Circular Australia

Value chain collaboration

Unlocking circular markets in Australia

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ARUP

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Authors

Lisa McLean, CEO, Circular Australia
Leanne Griffin, Circular Economy Services Leader, Arup
Adrian Doyle, Senior Consultant, Arup
Emily Gentilini and **Gian Marco Gentilini**, Senior Engineers, Arup
Samantha Choy and **Lachlan Johnston,** Engineers, Arup
Peer reviewers listed in the Acknowledgements

This research draws upon interviews with professionals involved in circular market across Australia (listed in the Acknowledgements). The findings and recommendations provided in this report are not representative of any single participant or their organisation.

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Acknowledgement to Aboriginal & Torres Strait Island people

We acknowledge the traditional custodians of Country throughout Australia and pay our respects to Elders past and present, and to all First Nations peoples. We recognise our economic activities are on Aboriginal and Torres Strait Islander lands and waters and commit to inclusive, respectful and thoughtful collaboration to undertake sustainable economic practices.

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Activating new circular economy markets in Australia

Circular Australia has built a national network of committed experts and organisations working to transition Australia to a circular economy by 2030. The circular economy is a systems transition - not one business or sector can make the transition on its own. Collaboration and co-design between industry, research, and government are the best ways to create a circular pathway in Australia.

Circular Australia's Industry Taskforce has leveraged the extended network of experts available through its members to deliver this research, which seeks to outline opportunities and a path forward to unlock circularity for Australian industries.

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Executive summary

With a circularity rate of around 4%, Australia's journey to build a circular economy will require many system changes. There are significant barriers to industry achieving circularity that are both economy-wide and value chain-specific. Breaking through these barriers to build new circular markets is essential to Australia's economic resilience. It also presents rare opportunities to cut embodied carbon and secure greater productivity and efficiencies, while creating the products and services of the future - without waste.

Unlocking Circular Markets is Circular Australia's latest report. In partnership with Arup, it maps out new market opportunities for a circular Australia by 2035. The report identifies major sources of lost value, and interrogates barriers and success stories to develop recommendations that enable businesses and organisations to make important circular transitions in their sectors. The result is five detailed value chain maps for Australian industry, covering processing, production, manufacture across key value chain case studies:

- **Lithium-ion batteries for mobility**
- **Polyethylene terephthalate (PET) bottles for beverages**
- **Green steel for the built environment**
- **Low carbon concrete for the built environment**
- **Textiles for fashion, upholstery and other goods**

Unlocking Circular Markets examines pathways to unlock circularity for Australian industries drawing on deep insights from Australian businesses and organisations including Circular Australia's *Industry Taskforce Members* who are evolving their own value chains to be circular. Ultimately, this report seeks to decouple Australian industry performance from resource consumption, enhance and maintain the value of our materials and products to capitalise on our competitive advantage.

There are many challenges in implementing circular solutions in an economy like Australia with institutional linear systems and markets that promote 'take make waste' market approaches - however the circular transition rewards are significant. For example accessing secondary resource markets by onshoring and building value chain capability in lithium could be worth up to AUD3.1B.

Unlocking Circular Market Principles encourages industry to create actionable strategies diving into their value chains and value networks. Building new circular markets starts with a circular or whole-of-life mindset across industry, businesses, value chains and end users. This includes being informed about material selection and composition and alternate sustainable practices and materials available to drive circular outcomes.

It emphasises the importance of collaboration and leadership particularly to coordinate States and Territories on strategic directions for individual materials and products, including through any potential *National Circular Economy Framework* and targets currently in development. This report recommends key reforms to overcome barriers to activate circular markets:

- **New circular planning, procurement, design and material requirements for renewable energy projects with whole-of-life carbon assessments**
- **Expansion of requirements and restrictions on exports such as textile waste, rPET and scrap steel while investigating the loss of resources in mixed plastic waste exports**
- **Minimum requirements and/or tax adjustments for imported products**
- **Investment in and funding for targeted nodes of the value chain**
- **Expanding the scope of product stewardship to capture and increase accountability for system externalities within value chains**
- **Fiscal interventions and eco-modulation to incentivise desirable activities/disincentivise undesirable ones.**

The value losses of Australia's circular economy are not widely mapped or understood. This foundational work through its five case studies shines a light on the significant opportunities to generate new products, services and markets from wasted resources. It provides building blocks for industries and governments to continue their circular journeys, creating a thriving Australian circular economy to 2030 and beyond.

Net Zero circular world

0

No Net Zero without circularity

Net Zero goals and action is driving a global economic transformation and with it new businesses, jobs, products, services and markets. This activity is strongly centred on the renewable energy transition. But even in a fully renewable energy system ongoing high consumption, a lack of circular design, engineering, infrastructure manufacturing and recycling will always drive high emissions and slow overall progress.

The rapid uptake of circular economy by G20 nations and Australia's trading partners demonstrates the importance of this economic framework as a pathway to prosperity, sustainability, resilience and carbon reduction. Circular approaches and practices, alongside targeted investment and regulatory change, are delivering greater value than traditional linear industry models across a number of industries.

As explored in CSIRO's *Australia's Circular Economy Comparative and Competitive Advantages*, low-carbon circular economy opportunities lay ahead for Australia based on our comparative advantages and they are ready to be harnessed. Circular economy has an essential role in reducing emissions in hard-to-decarbonise sectors but also to increase resource productivity and decrease value chain and climate risks for businesses. However, the current circularity rate in Australia remains at below the global 7.2% at around 4% and significant barriers to implementation exist across the value chain.[1]

1 Miatto A, Emami N, Goodwin K, West J, Taskhiri S, Wiedmann T, and Schandl H (2024) A comprehensive material flow account for the Australian economy to support the assessment of Australia's progress towards a circular economy. CSIRO, Australia.

Source of photo

Circular value chain principles

There are some important factors needed from industry to activate circular economy markets in Australia. This starts with a circular mindset across industry and across the relationship between businesses, value chains and end users, including consumers. Below are some key principles underpinning circular industries and the markets they are developing.

Connectivity

A circular industry is full of value chain connections, forming a network of businesses and stakeholders rather than linear chains. These connections can start anywhere, from designers working with recyclers to create products that can be disassembled and returned, to suppliers sharing equipment or facilities, or businesses re-connecting with product consumers to repair and take-back products.

Circular hierarchy

Successful circular economy industries are informed by the circular economy hierarchy which does not just rely on recycling but offers a plethora of activities to improve resource efficiency, value chain efficiency and productivity. International circular economy standards embrace hierarchies that start with design, refuse, rethink, source and reduce - moving to repair, reuse, refurbish, remanufacture, repurpose - ending with cascade, recycle, recover energy and remine. *See Circular Hierarchy on p8.*

Transparency

Circular industries make information transparent by formally and informally sharing data on origin, materials, environmental impact, maintenance and disposal guidelines. Formal approaches include product passports, eco-labels, disassembly manuals and ESG reporting. Informal approaches include collaboration, communities of practice, conferences and social media.

Forward-thinking

Circular industries look beyond a short-term time horizon to consider the value of their business including: the value it delivers to the community; resources used and the impact of that resource use on the planet over the long-term. They consider embracing circular business models like 'as a service' models that leverage the residual value of assets.[2] They consider value chain risks and importantly time horizons well beyond 5 to 10 years - focusing on 30, 50 or even 100 years.

2 Ellen Macarthur Foundation (2021) Examples and Case Studies https://www.ellenmacarthurfoundation.org/fashion-business-models/examples

Circular economy hierarchy

Applying a Circular Hierarchy to industry practices unlocks value across the entire value chain, assisting in the design of new markets, products and services needed for a thriving future Australian economy. This Hierarchy is inspired by Prof. Jaqueline *Cramer's Building a Circular Future*[3] and *International Organization for Standardization's (ISO)*[4] new 59,000 series of circular economy standards providing guidance for industry and government.

HIGH

Refuse	Preventing the use of virgin materials in solutions, products and services. Rethink solutions e.g. through sharing or as a service solutions
Reduce	Reducing the use of raw materials. Rethinking the way products are designed
Sourcing	Procuring sustainably. Choosing renewable resources, recovered, high recycled content easily broken down at end of life with no toxins/ pollutants
Redesign	Design products to be more efficient e.g. by dematerialising, designing for disassembly
Repair	Extend the lifespan of products through maintenance, restoration, keeping it at the highest value
Reuse	Re-use products for as long as possible by keeping pre-used items in the economy
Refurbish	Restore products to continue or exceed the expected lifespan/ covered by warranty or performance standard
Remanufacture	Generate a new product from secondary materials through manufacturing
Repurpose	Modify a product through reuse for a different function
Cascade	Sharing materials from one process to another to achieve resource use efficiency e.g. repeated use of renewable resources without contamination
Recycle	Processing materials into fibres or raw materials for reuse in the economy. Materials in this proccess can have higher order uses
Recover energy	Incinerate waste with energy recovery. Materials in this process can have higher order uses
Remine	Remining minerals or materials recovered from previously mined areas such as landfills

LOW

3 https://circulareconomy.europa.eu/platform/sites/default/files/building-a-circular-future-jacqueline-cramer-amsterdam-economic-board.pdf
4 ISO59004:2024 Circular economy — Vocabulary, principles and guidance for implementation

Circular markets

The five case studies below were selected as focal points to engage with deeper analysis and shine a light on the massive lost values and circular potential of Australian resources essential for a circular economy. For each case study below, selected to test with industry, the following process was undertaken.

1. *Map the current value chain to identify major sources of lost value*
2. *Generate a possible 2035 value network to outline future opportunities for Australian industry*
3. *Interrogate barriers and success stories to develop recommendations that enable circular transitions across these case studies and broader industry in Australia.*

This report reflects an industry view of opportunities obtained in 25 interviews and parallel desktop research. While this report was informed by industry research, it does not reflect the individual views of any of the industry organisations interviewed. Rather, it builds a picture of the key themes and insights drawn from this process.

Lithium-ion batteries for mobility

Polyethylene terephthalate (PET) bottles for beverages

Green steel for the built environment

Low carbon concrete for the built environment

Textiles for fashion, upholstery and other goods

CIRCULAR MARKET OPPORTUNITIES

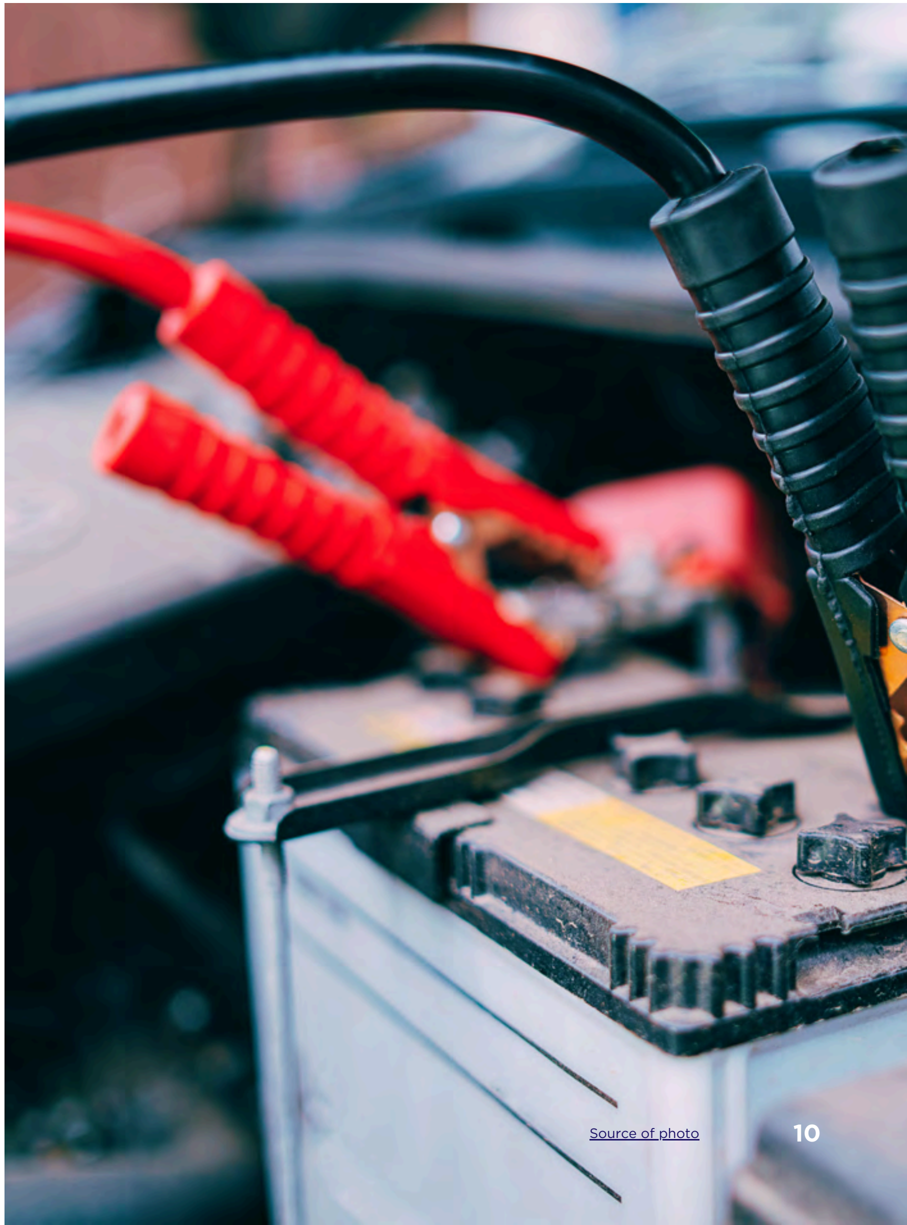
Lithium-ion batteries

Lithium-ion batteries (LIBs) are central to the electrification and decarbonisation of mobility systems. Over the coming decade alone, global battery demand is forecast to increase 18-fold with forecasts constantly accelerating.[1] That means by 2030 demand for lithium will be around 3 million mt/year. Australia is an important supplier in the current value chain delivering a massive 39% of global lithium extraction in 2023.[2] Circular economy opportunities for secondary lithium from batteries if unlocked could be as much as AUD3.1B.[3]

Australia is a serious participant in the global Net Zero transition, accessing significant virgin quantities of critical minerals for development of the world's batteries. These materials are primarily mined and exported as raw ore for materials processing overseas. However, over the next decade a circular opportunity worth between AUD0.6 and AUD3.1 billion remains[3] available for Australia in secondary resources from its own used LIBs - only 3% of which are currently recycled.[4] Securing resilience, reducing sovereign risk and retaining critical mineral supplies for domestic development will also be important considerations for Australia and its trading partners.

While China remains the dominant player for many of the value chain elements required for the global energy transition - including the battery value chain - many countries are seeking to grow their domestic capabilities. Countries are activating new markets via ambitious policies.

It is both an exciting time and challenging one for the Australian LIB industry. Demand for batteries and constituent materials is rapidly increasing while supply can fluctuate. Key challenges for lithium include: value chain volatility; environmental impacts; and collection and recycling quality. Industries and systems that support the manufacture of batteries, including lithium-based and non-lithium based components, must also scale rapidly to meet growing demand amid price volatility.



Source of photo

1 Accenture and Future Battery Industries CRC (2023) Charging Ahead
2 Australian Government (2024) Resources and Energy Quarterly
3 Zhao Y, Ruether T, Bhatt AI, Staines J (2021) Australian landscape for lithium-ion battery recycling and reuse in 2020 - Current status, gap analysis and industry perspectives, CSIRO, Australia
4 Langdon, R, Dominish, E., & Lara, H. (2023).B-cycle Benchmarking Program: Market Analysis & Fate Mapping, and Life Cycle Analysis.Sydney: Institute for Sustainable Futures.

