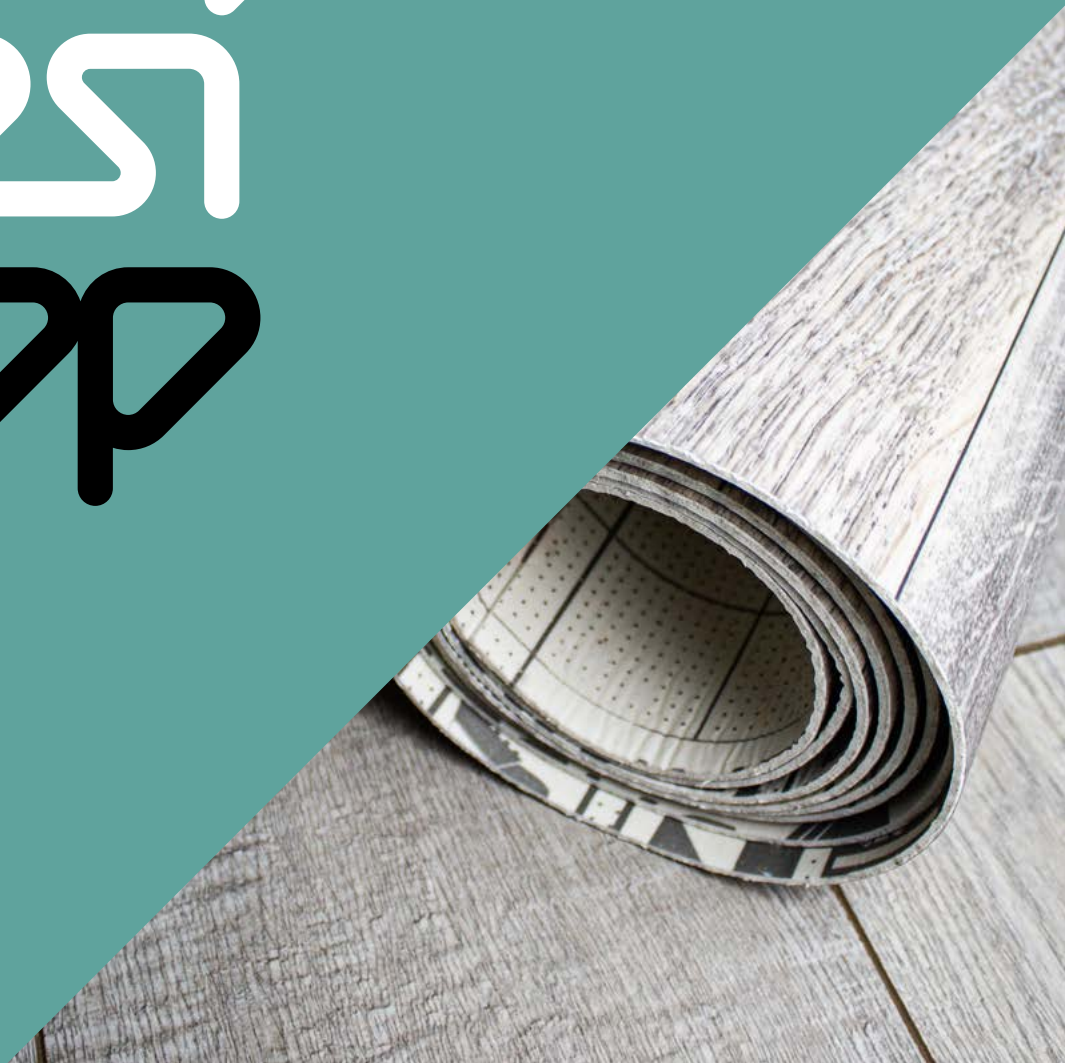
ARFA
AUSTRALIAN RESILIENT FLOORING ASSOCIATION

Resí loop



PART 1:
THE RESILOOP PROJECT

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THE RESILOOP PROJECT AND DESIGN OF A NATIONAL PRODUCT STEWARDSHIP SCHEME

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ARFA received $1 million funding from the Australian Government's Product Stewardship Innovation Fund (PSIF) in 2022–23 to undertake the research and design of a national industry-supported product stewardship scheme.

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EXECUTIVE SUMMARY

The resilient floorcovering market in Australia has grown steadily over the last two decades, driven by innovative design, development and uptake of new products, particularly Luxury Vinyl Tiles (LVT) and more recently, Hybrid or rigid core products.

Australia today consumes an estimated 22 million sqm or 95,000 tonnes of these products a year. Nevertheless, there is growing recognition that a resilient industry is one that meets it social licence to operate — that is, it meets the long-term approval of its stakeholders. Members of the Australian Resilient Flooring Association (ARFA) recognise this necessitates addressing expectations of delivering on not just product functionality and aesthetics, but also sustainability performance, including facilitating a circular economy.

Resilient floorcoverings are made from natural mineral fillers combined with materials such as vinyl, linoleum or rubber that give the product some elasticity. This lends the product a degree of flexibility and/or cushioning, delivering floors that are comfortable to stand and walk on, are durable and have acoustic benefits. Used in forms such as tiles, sheet and planks, they are suitable in both residential and commercial settings — from kitchens, living rooms and bathrooms to healthcare, schools, retail, offices and sports facilities.

ARFA, formed over 30 years ago, is an industry association that acts as the collective voice for companies in the sector. The association engages in advocacy, standards development, skills training, industry sustainability and market data collation. Since 2020–21, the agreed focus of its sustainability strategy has been to support development of a pathway to a circular economy for members' products in Australia.

Advancing a circular economy for resilient flooring products means not only improving how we source raw materials and manufacture the products — aspects well covered by third party ecolabel schemes such as Best Practice PVC, Global Green Tag and GECA — it also means retaining resources in productive use for as long as possible. This means improving upfront product design to enable long service life, repairability, reuse or repurposing, and ultimately, recyclability. It is about moving away from a linear "take, make, waste" approach in industry to thinking about — and taking responsibility for — a wholistic, circular system where 'waste' is virtually designed out and parties along the supply chain collaborate to retain resources in use, reduce environmental footprint and optimise value.

> ***We recognise that a product stewardship approach to improve recovery and recycling of our sector's products is just one step — albeit an important one — in the transition to a circular economy.***

A number of ARFA's members have developed company-based initiatives to take-back installation waste or flooring at end of first use for recycling. However, there has been growing recognition that whilst these are important steps in diverting waste from landfill, to achieve scale requires greater industry collaboration and investment in infrastructure in Australia. We need to develop and build capacity and capability here to aggregate compatible material across brands, reprocess it and reuse it in new, locally made, durable, valued products.

The Australian Government meanwhile has sought to implement policies to design out waste and pollution, keep materials in use and foster markets to achieve a circular economy by 2030. This has included policies to stimulate research and investment to expand Australia's capacity to sort, process and remanufacture key recycled materials as well as regulations to restrict certain waste exports.

To advance its sustainability strategy, in early 2022, ARFA was fortunate to be awarded a $1 million grant from the Australian Government through the National Product Stewardship Investment Fund (NPSIF) to develop a product stewardship scheme for resilient flooring.

This report is Part I in a series of three reports. It outlines the process, data analysis, research and field trials undertaken in the 12-month project timeline to inform the design and development of a national waste recovery and recycling scheme for resilient flooring materials

Data suggests there are up to 60,000 tonnes of material from the resilient flooring sector ending up in landfill, although this is equivalent to only 1% of Building & Demolition waste currently being sent to landfill.

From research of existing initiatives and technologies, it is evident that collection and reprocessing of resilient flooring products is feasible and technically possible. However, challenges remain in developing economically effective systems of collection due to:

- the diverse range of product forms and compositions
- the age of end of life products
- the wide geographic and use dispersal
- entrenched practices in the floor trade regarding laying, uplift and disposal
- a small number of suitable recycling plants in Australia
- lack of local manufacturing of floorcoverings and other products using similar material compositions.

Industry surveys and trials as well as stakeholder consultation completed as components of this project indicate there is broad interest from parts of the industry value chain to address the waste stream. Field trials demonstrated the feasibility of collecting installation waste with minimal contamination, sorted at source by product type. Recycling trials, however, showed that while the materials can be readily granulated, producing suitable quality, pelletised material is likely to require blending with virgin raw materials.

Reprocessing the recyclate into new end products remains a work in progress and a collection scheme cannot commence without known end markets. Extrusion trials to produce flooring accessory products need further fine-tuning and trials to develop higher volume, durable product concepts, such as new building profiles, require upscaling from lab trials and commercialisation. The industry recognises the importance of local innovation and the scheme business model intends investment in this area.

Part 2 of our series of ResiLoop reports describes the proposed product stewardship scheme design and funding model developed as a result of the work so far, while Part 3 sets out a roadmap to transition from the proposed design to operationalisation of a scheme in Australia.

ARFA believes that ResiLoop, by engaging manufacturers, distributors, specifiers, flooring contractors, recyclers and consumers, will succeed in influencing sector-wide behaviour changes to advance a circularity mindset.

PART 1: RESILOOP – THE PROJECT

About ARFA

The Australian Resilient Flooring Association (ARFA), formed over 30 years ago, is an industry association that acts as the collective voice for companies in the resilient flooring sector to advance and protect the interests of the industry in Australia. Its members represent leading companies and global brands that manufacture, import and/or distribute resilient flooring to the Australian market as well as allied businesses in the sector.

ARFA's strategy has been focused on supporting development of suitable skills training initiatives for the sector, industry data collation, advocacy, standards development and advancing sustainability of the sector.

Its sustainability strategy includes three key elements: education of the industry, improving transparency and developing the pathway to a circular economy for resilient flooring in Australia. To further this aim, ARFA initiated 'ResiLoop', a project to research, design and plan a national product stewardship scheme for resilient flooring products.

In late March 2022, ARFA received a grant from the Australian Government's National Product Stewardship Investment Fund (NPSIF) to kickstart the ResiLoop initiative. The allocation of this funding was based on ARFA's unique position as the leading industry association for the sector and the proposed project plan.

About the ResiLoop Project

Funded by the NPSIF, the ResiLoop initiative commenced in May 2022. The goal of ResiLoop is to improve the design, recovery, reuse and recycling of resilient flooring consumed in Australia by developing a business case, supported by proof of concept, for a national product stewardship scheme for resilient floorcoverings, together with a roadmap for the roll-out of the scheme in Australia.

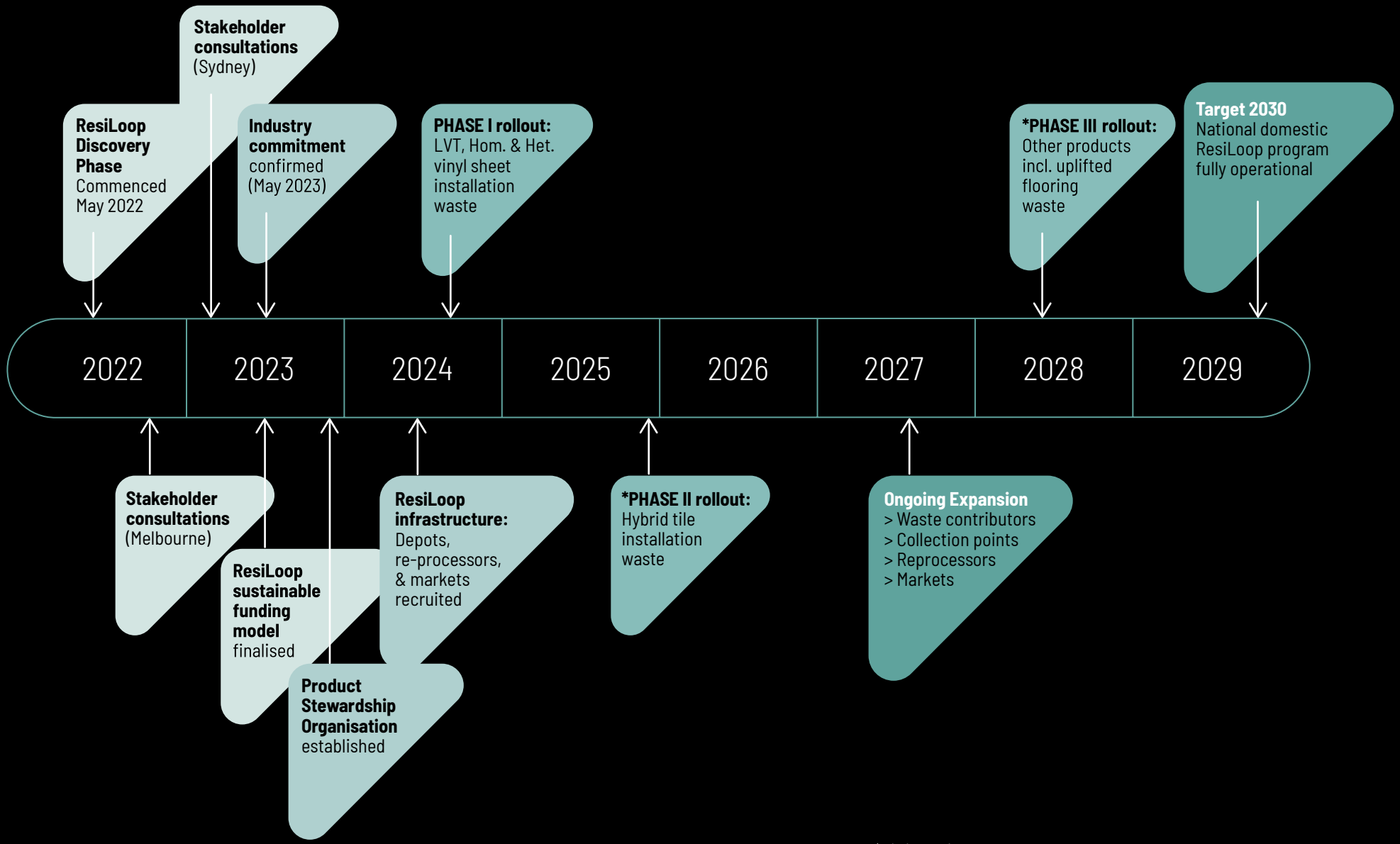
ARFA believes ResiLoop will drive sector-wide behaviour changes to advance practical product circularity by engaging manufacturers, distributors, specifiers, flooring contractors, retailers, recyclers and consumers.

The intended outcomes of the grant were:

- The establishment of a steering group with comprehensive supply chain representation;
- The development of a business case, supported by a proof of concept, for a national product stewardship scheme for resilient floor coverings. This includes a scheme design incorporating waste recovery logistics, feedstock demand and product uses and material flow analysis;
- The completion of field trials of a product stewardship scheme for resilient flooring products;
- The development of a roadmap detailing national roll-out of a scheme for resilient floor coverings including funding options.

Funding was contingent on regular progress reports demonstrating ResiLoop's progression towards the intended outcomes.

Figure 1: Overarching timeline of ResiLoop



* Timing subject to further research and development

About Resilient Flooring

Resilient flooring (or floorcoverings) refers to floorcoverings made from materials with some elasticity. This covers a range of products with varying compositions, including Luxury Vinyl Tiles (LVT), sheet vinyl, linoleum/marmoleum, rubber, safety sheet flooring, and hybrid/rigid core tiles. Resilient flooring is highly durable as a floorcovering and may be suitable for use in high-humidity locations such as bathrooms.

An estimated 22 million square metres of resilient floorcoverings are sold into the Australian market annually, equivalent to approximately 95,000 tonnes. The products are used across both commercial and residential sectors, including offices, hotels, healthcare facilities, educational institutions, sports facilities, supermarkets, retail shops and housing.

With a potential use life span of 30 years, there are two main points of waste generation:

- At the point of installation, when new product is being laid and off-cut/trim waste is generated in the laying process. Leftover materials referred to as roll-ends (sheet) and batch or stock ends (tiles) may also enter the waste stream. This material is considered to have minimal contamination from adhesives, sub-floors or legacy additives[1].
- At the point of uplifting flooring for replacement or demolition, where the uplifted floorcovering may be as much as 30 years old, giving rise to the potential it contains legacy additives. This is considered post-consumer waste and is likely to be contaminated with adhesives and sub-floor residues.

