste glass streams. Processing includes sorting and crushing and may or may not include washing. Similar terms include glass fines, glass sand or manufactured sand.
Recycled organics	A general term, used by industry, for products that are recycled from organic waste. This includes compost, soil conditioners, mulch and other products that can be applied to the land, for landscaping or soil treatment.
Slag	A general term referring to a by-product of iron and steel production. The cement industry often use ‘slag’ as a simplified description of ground granulated blast furnace slag – which is a ground or powdered pozzolanic material used in cementitious applications.
Slag aggregate	Blast furnace slag or granulated blast furnace slag (GBFS) that has not been ground to a powder and has no pozzolanic properties which can be used as an aggregate replacement.

Table of figures

Table of tables

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