LITHIUM-ION BATTERIES FOR MOBILITY

Australian opportunity

Australia is a significant producer of mined lithium in the form of spodumene concentrate delivering 39% of global extraction in 2023 with additional sources of extraction emerging over the next few years. Of this production, 96% was exported to China unimproved in the form of spodumene concentrate. The value of Australia's exports fluctuates alongside the price of lithium, with AUD9.9B in export earnings reported in FY2023-24.[5]

Australia is slowly expanding its capability to provide services across this value chain, with production of refined lithium hydroxide forecast to increase ~20% lithium carbonate-equivalent per annum between 2022 and 2030.[6] Australia currently does not have a role in electrochemical component production of battery cells and battery packs. While non-lithium based batteries, including sodium-ion batteries, may fill a portion of the world's demand, LIB technologies including lithium nickel manganese cobalt (NMC), lithium iron phosphate (LFP), and lithium manganese iron phosphate (LMFP) are expected to be dominant technologies. Forecasts by Tesla show it alone will need 30% more lithium carbonate than the world currently produces by 2030 - 1,000 kilotons yearly.[7]

Market challenges include:

- Providing the required levels of mobility to meet societal expectations and preferences, while optimising resource use and decarbonisation.
- Managing the rapid expansion of batteries reaching end of first life.
- Preventing negative impacts of disposal to landfill while retaining the value of components and materials within the value chain.

Production
Due to the chemical properties, cost and abundance of the lithium element, LIB are projected to form a major part of the global decarbonised electrified transport and mobility system.

Demand
The demand for LIB is forecast to continue to increase in the future alongside the projected transition in mobility tehcnologies from predominately internal combustion engine base (ICE) to battery-based. Forecasts can be up to 34% per annum, an 18-fold increased from 2020 to 2030.

The value chain
Component materials, including lithium, nicket, cobalt and iron, are improved via multi-staged processes prior to manufacture into Li-ion cells and assembled into batteries.

Australia's Role
Australia's role is anticipated to be small in driving this demand due to its relatively small population compared to large global markets. This makes export markets a key opportunity for Australia. Government efforts have focused on driving uptake of electric vehicles (EVs) through policies such as: AUD*500M Driving the Nation Fund for EV* charging infrastructure; *Australia's National Electric Vehicle Strategy* to increase EV demand and *the ACT Government's Sustainable Household Scheme* with zero interest loans up to AUD15,000 to buy new EVs. Policies also focus on optimising mobility material requirements by increasing public transport and rideshare.[8, 9 & 10]

5 Australian Government (2024) Resources and Energy Quarterly
6 McKinsey & Company (2023) Australia's Potential in the Lithium Market
7 "Tesla 2023 Investor Day" (2023) - YouTube
8 Driving the Nation Fund - Department of Climate Change, Energy, the Environment and Water
9 Australian Government (2023) National Electric Vehicle Strategy
10 ACT Government (2021) Driving into the Future

LITHIUM-ION BATTERIES FOR MOBILITY

Lost value

Major sources of lost value in the Australian LIB value chain

Environmental impacts of extraction
Globally, the extraction of critical minerals through mining is associated with negative environmental impacts including emissions, water use, ecological toxicity and human health impacts. Additionally, depending on the source of the critical materials, governance and social challenges including modern slavery impacts may be present or emerging.

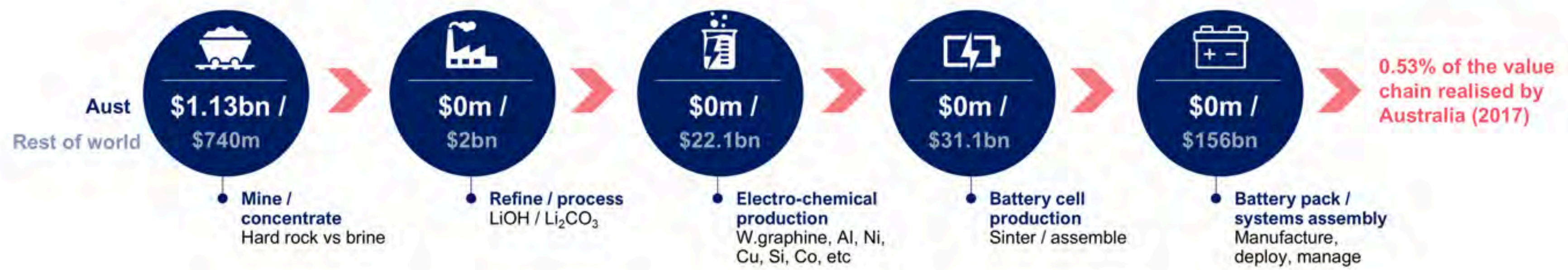
Inefficient use of materials for mobility
The continuation of current consumption approaches dominated by private ownership models throughout the EV market transition will result in an increase in carbon emissions and resource consumption. Battery materials will be best used to deliver the same mobility outcomes through public, active and shared mobility solutions. These outcomes include performance, safety, impact on traffic congestion, fuel/power generation efficiency, carbon, environmental impacts and excess requirement for road & parking infrastructure.

Disposal of batteries with reuse, remanufacture and recycling potential
97% of LIB are currently not recycled in Australia due to poor collection rates, offshore recycling and landfilling.[11] This results in lost value that could be between AUD4,400 and 17,200 per tonne of battery, totalling AUD603 million to 3.1 billion.[12] This is across all battery types, not just those for mobility.

The projected LIB waste generation in Australia is expected to be between 137,000 to 180,000 tonnes by 2036.[12] Diversion from landfill will be incredibly important for capturing this lost value and reducing local environmental impacts. It is also an opportunity to improve safety, with increasing numbers of fires caused by LIBs. In just the first six months of 2024 seven waste and recycling fires in NSW were caused by LIBs.[13]

Lost opportunity to value-add due to overseas processing
In exporting unprocessed lithium ore as concentrate, Australia only earns 0.53% of ultimate value of the materials worth AUD1.13 billion, as shown in Figure 1 below. Some 99.5% of an estimated AUD213 billion of the value of products derived from Australian lithium ore is added through offshore electro-chemical processing, battery cell production and product assembly, with more recent figures likely to show greater lost value when available.

Lithium-Ion battery value chain[14]



11 Langdon, R, Dominish, E., & Lara, H. (2023).B-cycle Benchmarking Program: Market Analysis & Fate Mapping, and Life Cycle Analysis. Sydney: Institute for Sustainable Futures.
12 Zhao Y, Ruether T, Bhatt AI, Staines J (2021) Australian landscape for lithium-ion battery recycling and reuse in 2020 - Current status, gap analysis and industry perspectives, CSIRO, Australia
13 FRNSW (2024) Jan-Jun 2024 FRNSW Battery Incident Data Breakdown
14 Australian Trade and Investment Commission (Austrade) (2018) The lithium-ion battery value chain. New economy opportunities for Australia

LITHIUM-ION BATTERIES FOR MOBILITY

Future directions

A circular future for LIBs will be part of an efficient mobility system based on public, active, shared and service-based transport and ride-sharing solutions that maximises the overall value and productivity of the value chain. There will be a focus on reuse, remanufacture and upcycling, supported by state-of-health testing, to retain materials in the system at the point of highest value. Australia will play a greater role in processing and manufacturing across the entire value chain retaining more value within the battery value chain in the domestic economy. Important circular economy opportunities include:

Optimising the mobility system to increase material productivity
An efficient, sustainable, reliable and resilient mobility system, meeting the needs of future Australians, will both reduce the number of vehicles and the material input of those vehicles. This future system will utilise multiple approaches including: the promotion of public transport; ride-sharing and other Mobility as a Service applications; and active transport enabled by policy and holistically planned infrastructure. This will also reduce requirements for road infrastructure and parking, and maximise the value generated from each unit of raw material.

Finding applications for second life
Due to their relatively large size (kWh) and weight (kg), batteries required for motor vehicles may be deployed for a variety of other purposes once they have reached the end of their useful life. 'Spent' vehicle batteries may retain up to 70% of their capacity and may be repurposed after testing and repackaging to: fill other mobility applications; act as home storage; power street lights; or provide backup power storage.[15] Motor vehicle suppliers are investigating mechanisms to retain battery ownership and sell into the repurposed market, reducing vehicle costs to consumers and providing additional revenue to the supplier. Battery designers are also incorporating reuse principles into design to facilitate second life applications.

Scaling battery recycling to meet demand
As LIB use becomes ubiquitous and opportunities for repurposing are exhausted, it will be imperative to develop the scale of the recycling industry. In other countries, where the transition to EVs is further advanced, businesses devoted to the recycling of LIBs are already present and may seek to invest internationally to where a supply of batteries for recycling will develop. In the future, there could also be requirements regarding the amount of recycled content that must be incorporated into batteries for sale within Australia, and urban mining to support better recycling.

Onshoring refining, processing, manufacturing of battery materials
There is value to be captured by Australia in the further processing of LIB materials and manufacturing components. This could include: development of refining, such as lithium hydroxide and lithium carbonate; processing of anode and cathode materials; cell production, and pack assembly capability on-shore. In the immediate term, the greatest opportunity may be in the refining of lithium hydroxide. Australia's abundant spodumene reserves, its established infrastructure, low-cost renewable energy and stable political environment, provide opportunities for strong returns. Onshoring will also create a market for recycled materials generated.[16] There are a number of recent examples of strong policy actions by governments designed to incentivise onshore processing and value chain resilience, including Indonesia's nickel ore export ban in 2020[17] and provisions in the USA *Inflation Reduction Act*.[18]

Case Study: Environstream & Ecobatt
Evironstream Australia and Ecobatt are examples of companies providing LIB recycling solutions in Australia. Global markets have more significant recycling operations established earlier to manage growing volumes of batteries reaching end of life.

15 Institute for Energy Research (2019) The Afterlife of Electric Vehicles
16 McKinsey & Company (2023) Australia's Potential in the Lithuim Market
17 The National Bureau of Asian Research (2022) Indonesia'a Nickel Export Ban
18 Centre for Strategic & International Studies (2023) Onshoring and Friend-Shoring in U.S. EV Supply Chains

LITHIUM-ION BATTERIES FOR MOBILITY

Barriers

Future directions cannot be fully realised without tackling key barriers:

- **Consumer behaviour:** Long-established consumer behaviours in mobility regarding the ownership and use of motor vehicles.
- **Low price of virgin materials:** Current recycling techniques, primarily multi-stage processing where lithium and other component metals are refined from ‘black mass’, provide metal feedstocks that are currently not price-competitive with virgin processed ores.
- **Volatility of commodity prices:** The price of commodities, including lithium, is highly volatile, which may impede the ability of projects to expand their extraction and production sufficiently to meet the growing demand.
- **International competition:** On-shoring of processing operations must be accomplished in the context of strong international competition against established and efficient operators, particularly in China.
- **Skills and labour:** Australia faces the challenge of attracting and training talented engineers, operators and consultants to facilitate the rapid build-out of these areas.

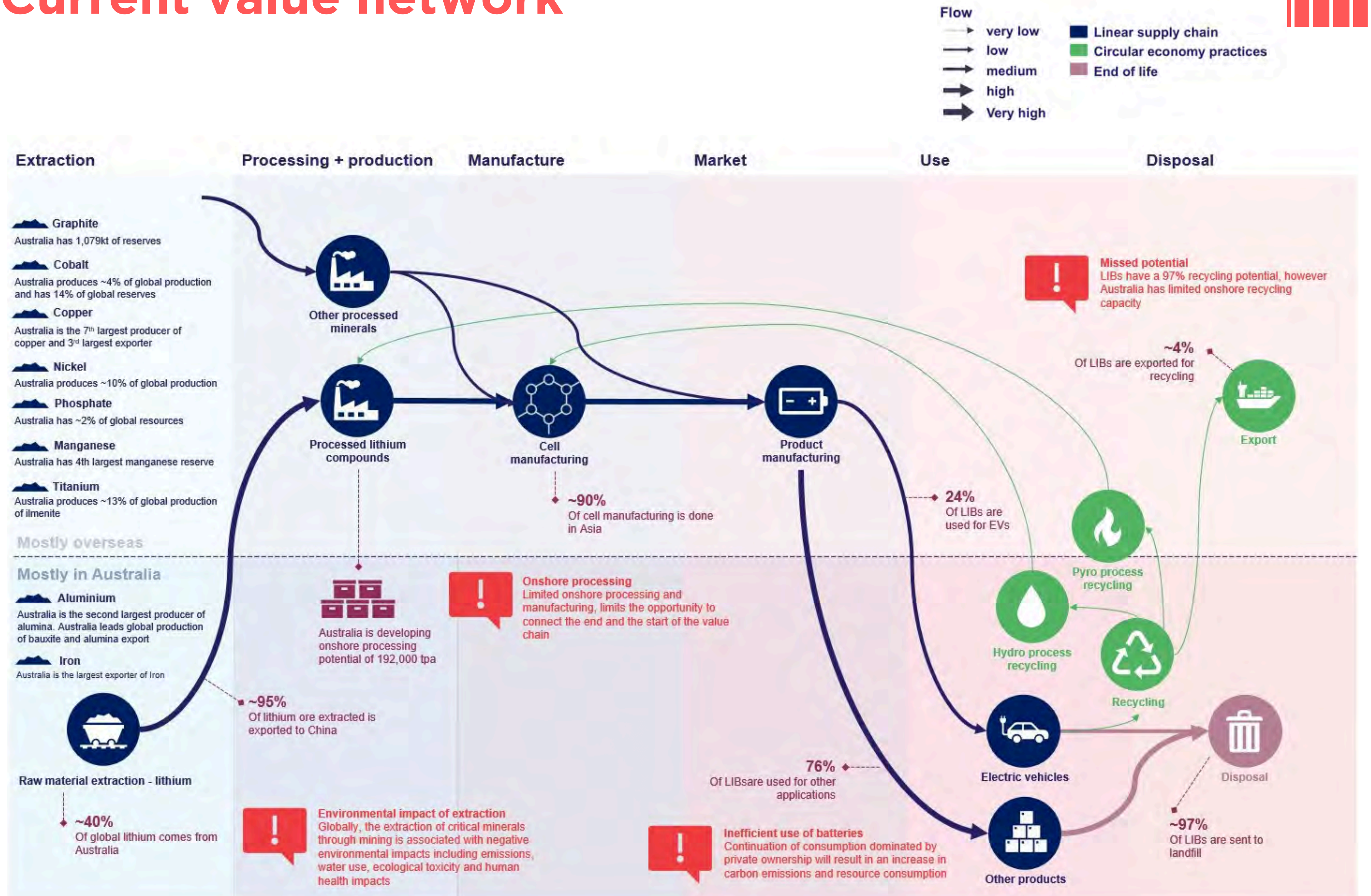
Case Study: Remanufacture, repurpose before recycling
Founded in 2022 in Victoria, *Infinitev* uses circular principles to extract greater potential from batteries. Used batteries are tested against key circular principles: *Remanufactured for continued vehicle use; Repurposed to energy storage for industrial use; Recycled into resale component materials.* Initial focus has been on the remanufacture and repair of used batteries from hybrid vehicles to prolong life and reduce the requirement for replacement with new.[19]

Case Study: Value chain partnerships for material recovery
Redwood Materials Inc. was founded in 2017 with a mission to build a circular value chain for a sustainable world and reduce fossil fuel by recycling materials from end-of-life batteries and electronics. The operation recycles batteries into component materials, refines and remanufacturing anode and cathode compounds for sale to the US battery manufacturing industry. Redwood is in partnership with *Panasonic, Ford* and *Amazon* to secure supply of feedstock for its operation. In its first operating year more than 225 tonnes of material from 1,000 batteries was successfully recycled. Redwood is now expanding operations from Carson City, Nevada to the domestic US market, employing over 700 people globally.[20]