1 Some substances once considered acceptable in engineering polymers to provide advanced product functionality and properties have undergone greater scrutiny and may no longer be considered suitable for use in today's products based on environmental and health risk and safety factors. These are known as 'legacy additives' and are today regulated and restricted in use under domestic or international regulations. Refer to page 38 for further discussion.

Industry Overview

The resilient flooring sector in Australia has grown strongly over recent years with increased demand for durable, affordable, low-maintenance flooring options in both commercial and residential settings.

Most resilient flooring used in Australia is manufactured overseas, with only one local manufacturer whose factory is based in Victoria. This adds to the complexity of the recycling challenge: there is a limited manufacturing base onshore to take recyclate feedstocks for manufacturing into new resilient flooring.

The distribution segment of the industry is thus primarily importers. There are a number of global resilient floorcovering brands with onshore sales and distribution networks to supply the commercial and residential building and construction sectors. There are also direct importers to the market (no onshore base) and some 'big-box' retail chains, such as Bunnings, that supply imported resilient products to market.

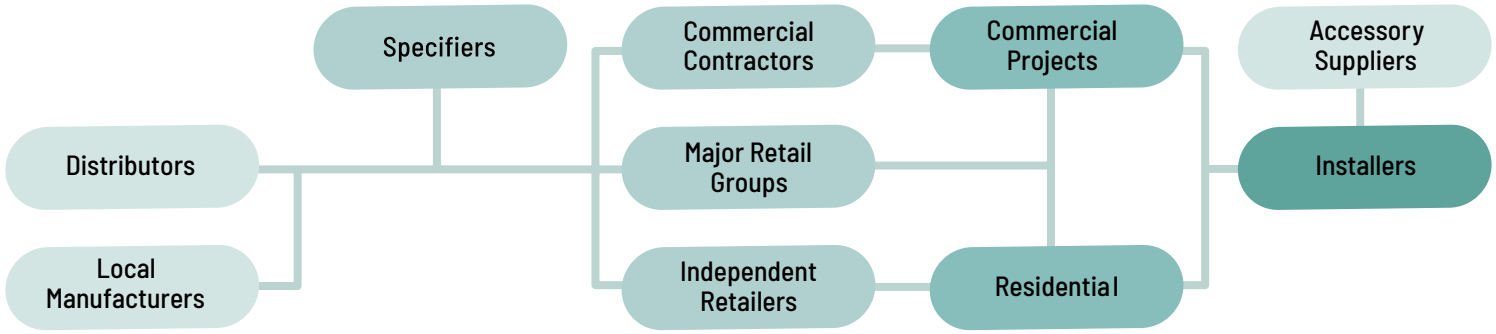
Floorcovering retailers play a crucial role in the resilient flooring industry, as they are the primary point of contact for residential end-users. Retailers in Australia include national chains, including large franchise groups, as well as smaller, independent retailers.

Commercial contractors are a key part of the supply chain, connected to specifiers, suppliers, installers and project managers. There is a large number of commercial contractors in each state, although ranging in size in terms of square metres laid per annum. Large contractors may lay 80,000 to over 100,000 sqm of resilient flooring a year.

Installation is the penultimate stage of the resilient flooring value chain, before the end consumer. It is carried out by the flooring technician trade. These sub-contractors are responsible for installing resilient flooring products in a range of commercial and residential settings, including hospitals, schools, offices, and homes. It is estimated that there are between 7,500 and 9,500 installers operating across Australia; however, it is an aging workforce with an attrition rate of about 1,000 per year and a shortage of apprentices entering the trade[2].

Accessory suppliers specialise in the supply of products, materials and equipment for trades to install or uplift floorcoverings. These businesses have depots around the country engaging directly with installers and contractors, supplying trims, adhesives, floor preparation materials and tools for resilient flooring.

Figure 2: Key parts of the value chain for resilient flooring in Australia



2 Source: Floor Covering Institute of Australia

Problem Statement

Resilient floorcoverings are durable, long-life products of widespread, growing use in buildings, made of a variety of materials and compositions. The installation of these products generates offcut or trimming waste and at the end of their use, they are uplifted and disposed. The recovery rate for recycling is very low and as there is limited resilient flooring manufacturing in Australia, there are virtually no existing markets for the recovered materials in this country. Small volumes of recovered waste have been sent to floorcovering manufacturers overseas for several years, however the export of plastic wastes is now difficult under the Government's 2021 Recycling and Waste Reduction (Export–Waste Plastics) Rules.

Recent Material Flow Analysis modelling[3] estimates annual consumption of vinyl resilient flooring in Australia to be 22.3 million square metres, or approximately 95,000 tonnes.[4] Although the products have lifespans of as much as 20 to 30 years, using a 15-year average life span, it is estimated that there is around 256 million square metres or just over 1 million tonnes of vinyl flooring currently in use. The modelling predicts around 5 percent of total flooring currently in use will reach its end of life annually; in the case of vinyl flooring, this means an estimated 48,000 tonnes of waste will be generated per annum.

Off-cuts generated by the installation of new floorcoverings results in an estimated 6–9,000 tonnes of 'clean' waste material annually. Less than 200 tonnes per annum of this waste is currently diverted from landfill.

Australia's National Waste Report 2022[5] estimated that around 5 million tonnes of Building and Demolition waste went to landfill in 2021–22. According to our data, the waste generated from vinyl resilient flooring (approximately 57,000 tonnes per annum) constitutes roughly 1 percent of this.

CONSUMPTION (2020)	22.3M SQM PA	95,000 tonnes PA
CURRENTLY IN USE	256M SQM	1 million tonnes
WASTE	5 percent of products in use 6,000 tpa off-cuts waste 60,000 tpa total waste generated	

An industry survey recently conducted under the ResiLoop project suggests that about 40 percent of flooring waste is left at the point of generation on construction and building refurbishment sites, while around 60 percent is removed by contractors and returned to contractor/retailer depots for disposal or dropped off at waste collection sites. Our aim is to divert increasing proportions of these wastes from co-mingled Construction & Demolition and Commercial & Industrial waste streams.

However, there is no adequate infrastructure in Australia at present to collect, sort and reprocess this waste material and virtually no applications identified for remanufacturing or reuse of the material at scale. There is a lack of data on the current management or condition of the waste generated, its composition by product type and materials, and the routes of recovery and disposal. Nevertheless, there are some initiatives overseas by individual companies and collective efforts of the sector to recover and recycle resilient flooring products, while some take-back schemes for other products currently operate in Australia. The European Resilient Flooring Manufacturers Institute claims that ERFMI members recycled more than 130,000 tonnes of vinyl flooring in 2019.

In Australia, we need to investigate and understand:

- The condition of resilient flooring waste and its suitability for recycling
- The type of recoverable and recyclable waste (by product type and composition)
- The stakeholders engaged in removal of end-of-use flooring and construction waste
- The technology options for reprocessing the waste into a valued recyclate
- The potential end markets for the recyclate

3 Material Flow Analysis has not been conducted for non-vinyl resilient floorcoverings. The consumption of non-vinyl coverings is considered to be much lower at less than 6 percent of the total market.

4 PVC Material Flow Analysis 2021 Blue Environment Pty Ltd, for Vinyl Council of Australia

5 The Department of Climate Change, Energy, the Environment and Water; Blue Environment Pty Ltd

Rationale for an Industry-Supported Product Stewardship Approach

At ARFA, we define product stewardship as a **shared responsibility across the supply chain** to minimise the impact of resilient floorcoverings throughout their life cycle. This approach is intended to contribute to the **transition towards a circular economy** by fostering improved product design, promoting durability and reuse, minimising waste and supporting and enabling product recovery and recycling so as to retain valuable resources in continued productive use.

An effective product stewardship scheme is just one, but an important, component of a circular economy. The contribution from a scheme for resilient flooring waste would include:

- Encouraging a reduction in waste generated by fostering durability, good maintenance and repair to encourage retention in use for longer
- Incentivising the phase out of restricted chemicals and designing future products for recycling
- Recovering and recycling more waste
- Reducing leakage by diverting waste from landfill and retaining materials in productive cycles.

ARFA has demonstrated its ongoing commitment to sustainability and circular economy principles through initiatives such as developing product performance standards, advocating for responsible government policies, educating members on product sustainability, and collaborating on industry-wide sustainability initiatives like ResiLoop. With a strong membership base that accounts for over 11 million square meters of resilient flooring products sold annually, ARFA is well-positioned to deliver an effective and sustainable product stewardship scheme that engages stakeholders across the supply chain. By building on its past efforts, ARFA continues to advocate for a shift away from a linear approach of 'take, make, waste' in the industry towards a circular system of sustainable and responsible practices throughout the entire lifecycle of resilient flooring products.

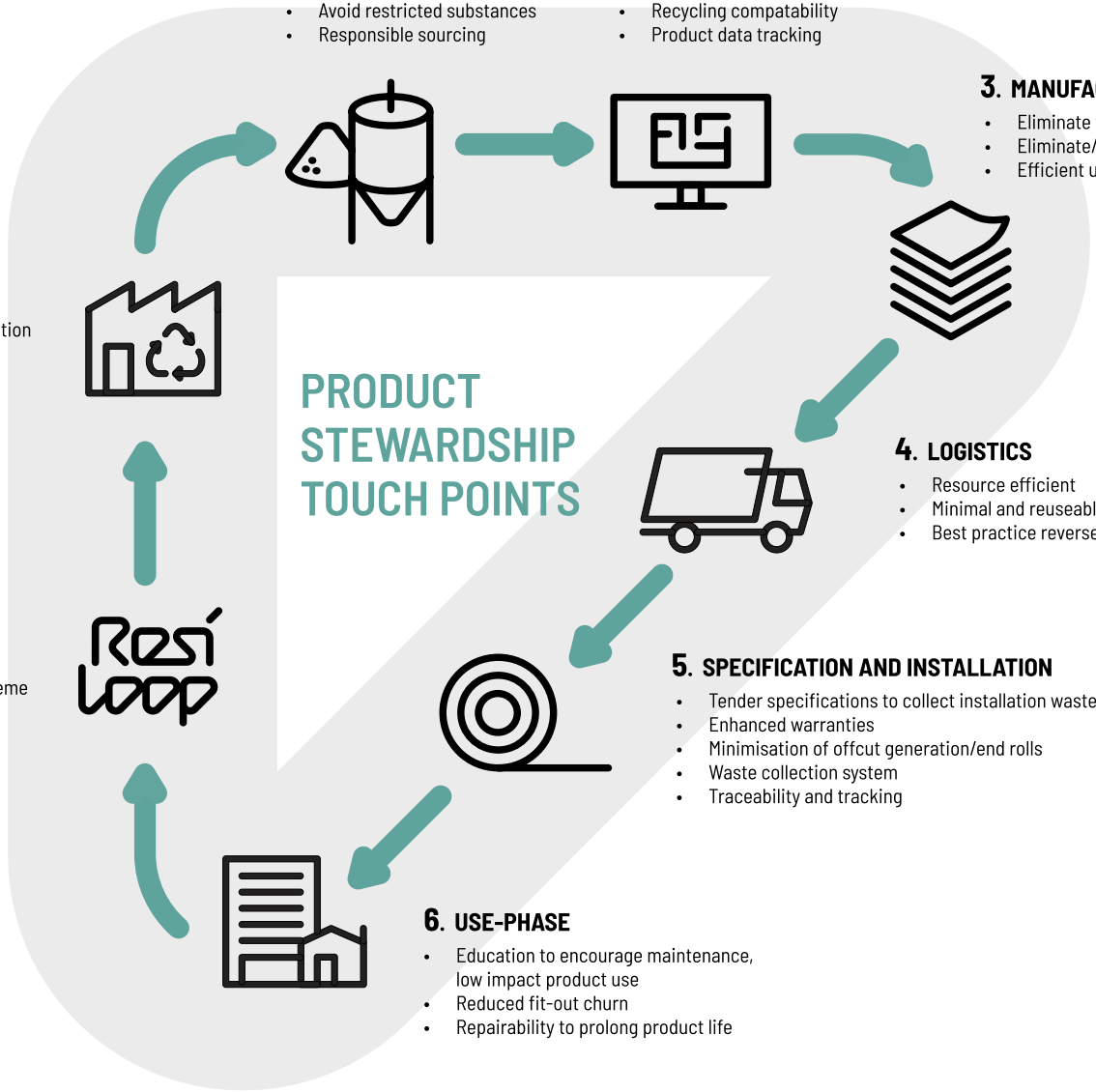
An effective, industry supported product stewardship scheme is seen as delivering both **broad community benefit** by reducing landfilling of waste and specific value across the industry by fostering collaboration along the entire supply chain. It will not only address the landfill impact from waste, but create a circularity mindset that will be welcomed across the marketplace. Economically, it will **stimulate innovation and job opportunities,** while **reducing reliance on fossil-fuel resources** by using post-consumer material.

Construction and demolition waste in Australia presents significant opportunities for circulating material value through recycling and **avoiding carbon emissions** related to manufacture of virgin building materials as well as existing disposal processes. In Sweden, a Life Cycle Assessment of the recovery and recycling of resilient flooring waste found that 2 tonnes of carbon equivalent emissions could be saved through the recycling of 1 tonne of vinyl flooring instead of sending it to waste for energy recovery, the usual disposal route in Sweden for resilient flooring[6]. According to this LCA, 900kg of that CO_2-e saving is related just to the replacement of virgin materials. PVC or vinyl is a 'low carbon' plastic — only 38% of its molecular weight is carbon compared to 86% for polyethylene. Manufacturing PVC products also consumes lower energy than other common plastics and it is estimated that for every kilogram of virgin PVC avoided through recycled PVC, 2 kg of carbon is saved (Source: VinylPlus.eu).

A successful product stewardship scheme will **assist participating companies** achieve environmental performance certifications, improve compliance performance in building or project rating tools and/or provide a competitive advantage to them in the market. In addition, it may **reduce the disposal costs** incurred by parts of the supply chain who currently bear the financial burden of waste disposal.

6 Separate collection and recycling of PVC flooring installation residue in Sweden — A system assessment, IVL Swedish Environmental Research Institute, Nov 2019

Figure 3: Product Stewardship Touchpoints[7]



7 Adapted from Dr Simran Talwar, Institute for Sustainable Futures, NSW, Presentation: Stewardship Benefits & Effectiveness Opportunities for local government, Waste Conference, Coffs Harbour, 5 May 2022

Government Policy Drivers

The Australian Government has been evolving policies and regulatory measures to reduce waste and boost recycling as well as to encourage investment in innovative manufacturing and the creation of sustainable jobs. The Government also intends to use its purchasing power to drive an increase in demand for recycled content products so as to underpin investment in new reprocessing facilities and product manufacture.

The National Waste Policy Action Plan 2019 outlines a set of targets and actions that guide Australia's investment and national efforts towards better waste management and circular economy until 2030 and beyond. These targets and actions were developed based on the 2018 National Waste Policy and are intended to achieve significant improvements in waste management and resource recovery practices, especially through promoting domestic recycling and stimulating investment in recycling infrastructure.

Key targets and actions of the plan include:

- Reduce the total waste generated in Australia by 10 percent per person by 2030
- Achieve an 80 percent average recovery rate from all waste streams by 2030
- Significantly increase the use of recycled content by governments and industry

To achieve these targets, the Australian Government put in place a series of new legislation aligned with the Recycling and Waste Reduction Bill 2020. These laws aim to effectively handle the environmental, health, and material effects of waste and also establish a legislative framework for the waste export regulations.

The Government also launched complementary initiatives such as the Recycling Modernisation Fund (RMF), which received an allocation of $190 million to support the modernization and transformation of Australia's waste and recycling infrastructure in 2020. The RMF aims to increase recycling capacity, reduce waste to landfill, and support the development of a circular economy.

The National Product Stewardship Investment Fund (NPSIF) was another initiative of the Australian Government aimed at supporting the development of new and improved product stewardship schemes in the country. The NPSIF was established in 2020 as part of the government's commitment to waste reduction and the circular economy, specifically contributing to the national target of 80 per cent resource recovery by 2030 under the National Waste Policy Action Plan.

Today, across states, territories and the federal government, the policy focus is on designing out waste and pollution, keeping materials in use and fostering markets to achieve a circular economy by 2030.

Key Aspects of an Effective Scheme

Through our scan of global resilient flooring schemes as well as domestic product stewardship schemes and literature review, we were able to identify common factors that contributed to the success of schemes.

Based on our research findings, the following aspects are identified as drivers of success for a product stewardship scheme for resilient flooring in Australia.

1. Broad Awareness

It will be critical that broad awareness of the scheme is generated with floorcovering installers and with specifiers, building owners and construction projects that purchase removal and installation services. These are the key stakeholder groups who can influence waste generation and incentivise recovery and recycling. To achieve this, we will focus on increasing the visibility of the scheme among relevant industry and trade associations, forums and events, TAFEs and training organisations.

2. Collaboration across the industry

Australia has very limited resilient floorcovering manufacture with only one producing the main category of vinyl flooring. Unlike overseas schemes where several manufacturers may reside and can accept back their own brand waste, the resilient flooring waste in Australia will be collected as a mixture of brands' products. It will therefore be essential that importer-distributor brand-owners, collaborate to research, identify and develop product stewardship and recycling solutions for mixed brand material in the non-floorcovering manufacturing sector. Ultimately, we need to have built a cohesive network of engaged participants throughout and possibly, beyond, the industry.

3. Easy-to-do process and good logistics

Time is money in the floorcovering trade which is paid per square metre laid. The process of collecting the waste generated by uplifting or installing floorcoverings by trade contractors needs to be easy and efficient, and become the norm across the sector. Adequately training installers to collect and bag the waste will be critical and diligence is required to ensure other materials and items are not thrown into the bags. Efficient transport of waste to minimise costs will be necessary.

4. Goal setting

Establishment and adherence to targets to reduce the volume of waste that can be sent to landfill or thermal treatment will drive the diversion of waste material towards collections and recycling. Increasing landfill disposal charges will also improve the incentive to divert waste to beneficial uses. The scheme will need to track waste contributions by installer collectors, and potentially by large projects to measure and report progress. Providing measured results and feedback to installers and collection points will be an important tool to recognise and reward collectors.

5. Tender documentation

To support a level playing field across the floor contracting industry, tenders and specification contracts have a major role in driving behaviour change. It will be necessary to raise awareness of the scheme among specifiers and purchasers of installation services to encourage the adoption of requirements within tenders and contracts that demonstrate resilient flooring waste is being diverted from landfill. Setting requirements for effective, measured and enforced collection and recycling of floorcovering waste is vital.

6. Growth in End Markets for Recyclate

Given the limited capacity in Australia for resilient floorcovering manufacture, identifying alternative end applications for the recyclates is critical to the scheme surviving. The recyclates generated by the scheme will be competing not only with quality virgin commodity materials but also with other sources of low-cost recycled vinyl, mineral fillers and rubber. Significant investment in suitable end applications and improvements to collection and transportation efficiency are likely necessities and the program will need to grow in line with available manufacturing demand and capacity.

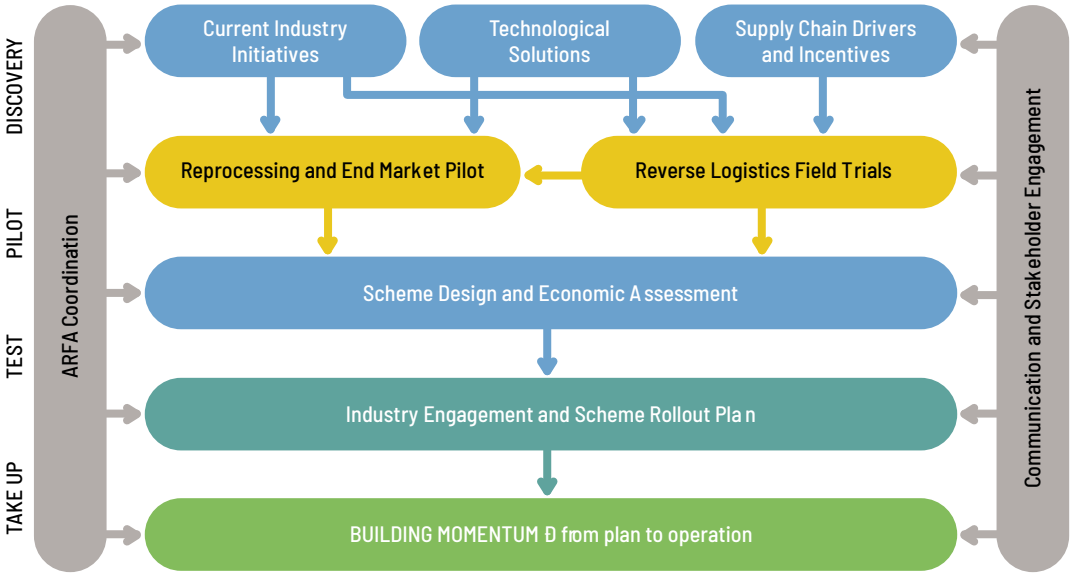
7. Clear roles and responsibilities

A sustainable, industry-supported product stewardship scheme requires a clear understanding of ownership of the scheme and roles and responsibilities to be clearly defined and accepted. Effective governance of the scheme and the organisation overseeing it is essential to deliver trust and confidence to all participants in the scheme and mutual benefit for all.

ResiLoop Project Methodology

ResiLoop engaged participants across the sector's supply chain, conducted research, and performed waste recovery and recycling trials to test various approaches in both residential and commercial sectors. The team also undertook business case modelling to understand costs, economic and social benefits, and identified strategies for equitable cost-sharing across the supply chain. This work helped inform the design and development of a national, commercially viable, waste recovery and recycling scheme.

Figure 4: Overview of the project's key activities



Outline of Project Plan

The project plan, developed in June 2022, comprised the overarching project goal, problem statement, success criteria, project activities, critical milestones, and scoping criteria.

The success criteria laid out the key aspects necessary for the ongoing viability of the final scheme. This includes:

- Establishing a waste collection system to recover resilient flooring waste for recycling;
- Putting facilities in place to reuse/recycle recovered material to a specification that has market value;
- Designing a funding model for participants across the industry value chain to ensure economic viability of the scheme;
- Identifying the framework, governance and resource requirements to manage and monitor the scheme in future.

Process

Reporting and decision-making

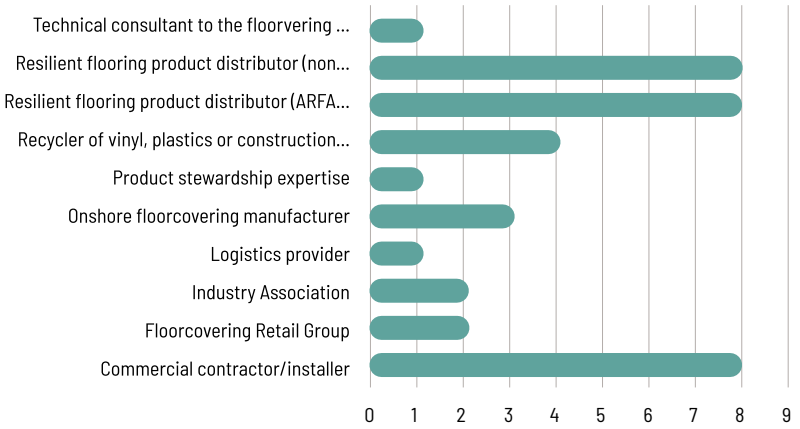
ARFA's Executive Committee, comprised of six executives from across the membership, provided oversight of the ResiLoop project and had final decision-making power. Other responsibilities included financial/expenditure management and monitoring risk management. The President and Executive received regular reporting from the ResiLoop Project Director.

A small Project Steering Group (PSG) was established in June 2022. The purpose of the PSG was to provide guidance and feedback to the ResiLoop Project Director and ARFA's Executive Committee in implementation of the ResiLoop initiative and to monitor progress in achieving agreed outcomes. It was determined that the PSG be a deliberately small expert, decision-making group, comprised of 5 to 6 members. It was chaired by ARFA Executive representatives and included ARFA member representatives and a representative of the Product Stewardship Centre of Excellence. The Group met with the Project Director at least monthly.

A Stakeholder Reference Group (SRG) was established with comprehensive supply chain representation *(see Figure 5).* Membership of the SRG was unlimited in number to ensure any interested stakeholder had an opportunity to participate. Nearly 40 senior decision-makers volunteered to join. The SRG acted as a consultative forum, providing a sounding-board for the team in the scheme's design development and expert, solution-based advice and feedback in implementation of the project.

An experienced facilitator, Spark Strategy, was recruited to expertly run the three planned workshops and optimize engagement with these key stakeholders.

Figure 5: Representation of SRG members (by no.)



'Discovery' Phase

The aim of the 'Discovery' stage of the project was to gather industry insight, including an understanding of supply chain behaviours, motivations, and industry challenges when it comes to recycling resilient flooring.

The phase involved the collection and analysis of data on resilient flooring, including stocks and flow study to establish the scale and nature of the challenge. A review of a range of resilient flooring products' material compositions was conducted to identify product suitability for inclusion in a product stewardship scheme. This analysis was used to determine acceptable waste criteria and priority products for Stage I and Stage II of the scheme.

Through literature review, interviews and direct communication with overseas industry participants, a global scan of resilient flooring recycling activity and schemes was conducted to help identify best practice and inform scheme design. International technical and research developments related to end-of-life reuse and recycling of resilient flooring were reviewed. Over 600 potential technical solutions for sorting and reprocessing resilient flooring materials were scanned to identify and shortlist technologies that may exist in Australia or have potential in an Australian context.

The project also formed a collaboration with the European Resilient Floorcovering Manufacturers Institute (ERFMI) and the US Resilient Floor Covering Institute to share research and data, information and developments in respective regions. The three associations met regularly through the course of ResiLoop.

Trials

The purpose of the trials phase was to instigate a proof of concept for recovery and recycling of resilient flooring waste in Australia. A contract to provide technical expertise to research and design the reprocessing trials was awarded to Arcadis/Full Circle Advisory, advisers on circular economy, sustainable design and engineering solutions. Arcadis reviewed the shortlist of technology options and local capability, identified potential reprocessing partners and end manufacturers and designed reprocessing and coordinated trials. Sample recyclate was provided to a number of potential manufacturers to analyse and test in product development. Pelletised recyclates were sent to expert laboratories for analysis of their properties. Refer to page 42 *(Global Technologies Scan)* for more detail.

A Technical Advisor was appointed bringing PVC formulation expertise to provide advice on suitability of recyclate for potential end market applications, including potential recyclate formulations, support identification of suitable end markets and assess costs and values of recyclate.

Circular Design Thinking (CDT) was engaged to finalise the design of logistic field trials for the waste recovery process. CDT coordinated field trials of the process with two major retail groups, two commercial contractors and a logistics provider. Collection trials took place across 14 different job sites in NSW, VIC and QLD in early 2023. These trials provided valuable feedback on the process as well as data on recovery and logistics costs and waste volumes. Refer to *Proof of Concept Trials* for more detail.

Scheme Design and Economic Assessment

Results of the Discovery phase and trials fed into the design stage of the project. RPS was appointed to draw upon this work to develop a business case for the scheme with economic modelling identifying capital and operational costs, conducting cost benefit analysis and designing the funding mechanism for the scheme.

Industry Engagement

The ResiLoop scheme design has been developed through extensive engagement with stakeholders, particularly with representatives from across the resilient flooring value chain, recyclers, manufacturers, other stewardship schemes, the waste industry and government. Consultation and engagement processes included:

- A survey, supplemented by in-depth interviews, with flooring contractors and retailers to support the design of the waste recovery process.
- Meetings with decision-makers, sustainability officers, sales and marketing and technical managers at product distributors, both ARFA members and non-members.
- Discussions with the Floorcovering Institute of Australia (FCIA), a peak body in the sector focused on skills development and training, and innovation and high technical excellence across the industry. Its members include a large number of installers and contractors as well as retailers.
- Presentations at industry events including ARFA, FCIA and the Green Building Council of Australia.
- Implementation of a communication strategy to raise awareness of ResiLoop across the industry and to ensure relevant stakeholders are kept informed, encouraged to participate and will be supportive of the final scheme. Regular social media posts across LinkedIn and Instagram were maintained, a dedicated web page developed on ARFA's site, and relevant trade press distributed. EDMs were distributed to over 850 industry contacts and regular updates provided to ARFA members. These activities have resulted in a steady growth of ResiLoop's online presence.

- Engagement with representatives of the built environment and C&D waste service providers to map current activities in both residential and commercial construction waste practices in relation to the generation and handling of resilient flooring waste.

Key Consultants Engaged

The following consultants were employed during the project:

- Arcadis/Full Circle Advisory – advisers on circular economy, sustainable design and engineering solutions
- Circular Design Thinking – advisers on logistics and circular economy
- RPS – to conduct the financial modelling and business case development for the national scheme
- Global Plastic Services – bringing experience in PVC formulation and recycling
- Circular Resources Australia – to conduct a risk assessment of the proposed scheme process
- Spark Strategy – facilitation services in relation to stakeholder engagement
- DesignIS: – branding development and graphic design
- Dentsu Creative Public Relations

Prior Work

A few significant pieces of work established the context and scale of vinyl (or PVC) and resilient flooring waste in Australia. These works provide the background for ARFA's decision to develop a national product stewardship scheme.

In 2005, a national PVC Waste Audit[8] conducted by Nolan ITU for the Vinyl Council of Australia gathered data on the amount of vinyl waste entering Australia's waste stream annually from a wide array of applications used in every sector of the economy.

In 2021 a Material Flow Analysis commissioned by the Vinyl Council, updated the work of the 2005 Waste Audit. It modelled a significant increase in vinyl resilient flooring product consumption and the volume of end-of-life product currently entering the waste stream.[9]

A research project conducted in 2017 by the Vinyl Council of Australia in collaboration with Boral and the University of New South Wales looked at the viability of recycling resilient flooring. The project found that vinyl flooring material can be re-ground in Australia with relatively simple recycling technology into a compound containing a high proportion of filler (calcium carbonate). The materials can safely be utilised in applications where the processing temperature is below 250˚C and this recyclate has the potential to replace aggregate in masonry products as it meets performance tests and standards. The greatest success involved homogenous vinyl flooring.

However, its use in the masonry application would come down to whether a highly economical system of recovering the waste, reprocessing it and supplying it to the manufacturer can be developed as the raw material it replaces (effectively sand) is low cost.

8 Hyder 2005, "National PVC Waste Audit, Final Report December 2005", NOLAN-ITU Pty Ltd (now Hyder consulting).

9 See Vinyl flooring consumption in Australia on page 22

Hardened concrete blocks with various weight of vinyl flooring showing density (0 percent, 10 percent, 20 percent, 30 percent), Boral Lab[10]

The study also found uplifted flooring waste (nearly 20–30 years old) and new off-cut flooring waste have similar elemental composition, with calcium carbonate as major element. Both types of flooring can be treated in a similar manner during reprocessing.

Flooring contractors were identified as key to the success of recovering vinyl materials and were found to be motivated by the current cost of waste disposal.

These findings established context for the technical aspects of resilient flooring and helped inform ResiLoop's technical development strategy.