19 InfiniteEV
20 Redwood Materials

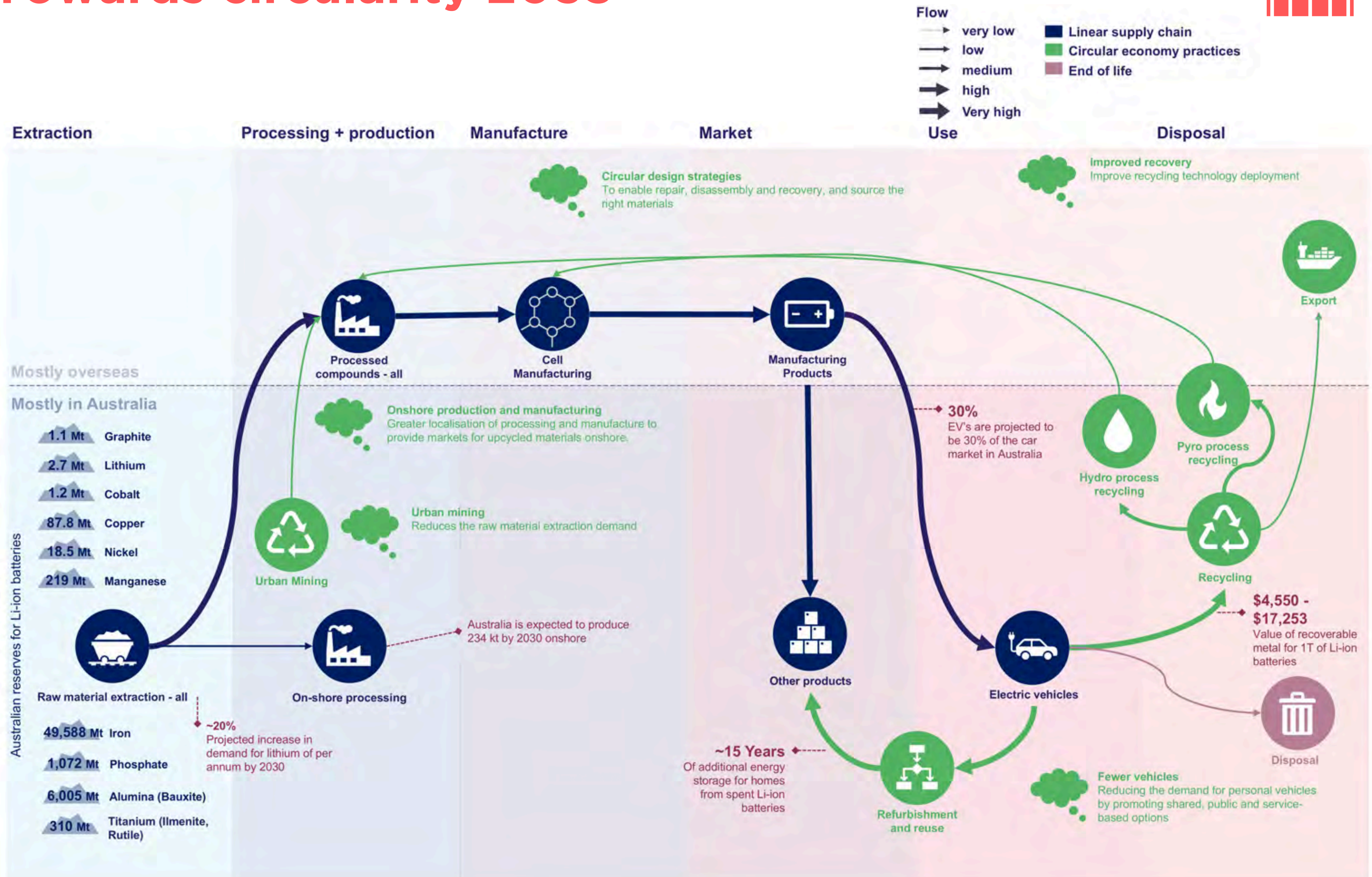
LITHIUM-ION BATTERIES FOR MOBILITY

Current value network



LITHIUM-ION BATTERIES FOR MOBILITY

Towards circularity 2035



CIRCULAR MARKET

PET bottles for beverages

Plastic is ubiquitous in Australia and especially across the food and beverages sector. In 2020/21, 113,250 tonnes of single-use PET bottles[1] were placed on the market across Australia, and marked as eligible for return by the various state-specific product stewardship Container Deposit Schemes (CDSs). Market size for this category of PET is projected to grow by 6.9% from 2024 to 2032.[2] Challenges for the PET value chain include consumer preferences, environmental impacts and improper sorting at end-of-life.

Most of the plastic bottles used in Australia are manufactured domestically, primarily using imported PET resin processed in China.[3] Market size of the plastic bottle manufacturing industry is AUD1.7B[4] in Australia, with the whole beverage industry valued at AUD133B.[5] PET continues to be a preferred material for single-use non-alcoholic drinks by consumers and the beverage industry due to its physical properties, including light weight, transparency, impact strength, UV resistance, durability, and ability to pair with a lid. Manufacturers are very responsive to these consumer preferences, while also considering decarbonisation and Australian Packaging Covenant Organisation targets when practical.

If collected, PET is readily recyclable via a variety of mechanisms including re-extrusion, mechanical recycling, chemical recycling or energy recovery. It produces a variety of new products and acts as a feedstock for new PET products. PET products may be recovered through sorting of co-mingled recycling streams or through CDSs, which are well established in most Australian states and territories. CDSs involve the collection of used bottles directly from consumers at a collection facility or vending machine, often in return for 5c or 10c payment per eligible container.

1 Return and Earn (2023) Return and Earn Annual Statutory Report 2022-23
2 imarc (2024) Australia PET Bottle Market Report market overview
3 WITS World Bank (2023) Australia Polyethylene Terephthalate, in primary forms imports by country in 2023
4 IBISWorld (2024) Plastic Bottle Manufacturing in Australia
5 Expert Market Research (2024) Australia Food and Beverage Market Size and Share Outlook

Source of photo

PET BOTTLES FOR BEVERAGES
Australian opportunity

Lifecycle outcomes for different beverage container types

There are trade-offs when selecting materials for containers and often tailored data is not available. An international study in 2020 across the US, Europe, and Brazil, identified major differences in lifecycle outcomes for three common single-use beverage container types; glass, aluminium and PET.

Aluminium cans had the lowest global warming potential at 0.09 kg CO_2-eq per 1L of beverage, compared to glass at 0.66 kg CO_2-eq and PET 0.10 kg CO_2-eq.[6] However, this is only one study and these values can vary by location, supplier, beverage, improvements to production processes, and over time. For example, aluminium recycled content, share of renewable energy inputs and transport distances all impact the carbon intensity.

Having better, publicly available Australian-based data and supporting businesses to complete assessments using this data would aid in improved decision-making for material selection. The recyclability of bottle materials is an important factor when considering long-term resource outcomes for Australia.

Case Study: Woolworths circular value chain collaboration
Woolworths have collaborated up and down the value chain to create better recycling outcomes. After working with their recyclers to identify key sources of lost value – residual waste and contamination – Woolworths engaged with packaging manufacturers to create clear plastic lids for milk. Reducing contamination and maximising recycled stock outcomes as uncoloured bottle caps can be recycled into a greater variety of products than coloured caps. After transitioning their Australian supermarkets in 2024, Woolworths expects improved recyclability of 290 tonnes of milk bottle caps and 370 tonnes of water bottle caps per year.[7]

Case Study: Partnership across the Australian beverage industry
Circular Plastics Australia is a joint venture between Pact Group, Cleanaway, Asahi Beverages and Coca-Cola Europacific Partners (CCEP). Since establishing this partnership in 2021, two PET recycling facilities have been commissioned and are now operational, each having a processing capacity of over 20,000 tonnes (1 billion bottles) per year. The first facility was opened in December 2021 in Albury-Wodonga, NSW, and a second facility opened in December 2023 in Altona North, VIC. Each actor in the value chain leverages their area of influence to create mutual benefits for all parties within the partnership. Cleanaway utilises its collection and sorting network to supply available PET to the facilities. Pact Group provides technical and packaging expertise, and are responsible for running the facilities. Once reprocessed, CCEP and Asahi Beverages will purchase the recycled PET from the facility to use in their respective products. This collaboration has accelerated the ability for local reprocessing capacity of PET, and the availability of recycled PET resin in Australia.[8]

6 Ball (2020) Lifecycle Assessment
7 Woolworths (2024) Sustainability Report
8 Circular Plastics Australia and Asahi (2021) Media Release 244

PET BOTTLES FOR BEVERAGES

Lost value

Major sources of lost value in the Australian PET value chain

Leakage of plastic waste to landfill or the environment
As a petrol-based polymer, PET does not readily decompose when released into the environment, and has a high impact when directed to landfill or the marine environment. Currently 36% of CDS- eligible plastic is lost to landfill or becomes environmental waste.[9] In Australia, approximately 130,000 tonnes of plastic leaks into the marine environment every year. This mainly occurs close to urban centres.[10]

With the continued growth in demand for PET products and persistently low rates of collection and recycling, it is expected that the volume of plastic ending up in landfill or the earth's oceans will continue to grow. This could signficantly increase the occurrence of a variety of issues, including entrapment of wildlife, ingestion of whole products as infant sea creatures are fed plastics and degradation to microplastics, which negatively impacts the food value chain and broader marine ecosystem.

Reliance on single-use plastics
The single-use model is a wasteful approach – around half of plastic globally is designed to be used once before it is thrown away.[11] While some manufacturers and consumers are shifting towards reusable beverage containers where possible, this is not common practice for most Australians. There may be alternative materials for containers that achieve better environmental and economic outcomes, however, this needs to be considered in a holistic way. Switching materials can have unintended consequences, such as increased water consumption or greenhouse gas emissions, or reduced end-of-life potential. Regardless of the material, a single-use approach does not adequately consider long-term resource use.

Exported PET
Current recycling practices focus on mechanical recycling techniques, which produce recycled PET resin (rPET) as a product. Approximately 12,000 tonnes of PET collected for recycling in Australia is exported, despite local reprocessing capacity being available.[12] The material is exported mainly to New Zealand, Belgium, Malaysia, and Indonesia. This reduces the opportunity for the local bottle manufacturing industry to incorporate this feedstock into its manufacturing processes, and subsequently requires the import of additional virgin PET.

Insufficient source-separation of bottles
When bottles are recycled through Material Recovery Facilities (MRFs), there is a loss of value associated with recovery compared to recovery at CDS collection points. Bottles collected through CDS collection points are often higher-quality and less contaminated than through MRFs. Due to the current low rate of recovery compared to materials consumed, Australia's local recycling capacity is not fully utilised due to limited feedstock. Australia has an estimated reprocessing capacity of 90,000 tonnes per annum across four sites. 100% of PET bottles collected through CDS return points are recycled locally.

Despite more than a thousand CDS collection points established throughout Australia (over 600 points in both NSW and VIC each) only 52% of PET bottles were recovered through collection points in 2021-22. An additional 12% of PET bottles were recovered by MRFs, indicating many are still placing their bottles into co-mingled recycling systems. Lost value is likely to be attributed to the "away-from-home" market such as at schools, offices, stadiums, and events. To fulfil market demand, the local bottle manufacturing industry imports rPET resin from overseas or supplements their product with virgin PET.

9 Return and Earn (2023) Return and Earn Annual Statutory Report 2022-23
10 Department of Agriculture, Water and the Environment (2021) National Plastics Plan Summary
11 UNEP (n.d.) Beat Plastic Pollution
12 Department of Climate Change, Energy, the Environment and Water (2024) Waste Export Summary Oct-Dec-2023
*Note: This value includes both PET bottles and other containers. Limited data was available on the export of PET bottles individually

PET BOTTLES FOR BEVERAGES
Future directions

A circular future for PET bottles will involve reduced demand for virgin PET resins, through greater utilisation of reuse solutions. Material selection will be based on measured lifecycle outcomes, including end-of-life pathways available and long-term visions for materials in Australia. A consolidated approach, led by government and bottle manufacturers and suppliers, is required to fully address the issues associated with the PET bottle value chain. Key opportunities identified include:

Alternatives to single-use
Planning for reusability instead of single-use and the marketing and education shift required alongside this are important steps. This would be simplest to implement through water fountains, refill stations, reusable cups within food courts, sporting events and other 'closed' environments, and the shift to more bulk products for consumers.

Improve the CDS collection rate
An expansion in the quantity and proportion of PET bottles recovered through CDS will be critical to improving efficiency and increasing the proportion of recycled materials used for PET and other plastic manufacturing. This expansion could significantly reduce the quantity of PET lost to landfill or the environment. The collection rate would need to be improved through expanding actions already in place – collection points, harmonisation, education and incentives.

Informed material selection
Alternatives to PET such as glass, aluminium or emerging bio-based materials exist. However, selection of materials for bottles should be based on a holistic assessment. Lifecycle impacts such as water consumption, toxicity and greenhouse gas emissions need to be measured and compared. The likely end-of-life fate of these materials and the availability of adequate collection, sorting and recycling infrastructure also needs to be considered. Ideally, this would be informed by a national strategy for resources in Australia.

Local and advanced recycling for high-quality PET resin
PET recycled through mechanical recycling can be recycled around 6 times before plastic degradation occurs. Theoretically, as the PET degrades, it will need to be supplemented with a proportion of virgin resin to improve the quality of the bottle. Advanced recycling could offer an alternative high-quality PET resin to virgin resin for supplementing the bottle production process. If local advanced recycling capability can be built and technologies developed, the production of high-quality rPET will support more circular domestic bottle manufacturing capacity and the reduction of imports.

Standardised recyclable bottles
A standardised approach to PET bottle design in Australia would maximise recycling efficiency. Minimum standards should start with clear PET and roll out to uniform labels, adhesives, lids, and etching.

Source of photo

PET BOTTLES FOR BEVERAGES

Barriers

Future directions cannot be fully realised without tackling key barriers:

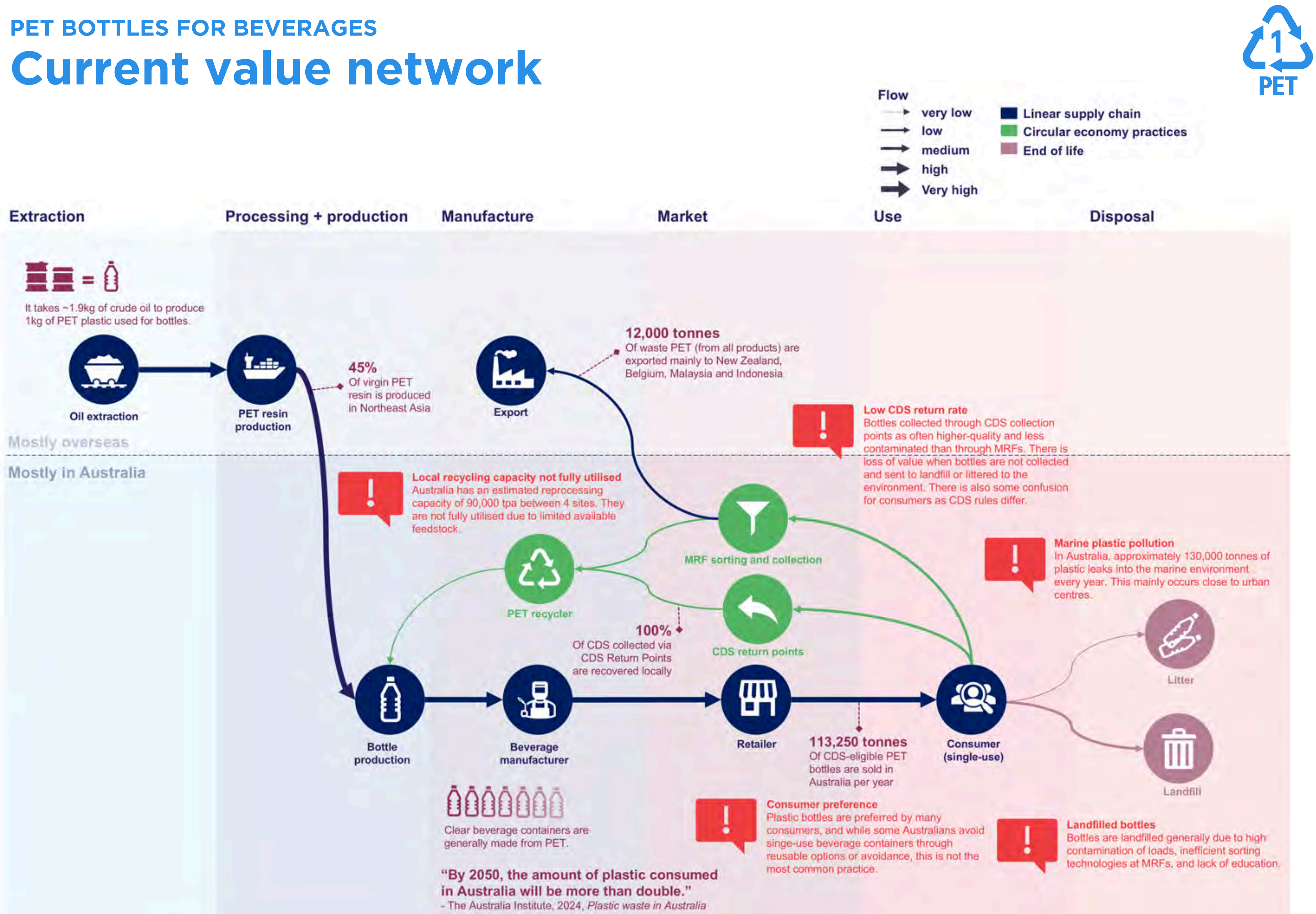
- **Consumer behaviour:** Uptake in CDS recovery is reliant on the public to properly manage plastic bottles following use (where CDS points are available). Bottles may continue to be improperly disposed of in situations where it is not convenient to collect or deposit, or if consumer awareness is lacking. Further, bottles are sometimes landfilled when collected as part of commingled recycling collection loads, which may be highly contaminated.
- **Scaling up:** The development of increased domestic advanced recycling capacity and bottle manufacturing capacity must be aligned to prevent over-capitalisation and scaling issues. For example, the soft plastics collection program, REDcycle, was suspended in 2022 due to limited demand for end-products and limited scale of recycling infrastructure available to process the collected material.[13]
- **Competition:** rPET is lost to overseas markets and cheap virgin PET is appealing to businesses due to lower prices.
- **Data on materials:** Limited data on materials and products makes it challenging for both businesses and consumers to make informed decisions about their purchase, and also for governments to make evidence-based policy decisions.

Source photo

13 ABC News (2023) One year on from REDCycle's collapse, Australia remains without soft plastics recycling program

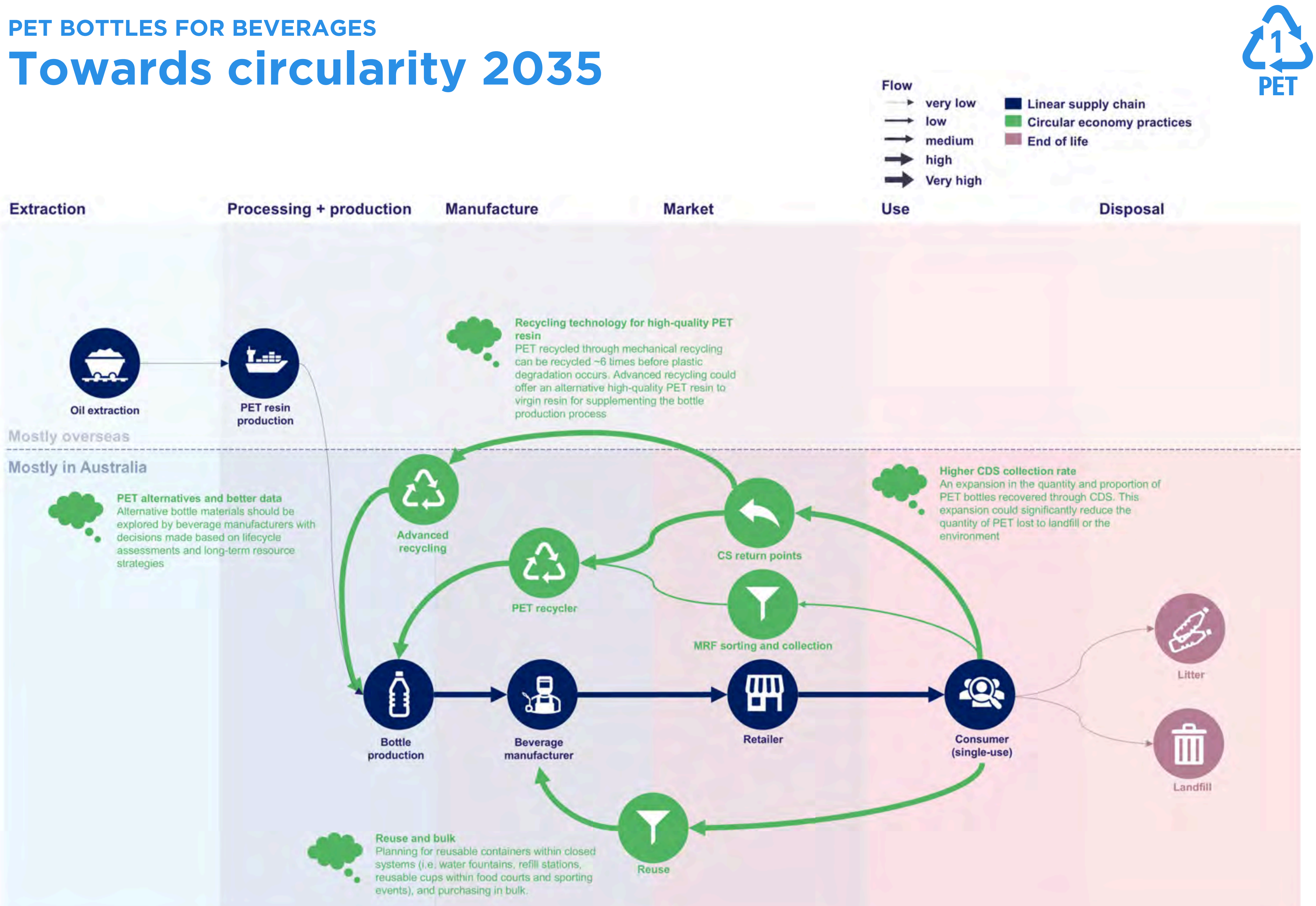
PET BOTTLES FOR BEVERAGES

Current value network



PET BOTTLES FOR BEVERAGES

Towards circularity 2035



CIRCULAR MARKET

Green steel in the built environment

Australia is the world's largest exporter of iron ore, contributing AUD136 billion to the economy.[1] Exported iron ore is converted into iron overseas via a high-emissions process. Iron is a key ingredient in steel making, thereby contributing to an industry that is responsible for 8% of overall global greenhouse gas emissions.[2] Australia can leverage its renewable energy and iron ore resources to produce green iron and steel onshore, reducing emissions and increasing the value of exports. Key challenges are the cost of sustainable production processes and overseas competition.

Australian iron ore extraction accounts for 36% of global production. This is mostly exported overseas and processed into iron in coal-fired blast furnaces. Domestically, Australia has two primary steel production sites; Bluescope's Port Kembla and Liberty Steel's Whyalla. While these sites supply 65% of domestic steel, they are relatively small, accounting for only 0.3% of global production.[3] A small portion of Australian steel products are exported, contributing AUD1.2 billion to Australia's economy.

In Australia, more than 90% of steel is recycled at the end of life. Recycled steel is less resource-intensive than primary steel, eliminating the need for over 1400 kg of iron ore, 740 kg of coal and 120 kg of limestone for every 1000 kg of steel scrap recycled into new steel.[4] Steel is a highly tradable good, and Australia's steel industry faces competition from international producers, particularly in regions with lower production costs and environmental standards. This pressures Australian producers to invest in new technologies to remain competitive, which is challenging given the capital costs of new equipment and the need for significant facility and energy infrastructure upgrades.

Attention is shifting to the production of green iron and green steel in Australia. There are no agreed definitions of green iron or green steel, however in this report they refer to iron and steel produced using renewable energy. Shifting away from fossil fuels reduces greenhouse gas emissions compared to conventional production. Exceptional renewable energy resources in Australia make it ideal for the production of green hydrogen, which would need to be an input into the process. Green hydrogen is clean energy produced through the electrolysis of water powered by renewable energy inputs. Large-scale projects are under development that could supply onshore production of green iron.

Source of photo

1 Department of Industry, Science and Resources (2024) Resources and Energy Quarterly March 2024
2 McKinsey & Company, 2020, Decarbonization in steel
3 Australian Steel Institute (2021) Capabilities of the Australian steel industry to supply major projects in Australia
4 Australian Steel Institute - Reduce, Reuse and Recycle

GREEN STEEL FOR THE BUILT ENVIRONMENT

Circular opportunity

Making green iron ore and steel

Australia has two main iron ore resources: hematite and magnetite mineral ores. Hematite extraction is already well established in Australia and accounts for 96% of Australia's iron ore exports. While there are significant reserves of magnetite (37% of Australia's iron ore reserves), these are currently underutilised due to the preference and suitability of hematite for traditional steelmaking.[5]

However, magnetite is the current preferred global feedstock for green steel, which with current technology, can be processed into green iron and green steel through direct reduction iron (DRI) plants. This established technology accounts for about 10% of global iron production, but none in Australia. The key advantage of this technology is that it can be operated with lower-carbon or zero-carbon fuels such as green hydrogen, greatly reducing greenhouse gas emissions.

In Australia, the green hydrogen necessary to make the technology 'green' is not yet available at the required volumes. In the future, it is anticipated that hematite will also undergo DRI and be used to make green iron and green steel, however this will require an additional processing step of electric smelting furnace or ESF, which is not currently ready globally.

5 Geoscience Australia Iron Ore
6 Institute for Energy Economics and Financial Analysis (2023), Unlocking the potential of magnetite ore for Australia's iron and steel transition
7 RenewEconomy (2024) BHP to pilot green smelting furnace using electricity, hydrogen and pilbara iron ore

Case study: Magnetite's green potential
Magnetite is a type of iron ore found in Australia. Interest is growing in mining magnetite due to its potential to be turned into green iron and therefore green steel using existing technology. Fortescue Metals Group recently commenced magnetite extraction from the Iron Bridge mine in South Australia which could be converted into green iron at Liberty Steel's Whyalla facilities, whose blast furnace will be phased out to build a new direct reduction iron (DRI) facility.[6]

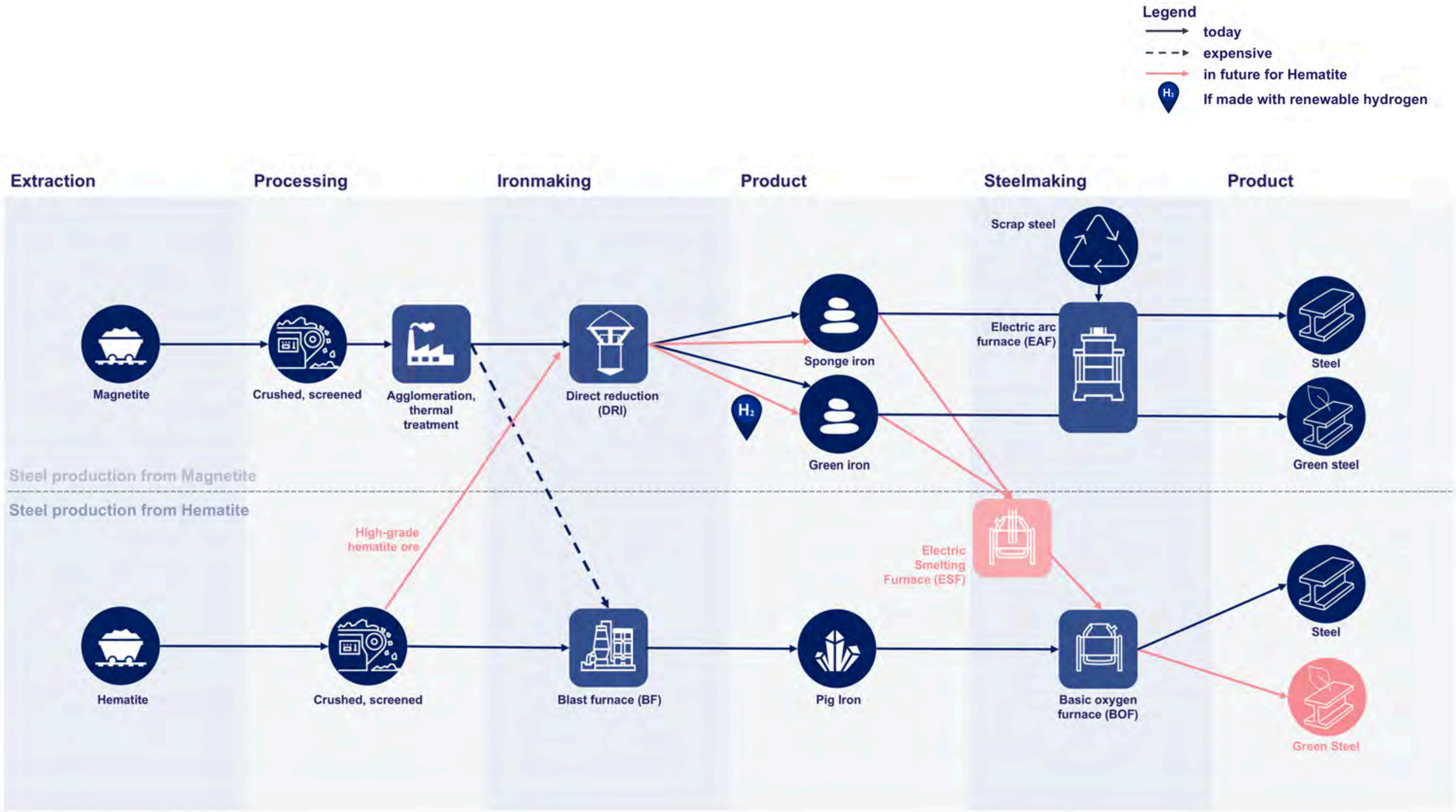
Case study: Circular steelmaking
New iron ore processing and ironmaking methods have the potential to enable the use of hematite in green iron production, further enhancing Australia's iron production opportunities. Companies such as BlueScope, Rio Tinto and BHP have partnered to investigate the potential of electric smelting furnace (ESF) technology. When combined with the established DRI and basic oxygen furnace (BOF) processes, this technology could support green steel production from hematite.[7]

Case study: 3D scanning
BridgeFab a Brisbane-based steel fabrication company implements 3D scanning technology to improve design accuracy and efficiency and to minimise waste.

Case study: Best practice collaboration
The Steel Sustainability Australia program engages the entire steel value chain to comply with best practice sustainable operations.

GREEN STEEL FOR THE BUILT ENVIRONMENT

Circular opportunity



GREEN STEEL FOR THE BUILT ENVIRONMENT

Lost value

Major sources of lost value in the Australian steel value chain

Steel to landfill
Recycling rates for steel are high, however around 500,000 tonnes of steel end up in landfill each year.[8] This is a notable loss in value in the steel value chain.