10 ReFloor: Vinyl Resilient Flooring Recycling Project January 2015 - December 2017, Vinyl Council of Australia

KEY FINDINGS FROM THE DISCOVERY PHASE

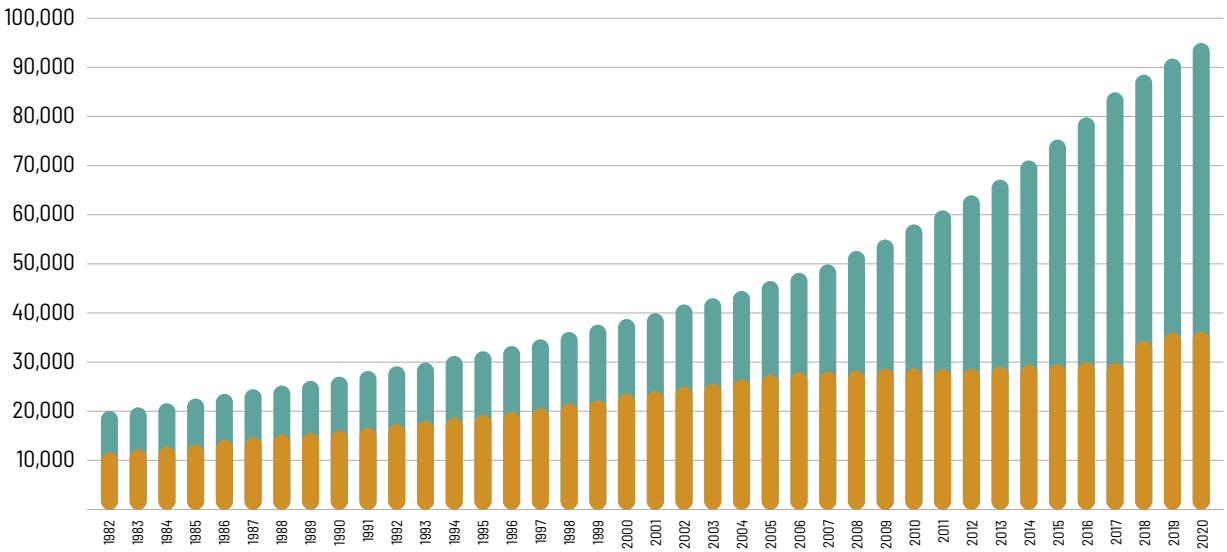
Material Flows Analysis and Market Data

The updated Material Flow Analysis (2021) estimates that between 1981 and 2020, the volume of vinyl resilient flooring products increased 380 percent. From the mid 2000s, the consumption of the new ranges of tile products increased markedly as illustrated in *Figure 6*.

By 2020, approximately 95,000 tonnes of these products were consumed a year, equivalent to an estimated 22.3 million square metres of floorcovering.

ARFA commissions a quarterly market data report in which members report to an independent third party their sales data for compilation into an aggregated report. Individual company data remains strictly confidential. As of the end of 2021–22 financial year, ARFA's 12 members accounted for an estimated 47 percent of the market. As of 31 May 2023, ARFA's membership base had increased to 15 product distributors.

Figure 6: Vinyl flooring consumption in Australia (tonnes per annum)



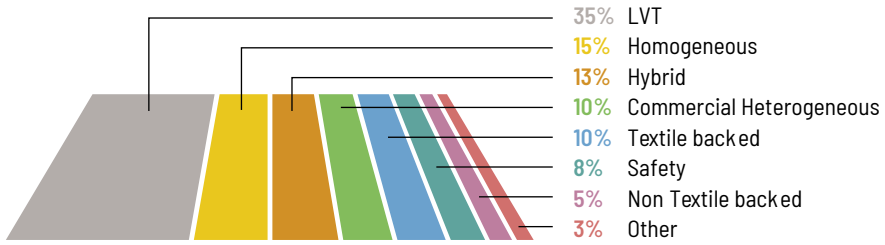
The market is thought to consist roughly of one third Luxury Vinyl Tile (LVT) — the largest single product category — one third commercial homogeneous and heterogeneous coverings, and one third accounting for all other types (safety, residential sheet, hybrid and rigid core, linoleum, rubber and other non-vinyl products).

Resilient floorcoverings are durable products with service life up to 35 years. It is assumed that the **average lifetime use is 15 years.** On this basis, Australia would have slightly over 1 million tonnes of vinyl resilient flooring still in use.

Of this stock, the modelling estimated that 4.6 percent (48,000 tonnes) enters the waste stream every year as uplifted vinyl flooring.

In addition, based on the annual consumption data, it is estimated that around 6,600 tonnes of waste is generated from installations due to trimmings and offcuts. Industry feedback suggests that the installation offcut rate is approximately 10 percent for sheet flooring and 5–7 percent for LVT and hybrid/rigid core tiles. Hybrid tiles are significantly heavier per square metre than other products leading to this category accounting for a significant share of total installation waste despite lower volumes in the market. This is represented in *Figure 7*.

Figure 7: Proportion of total installation waste annually by product type



Including non-vinyl products[11] and the unused ends of rolls/stock ends, the total waste generated in the sector is estimated to be potentially 57,000–60,000 tonnes per annum. *Figure 8* illustrates the composition of this waste:

Figure 8: Composition of total annual resilient flooring waste

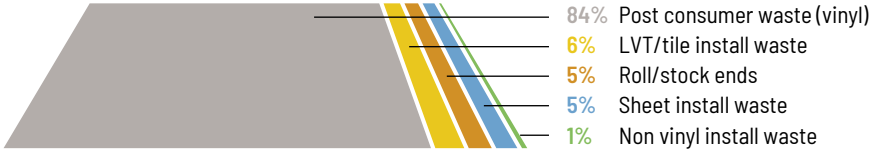
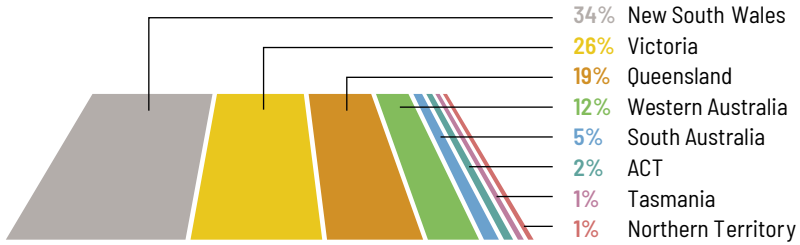


Figure 9: Geographic spread of post-consumer resilient flooring waste
Source: Material Flow Analysis 2021

11 Note that a Material Flows Analysis has not been completed on non-vinyl resilient floorcoverings such as linoleum, cork and rubber. Our waste estimate is based on consumption data obtained through ARFA's quarterly market report.

Figure 10: Geographic distribution of post-consumer resilient flooring waste by state
Source: Material Flow Analysis 2021



SUMMARY OF KEY DATA:

Annual consumption (vinyl) 2020:	95,000 tonnes 22.3 million square metres
Total waste generated annually (all):	57–60,000 tonnes
Installation waste generated annually:	9,660 tonnes including estimate for roll- /stock-ends

Global and Local Initiatives Scan

Summary of Existing Resilient Flooring Schemes

ResiLoop conducted a global scan of existing product stewardship and take-back schemes and initiatives for resilient floorcoverings. Over 40 schemes were identified across the United States, Europe, Asia and Australia that operate waste recovery and recycling initiatives for resilient flooring. Some are operated by individual companies, some by groups of companies and some are cross-industry collaborations. National schemes were identified in Sweden, France and Korea. Schemes and initiatives involving carpet waste were also reviewed.

Geographically, Europe has possibly the best coverage of schemes with schemes operating out of France, Germany, UK, Sweden, some recovering products from across the continent. Australia has limited scheme operation, coordinated by specific distributors taking back certain product waste and exporting it to Europe or re-supplying into the charity sector. A number of schemes are offered in the US and some schemes are operating In Korea and Japan.

Product Coverage

- Sheet vinyl and LVT are the most commonly accepted materials. Textile or felt backed sheet flooring is usually restricted. Most existing schemes relate to vinyl floorcoverings, although a couple of linoleum schemes and a rubber flooring scheme were identified.
- Many schemes only accept pre-consumer materials such as installation wastes and roll-ends to avoid the risk of legacy additive contamination, or if they do collect post-consumer[12] materials, they restrict them to newer product ranges with specific age cut off dates (eg., post 2011) or that meet certain specifications. Reference to acceptance of REACH compliant products only is common.
- Company schemes tend to only accept their own products but may include competitors' waste on a case-by-case basis.
- In Sweden and France, waste is collected sorted by brand as opposed to product type as material can be returned to brand owners who operate their own recycling processes or plants.
- Post-consumer uplifted flooring is often contaminated with silicone used to fill seams when installed, and adhesive and sub-floor residues which may be necessary to remove to improve recyclate quality.

Collection system

- Schemes usually require supply chain members such as contractors, installers and retailers to sign up to the scheme to participate.
- Typically, bulk bags or pallet boxes are used to collect and transport flooring waste. Useful information on logistics systems and costs has been obtained.
- Processes for collecting roll ends/stock ends may also be included.
- Training installers is important to ensure waste is properly sorted and aggregated.
- Protection of bags/bins from contamination (including by weather) is crucial.
- A couple of businesses in Australia implement take-back schemes for foam underlay for carpets. Installers/sub-contractors return the waste underlay to retailers from where it is collected and returned to local factories for recycling back into new underlay. A site visit to one of these recycling plants was conducted. Given similarities with ResiLoop's aim, there may be potential opportunity to collaborate on take-back logistics.

12 ResiLoop refers to 'post-consumer' as material or products that have reached their intended end user, and which are no longer being used for their intended purpose. 'Pre-consumer' waste therefore refers to materials and products entering the waste stream prior to this stage of the lifecycle and includes waste generated during the installation stage. Although this may not be consistent with how some standards and bodies define waste streams (where installation waste is included as 'post-consumer' waste), it helps us segment the waste stream based on product age (current market offering versus older end-of-life product).

Collection Volumes

- Targets and volumes recovered by schemes vary considerably, with the highest volumes recovered being post-industrial waste. Installation waste is the next largest volume collected.
- The European recycling plant AgPR has recycled up to about 1,500 tonnes pa (capacity 1,800 TPA) and is probably the largest third party reprocessor of post-consumer flooring waste.
- Company schemes have targets between a few hundred tonnes per annum to ambitious plans of many thousands of tonnes (including manufacturing generated waste).

Recycling Technology

- Pre-sorting is important including by product type, colour and/or brand. Colour sorting is particularly important for resilient flooring manufacturers taking back waste as comingled colour will produce only grey recyclate, limiting reuse in new floorcoverings.
- Companies commonly report mechanical recycling with shredding and or granulation, washing, drying and recycling into a powder. Processes to remove adhesives and other residues may be required.
- Wastage rates (non-recyclable) from recycling may be as high as 25 percent.
- Linoleum can be shredded or granulated, milled or micronised and sieved to a fine powder.
- Several emerging technologies are looking at different processes for identifying and or extracting legacy additive containing materials.[13]

Recyclate Destiny

- Recycling of 'clean' waste into new sheet flooring products and flooring backing is mentioned by a number of scheme operators. Backing is reported as tolerating 30 percent recyclate content.
- Other products that are referred to as accepting recycled flooring include membranes, traffic cone bases and barriers, hose, car or floor mats.
- Recycled linoleum can be used as a filler in new flooring.
- In Europe, some recovered flooring waste is sent for thermal recovery in Waste to Energy plants.

Costs, Fees, and Charges

- The challenge is the cost of recovery and processing versus the low value of the recyclate. A low polymer/high mineral filler content of recyclate effectively means the recyclate is treated as filler, which has a very low market price.

VALOBAT is a Product Stewardship Organisation (PSO) being established under French legislation which requires collection and separation of different building materials including plastics. Suppliers of construction materials and products are obligated to register with a PSO to finance the end of life of their products. Resilient flooring collection will operate through setting up collection points through the distribution network. Contributors include local manufacturers, importers including some contractors, distributors and retailers with their own brands. Scheme fees are based on tonnes put onto market. Valobat makes a budget for expected waste recovery volumes and operational costs for the product category and divides it by the product suppliers' tonnes. The current net fee for resilient floorcoverings is reportedly ~€9 per tonne (A$14.75/tonne or approx. A$0.07/sqm).

13 See page 44 for a review on international technological developments related to resilient flooring recycling

- It has been quoted that the average cost for collection in Europe is €0.50–€0.60/m^2 (incl dumpster rental, transportation and recycling of waste) (equivalent to about A$170–204/tonne).
- Fees vary from allowing free drop-off of wastes by flooring contractors to charging modest fees to contractors/installers to register for a scheme, or for construction projects to participate, or for collections from participants. A company scheme operator may waive fees where their company's replacement product is being laid.
- In one scheme, fees are paid by brand owner based on the volume of their product collected.
- Post-consumer vinyl flooring has been successfully recycled in Korea since 2008 under a voluntary agreement between producers and the Minister of Environment for collection and recycling of flooring. A new regulated Extended Producer Responsibility (EPR) requirement commenced in 2023, where manufacturers or importers of vinyl flooring must attain a mandatory recycling ratio for the product type. The EPR system is intended to share the economic burden between producers and recycling business operators where the contribution from scheme members is considered an economic incentive for recycling companies to actively participate in the collecting, sorting, and recycling of the product.[14] A recent study of the costs of recycling vinyl flooring in Korea suggest it costs USD USD360/tonne (A$533/tonne as of 8 May 2023) to collect, sort and reprocess the waste material. The average sale price of the recyclate in Korea is estimated to be USD420/tonne (A$622/tonne).[15]

Incentives to Recover

- In Australia, building rating tools such as Green Star and NABERS have waste management components in which it may be possible to seek recognition of participation in a product stewardship scheme. In Europe, there is an incentive for projects to attain the recycling certificates recognised in BREEAM.
- Vinyl is a 'low carbon' plastic — only 38% of its molecular weight is carbon compared to 86% for polyethylene. Manufacturing PVC products also consumes lower energy than other common plastics. It is estimated that for every kilogram of virgin PVC avoided through use of recycled PVC, 2 kg of carbon is saved.[16]
- The avoided carbon emissions from not using virgin PVC compound for manufacturing new products has been estimated to be approximately 900kg CO_2-eq per tonne of flooring recyclate used.[17]
- It is reported that 1 sqm of vinyl flooring recovered can produce 1 sqm of new floor and save 9.8kg - 11.8 kgCO_2/SQM.[18] One company reports carbon savings of over 30 percent are possible using recyclate in new LVT.

14 Kim, D-W. *et al* A Study on the Calculation of the Standard Recycling Cost of PVC Profiles and Flooring Waste in Korea. Recycling 2023, 8, 37. https://doi.org/10.3390/recycling8020037

15 Ibid.

16 VinylPlus.eu

17 Based on a Swedish case study. Sourced from "Separate collection and recycling of PVC flooring installation residue in Sweden - A system assessment", IVL Swedish Environmental Research Institute, Nov 2019

18 Reported by the ReStart program

Schemes/Initiatives Reviewed	
AgPR	ReStart
Back to the Floor	re[TURN]
Carpet America Recovery Effort	Revinylfloor
Circular Floor	Revise Floor
Eco-Grip Floor / Allied Industries International, Inc	Sangetsu Sample Book Recycling
Forever & Ever	Second Life/FloorToFloor
On&On™ Recycling	Step Recycling
PVC Next	Valobat
Recofloor	Vloer Retour
Re.Form	

Companies Interviewed	
Airstep	Karndean International & UK
Altro APAC	Kenbrock Flooring
Amtico International (now part of Mannington US)	LG Hausys
Andrews Group The / Bolon	Milliken (Australia)
Armstrong Flooring	Pegulan Floor Covering
Aspecta Flooring (distributor HMTX Group in AUS)	Polyflor Australia & UK
CFL Flooring	QEP Australia
Dunlop Flooring	Shaw Contract
Gerflor Australasia & Europe	Signature Floors ANZ & Europe
Interface Australia	Tarkett Australia & Europe

US Floor Recycling Initiatives Reviewed	
B. Schoenberg & Co., Inc.	Nu-Pro Polymers, Inc.
Ben-Mor Cables, Inc.	Oscoda Plastics, Inc.
Duro-Last, Inc.	Plastic Recuperation Cowansville Ltd.
Lakeland Polymers, LLC	SelecTech, Inc.
Noble Manufacturing, LLC	Tarkett North America Inc.
Norwich Plastics, Inc.	Wilson Industries Inc

Australian Product Stewardship Scheme Review

Over twenty Australian non-floorcovering product stewardship schemes were reviewed to help identify best practice in an Australian specific context. These schemes mainly operate Australia-wide, but a few are state-based. The majority are voluntary, industry led initiatives; one is co-regulatory; a handful are mandatory. There are also a small number of companies that run for-profit initiatives that were included if relevant. Since this review, the Product Stewardship Centre of Excellence has launched the *Product Stewardship Gateway* as a database of existing and emerging product stewardship initiatives in Australia. It provides publicly reported environmental, social, and economic outcomes for these schemes.