Unprocessed scrap metal export
More than a third of waste steel is exported overseas, leading to a loss of value that could be generated in Australia and increasing the risk for the environment if processed in countries with less rigorous environmental laws. Waste export bans for example on scrap vehicles, should be considered to prevent this loss.[9]

Quality degradation of recycled steel
Recycling steel impacts its quality and can result in a 20% reduction in economic value compared to virgin steel. This is due to contamination from impurities and contaminants such as copper during recycling which compromise steel's alloy composition and quality.[10] Improving recycling processes will be essential to recoup this lost value and ensure recycled steel is always suitable for high-grade applications.

Impact of greenhouse gas emissions
The scale of greenhouse gas emissions from the steel sector is such that this industry contributes materially to human-made climate change. The steel industry is responsible for 8% of global CO2 emissions.[11]

Energy intensity of recycling
Recycling of steel is an energy intensive process at 0.6 MWh/tonne of steel and requires collection, storage, transportation and manufacturing infrastructure.[12]

Environmental impact of iron ore extraction
The extraction of iron ore impacts the environment through habitat destruction, contamination of soil and water, and greenhouse gas emissions including from lost carbon sinks. Open-pit mining necessitates the removal of large areas of vegetation and topsoil to access underground ores. Ore mining and processing also requires large volumes of water, which can lead to water stress and contamination.[13] Mine tailings, which are the left-over materials from minor ore processing, can also present a risk to the environment. There are additional impacts related to auxiliary supporting infrastructure, such as roads, rail and labour accommodation.[13, 14]

Case study: AUD374 million lost value from unprocessed scrap exports
Modelling conducted by Australian Economic Advocacy Solutions indicates that the unprocessed steel scrap exports lead to a loss of AUD374 million to the Australian economy, as well as over 2000 jobs. According to the Australian Steel Institute's chief executive Mark Cain, "a ban on exports would free up an extra 800,000 tonnes of processed scrap to the domestic market", as well as decrease the Australian steel sector's emissions and protect the environment offshore. The Commonwealth's Recycling and Waste Reduction Act 2020 has export bans in place for unprocessed tyres, glass and plastic. By including unprocessed ferrous scrap metal in the export ban list it will be possible to keep value within Australia.[15]

Case study: Structural steel reuse
In Australia, the reuse of structural steel elements in situ within existing buildings has been demonstrated, however the reuse of steel recovered from existing structures and used in another project is less common. Globally there has been a growing demand for second-hand steel due to its opportunity to reduce the embodied carbon impact of a new development. In the UK the Steel Construction Institute have developed guidance on the assessment, testing and design principles for structural steel reuse, demonstrating the industry's progression in this area.

8 Australian Bureau of Statistics (2019) 4602055005_201819 Waste Account Australia, Experimental Estimates, 2018-19
9 National Waste and Recycling Industry Council (2023) Economic and Environment Benefits from an Australian Unprocessed Ferrous Scrap Metal Export Ban
10 Material Economics (2020) Preserving value in EU industrial materials - A value perspective on the use of steel, plastics, and aluminium
11 World Economic Forum (2023) Climate change is costing the world $16 million per hour
12 Metals (2024) Towards the Circularity of the EU Steel Industry
13 UK GBC - Iron Ore Embodied Impacts
14 Birat (2020) Society, Materials, and the Environment: The Case of Steel, Society, Materials, and the Environment: The Case of Steel
15 Australian Steel Institute (2023) ASI calls for ban on unprocessed ferrous scrap exports

GREEN STEEL FOR THE BUILT ENVIRONMENT

Future directions

Circular market approaches

A circular future for steel should be ‘green’ but it should also be efficient and focus on maintaining existing steel at its highest value. Design for disassembly should be common practice to expand on existing recycling success and enable greater reuse both in situ and between projects. This would be enabled by material passports and partnerships across the value chain. Opportunities include:

Green iron and steel production

Australia has both the largest reserves of iron ore and world-class renewable resources needed to produce large volumes of low-cost green hydrogen. Beyond satisfying internal demand for green steel there is opportunity to export a low-carbon commodity considerably more valuable than the initial raw material ore. In the context of global net zero carbon commitments, a low-carbon commodity has increased demand and value.

Efficient design strategies

Materially efficient structural designs reduce the total tonnage of steel required to achieve the same result in construction projects, reducing associated environmental impacts throughout the value chain.[16, 17] Additionally, fabrication technologies like additive manufacturing can reduce material waste and enable the production of more sustainable steel products.

Improved waste sorting

Improved sorting and recycling techniques, digital tracking systems and increased automation can enhance the efficiency and effectiveness of recycling. By limiting the presence of contaminants in the recycling waste stream it is possible to maintain the quality of the steel at its maximum value.

Design for disassembly and material passports

These strategies enable better traceability, separation, maintenance and end-of-use outcomes for steel. It should be noted that steel structure is typically cut out of a building near the joint into shorter lengths and therefore disassembly is not a precondition for reuse.

‘As a service’ business models

These models shift the focus from ownership to access. Instead of selling steel products outright, companies offer them as a service, where customers pay for use of the product over time. This model encourages manufacturers to design products that are durable, easy to maintain, reusable and recyclable, since owners keep the residual value of the asset and have responsibility over the product’s lifecycle. It also enables better tracking and management of products.

Value chain partnerships

Partnerships can include suppliers, recyclers, manufacturers and end-users working together to optimise the use of resources, improve recycling processes and develop new circular business models. By sharing knowledge and resources, value chain partnerships can support changes that benefit the whole industry, such as improving material traceability.

The scale of the green iron value chain

Unprecedented renewable energy generation will be required to allow the decarbonisation of the steel industry. To onshore the processing into green iron of 30% of current iron ore export would require the installation of additional 240 GW of wind and solar PV,[18] or four times the installed power generation in the National Electricity Market today. The opportunity would be equally impressive, with an export value of green iron estimated at AUD120 billion.

Take-back schemes and more reuse

Take-back schemes involve the collection of end-of-use steel products for reuse or recycling. Within these schemes, manufacturers can ensure that steel products are returned to the production cycle or are reused at maximum value.

16 Steel Australia (2024) Building Brisbane: BridgeFab sets the benchmark
17 BridgeFab
18 Based on 1.6 tonne of ore per tonne of steel, 50kgH2/tonne of steel; Hydrogen plant: 60 kWh/kgH2 efficiency, 60% utilization rate, 2.5 renewables/electrolyser capacities ratio; NEM capacity: 62 GW; $700/tonne green iron cost of production.

GREEN STEEL FOR THE BUILT ENVIRONMENT

Barriers

Future directions cannot be fully realised without tackling key barriers:

- **Increased logistics complexity:** Effective take-back schemes require collaboration between manufacturers, consumers, and recycling facilities to create a seamless process for collecting, sorting and testing of used steel products
- **Green hydrogen availability:** The availability of green hydrogen is crucial for the production of low-emission iron. However, producing green hydrogen at scale requires substantial investment in renewable energy infrastructure and electrolysis systems, and the cost of hydrogen is currently many times higher than conventional fuels, adding to the cost of the final green iron product.
- **Circular design awareness:** Circular design strategies for steel have limited awareness, guidance and uptake, though global standards are emerging.
- **High costs for industry transition:** Transitioning to more sustainable steel production methods, such as using hydrogen-DRI and EAF, requires substantial financial investment. The high costs associated with developing and implementing these technologies, coupled with the economies of scale required to make projects viable, pose significant challenges. Moreover, the economic viability of these technologies depends on the availability and cost of renewable energy and hydrogen, which are still developing sectors in Australia. This can slow down the transition process and delay the uptake of green iron and steel production.

Case Study: Electric Arc Furnaces

In Australia, InfraBuild Steel recycles waste steel into new products in electric arc furnaces (EAF). These facilities cover 20% of Australia's steel demand. InfraBuild Steel have developed and now produce Sense600, a higher-grade reinforcement steel produced from 100% recycled steel. By using this product, they claim that 16.7% less raw material can be used due to the higher strength. This product does require early engagement with design engineers to realise the potential savings in using reinforcement with a higher strength than 500N typically used.[19, 20]

Case Study: Blast furnace phase out

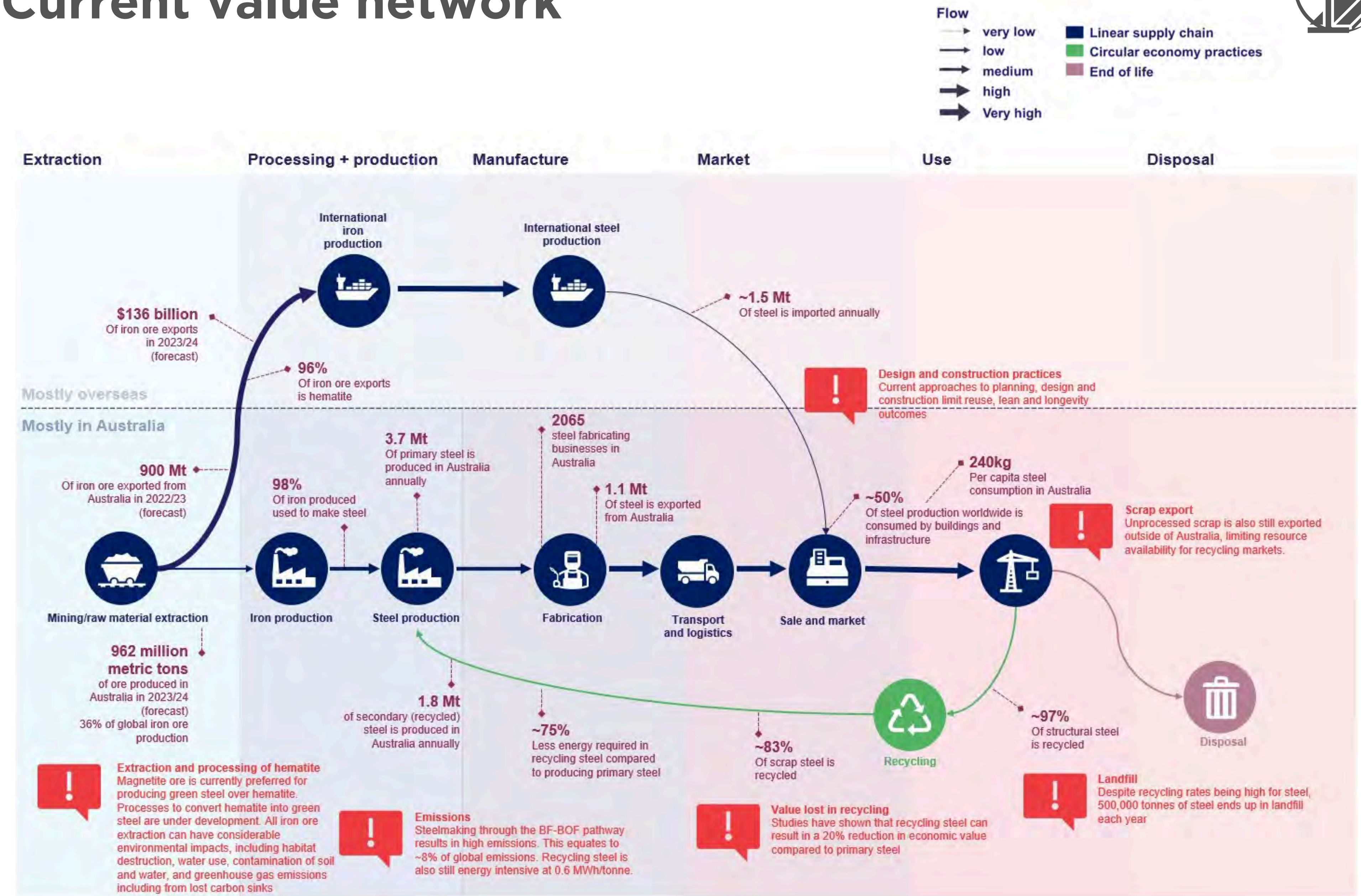
In 2023 Liberty Steel announced the phase out of coal-based steelmaking at the Whyalla plant, one of the two remaining blast furnaces in Australia. The conventional furnace will be initially replaced by an electric arc furnace system, fed by domestic steel scrap. Liberty Steel are also planning the installation of a 1.8 mtpa direct reduction iron (DRI) plant, which would process magnetite ore into iron. The DRI process will initially use a mix of natural gas and hydrogen, before transitioning to 100% green hydrogen. The development follows successful trials for upgrading Whyalla's magnetite pellets production to direct reduction grade.[21]

Source of photo

19 Meeting with Infrabuild, 17/09/2024
20 Sense600 by Infrabuild
21 Government of South Australia (2023) GFG to phase out coal-based steelmaking at Whyalla with $485 million investment