Product Acceptance Criteria

- Most initiatives require pre-sorting prior to collection / drop off. This is made as simple as possible, dependent on product type and collector.
- Some, but not all, schemes limit collection and recycling to products produced by suppliers that are part of the program. If feasible for recycling, both partner products and *ad hoc* products may be accepted, but incentives are usually provided for products of partners to the scheme.
- Logos or labels are a common strategy for ensuring the product collected has contributed financially to the scheme and is suitable for recycling.

Collection

- Free collection units are sometimes provided by the scheme operator (where the scheme can cover these costs). Smaller schemes may require participants (businesses or organisations) to provide their own collection points and transportation.
- Issues with stockpiling may occur when collections do not happen frequently, especially in regional areas where the cost-benefit of regular collections is an issue.
- Some schemes offer a backloading service to collect materials from construction sites.

Table 1: Examples of levies in Australian product stewardship schemes

AUS Scheme	Levy / fee
MobileMuster	42c per handset
Batteries	4c/24g Equivalent Battery Unit (EBU)
DrumMuster / ChemClear or AgVet chemicals	6c per litre or kg
Paintback	15c per litre paint
Oil	8.5c per litre
Mattresses	$17.50 per unit

Costs and Fees

- The most common fee structure was a fixed levy based on functional unit of product imported and/or sold. These metrics were based on sales data submitted to a third party to maintain confidentiality.
- One scheme differentiated fees across the supply chain based on 'type of business'.
- An additional fixed fee may be charged to consumers to cover recycling costs.
- Several schemes were identified with rebates or benefit arrangements to incentivise participation and collection of desirable waste.
- Division of fees was dependent on scheme structure, but common aspects were
  - scheme administration;
  - levy management and collection;
  - undertaking education, awareness, and information activities;
  - monitoring, auditing, and reporting on the development of the scheme; and
  - research and development.
- Some schemes had a threshold for mandatory participation, based on minimum manufacturing/import rates.

Enforcement

- Commitments are often enforced via random and risk-based audits. This may be a requirement of Australian Competition and Consumer Commission (ACCC) authorisation or the scheme operator. Failure to adhere to commitments may lead to revocation of a Participant's accreditation.
- Rebate systems may help adherence, as they are only paid when the product is recycled.

Incentives and Marketing

- Most schemes were ACCC authorised, some also accredited under Federal or Queensland state product stewardship scheme accreditation.
- Members of schemes are usually provided with marketing collateral (including access to logos) that they can use for campaigns and promotions.
- Some scheme operators collaborate with retailers to promote, and retailers may be encouraged to preference accredited suppliers. Retail staff are educated on the initiative and are taught to promote it to customers.

Factors Influencing C&D Waste Management and Recycling

Construction and demolition (C&D) waste refers to waste which is generated during the construction, renovation, and demolition of buildings and other infrastructure. This type of waste typically includes materials such as concrete, bricks, wood, metal, plastics, and other building materials. The proper management of C&D waste is important for both environmental and economic reasons.

Australia's *National Waste Report 2022* found that despite a landfill diversion rate of over 80 percent, building and demolition materials were the second largest source of landfill contribution, after organics. About 5 million tonnes of waste from this activity is sent to landfill.

Recovering and recycling resilient flooring from C&D waste presents several challenges for the ResiLoop project, including

- contamination,
- lack of recycling infrastructure,
- cost of recycling including transport,
- regulatory barriers limiting market demand, and
- the mix of different materials present in C&D waste which makes it difficult to sort and separate.

Currently, flooring is often deprioritized in favour of other common C&D waste, such as concrete, wood, and metal, which are far higher in volume, easier to recycle and have higher values in recycling markets.

Consultation

ResiLoop conducted research and interviews with C&D waste recovery contractors and the Australian Council of Recycling (ACOR) to determine current practices and attitudes towards managing C&D waste in Australia.

A multi-residential construction site was visited to see first-hand how flooring installation waste was being managed and handled.

The major waste streams handled are concrete/masonry, timber, plasterboard, metals and cardboard. Common practice is to treat flooring waste as residual waste and send it to thermal treatment or landfill. ResiLoop faces a challenge in addressing flooring waste due to the volume and higher priority placed on other waste streams. However, C&D waste management contractors are under pressure to continue to increase diversion of residual wastes from landfill.

The residential construction site visited was already implementing a requirement for sub-contractors laying floors such as LVT and Hybrid tiles to remove waste from site as part of their contracts.

Once small fractions of waste like resilient flooring offcuts are binned on site and form part of the comingled waste stream, it is a challenge to recover the product.

Separate skips or large bins on site just for floorcoverings are likely not viable due to the high risk of contamination by foreign materials being added, and the logistical challenge of coordinating bin collections and site access with third parties.

Some major C&D waste recyclers are interested in investigating recovery opportunities for vinyl flooring from their 'residual' waste fraction to support their resource recovery targets and reduce their landfill disposal costs. The preference from those interviewed is a product take-back system for collection.

The following aspects of effective C&D waste management are drawn from a paper which systematically reviewed stakeholder-associated factors influencing C&D waste management.[19]

19 Zhao, X. Stakeholder-Associated Factors Influencing Construction and Demolition Waste Management: A Systematic Review. Buildings 2021, 11, 149. https://doi.org/10.3390/buildings11040149

1. Regulations

Effective C&D waste management practices require underpinning legislation and regulations to provide legal obligations and frameworks that are monitored and enforced. Enforcement is key to ensuring practices are maintained properly.

2. Financial incentives

Incentives such as government subsidies and rewards are crucial to promoting and enhancing the adoption of C&D waste management practices and developing the waste recycling market by offsetting expenses. Landfill levies, which increase the cost of C&D waste disposal in landfills, need to be used to encourage the reuse and recycling of C&D waste materials. However, the cost burden of C&D waste management should be delicately balanced across value chain stakeholders, as the industry is sensitive to cost.

3. Advances in technologies

Advancements in technologies such as barcode technology, GPS, and BIM have significantly improved the efficiency of C&D waste management in the past two decades. Waste sorting, treatment, and recycling technologies have also matured, making the recycling process far more efficient.

4. Recycling markets

The availability and location of C&D recycling facilities has implications on the differential between transportation costs and landfill levies. Where logistics costs are greater than landfill levies, subsidies (from industry or government) and incentives are going to be required. The lack of specifications, technical, or quality standards for recycled products can also cause concerns about their quality, resulting in decreased demand and resistance to using them.

5. Knowledge, awareness, attitude, and behaviour of stakeholders

Human-related factors, such as knowledge and skills, awareness, attitude, and behaviour of clients, designers, and contractors, greatly influence how these stakeholders engage with C&D waste management. Training and education are essential to ensuring environmental awareness and better relevant knowledge and skills regarding waste management.

Other project-specific factors include:

- Low-waste design & construction
- Coordination and communication across construction stakeholders
- Inclusion in contracts
- Effective contract management & enforcement
- Waste management plans
- Effective site planning and material management
- Site inspections
- Incentives for contractors/sub-contractors
- Rework minimisation

A Role for Assessment Tools and Contracts

Building assessment ratings tools, such as Green Star in Australia, are used to evaluate the environmental performance of buildings and their impact on the environment. Uptake of these tools in the construction industry has grown in the past 20 years, as they provide a standardized method for evaluating the sustainability of buildings and can help to promote more sustainable building practices, including waste recovery and recycling.

Green Star

Developed by the Green Building Council of Australia in 2003, Green Star is a voluntary sustainability rating system for buildings and communities. It provides a framework of best practice benchmarks for sustainability and performance. Since 2013, this has included a Construction and Demolition Waste credit which aims to encourage and reward management practices that minimise the amount of C&D waste sent to landfill from base building and/or interior fit out works.

The credit requires the use of waste contractors and waste processing facilities that have been independently verified for compliance with minimum standards of reporting. Accurate measurement and verification of outbound recyclables and residuals by the waste contractor is necessary to confirm diversion from landfill. An auditor's report is to be provided to Green Star projects by the waste contractor as supporting evidence to demonstrate compliance with the relevant credit and rating tool.

The target is an 80 percent or 90 percent diversion rate.

Building assessment rating tools, like Green Star, through refinements of criteria, could provide a means to incentivise uptake of product stewardship schemes like ResiLoop. Companies that use ResiLoop in their construction projects would demonstrate diversion of flooring waste from landfill to meet rating requirements. ResiLoop may need to offer project specific data.

By leveraging existing building assessment rating tools, ResiLoop may better demonstrate the benefits of participation and incentivise brand owners, contractors and floor layers to join the scheme.

Green Contracts

According to the UK Green Building Council's report "System Enablers for a Circular Economy," green contracts and leases are important industry enablers for promoting circularity in the construction sector. The UK GBC advocates that such contracts should include legally binding obligations on circular principles for fit-outs, waste avoidance, and responsibilities for deconstruction. Mainstreaming green contracts would hold parties accountable to a set of agreed clauses to advance circularity and minimise or avoid unsustainable practices.[20]

Additionally, the Building Better Partnership UK recommends embedding sustainability requirements such as construction waste requirements as part of the contractor's agreed scope of works through the project management, reporting, and assurance processes, both in terms of the design solutions and the methods of construction. It also emphasizes including all waste management requirements, targets, and the use of a Site Waste Management Plan as well as monitoring project progress and gathering associated data to assure the delivery of requirements. [21]

The success of ResiLoop will depend to some extent on its inclusion or recognition in green contracts to promote circularity in the construction sector. These obligations will help to hold parties accountable for circularity and encourage education and collaboration among industry.

20 UK Green Building Council, 2023, System Enablers for a Circular Economy

21 Building Better Partnership UK

The Role of the Construction Sector in ResiLoop

- Tenders for construction projects should include waste minimization and management requirements, and priority should be given to contractors with a proven track record in waste minimization, recovery, recycling, and legal compliance. The selection criteria for tender should include contractors' construction and demolition waste management plans, policies, and past performance.
- Contracts should set out waste and recycling targets for contractors and subcontractors to minimise rework.
- Supply chains could be examined for ways to reduce wasted resources, both at the design stage and end of a project and higher waste recycling/reuse rates advocated for by breaking down waste into sub targets and potentially collaborating with a waste management company.[22]
- On-site waste sorting and treatment can increase recycling rates, reduce pollution, and cut transportation and disposal costs. Adequate space needs to be allocated for these processes to avoid interference with other construction activities and prevent contamination. Regular inspections are necessary, and contractors could benefit from on-site incentive systems.
- BIM phase planning can reduce construction waste by helping prevent construction reworks caused by unexpected design modifications and errors and enabling just-in-time delivery of materials, equipment, and labour force, which reduces premature material damage. It also serves as a data repository to streamline the data flow between the central building information model and LCA tools, thus facilitating sustainability assessments. BIM-based design validation can avoid 4.3 percent to 15.2 percent of construction waste generation[23].

22 **Built** "*Demystifying the Circular Economy: A practical guide for moving towards a Circular Economy in the built environment*" **2023**

23 **Won J, Cheng JCP, Lee G.** *Quantification of construction waste prevented by BIM-based design validation: Case studies in South Korea* **Waste Manag. 2016 Mar;49:170-180. doi: 10.1016/j.wasman.2015.12.026. Epub 2016 Jan 2. PMID: 26754615.**

Outcomes from the Contractor Survey

The project team surveyed Australian floor laying contractors, twenty-four of which responded with 18 from the commercial sector and the remainder working in the residential sector. In addition, detailed interviews were held with five contractors.

In commercial work, homogeneous sheet is the most commonly laid product, followed by heterogeneous sheet and Safety flooring, then LVT. Residential contractors most commonly lay LVT and Hybrid products.

All residential contractors are dealing with post-consumer waste from uplifted floors as well as installation waste, whereas 2/3 of commercial contractors' work is new flooring ie., installation waste only.

Commercial contractors estimate installation wastage rates are 11 percent for Sheet flooring and 5 percent for LVT. Residential contractors' estimates are slightly higher at 12 percent for Sheet and 7 percent for LVT.

With Commercial contractors, about half of the contractors claimed to bin most of their waste on building sites. Across the survey cohort, it was estimated an average of 40 percent of waste generated is disposed of on building sites, with no direct cost to the contractor.

This suggests 60 percent of the total waste generated is taken back to a contractor's premises. Of this, 41 percent is disposed of as Commercial and Industrial (C&I) waste at their expense. The remainder is stored or returned to a supplier or retailer. All but one contractor takes some waste back to their premises for disposal/return, but the amount varies from 15 percent of all waste they generate to 90 percent.

In the residential sector, while a similar amount of waste on average is taken back by the installer for disposal at their premises as C&I waste (45 percent), less waste (28 percent) is disposed of at project sites; almost a quarter of the waste is returned to the retail store for disposal or take-back; and 2 percent kept for reuse/return to supplier.

Figure 11: Commercial Waste Disposal Routes

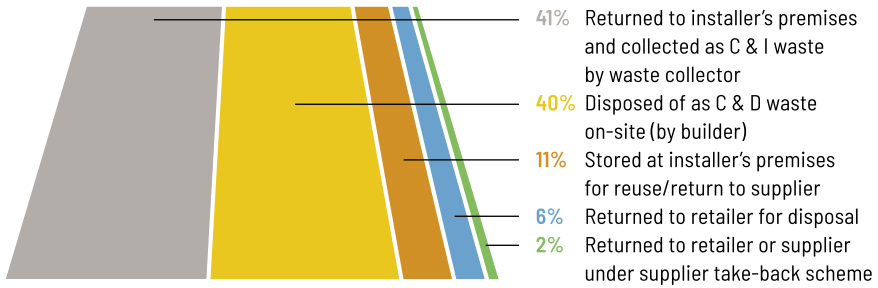
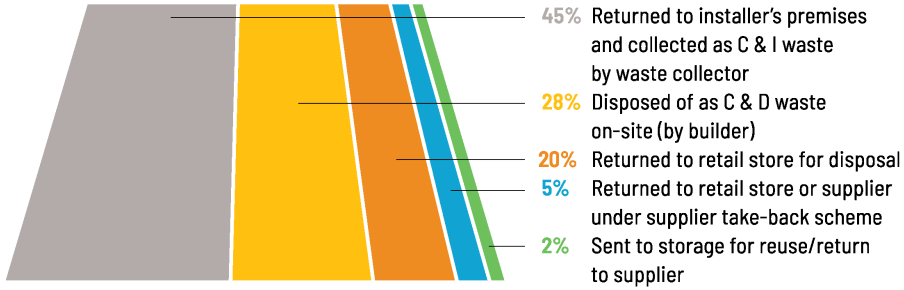


Figure 12: Residential Waste Disposal Routes



In the residential sector, three-quarters (77 percent) of the waste is estimated to be post-consumer. In the commercial sector, on average, over half the waste would be post-consumer material. However, contractors are not actively measuring their waste disposal — more than one-third have no idea how much waste they generate and send for disposal. Some estimate a large skip worth (7.5 m^3) a month, others 5–6 tonnes per annum.

Likewise, in terms of cost, contractors quoted annual waste disposal cost estimates varying from $2,000 to $50,000 with an average of around $17,500. How much cost they bear will of course depend on the proportion of their work that is commercial and their ability to use the project C&D waste collection services, or the ability to return residential waste to the retailer.

It was noted that sorting of floorcoverings should ideally be done at source by contractors, preferably at the installation job site, or for small sites, at the contractor's depot. However, it is also recognised that industry education will be necessary to encourage waste to be taken back from job sites as not all installers currently remove waste. The collection of installation waste needs to be highly efficient for sub-contractors as they are paid per sqm laid and will want to limit or save time in dealing with their offcut materials.

With retailers, it was reported that most of the waste generated is carpet and underlay; LVT is a small proportion of their waste stream, and it may therefore take longer for retailers to collect full loads of resilient floorcovering installation waste from residential sites other than multi-residential developments.

Installers in the residential space may sub-contract to several retailers. They will therefore likely want the option to return waste to any retail Collection Point.

Nevertheless, over 80 percent of the contractors surveyed confirmed that if there was an industry waste collection system in place, they would be willing to ensure flooring waste is sorted into separate bins or bags by (for example) product type.

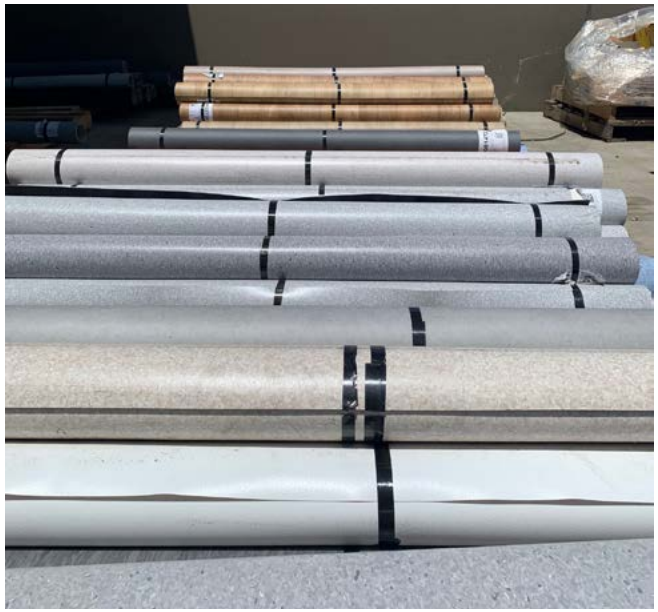
80% of contractors would support an industry waste collection system

Stock and Roll-ends

Stock (or batch) and roll-ends refer to leftover flooring materials that remain after installers have completed a job, or are discontinued lines at suppliers. These materials are often heavy sheet rolls or remaining boxes of tiles that tend to be taken back from the job site and stored in either the installer's or supplier's depot. They may be stored in case they can be used on another similar job, sold or used for repairs or sometimes donated to charities. (ARFA has promoted Habitat for Humanity's ReStores as one option).

Due to their weight and size, these materials are costly for companies to dispose of, often ending up stored for long periods of time and eventually sent to landfill.

ResiLoop has investigated the possibility of adding stock and roll end collections to its scheme which would make a significant contribution to diverting resilient flooring waste from landfill. This would also help contractors, product suppliers and retailers clear out unwanted materials more regularly and free up valuable warehouse space.



Stock and Roll-end Survey

ResiLoop widely distributed a survey to commercial contractors and installers to gather insights on the best approach for introducing stock and roll end collections to the ResiLoop scheme. The survey aimed to determine a collection service's capacity and frequency requirements, how to promote economic and logistical viability and to gauge industry interest. A total of 34 respondents participated in the survey, including 23 commercial contractors and 11 residential contractors.

Key learnings:

- These left-over materials are a significant source of material. Any good contractor will try to optimize efficiency of material use to close the gap between quantity supplied and floor area laid, reducing the cost of materials. Nevertheless, some degree of stock and roll ends appear unavoidable.
- A few respondents were already part of existing company take-back programs, re-sold or reused materials through "various means". Around 85 percent of respondents had not explored the potential to donate larger quantities of stock and roll ends to charities such as Habitat for Humanity where it was available.
- The quantity of roll ends or boxes of tiles returned to depots varied based on the size of the business, but on average, contractors returned nine rolls of floor covering and five boxes of tiles per month.
- Stock and roll-ends were generally held in stock for many months, with the majority eventually ending up being sent to landfill.
- There was strong interest among respondents for a cost-effective stock and roll end collection service that can cater to both metropolitan and regional areas. The preferred collection frequency was every quarter or on a booked-on-request basis.
- There was a preference that rolls are taken whole and the contractors are not required to cut to smaller pieces.

ResiLoop's business modelling has not included the collection and recycling of this material but considers that the scheme would be well placed to provide a pathway for it. It is recommended that ResiLoop develop a fee for service to collect and recycle the material. This fee should be determined by obtaining quotes from logistics providers and recyclers to collect and recycle the material respectively and priced so as not to have any material impact on ResiLoop's overall cashflow.

Product Compositions

ResiLoop collated data on compositions of a range of brands' resilient flooring products to understand the recyclability of different materials and identify product suitability for inclusion in a product stewardship scheme.

Homogeneous sheet product consists of a uniform layer of natural mineral filler and vinyl compound, and was found to be relatively consistent in composition across brands.

Heterogeneous sheet products have a layered structure, with variations in backing materials based on performance requirements such as acoustic insulation. However, their compositions remained relatively similar across different brands.

Luxury Vinyl Tiles (LVT) products were found to contain a wider range of substances, although this may be partly accounted for by the larger number of products in this category reviewed.

Table 2: Number of different substances found in products analysed

No. of products reviewed	Product category	No. of different substances identified across category
3	Homogeneous sheet	33
6	Heterogeneous sheet	22
15	LVT	43
6	Hybrid/rigid core	56

Tables on next page indicate typical compositions found in our analysis across the three main categories of resilient flooring (Homogeneous, Heterogeneous and LVT)[24].

The percentages listed for each substance highlight the range in concentration across the range of brands reviewed. As the results suggest, the concentration of substances can vary greatly between product types and between brands within the same product category. PVC concentration, for example, can be as low as 18 percent in LVT up to 50 percent in sheet compositions. However, even within the LVT category, concentrations can vary greatly according to brand — between 18–47 percent in LVT. This means that recycling comingled brands of products will produce variable recyclate compounds from one batch to another, adding significant complexity to recycling and lowering the value of recoverable waste.

Figure 13: Examples of structure of LVT products

24 Safety flooring has a very similar composition to sheet, with the addition of aluminium oxide and/or silica to the surface to provide anti-slip performance. These substances are highly abrasive to recycling equipment.

Examples of non-vinyl-based products including Linoleum, polyurethane and rubber were also reviewed but data on different brands was more limited. A single example of each was reviewed. Compositions ranged from 12 to 26 chemical substances and materials in the product.

Natural mineral fillers are added to resilient flooring formulations to reduce cost and improve product performance. They are considered relatively low carbon and abundantly available resources.

Calcium carbonate is the most commonly used mineral filler and substance, found in high concentrations, up to 70 percent. However, the concentration used can vary greatly — as low as 23 percent in some cases. Alternative mineral fillers that may be used are dolomite and magnesium carbonate.

Plasticisers help give resilient flooring flex and pliability. The most common plasticizer found across all categories was Bis (2-ethylhexyl) terephthalate DOTP, an unrestricted plasticiser accepted as a safe replacement for the ortho-phthalate plasticisers that are now regulated under REACH and other international regulations. The concentration range of DOTP varied from 1–15 percent.

We identified 13 other substances that may be used in low concentrations, but that weren't consistently found across brands and product types. No restricted substances were found.

These findings indicate the complexity of recycling resilient flooring products due to the variability of substances and their concentration ranges, which can differ greatly even between brands producing the same product type. The high quantities of mineral fillers, plasticizers, and other substances add to the challenges of recycling and determining a suitable end market for the product.

Table 3: Composition range for Homogenous Sheet – from publicly available data

Component	Typical proportion (% by weight, range)
Calcium carbonate ($CaCO_3$)	30–45%
Polyvinyl chloride (PVC)	35–50%
Non-Phthalate (PHT) Plasticiser	12–25%
Epoxidized Soy Bean Oil (ESBO) and/or Epoxidized Linseed Oil (ELO)	0.6–2%
Stabiliser	1-3%
Process Aids	<1%
Titanium Dioxide (TiO_2)	1-2%
Pigments	<1.2%
Coatings	0.1–0.5%

Table 4: Composition range for Heterogeneous Sheet – from publicly available data

Component	Typical proportion (% by weight, range)
Calcium carbonate ($CaCO_3$)	25–45%
Polyvinyl chloride (PVC)	36–47%
Non-Phthalate (PHT) Plasticiser	12–21%
Stabiliser	0.5–4.4%
CPVC Binder	36%
Titanium Dioxide (TiO_2)	0.4–4.5%
Coatings	0.1–0.3%
Fire Retardants	2.8%
Reinforcement	2.2%

Table 5: Composition range for LVT – from publicly available data

Component	Typical proportion (% by weight, range)
Calcium carbonate ($CaCO_3$)	27-69%
Polyvinyl chloride (PVC)	18-47%
Non-Phthalate (PHT) Plasticiser	8-20%
Epoxidized Soy Bean Oil (ESBO) and/or Epoxidized Linseed Oil (ELO)	1–1.2%
Stabiliser	<1%
Titanium Dioxide (TiO_2)	<1%
Pigments	<0.3%
Coatings	<0.3%
Fire Retardants	2%
Reinforcement	1.2–10%

Legacy Additives

Given the durability of resilient floorcoverings, end of first use products may be 10–35 years old. The average life expectancy is taken as 15 years. As with other durable products, this raises challenges in recycling the materials as some product may contain chemicals that have been more recently retired from use under international and domestic regulations. Although products manufactured today have ceased use of such chemicals, there is a significant challenge in transitioning to a circular economy if old products containing 'legacy additives' are not acceptable for recycling into new articles.

Legacy additives are substances now classified as, for example, persistent organic pollutants and Substances of Very High Concern that have been restricted from use in products by national and international regulations. In the case of resilient floorcoverings, legacy additives may include asbestos backings (used prior to 1984), ortho-phthalate plasticisers, and lead-based processing aids.

Recycling of technical and engineered plastic products, including construction products, electronic and automotive, will be severely limited if legacy additive-containing material cannot be reused. Determining proper safeguards for recycling these materials is therefore essential to moving from a linear to a circular economy model.

The ResiLoop project advocates for the recycling of legacy materials under certain conditions:

- Developing recycling techniques to identify and segregate waste with certain additives, for example, using tailored sorting technologies that identify ortho-phthalate plasticisers.
- Recycling segregated materials into virgin-blended recyclate feedstocks with a diluted additive content that meets legal thresholds.
- Co-extruding materials so that recyclate containing legacy additives is encapsulated into a core layer between virgin layers to minimise leakage or exposure.
- Implementation of traceability or transparency systems to aid future recycling
- Safely extracting legacy additives to reprocess or destroy them, improving the availability of readily marketable recyclate

While the ultimate goal is to stop the recirculation of certain substances, intermediate steps need to be taken, including extensions to phase-out dates to account for recycling of legacy additives. Existing and emerging initiatives can play a key role in promoting safe and sustainable design, improving information, and coordinating industry-wide approaches to manage these chemicals. This will result in a safe and trusted circular economy in Australia, which not only safeguards human and environmental health but also helps create economic benefits.

User pays approach for end-of-life flooring

Once solutions have been identified to address legacy additives and contamination in end of life floorcoverings, a potential option to commence recovery of end of life flooring is to develop a user pays system. In this scenario, the building owner pays a fee per square metre of floor area to be uplifted. The fee is paid direct to Resiloop. ResiLoop registered uplifters would be recommended for this work with the cost of uplifting a matter for the building owner and uplifter. The floor trade would be instructed to uplift the floor and direct the waste to a Collection Point or direct to a ResiLoop scheme contracted recycler. ResiLoop would cover the logistic/ transport cost.

Product Impact Assessment and Prioritisation

ResiLoop conducted a product impact assessment across resilient flooring types to identify product suitability for inclusion in the product stewardship scheme.

Building on findings from the 'Discovery' phase, the product impact assessment was calculated against the four criteria in *Table 6* (right).

Each product type was ranked against the subcategories according to a 5-point scale[25]. Only direct impacts and evidence were assessed; implied impacts were not included. The priority rankings were categorised based on the weighted rankings:

- **Low:** Total score 45 percent or less
- **Moderate:** Total score between 45–55 percent
- **High:** Total greater than 55 percent

The results suggest the priority wastes to be addressed immediately are Homogeneous sheet, non-textile backed Heterogeneous sheet, and Luxury Vinyl Tile with the remainder, lower volume, more complex composition floors warranting additional research[26].

Table 6: Product impact assessment criteria

Material and Waste (30 points) Weighting 30%	Societal Impact (30 points) Weighting 15%	Environmental (25 points) Weighting 30%	Economic and Financial (25 points) Weighting 25%
Material occurance of waste material (quality)	Community expectations — level of issue	Environmental harm — extent of direct impacts	Current disposal cost — landfill
Hazardous material toxicity	Health and safety — community	Illegal dumping — number of cases	Available technology
Resource recovery / landfill diversion (%)	Health and safety — industrial practices	Lifecycle impacts — resource use	Waste composition and value
Stockpiling of waste materials — scale of issues	Legal action and costs (eg. environmental harm, OHS)	Lifecycle impacts — environment and OHS	Recyclate specification quality
Overseas exports — amount exported (%)	Jurisdictional regulations	Material value — loss of resources	End markets
End of use overseas exports — maturity of tracking system	Industry standards		

Table 7: Product category prioritisation

Product Type	Weighted Ranking	Priority	Comments
Product 1. **Vinyl Sheet - Homogeneous**	58 percent	**High**	First Stage implementation
Product 2. **Vinyl Sheet - Heterogenous**	56 percent	**High**	First Stage implementation
Product 3. **Vinyl Sheet - Safety**	47 percent	**Moderate**	Research for 2nd Stage implementation
Product 4. **Luxury Vinyl Tile**	53 percent	**Moderate/High**	First Stage implementation
Product 5. **Vinyl Composite Tile**	42 percent	**Low**	Review in 2nd Stage for 3rd stage implementation
Product 6. **Linoleum Sheet**	38 percent	**Low**	Review in 2nd Stage for 3rd stage implementation
Product 7. **Rubber Sheet**	44 percent	**Low**	Review in 2nd Stage for 3rd stage implementation
Product 8. **Hybrid Resilient**	46 percent	**Moderate**	Research for 2nd Stage implementation

25 This assessment stage was aligned with a 2018 draft Government 'Assessment Action Escalation Process' used in prior similar work.

26 See *Figure 14* for a schematic of the stages.

Figure 14: Schematic of Stages

Safety Flooring has the recycling complication of aluminium oxide and/or silica being added to the surface to provide anti-slip performance. The hardness of these additives can be problematic for granulators but there is evidence that crushing-style granulating equipment may provide a solution.

Feedback was gathered on the proposed products for recovery and recycling/ implementation stages at the first Stakeholder Reference Group (SRG) in November 2022, with 24 key stakeholders from across the resilient flooring supply chain participating.

There was consensus that the product categories prioritised for the first stage of scheme implementation were appropriate. Reasons given for this were:

- Aligning with overseas approaches
- Keeping it simple and measurable
- The large volumes of these materials
- Ease of identification
- Closely compatible product compositions

It was proposed, however, that consideration be given to addressing Hybrid (rigid core) product wastes early given this is a new, rapidly growingmarket. Hybrid products tend to have a shorter use life of around 7 years due to their easy de-fit, and they are a floating floor product that do not have adhesive or subfloor contamination. As a result, both post-consumer and installation waste from Hybrid tiles could be considered.

The more varied composition of these products and the integration of backing materials was noted as presenting potential complications for recycling. It is for these reasons Hybrid has been prioritised for research to establish their recycling in Stage II. Consideration should also be given by manufacturers and suppliers of these products to how to extend the lifetime use of them through repair, reuse and resale in order to address improving the circular economy of this market.

Finally, Stage III aims to incorporate all vinyl flooring products and non-vinyl resilient flooring products, including Rubber and Linoleum flooring and post-consumer products.

Acceptable Waste Criteria

The Acceptable Waste Criteria was developed as a set of guidelines to determine which waste materials are to be included in each stage of the ResiLoop project. This ensures that the waste materials are managed in a safe and environmentally responsible manner and can be effectively recycled.

A draft criterion was created based on the learnings of the 'Discovery' stage, noting that:

- Cushion backing may be problematic for recycling because residue foaming agent may remain in the recyclate and may continue foaming in reprocessing the material which would impact the recycled material's quality.
- Aluminium trioxide and carborundum, used in safety flooring, have high Mohs scale hardness and may impair recycling equipment. Trial tests would be needed to determine how best to reprocess the material and the effects on the mechanical properties of the final product. They may only be acceptable at a concentration level of less than 0.1 percent of the recyclate.
- PET in waste material may be problematic as it is incompatible with PVC; a maximum threshold of 0.01 percent proposed.
- Material size is related to shredder equipment and its size, with most shredder machines having large intake openings. A recommended length of 1.5 meter and a width of half the size of shredding opening intake machine is recommended.