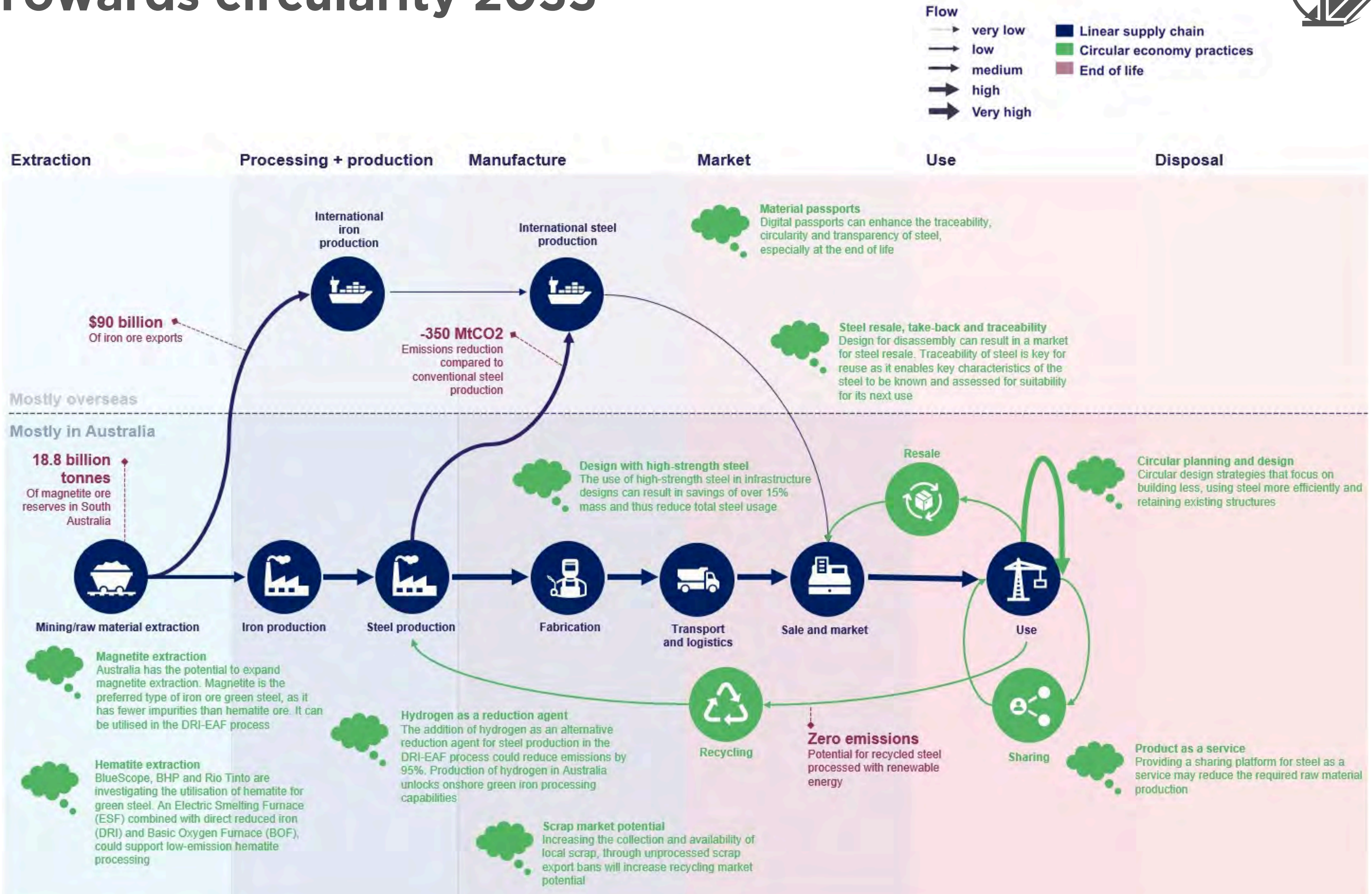
GREEN STEEL FOR THE BUILT ENVIRONMENT

Current value network



GREEN STEEL FOR THE BUILT ENVIRONMENT

Towards circularity 2035



CIRCULAR MARKET

Low carbon concrete

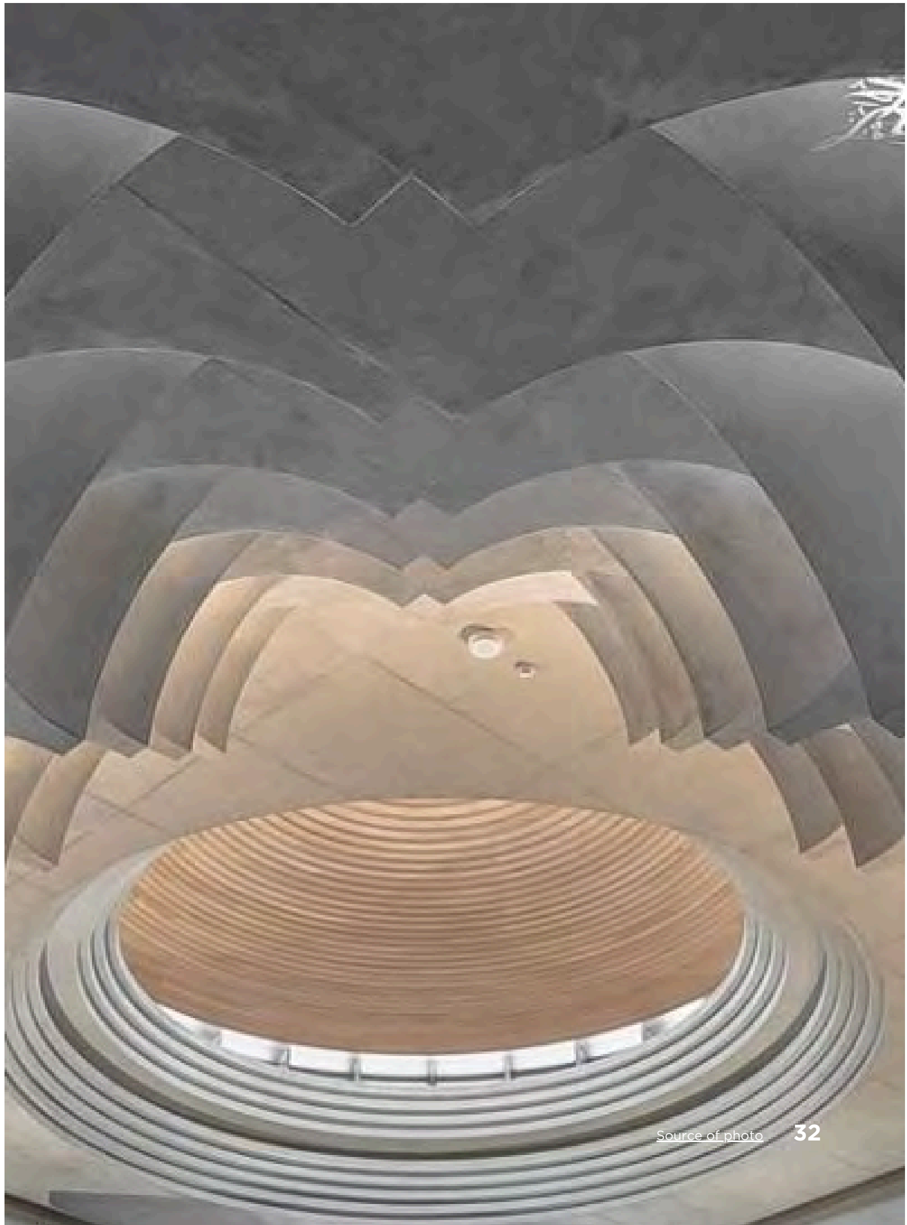
Concrete is the second most consumed substance in the world after water. In Australia, 40% of all concrete produced annually is used for infrastructure, 30% for housing, and 30% for commercial and other non-residential buildings.[1] The industry contributes AUD12 billion to the Australian economy annually and produces 9.8 million tonnes of cement, and around 29 million cubic metres of concrete.[2] Key challenges for the industry include the availability of raw materials, uncertainty over customer demand, standards, and emissions intensity of clinker.

Concrete is a material made from cement, crushed stone, gravel, sand and water. 150 million tonnes of rock, sand and gravel are extracted per year for the concrete industry in Australia and more than 2000 active quarries and five major cement plants contribute[3] to domestic supply.[2] As of 2021, Australia imports 0.57 million tonnes of cement per annum and produces 9.69 million tonnes.[3]

The versatility and durability of concrete make it valuable in modern construction with 29 million cubic metres of ready-mixed concrete produced annually in over 1,500 batching plants across Australia.[1] Concrete is used in vast volumes and with the demand for construction predicted to grow in Australia by almost 40% by 2050, the demand is growing. Low carbon mixes are becoming more readily available and are still emerging. Low carbon material options include increasing supplementary cementitious materials (SCMs) such as fly ash or blast furnace slag, geopolymer concrete, and calcined clay.

Low carbon concrete progress

The availability of key SCMs such as fly ash and blast furnace slag are reducing. Fly ash is captured ash from coal fired power stations. Blast furnace slag is collected from blast furnaces during the smelting process to create steel. Both SCMs can be used to decrease the carbon intensity of concrete. Most fly ash in Australia comes from power stations scheduled to be closed as part of Australia's energy transition in the next 15 years. Similarly, the smelting industry is transitioning to more efficient electric arc furnace processes which doesn't produce a slag suitable for use in concrete. To meet demand, Australia can rely on imported fly ash and other SCMs - calcined clay, lithium slag or dam/pond ash (dam stockpiles of old fly ash). Testing is required to demonstrate performance and update standards. Geopolymer concrete, which doesn't include cement, is a promising option to reduce carbon, however it is not yet available at scale due to limits of existing standards and specifications, value chain maturity, and costs of adoption.



Source of photo

1 VDZ (2021) Decarbonisation Pathways for the Australian Cement and Concrete Sector
2 Cement Concrete & Aggregates Australia (n.d.) Making Australia Strong
3 Cement Industry Federation (2023) Australian Clinker and Cement Production

LOW CARBON CONCRETE FOR THE BUILT ENVIRONMENT

Lost value

Major sources of lost value in the Australian concrete value chain

Environmental, economic and social impacts of greenhouse gas emissions

The emissions from concrete manufacturing account for 6-7% of global greenhouse gas emissions and 1% of Australia's overall emissions profile.[4]

Identifying where carbon emissions come from in the value chain reveals multiple opportunities to apply circular strategies for carbon reduction:

- 55% of the greenhouse gas emissions of the Australia cement and concrete sector originate from the calcination of limestone to produce clinker and are commonly referred to as 'process emissions'.
- 26% can be identified as fuel-based emissions mainly from heating the cement kiln.
- 12% are indirect emissions from electrical energy usage. Indirect emissions based on the transport of cement and concrete to the customer are estimated to be 7%.
- Australia imports 43% of clinker for the use in cement, creating additional emissions for the transport of the clinker.[4]

Slow uptake in low carbon options

Reducing the clinker content, also known as the clinker factor, of cement has the dual benefit of lowering both the embodied carbon emissions and the use of virgin materials, however uptake of these solutions is slow.

Short lifespans and reduced end-of-life outcomes

Short lifespans through premature demolition and limited recycling options hinder circular and carbon outcomes for concrete. At the end of life, concrete is often downcycled, being crushed for lower-value uses such as aggregate for road base. Around 15% ends up in landfill. Gate fees play a role in the quality of recycling that occurs by shaping the economic incentives for proper sorting, processing, and reuse of materials. When gate fees at landfills are high, they encourage the diversion of clean concrete waste toward recycling facilities, which improves the quality of recycled aggregates by reducing contamination and enabling efficient processing.

Source of photo

4 VDZ (2021) Decarbonisation Pathways for the Australian Cement and Concrete Sector

LOW CARBON CONCRETE FOR THE BUILT ENVIRONMENT

Future directions

Circular market approaches

A circular future for concrete will be part of a wider shift to a circular built environment where existing assets are retained, adapted and refurbished. Retention of concrete structure in situ for as long as possible is the optimal scenario at a building's end of life, reflected higher in the waste hierarchy than recycling.

Prioritising circularity alongside low-carbon

Considering circularity when choosing, promoting, researching and investing in low-carbon strategies is important for delivering long-term environmental and economic benefits. This must include examining the whole-of-life costs and impacts. Examining whole-of-life costs helps identify ways to reduce waste, reclaim materials, lower emissions, and ensure sustainable, cost-effective outcomes over time. For example, inclusion of plastics in concrete that use technical resources that may be difficult to separate and recover at end of may not represent a 'circular' solution. Whereas, incorporating remineralisation of concrete through injection of captured carbon dioxide, is both low-carbon and circular. This emerging technology requires demonstration at scale.

Increasing clean collection and recycling

Concrete can be crushed and used as aggregate for new concrete or downcycled into aggregate which can be used as aggregate in other applications such as road base. Incentives and disincentives are needed to ensure concrete waste remains clean and in better quality when it is received by recycling facilities, as this leads to superior recycled products.

Circular planning and design

Circular design strategies that focus on building less, using concrete efficiently and retaining existing structures create material, community and economic value, and are required for achievement of 2050 Net Zero goals.[5] Selecting the right concrete mix can also support this, for example utilising high strength lower volume options such as ultra-high-performance concrete. Precast concrete elements are often a more circular option than cast in situ due to standardised sizing, which is optimal for reuse at end of life.

Design for Disassembly

Designing concrete structures with flexibility in mind is crucial for ensuring a long lifespan. By designing for disassembly, concrete elements can be more easily recovered through incorporation of readily dismantled (potentially modular) components for repair, maintenance, reuse and recycling. Components retain more of their original value and functionality, reducing downcycling and waste.[6]

Material passports

Enhanced traceability of concrete could optimise material recovery and reuse. Concrete elements can be identified using a material passport - a digital dataset of key characteristics to give the item value for present use and future recovery. Material passports assist structured selective demolition by simplifying material identification. At recycling facilities, passports could inform recycling processes to maintain material quality. In concrete production, passports could provide information on the composition and properties of recycled aggregates, enabling the selection of eco-friendly mix designs and the tracking/verification of outcomes. This helps promote optimal mix designs that use less cement and incorporate recycled materials.

5 Watari, Cao, Hata & Nansai (2022) Efficient use of cement and concrete to reduce reliance on supply-side technologies for net-zero emissions. Nature Communications.
6 Salama (2017) Design of concrete buildings for disassembly: An explorative review. ScienceDirect.

LOW CARBON CONCRETE FOR THE BUILT ENVIRONMENT

Barriers

Future directions cannot be fully realised without tackling barriers:

- **Low carbon, circular policy:** Government purchasing power and policy drivers can drive the market demand.
- **Virgin material competition:** Virgin materials are often more affordable and accessible due to established, large-scale manufacturing processes and efficient value chains. In contrast, recovered materials face challenges with inconsistent supply, variable quality, and the need for process or facility adjustments.
- **Industry change:** Low carbon concrete alternatives often require different mixing and curing times and handing requirements. Increased industry awareness and training is necessary to drive adoption into workflow and programming.
- **Lack of harmonised standards:** Australia does not have a standardised approach to developing, testing, trialling and approving low and circular carbon concrete mixes.
- **A culture of innovation:** In parts of the concrete sector, reliance on traditional practices stifles adoption of new solutions which can hinder market investment needed to drive sustainable innovation.
- **Circular design awareness:** Circular design strategies for concrete have limited awareness, guidance and uptake, though global standards are emerging.
- **Sorting and recycling infrastructure:** Limited investment in and incentive for demonstration of high-quality sorting and recycling facilities for concrete.

Case Study: Government policy driving demand for alternative solutions
The Recycled First Policy and ecologiq program in Victoria was the first government policy to mandate the use of recycled and reused materials, before virgin materials, in all major transport infrastructure projects. This significantly drove the demand for recycled materials in core construction and led to widespread adoption. The success of the policy has also paved the way for the trialling and adoption of low carbon alternatives.[7]

Case Study: Fossil fuel free additives
Major Road Projects Victoria, Arup, University of Melbourne and Hanson Australia recently piloted the first use of calcined clay as a supplementary cementitious material, on the Mickleham Road Upgrade project. The innovative mix replaced 30% of the traditional cement binder with calcined clay, exceeding the target compressive strength requirements.[8]

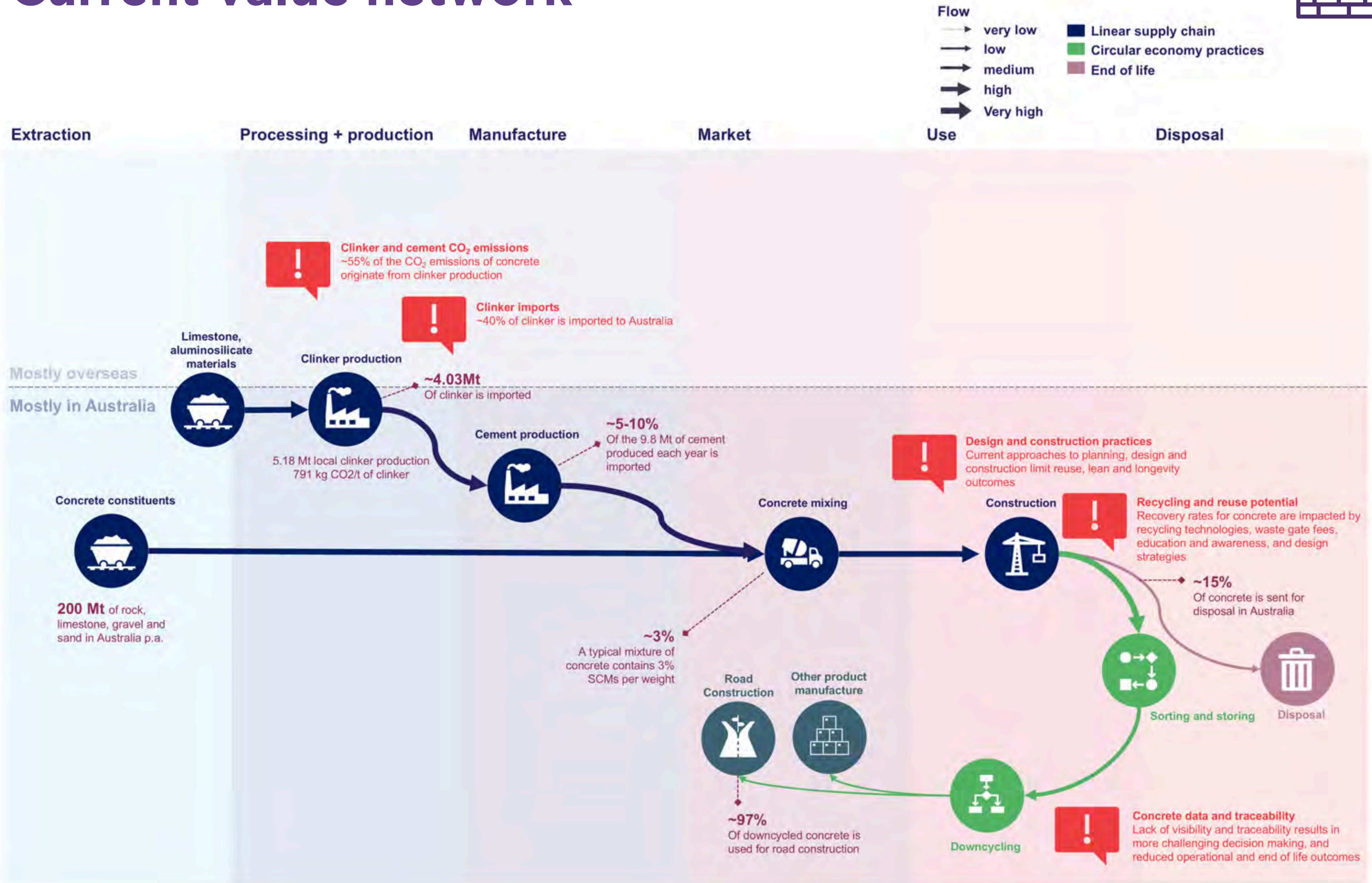
Case Study: Wagners Earth Friendly Concrete (ECF)
In Australia, Wagners pioneered the manufacture and use of geopolymer concrete in the build of their Wellcamp Airport. Geopolymer concrete is a sustainable alternative to traditional Portland cement concrete, using industrial by-products like fly ash and slag as binding agents, significantly reducing carbon emissions. Wagners used 30,000m3 of EFC in the airports taxiway, aprons and pavement areas. Geopolymer concrete offers up to 80% emissions reduction compared to Portland cement based concrete, increased durability with resistance to chemicals, shrinkage and cracking, alongside comparable mechanical properties.[9]