Following consultation with the Stakeholder Reference Group, the following Acceptable Waste Criteria was finalised for Stage I:

PRODUCT CATEGORIES

Luxury Vinyl Tiles	Homogeneous sheet vinyl	Non-textile-backed Heterogeneous sheet vinyl

Collection of ResiLoop scheme registered products only.
Hybrid/rigid core/modular tiles, Safety and textile-backed and textile-containing sheet & tile products may be included in reprocessing feasibility trials in preparation for inclusion in Stage II.

WASTE STREAM SOURCES (both Commercial and Residential)

Installation off-cuts	Stock and Roll-ends	Clean, unused returned product

ACCEPTABLE PRODUCT COMPOSITION

Acceptable	Not Acceptable
• **Type I** and **Type II** non-textile backed vinyl sheet products complying with ISO standards 10581 (homogenous vinyl flooring)[1] and 10582 (heterogenous vinyl flooring)[2] • LVT • Phthalate-free • REACH compliant	• ISO classified Type III sheet products (binder content < 35 percent in HO and < 30 percent in HE products) • Ortho-Phthalate plasticised material • Textile, felt, cushion/foamed or cork backed products • CPVC binder content • Aluminium trioxide, carborundum, quartz > 0.1 percent bw (Safety floor) • Polyethylene Terephthalate PET > 0.01 percent bw • Lead-based heat stabilisers • Non-vinyl floor coverings

1. ie. Minimum binder content of >35 percent by weight
2. ie. Minimum binder content in the wear layer of >30 percent by weight

WASTE PREPARATION FOR COLLECTION

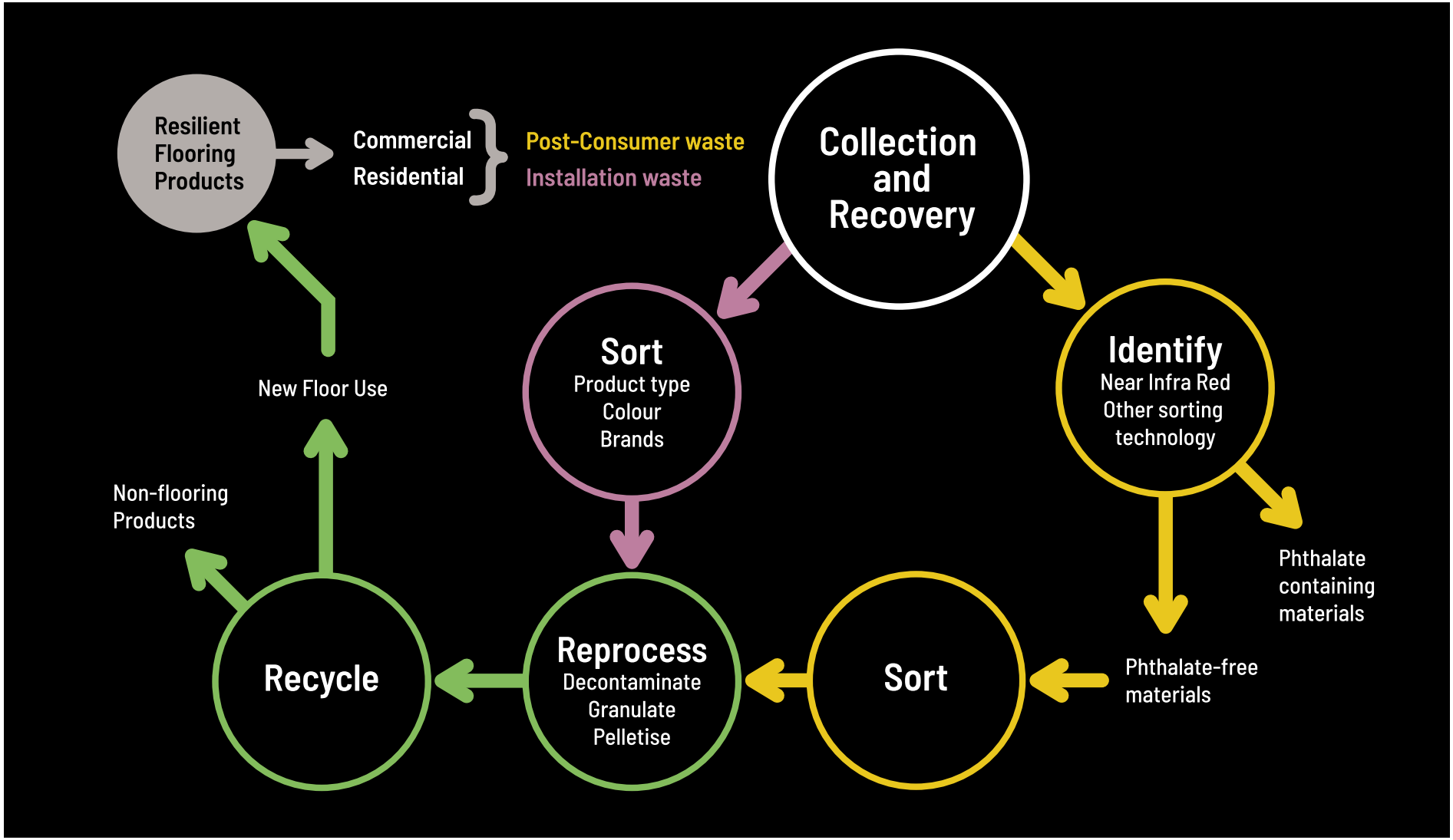
- Large pieces or rolls to be cut to max 1.5 metre lengths*
- No textile backing
- No packaging
- No adhesive

* Width of scrap may be determined by shredder machine size

Global Technologies Scan

Research undertaken in the Discovery phase provided insights into potential recycling process flows, summarised in *Figure 15*.

Figure 15: Schematic of waste reprocessing flows



VinylPlus explains that conventional technologies refer to long established processes which usually sort, shred and separate components within the waste stream, resulting in granulated recycled PVC that can be used in the manufacture of new products. Non-conventional technologies cover alternative processes that often use solvent-based processes or pre-processing to access PVC from more difficult or complex waste streams[27].

Uniform grinding, cleaning and washing of waste to remove dirt and dust are key to recycling. PVC waste requires good separation from other plastics before mechanical recycling. Having a reduced variety of polymers in the waste mix enhances the likelihood of achieving effective separation. The feed should have a uniform material composition and then be mixed with a certain amount of virgin materials and other additives to get a consistent formulation for end use. As it is hard to separate pigments from PVC, recycle from coloured products like flooring will generally be grey.

27 *PVC recycling technologies*, **2017, VinylPlus**

High mineral filler content, such as found in resilient flooring, reduces the capacity of the recycling process and may contaminate equipment requiring extra cleaning of extrusion lines.

Arcadis was commissioned to identify technology providers/potential recyclers and confirm existing and emerging technologies in Australia which could be applied immediately to sort, separate and reprocess flooring waste into suitable recyclate feedstocks for manufacturing. They reviewed domestic and short-listed international technologies to identify potentially suitable recycling technology in Australia, including:

- Investigating technologies and methodologies for sorting waste streams into relevant categories
- Identifying partner(s) for conducting recycling trials
- Design and prepare costings to conduct reprocessing trials of targeted resilient flooring wastes with the highest likelihood of success in producing marketable recyclate feedstocks
- Identify potential end markets for recyclates in Australia, including formulation specifications that need to be met.

The reviewed technologies were sourced from a shortlist of 16 technologies provided by ARFA, stemming from a larger report by the European Resilient Floorcovering Manufacturers Institute. The shortlisted technologies were ranked according to technical maturity, as well as their relevance in the Australian context, with particular focus on availability, suitability for small quantities and potential for integration with existing collection or sorting practices.

Six technologies with the most potential in the Australian context were identified as summarised in *Table 8*, on page 44.

Table 8: Summary of highest ranked technologies in the Australian context

Process Type	Process Description	Relevance	Company / Technology examples
MECHANICAL	Cryogenic process producing a micronized product	• Relevant as it has been used in Australia before (Cryogrind) • Proven effectiveness at separating PVC from other polymers with similar density. However, the cryogenic process was suspended in Australia due to high cost (providing liquid nitrogen), hence commercial viability is questionable • Can cope with contamination, making it suitable for post-consumer vinyl, including mixed vinyl from C&D waste.	AgPR, a plant in Germany currently operating and recycling post-consumer resilient floorcovering waste
CHEMICAL SEPARATION	(1) Using dissolution in Tetrahydrofuran solvent to separate PVC from legacy plasticisers. Predecssor to Creasolv™	• Capable of high quality output. • Tested with flooring materials • Suitable for pre- and post-consumer vinyl, including from C&D waste (with cleaning).	Fraunhofer IVV / CreaCycle Development
	(2) Creasolv™ process	• Selectively dissolves target polymer • Shown to be able to separate PVC from plasticisers with the plasticisers to be reprocessed into REACH compliant chemicals using rehydrogenation. • Tested with flooring waste • Could be highly relevant subject to successful trials, scalability and cost effectiveness. • Could facilitate separation of clean resin from various vinyl materials. • Technology has potential but requires higher Technology Readiness Level (only pilot plant available)	Pilot plant being built in Europe (behind schedule) Fraunhofer IVV, Germany and ERFMI / Circular Flooring Project, EU
	(3) Supercritical CO_2	• A proven, emerging technology eg. used to extract caffeine from coffee • Initial trials suggest potential to remove very effectively legacy additives from polymer streams • Yet to be proven at commercial scale on post-consumer PVC flooring products. • May become highly relevant if viability is demonstrated through testing, proof-of-concept pilot plant and commercial scaling for PVC flooring products. • Suitable for pre- and post-consumer vinyl including from C&D waste (with cleaning)	Being explored by ERFMI with Centexbel, the institute for plastic and textile innovation, Belgium
	(4) EU Polysep / PVC Separation	• Utilising Australian PVC Separation™ technology, a solvent based specific catalytic process which de-laminates multi-layer products • Highly relevant for separation of PVC compounds from non-vinyl layers, therefore potentially suitable for hybrid products • Tested on samples of a range of flooring products in Australia. Trials suggest it may have potential for separating and removing legacy plasticisers • Technology still requires more testing and needs to be commercially proven	PVC Separation ™ Licensed to Polymer Comply Europe, the consulting arm of EUPC in Europe who are commissioning a small pilot plant in Europe in 2023 for further testing
OPTICAL SORTING	(1) using THz systems for spectroscopy analysis	• High relevance for black plastics, such as sorting black backed flooring • Can sort pre- and post-consumer resilient flooring • May be able to detect PVC and phthalates simultaneously, enabling waste sorting into different streams for reprocessing	Austin AI Sorting Small company; plastics technology beta stage; have not used it for PVC; would need to do further development with ERFMI
	(2) using spectroscopy sensors	• Highly relevant, as can be used in existing sorting facilities to separate black plastics • Can sort pre- and post-consumer resilient flooring • With adaptations, may be suitable for PVC flooring wastes	Autosort Black from TOMRA

The value chain and quality control of resilient flooring material is less complex for pre-consumer feedstock *(Figure 16)* compared to post-consumer flows *(Figure 17)*. This is because the supply of 'clean' and source-separated materials reduces the need for complex collection, testing, and sorting processes associated with mixed or minimally sorted end-of-life materials from building sites.

One key downstream factor to be taken into consideration for the recycling process is the type of equipment or process used by the purchaser of recycled vinyl. Some re-manufacturers use granulated material and others require flakes or powder, which determines the physical characteristics of the output product and may influence the offtake value.

While there is no single ideal recycling process for resilient flooring, a facility needs to produce one or more outputs that meet actual demand from manufacturers while operating profitably. From a technical point of view, it should be able to accept a cross-section of product compositions within the same product category and generate an output that has a market demand and a consistent or predictable value.

Resilient flooring represents only a small proportion of total PVC waste, the collection of which differs according to application, specification and consistency. Given that, the most cost-effective model for vinyl flooring recycling may be to utilise processors that are already operating in Australia who can batch process PVC wastes, rather than invest in a new, flooring waste-specific facility. However, a new facility with sorting, separating and washing capabilities could complement existing infrastructure rather than duplicate existing processing, such as micronising, compounding, extrusion and pelletising.

Figure 16: Pre-consumer resilient flooring recycling process

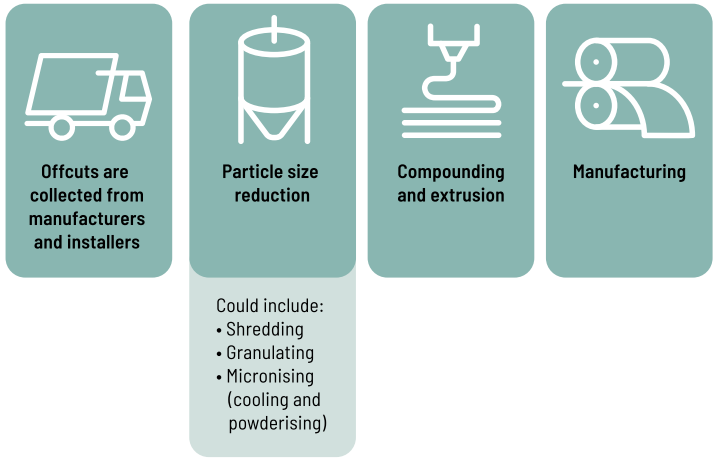
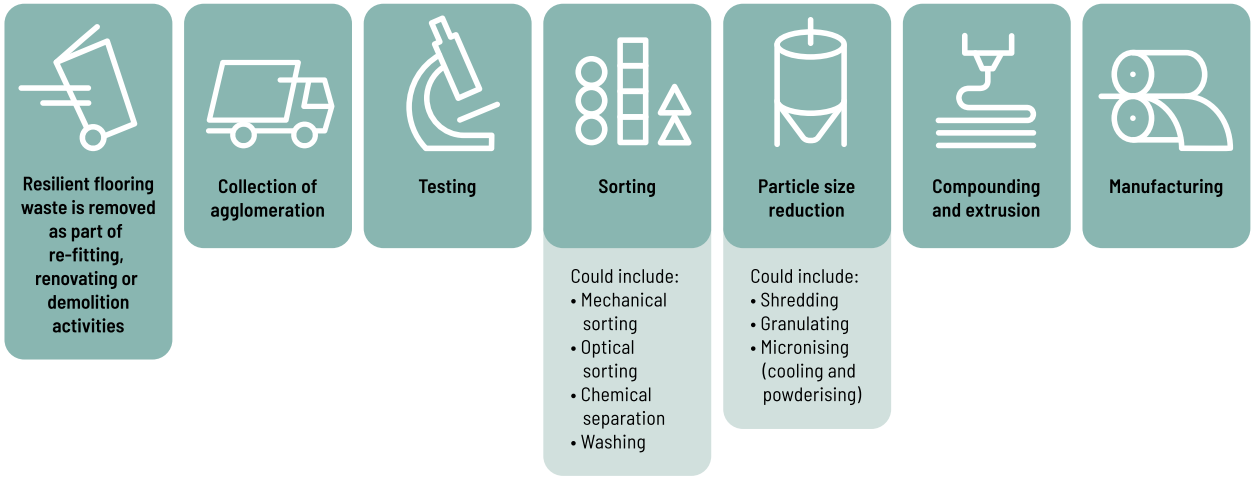


Figure 17: Post-consumer resilient flooring recycling process



Australian Recycling

Arcadis, on behalf of ResiLoop, conducted a scan of Australian recyclers and equipment suppliers to better understand the current Australian recycling context and assess local recycling capabilities.

Contact was made with nearly 60 organisations involved in the manufacture of vinyl compounds, products or the recycling of PVC (vinyl). Most conducted operations in Victoria and New South Wales, followed closely by Queensland.

As many companies were not dedicated recyclers, they often had no, or limited, sorting facilities or process. Therefore, product waste received needs to be pre-sorted. Several referred to only accepting 'clean', uncontaminated product waste so that washing and further separation was not necessary. One stakeholder has established a demonstration process for material separation using a chemical technology to facilitate recycling of composite products.

To use consistent technology for the particle size reduction process in resilient flooring recycling, we refer to:

- *'Shredding'* as producing materials with a particle size of >10mm
- *'Granulation'* as producing particles <10mm
- *'Micronising'* as producing particles <1mm[28].