Case Study: Enhancing low carbon performance
Boral has developed proprietary ZEP® technology that allows for the production of concrete with good early-age strength, excellent drying shrinkage properties, and superior durability. The technology mitigates common issues associated with high cement replacement mixes, such as delayed setting times and reduced strength, making lower carbon concrete a viable option for a wide range of construction projects. Other concrete suppliers within Australia have also developed admixtures to enable high early age strength.[10]

7 Victorian Government (n.d.) Recycled First Policy
8 Victorian Government (2024) - Joint Project Develops Low-Carbon Concrete
9 Wagners (2021) The Australian Museum recognises Earth Friendly Concrete by Wagners as one of Australia's top climate solution technologies
10 Boral (n.d.) Lower Carbon Concrete

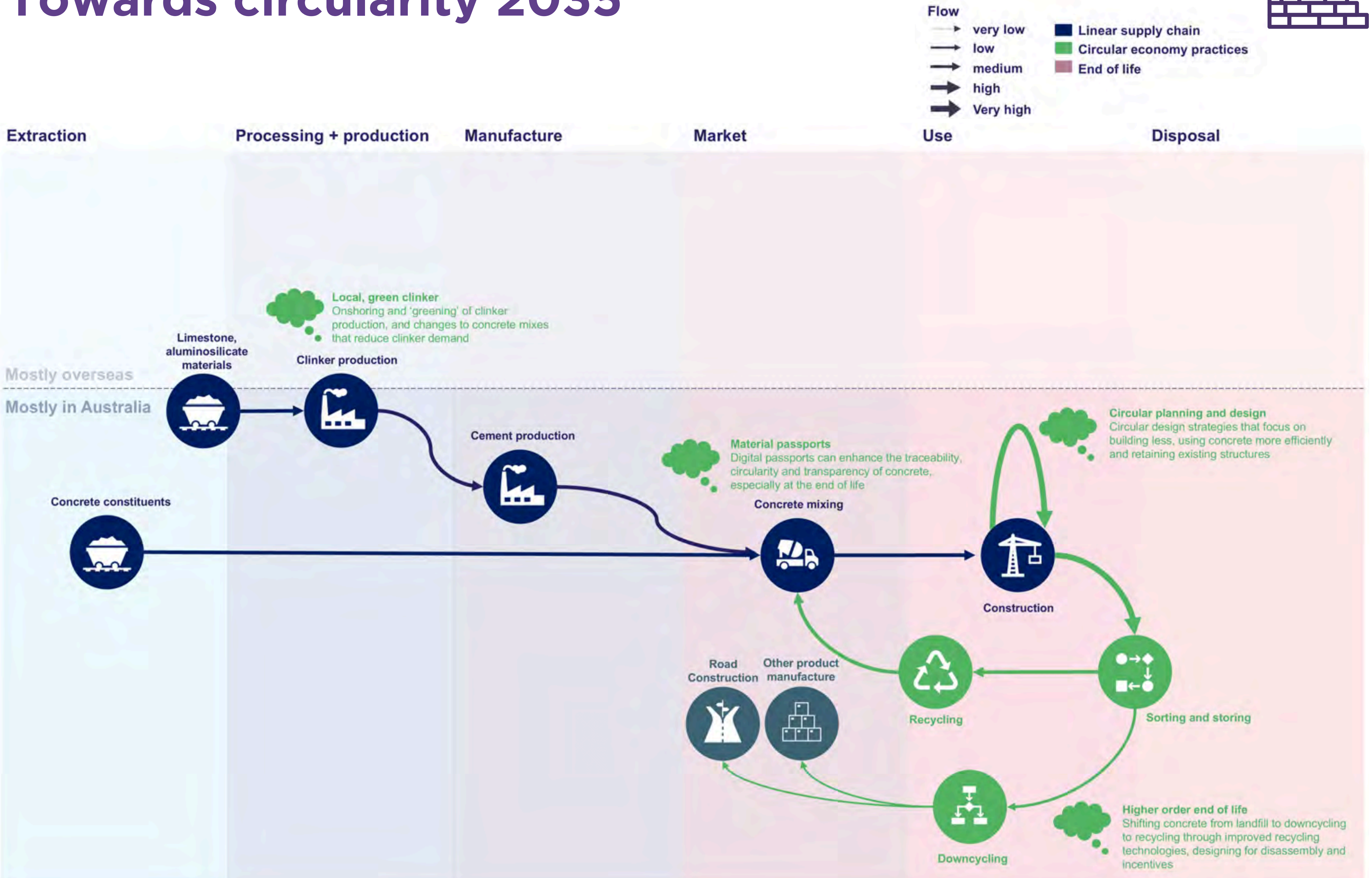
LOW CARBON CONCRETE FOR THE BUILT ENVIRONMENT

Current value network



LOW CARBON CONCRETE FOR THE BUILT ENVIRONMENT

Towards circularity 2035



TEXTILES FOR FASHION, UPHOLSTERY AND OTHER GOODS

Textiles

Australia is amongst the highest consumers of textiles in the world, especially fashion garments.[1] The average Australian purchases 56 brand new clothing items a year, pays ~AUD13 per item, and uses each seven times before it is discarded. The clothing and textiles industry contributed AUD27.2B to Australia's economy and 489,000 jobs in 2021,[2] with the largest share of jobs from the retail sector. On the supply side, Australia is a significant producer of wool, merino wool and cotton, however manufacture of textiles is limited. Key challenges for the value chain include quality, traceability, utilisation and end of life outcomes.

In Australia, textiles are used to manufacture a diverse range of products. 37% are garments, 17% manchester and homewares, 10% carpet, and 36% 'uncategorised' as they form parts of a complex range of products.[3] The fashion market is dominated by synthetic polymers, with polyester accounting for 52% of total fibre use in clothing. Cotton is the second highest fibre type used at 24%, and the remaining fibres consist of various natural and synthetic fibres.[4] The fashion industry is characterised by high turnover and small margins on many products, and Australian businesses can struggle to compete with imported products. There is also very limited visibility over the textile value chain which is largely based overseas.

Synthetic or natural?

There are trade-offs for both natural and synthetic fibres, and impacts such as high water use, land use, greenhouse gas emissions, recyclability, durability and nature need to be considered. For example, a polyester shirt has a greater carbon footprint than a cotton shirt (5.5kg vs 4.3kg CO_2-e).[5] On the other hand, cotton production requires 250-350kg water to produce 1kg of fabric, in comparison to polyester which requires 200-300kg.[6] The production of virgin fibre, regardless whether natural or synthetic, requires high water use, high land use (if natural) or extraction of natural resources, and heavily impacts biodiversity.

Source of photo

1 The Australian Institute (2024) The Seamless scheme and developing an Australian circular textiles industry
2 Australian Fashion Council (2022) Industry Modelling Report
3 DCCEEW and Blue Environment (2022) National Waste Report 2022
4 Australian Fashion Council (2022) National Clothing Product Stewardship Scheme – Clothing Data Report
5 World Resources Institute (2017) The Apparel Industry's Environmental Impact in 6 Graphics
6 Zhu, Chen, Liu, Chen, Zhang, Wang, X., Wang, L. (2022) Assessing baseline water footprints of natural fibre textile products in China

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Lost value

Major sources of lost value in the Australian textiles value chain

High turnover of low-quality garments.
Australia is a significant consumer of fashion by volume. The average Australian purchases 56 brand new clothing items a year, pays ~13 per item, and uses each seven times before it is discarded.[7] In the last 15 years, global clothing production has approximately doubled but clothing utilisation has decreased by almost 40%.[8] One 67 consequence is that 227,000 tonnes of clothing is discarded to landfill in Australia each year.[9] The fast fashion industry often produces inexpensive, non-durable clothing to meet consumer demand, with short turnarounds for new styles and trends. Recent investigations have also reported the presence of harmful chemicals (i.e. lead, PFAS, pthalates) in clothing sold from fast fashion giants.[10] The vast majority of clothing consumed in Australia is imported, with 97% coming from overseas, which limits the visibility, traceability and control of the impacts of these products.[11]

Microplastics
35% of microplastics released to oceans globally originate from washing synthetic textiles.[12] This release can cause developmental abnormalities and tissue damage in marine life, and accumulates through biomagnification, disrupting the marine ecosystem.[13]

Complexity of textile products and limited traceability
The yarn choice, product design and end-of-life sorting of products limit the ability to repair products and recover resources at their highest possible value. Combined fibres (mixes of fibres) are more difficult to recycle than mono-materials (made from a single fibre or material type). Separation processes are not mature enough to handle textiles comprised of a mix of fibre types, often including a combination of synthetic and natural fibres. However, some companies such as Blocktexx have developed technology which enables the recycling of textiles from mixed fabric compositions,[14] however these operations are not yet at a large scale. Fastenings, accessibility of collection points, consumer behaviour and an overall lack of design for disassembly strategies also limit the ability to sort and recover textiles. Limited traceability of products makes it challenging for consumers, retailers, recyclers and governments to make informed choices related to textile products.

Downcycling
In Australia, current sorting practices, waste facility technology and preferences to export textile waste limit opportunities to upcycle and retain value here and are also creating environmental impacts overseas. There is limited formal recycling capability for textiles in Australia, with only ~7,000 tonnes of clothing recycled annually, most of which is downcycled into other products. Recycled content in the production of textiles can also lead to downcycling from other streams. For example, recycled polyester is typically sourced from PET bottles, which may be diverting valuable resources from the PET value chain.

7 The Australian Institute (2024) The Seamless scheme and developing an Australian circular textiles industry
8 The Ellen Macarthur Foundation (2019) Fashion and the circular economy - deep dive
9 Australian Fashion Council (2022) National Clothing Product Stewardship Scheme – Clothing Data Report
10 Good On You (2024) Toxic chemicals in ultra fast fashion could be harming your health
11 Monash University (2024) Sustainable Shopping: We're asking the wrong question
12 Boucher, Friot (2017) Primary Microplastics in the Oceans: a Global Evaluation of Sources
13 Veerasingam (2022) Effects of Microplastics on Fish and in Human Health
14 Blocktexx

TEXTILES FOR FASHION, UPHOLSTERY AND OTHER GOODS

Future directions

A circular future for textiles will enable the purchase of fewer but higher quality items (e.g. greater durability, higher thread count, repairable) and items with greater recyclability potential (e.g. mono-materials, fewer fasteners). The life of products will be extended through repair, sharing and rental opportunities, and enhanced sorting, reuse and recycling will be supported by evolving technologies and behaviours. Key opportunities identified include:

New technology for waste textiles
New and improved technologies for sorting and processing textiles in Australia will support more quality garments being sorted and chosen for resale, while 'unwearables' and low-quality garments will be downcycled or recycled through textile-to-textile recycling, once appropriate technologies are available. Increasingly, this sorting can be completed by machines, reducing the reliance on consumer behaviours around sorting and collection.

'As a service' and rental business models
This could apply to all product types and includes resale, sharing and rental platforms. For garments, this is already occurring on a small-scale and makes up a small percentage of total clothing in use. Repair business models such as brand repair take-back programs, repair businesses such as seamstresses, tailors, shoemakers, and access to education and equipment such as sewing classes will extend the life of products. These repair options will be supported or even developed by brands and product developers themselves and enabled by the 'right to repair'.

Yarn and garment passports
Digital passports will enhance the traceability, circularity and transparency of the clothing industry by sharing information on product origin, production, specifications, care and end-of-use instructions. By 2030, all textile products sold in the EU will require a Digital Product Passport and Australia will need to align with this global shift.[15] Australian yarns could develop passports as a way to increase their appeal in international markets with a strong ESG focus.

Design for circularity, informed by lifecycle assessment
Design will be crucial in enabling quality and durability of clothing and textiles throughout its life, and ease of recyclability at end-of-use. Recycled, organic and renewable fibres will be prioritised where appropriate. Production of natural fibres in Australia will focus on practices that minimise impact to soil health, water, and biodiversity, especially for cotton and wool. Textile product designers and recyclers will communicate openly to create products that are more readily repaired, disassembled and recovered. This will include limiting the amount of non-fibre material in the design (i.e. zippers, buttons, accessories) and the use of mono-materials (single-fibre fabrics).

15 World Favor (2024) EU Digital Product Passport: What it means for the textile industry

TEXTILES FOR FASHION, UPHOLSTERY AND OTHER GOODS

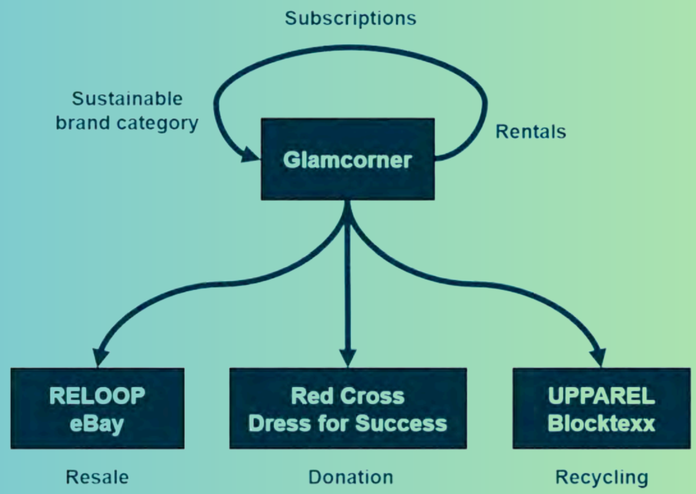
Barriers

Future directions cannot be fully realised without tackling key barriers:

- **Unclear direction:** Lack of incentive for brands to design for circularity and limited definition of what circularity outcomes would be targeted in Australia.
- **Consumer preferences:** Producers are responding to consumer behaviours, including a preference for lower price and trends, over quality.
- **Traceability:** Traceability and information available to consumers when they purchase products and at the end-of-use is limited.
- **Cost of services vs. products:** Costs of services such as repair and rentals do not create a significant incentive.
- **Sorting and recycling infrastructure:** Limited investment in and incentive for high quality sorting and recycling facilities.

Case Study: Technology improvements in sorting and recycling
Textiles2Textiles – a partnership of Wieland Textiles and Retail Experts – is an ambitious organisation based in Wormerveer, the Netherlands. Their Fibresort installations are paired with optical detection to sort post-consumer textiles into 45 categories based on their fiber composition, structure and color. They then aim to supply only to high-value recyclers to develop homogeneous, clean and traceable textile resources.[16]

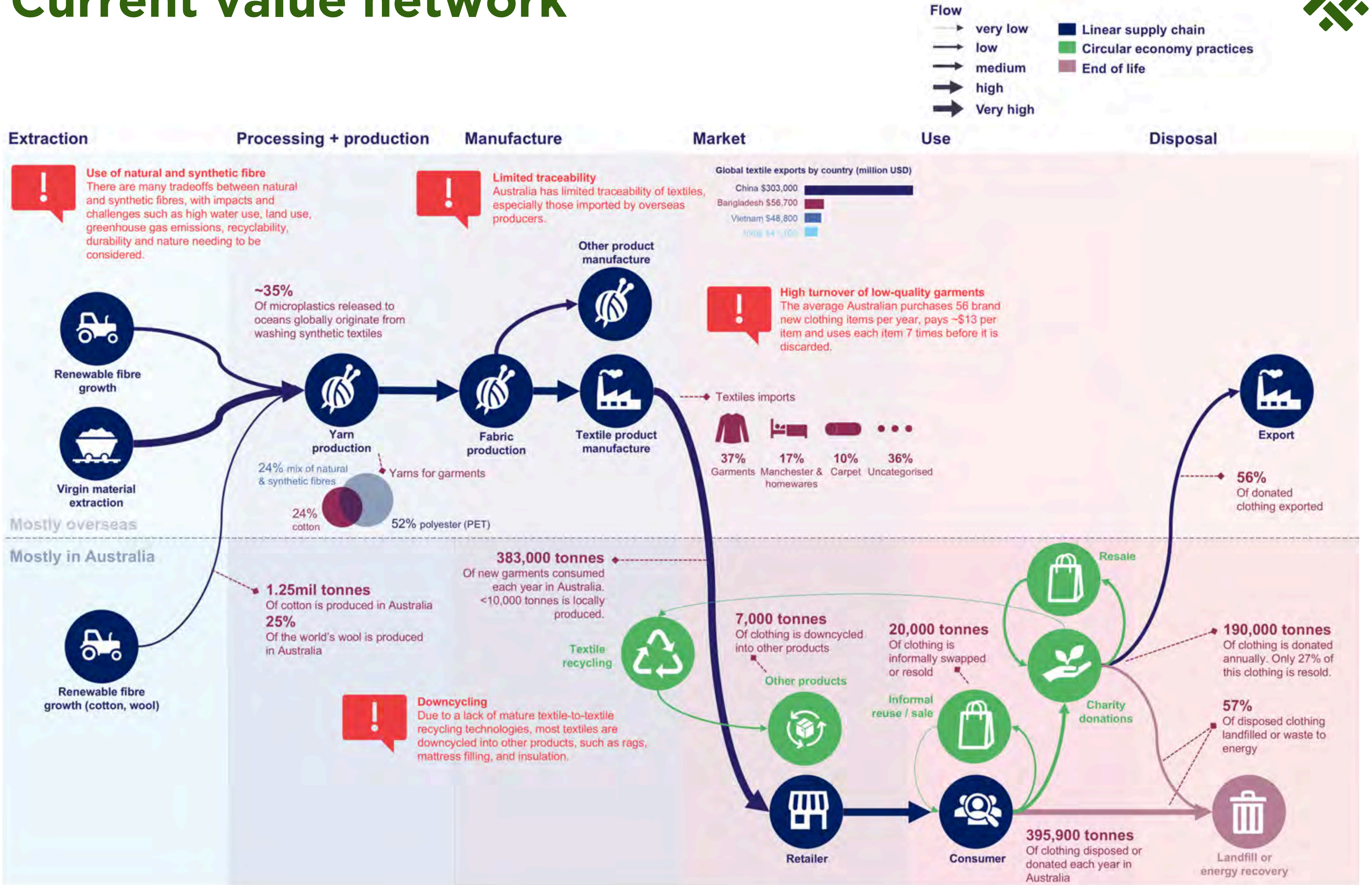
Case Study: Collaboration for higher order textile use
There are many examples of Australian businesses in the market collaborating to encourage higher-order reuse and recycling. For example, GlamCorner, an Australian online clothing rental platform, resells any clothing that is no longer in 'as new' condition to their sister company, REPLOOP, or eBay; or donates these items to one of their charity partners. If the items are not fit for re-use, GlamCorner has partnered with textile recyclers to use the clothing to create new yarn or shred for use in products, like insulation.[17]



16 FibreFarm
17 GlamCorner

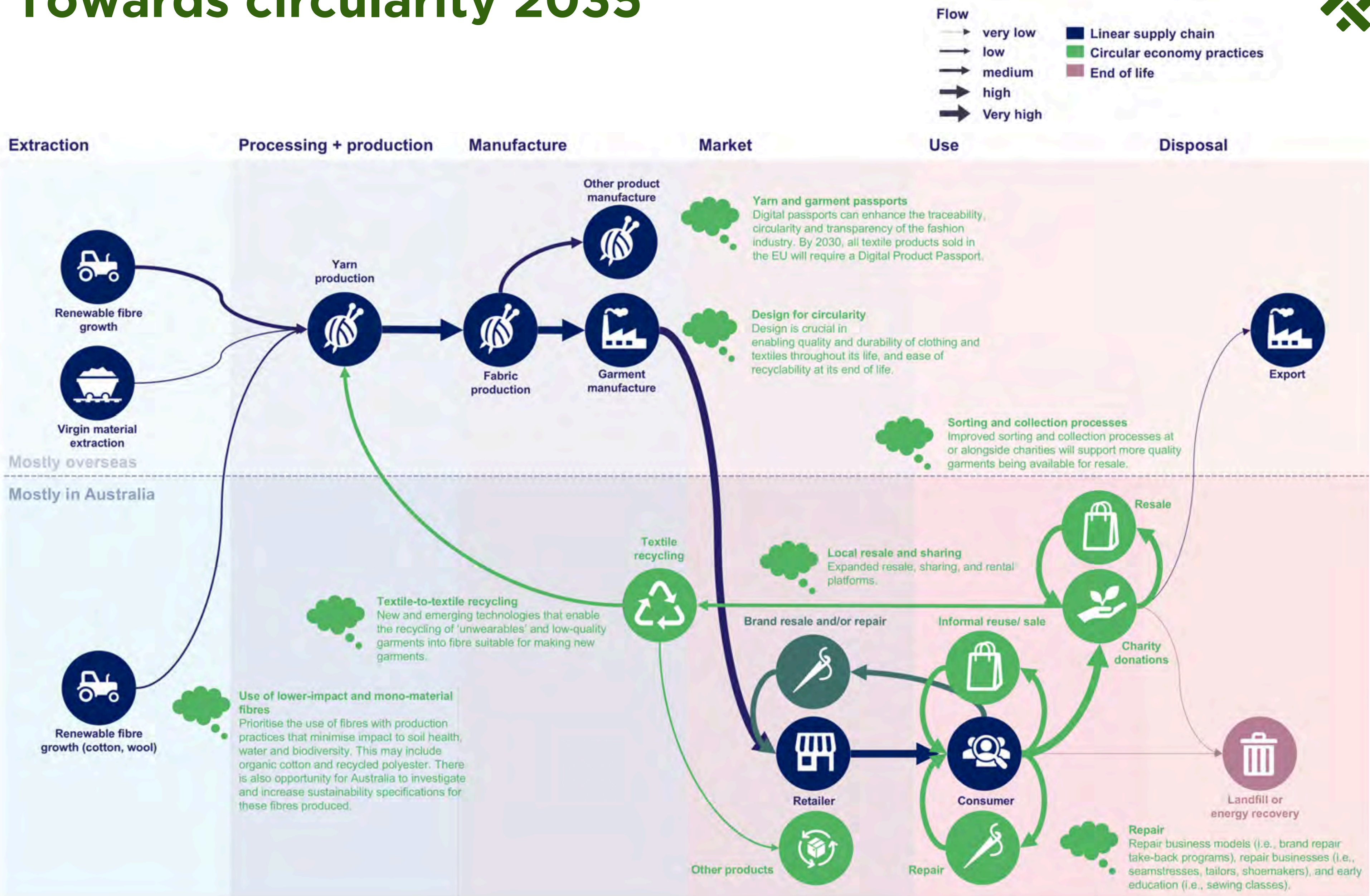
TEXTILES FOR FASHION, UPHOLSTERY AND OTHER GOODS

Current value network



TEXTILES FOR FASHION, UPHOLSTERY AND OTHER GOODS

Towards circularity 2035



Recommendations

The Australian Government has a critical role to play in incentivising desirable outcomes, restricting the negative ones and providing overall leadership and support to industry, communities, states, territories and local governments. State, territory and local governments have important roles to play in enabling the industries and communities within their jurisdiction. Ultimately, leadership, coordination and harmonisation across governments will be a critical success factor enabling industry to plan ahead and operate efficiently. Recommendations for collaboration across levels of government are outlined below. Together they indicate where investigation and experimentation is needed, with specific reference to the five case studies in this report - noting some actions are already underway.

1. **Incentivise desirable activities, services and materials, and discinsentivise the undesirable ones through fiscal interventions and eco-modulation:**

- Introduce discounts, tax reductions or other incentives for remanufacture and repair services for textiles and LIBs.
- Advocate for consistent approach to landfill bans for critical resources.
- Create incentives for textiles businesses and retailers to prioritise the reuse and resale of clothing, utilise organic materials e.g. organic cotton, recycled materials e.g. recycled fibre, and avoid harmful materials e.g. virgin fibre.
- Appropriately tax fast fashion or low-quality clothing *e.g. France is proposing a levy starting at AUD8 and to rise to 16 by 2030.*[1]
- Increase the gate fee for landfilling construction and demolition waste or reduce the gate fee further for recycling, and encourage contractors to adopt selective demolition techniques to enable high quality recycling. These techniques involve carefully dismantling structures and sorting materials at the source, and enabling cleaner and better quality recycled content products.

2. **Support and expand the scope of product stewardship to capture and increase accountability for system externalities within value chains:**

- Include EV batteries within the B-cycle scope and support the scheme to shift to eco-modulation.[2]
- Incentivise secondary markets for concrete and steel, and higher order circularity before recycling.
- For textiles, EPR systems should consider disincentivising new products containing harmful chemicals, support waste clean-up, recycled water use, and regeneration in communities most affected by textile waste pollution, and internalise the cost of waste management.
- Provide financial incentives for companies who participate in product stewardship schemes.

3. **Expand requirements and restrictions on imports and exports:**

- Consider further bans and/or reduction in the export of textile waste, rPET and scrap steel, and investigate the loss of steel currently exported mixed with waste plastics.
- Consider minimum requirements and/or tax adjustments for imported products. For example, LIBs for sale in Australia – covering materials e.g. recycled content, data e.g. product passports and design e.g. design for disassembly, aligning with EU regulation where possible.

4. **Provide Australians with the education, training, new skills and access to circular services needed to transition:**

- Support for nation-wide education initiatives such as textile repair workshops for the community or in schools or campaigns for container deposit schemes.
- Further expanding Container Deposit Depots or Reverse Vending machines considering suburbs that do not have convenient access to one yet, and locations with high traffic due to tourism or otherwise.

1 Financial review (2024) France has a plan to end fast fashion – now Australia does too
2 B-Cycle Resources

Recommendations

5 Leverage government investment in infrastructure to create policy that shifts behaviours of designers, suppliers and contractors:

- Develop circular planning, procurement, design and material requirements for renewable energy projects. Require whole-of-life carbon assessments, inclusion of circular procurement criteria, metrics such as material productivity or non-virgin content, and other measures. LIBs, steel and concrete would be part of these.
- Review Victoria's Recycled First policy and explore a national version that considers circular and low carbon strategies including but also beyond recycled content for major infrastructure.
- Introduce nationally-consistent requirements for tenderers for all infrastructure projects procured by government and a two-pass process in building and infrastructure commonwealth procurement to genuinely explore circular innovation before approaching the market, as highlighted in the CEMAG Interim Report (2024).[3]
- Continue to invest in public, active, shared and service-based transport solutions, and enable Australians to reduce their dependence on private vehicles.

6 Lead and coordinate across states and territories on strategic directions for individual materials and products, including through any potential National Circular Economy Framework and national targets and indictors:

- Set national strategic direction for materials for beverage containers. Identify where and when aluminium cans could and should be adopted, and set the policy levers to enable this.
- The development of increased domestic advanced recycling capacity and bottle manufacturing capacity must be aligned and harmonised nationally to prevent overcapitalisation and scaling issues. Government and private incentives should align to allow concurrent development of capacity to reduce overall system costs.
- Harmonise concrete standards specifications across all states and territorites to optimise potential for scale of low carbon circular concrete.

7 Invest in targeted nodes of the value chain and provide funding to support greater connections between these nodes.

- Promote and invest in the refining of lithium including lithium hydroxide and lithium carbonate, processing of anode and cathode materials, cell production and pack assembly capability on-shore.
- Ongoing development of LIB recycling technology to improve recycling processes is required as recycling techniques provide metal feedstocks that are currently not price-competitive with virgin processed ores.
- Invest nationally in textiles sorting and recycling polyester, cotton, and mixed fibre compositions.
- Invest in advanced recycling technologies to support the local rPET reprocessing value chain and reduce the reliance on imported virgin PET resin in the future.
- Continue to implement recommendations of the Productivity Commission Inquiry Report on Right to Repair (2021),[4] especially where actions are relevant to product labelling schemes and reuse.

8 Enable standardisation and traceability, including through data availability.

- Fund the creation and publication of data on materials and waste including but beyond global warming potential, that enable better decision-making on material selection, design and end-of-use for Australian companies.
- Develop a national approach on material and product passports, as well as eco-labelling, including for textiles, LIBs, concrete and steel products.
- Encourage voluntary sustainability reporting on the materials-focused aspects of AASB S1.[5]
- Adopt, develop and endorse circular design standards for the built environment and consumer products, and require industry to respond to these through increasing mandatory elements over time.

3 Circular Economy Ministerial Advisory Group (2024) Interim Report
4 Productivity Commission (2021) Right to Repair Inquiry Report
5 Australian Accounting Standards Board (2024) Australian Sustainability Reporting Standard S1

Acknowledgements

Circular Australia has built a national network of committed experts and organisations working to transition Australia to a circular economy by 2030. Circular Australia's Industry Taskforce committed to deliver this research, leveraging the extended network of experts available through its members to activate new circular markets. Collaboration and co-design between industry, government and research is the way to create a circular pathway for Australia. The circular economy is a systems transition - not one business or sector can make the transition on its own.

Arup researchers and peer reviewers

Leanne Griffin, Circular Economy Services Leader
Joyanne Manning, Resources Business Leader
Adrian Doyle, Senior Consultant
Emily Gentilini, Senior Engineer
Gian Marco Gentilini, Senior Engineer
Samantha Choy, Engineer
Lachlan Johnston, Engineer
Amy Smith, Senior Consultant
Lauren Howe, Senior Engineer
Henry Moore, Waste Strategy Leader
Emily Brown, Senior Librarian
Sarah Schatz, Consultant

Circular Australia contributors

Lisa McLean, CEO
Louella Carr, Communications Engagement Manager
Industry Taskforce Members
Special contribution Bronwyn Voyce, Founder, Civic Futures Lab

Interviewees

Australian Beverages Council
Australian Retailers Association
Australian Steel Institute
BlockTexx
Boral
BC Consulting
Centre for Technology in Water and Wastewater, UTS
City of Sydney
Cleanaway, Circular Plastics Australia
Coca-Cola Europacific Partners Australia
Forward Thinking Designs
Infrabuild
The Iconic
Koskela
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School of Health and Social Development, Deakin University
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Sustainable Health and Environment Network, Deakin University
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Woolworths
workbenchX
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