The most common particle size reduction method used was granulation with common particle size between 1–5mm. However, some of the recyclers had experimented with shredded materials.

Within the stakeholders contacted, there was a reasonably even spread of flexible versus rigid PVC feedstock processing capabilities, and a few currently addressing rigid PVC stated they would be able to process both. The focus of the ResiLoop project is a combination of PVC and plasticiser rendering it a flexible product. Therefore, it is important to distinguish between rigid and flexible PVC as the recycling processes and potential product applications are different.

Challenges with finding viable end markets with strong demand for PVC recyclate was consistently mentioned by stakeholders. One stakeholder was no longer receiving and shipping PVC due to the purchase price being too low. Another mentioned no longer being able to find end markets for flooring recyclate specifically.

The re-start up of cryogenic technology in Australia is also symptomatic of current market challenges. The cost of cooling the PVC using liquid nitrogen for the purposes of micronisation was prohibitively expensive and currently unsupported by offtake prices to offset the cost of preparing this recycled material.

From this scan of recycling in Australia, a shortlist was created of potential recyclers and manufacturers that were willing to participate and have most, or all of the required equipment for a trial.

Like many other plastics in Australia, the opportunity for recycling resilient flooring is constrained by scale and demand, with limited manufacturing in Australia to reprocess material and provide an end market. For a recycling solution to be successful, it needs to be contextually appropriate across the supply chain, create value and service end markets with strong and reliable demand. The cost of recovery and recycling of polymers in Australia is another challenge in the context of the value created — the price of recyclate is constrained by the need to compete with high quality, commodity virgin products. Therefore, systems or market interventions are required if Australia wants to increase the recycling rate.

Key success factors:

- Support for the initiative
- Value of recyclate
- Contamination rates
- Training & communication requirements
- Data collection process

28 See Appendix 1 for definitions of recycling terminology.

Developing End Markets

Due to limited manufacturing in Australia and reliance on imported products, the availability of local end markets is limited. The recycling of resilient flooring is further complicated by the high levels of natural mineral filler in the material, which results in a low market value of the recycled product. To address this challenge, there is a need for a contextually appropriate solution in Australia that creates value and services end markets with strong and reliable demand.

RPS reports that the key commercial factors to be considered as part of any business case are:

- The amount and types of vinyl waste arising in the market on an annual basis, which will determine the potential scale of a facility and is an important factor in determining the capital required.
- The amount of resilient flooring waste available at reasonable cost of collection and aggregation to process.
- The amount of value uplift possible via a recycling process, determined by the difference between the waste input cost and the recyclate output revenue. This differential will significantly influence the viability of any process, but also the scale required to achieve a viable throughput.

The value of recycled vinyl will depend on a number of factors as PVC is a compounded product made from PVC resin, additives and filler material. The value of virgin unplasticised PVC ranged between $1.00 – $1.20/kg in November 2020 and $1.60 – $1.70/kg in February 2022[29]. Some of the fluctuation will be subject to the value of the price of oil, as that is a key feedstock in PVC resin manufacture. However, the PVC compound typically in resilient flooring contains a relatively large fraction of so-called filler materials, the most common one being limestone ($CaCO_3$). Limestone is a relatively cheap product (approx. <$500/t) and can make up over 60 percent of some flooring, therefore significantly lowering the value of the waste per tonne.

A benefit of natural mineral fillers is their relatively low carbon footprint as a naturally occurring mineral which regenerates naturally and at a faster rate than consumption so it can be considered a 'renewable' resource. It does not require an energy-consuming chemical reaction to produce like polymers do, and has been estimated to have a carbon footprint of about 300kg CO_2-e / tonne[30].

ResiLoop conducted research and collaborated with experts to determine the best end market applications for the scheme. Global Plastic Services (GPS) was also commissioned to provide advice on suitability of recyclate for potential end market applications, including potential recyclate formulations, identification of suitable end markets and understanding of costs and values of recyclate.

The value in vinyl resilient flooring recyclate is largely in its plasticiser content. The value of plasticiser varies between $2.35 and $2.75 per kg.

To address this, a possible solution would be to identify a formulation where additional PVC resin can be added without the need for virgin plasticiser, to create a flexible formulation. One potential application identified is cable outer sheathing, as cable manufacturing is the largest market for plasticised PVC compounds locally. The project was informed by industry representatives, however, that due to stringent regulatory standards for cable products, use of recycled material is precluded.

29 **ResiLoop Recycling Trial Scoping Report – Working Document 07/02/2022, Arcadis**

30 https://www.fiberjournal.com/calcium-carbonate-enables-sustainability-in-polymer-fiber-applications/

Potential Outlets of PVC recyclate

Overseas experience suggests that PVC recyclate containing fillers, glass fibres and plasticisers can be reprocessed into:

- flooring products — including the core layer of LVT, Hybrid tiles and Vinyl Composite Tiles and outdoor and industrial floorcoverings,
- flooring accessory products like coving and ramps,
- non-flooring products such as co-extruded pipes, traffic management products (traffic cones, traffic calming products etc), membranes, profiles.

PVC recyclate with containing low levels of legacy additives may be recyclable in the core of a sandwich structure product like Hybrid tiles or other durable products with a virgin top layer to seal the core layer and avoid diffusion of additives.

Infrastructure applications

Following the research project commissioned by the Vinyl Council in 2017 (refer to page 20) which found that vinyl flooring material can be re-ground in Australia and processed as a replacement aggregate in concrete masonry products, ResiLoop conducted a review of research into infrastructure applications of recycled plastics and other materials in Australia. The main end markets identified were:

- Concrete and pavement
- Bricks/construction blocks
- Railway infrastructure
- Noise barrier walls
- Trench backfill
- Modular elements for tram stop platforms
- Hold-down clips and purlins for structural grating and roofs

The highest quantities of recycled materials suitable for replacing conventional materials include reclaimed asphalt pavement, which accounts for 26 percent of the recycled materials tonnage, followed by recycled crushed glass at 24 percent and crushed concrete at 18 percent.

One study found that post-consumer deconstructed carpet's calcium carbonate content can be used at concentrations of 5–15 percent as replacements for Portland cement and fine aggregate.[31] Another study found that the addition of 10–30 percent calcium carbonate enhanced the mechanical properties of high-density polyethylene-based wood/plastic composite.[32]

31 **Patrick Cunningham, Peter Green, & Sabbie Miller,** *Utilization of post-consumer carpet calcium carbonate (PC4) from carpet recycling as a mineral resource in concrete.* **Resources, Conservation and Recycling, Volume 169, 2021, https://doi.org/10.1016/j.resconrec.2021.105496**

32 **Cai Hongzhen, Yang Keyan, & Yi Weiming,** *Effects of calcium carbonate on preparation and mechanical properties of wood/plastic composite. IJABE,* **Volume 10, No. 1, 2017**

New Product Development for Flooring Wastes

ResiLoop approached polymer scientists with expertise in polymer formulations at a number of universities to discuss the potential for researching and developing new polymer formulations for manufacturing end applications in Australia based on recyclate from flooring.

Potential research projects may explore:

- Formulation manipulation for a specific outcome
- Increasing understanding of the material properties so as to leverage its good properties and increase the value of the recyclate
- Characterising the material and the homogeneous feedstocks required to improve the outputs.

The Centre for Sustainable Materials Research and Technology (SMaRT) at UNSW proposed a feasibility study on utilising waste PVC to produce composite panels, including identification of the best application for composite panels, optimisation of processing parameters for producing composite panels for the identified application, and characterisation of the resulting products.

Projects are typically 18–36 month Masters and PhD research commissions although shorter term undergraduate projects can be commissioned in line with academic timetables.

After considering the research scope from UNSW and potential research areas proposed by other institutions, given the timeline required and the high risk involved in the development of a new product, it was decided to defer the potential research areas proposed by UNSW and other institutions. It was found that developing new polymer formulations from scratch within ResiLoop's 12-month timeline would present significant challenges and uncertain outcomes. Instead, we decided to conduct trials with existing manufacturers already familiar with processing PVC compounds.

Evaluation of Export Market Potential

ResiLoop investigated export markets for reprocessed, pelletised resilient flooring waste material. Key factors affecting the feasibility of exporting the material include the cost of shipping freight and the trade price for recyclate.

Analysis indicated that the material recyclate would likely not be economically viable due to the low proportion of PVC in the material, making the value of recyclate quite low. Additionally, the cost of sea freight, geographical location of potential customers and PVC global prices are also factors that affect the economic feasibility of exportation.

However, changes in global supply and demand of polymers and compounds and policies incentivising recycling in destination countries, may affect future sales price.

Proof of Concept Trials

Reprocessing Trials

The purpose of the trials was to test, within ResiLoop's project timelines, the reprocessing of targeted resilient flooring wastes with the highest likelihood of success in producing marketable recyclate feedstocks and diverting waste from landfill. This includes the assessment of whether recycled resilient flooring from pre-consumer sources can be incorporated into flooring accessories and other high-value applications. Arcadis and ARFA are not expecting a 100% substitution with recycled materials; rather, the aim was to achieve a proportional substitution, such as 20–40% of virgin PVC compounds.

The first trial, which focused on the substitution of virgin material with recycled material was conducted in the first quarter of 2023. The target materials were installation pre-consumer waste including off-cuts, product not meeting relevant market specifications ('off spec') and stock and roll ends.

The trial participants and respective roles are outlined in the table opposite.

Around 500 kg per product type (Homogeneous, Heterogeneous and LVT) was supplied to RBM. The waste materials – sorted by product type — were shredded, granulated, compounded and pelletised to make granules/pellets. The granules were approximately 4mm in size. Additional pigment and lubricant were added during compounding.

Initial trials have been undertaken to determine the make-up of products and how they might be processed, moving towards a solution of having them able to be re-processed into finished goods. Manufacturers documented their reprocessing including any addition of virgin ingredients, as well as temperature, pressure and other processing parameters.

Table 9: Participants and roles

Participant	Role
Arcadis Australia Pacific (Arcadis)	Arcadis designed and managed the trials as well as co-ordinated the laboratory testing and issued a report summarising the trial outcomes.
Australian Resilient Flooring Association (ARFA) / ResiLoop	ARFA coordinated supply of uncontaminated pre-consumer waste from member companies and the waste recovery trials and provided advice on product compositions, formulations and analysis.
RBM Plastic Extrusions (RBM)	RBM processed waste materials into an agreed interim product (black pellet) and re-processed some of the interim product into flooring accessory product.
Armstrong Flooring	Armstrong Flooring received a portion of the pellets produced by RBM and extruded them into flooring accessory product.
Think Fencing	Think Fencing received a portion of each of the waste types, processed and tested them relevant to their product specifications.
Laboratories: Intertek, ExcelPlas	Labs received pelletised product from RBM in small samples to test for hardness, specific gravity, PVC K value, mineral filler particle size, filler content proportion, PVC content proportion and reported on these findings.

Results: Trial 1

HE material (heterogeneous)

Specific Gravity	1.485
Hardness	86 Shore A

The first trial had no issues in the compounding process and produced a good-looking pellet without the addition of additives or processing aids. However, extrusion of the pelletised material into flooring accessory product produced very poor results, possibly due to the presence of foaming agent in the material. It led to a very rough surface finish, as it was not homogenizing through the extruder barrel.

HO (homogeneous)

Specific Gravity	1.6
Hardness	96 Shore A

Initial compounding produced a very poor-looking pellet and there appeared to be contamination by an incompatible material. The pellets did not form uniformly; instead, they took onrandom sizes and shapes. The final form was more brittle than the HE product.

LVT (Luxury Vinyl Tile)

Specific Gravity	1.71
Hardness	93 Shore A

Initial compounding produced a very poor looking pellet with the material having difficulties in running through the machine. The pellets were not produced uniformly.

Both the HO and LVT produced more dust during the shredding and granulating processes than the HE material. To improve the products suitability for reprocessing and remanufacturing, plasticisers and additives are required.

Additional LVT waste material will be reprocessed using ratios of 50 percent virgin compound:rLVT and 75 percent virgin:rLVT

Granulated heterogeneous material in mixer

Extrusion of recyclate

RBM and Armstrong used the pelletised recyclate to trial extrusion of flooring accessories. The initial trial used 100% recyclate and unsurprisingly, the outcome was very poor as the material started to foam and did not form sharp edges.

Further extrusion trials were undertaken to find an appropriate ratio between the rVinyl and virgin materials. The goal is to find the maximum substitution rate without any loss to flooring accessory product quality.

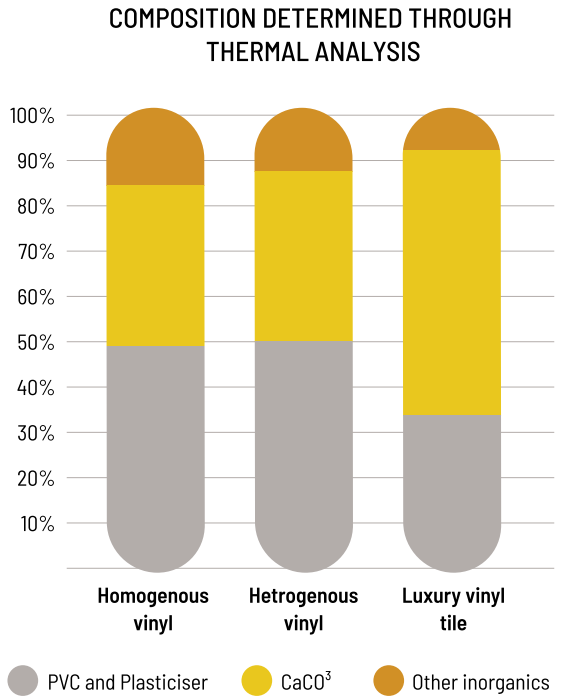
Analysis of materials

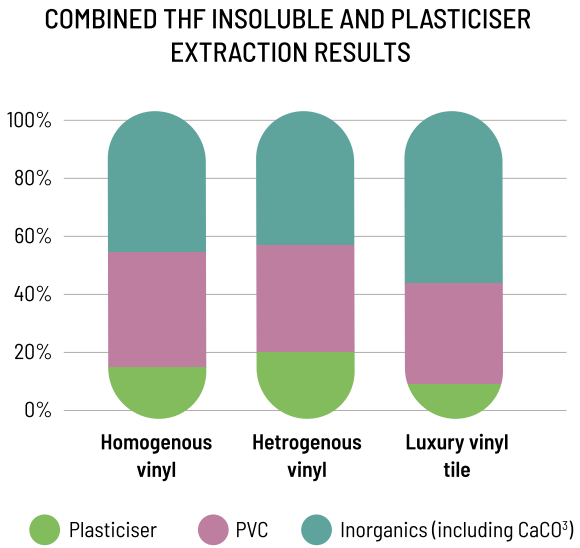
The recyclate was tested by independent laboratories, using Nuclear Magnetic Resonance (NMR) Spectroscopy, Tetrahydrofuran (THF) soluble/ insoluble analysis and Thermogravimetric Analysis (TGA), for

- Hardness
- Specific gravity
- PVC K value
- Mineral filler particle size
- Filler content proportion
- Other known properties

The results showed approximate alignment between the two test methods, NMR and THF as shown in *Figure 18.*

Figure 18: Compositional estimations through thermal analysis and THF





The results confirmed the assumed formulations for LVT, Heterogeneous and Homogeneous products. This enables ResiLoop to offer solutions to recyclers with greater confidence, depending on the specific formulations required for end markets and applications. The final formulations, optimised with the addition of lubricants and stabilisers would be as follows:

Homogeneous Flooring (per hundred resin (phr)

PVC	100.0
Plasticisers	48.5
Calcium Carbonate	110.6
Other Fillers	40.0
Stabilizer	2.4
Lubricants	0.5

Heterogeneous Flooring (phr)

PVC	100.0
Plasticisers	36.1
Calcium Carbonate	125.8
Other Fillers	36.9
Stabilizer	2.4
Lubricants	0.5

LVT Flooring (phr)

PVC	100.0
Plasticisers	48.5
Calcium Carbonate	262.6
Other Fillers	32.6
Stabilizer	2.4
Lubricants	0.5

Results: Trial 2

In this trial, the pelletised flooring materials were blended together and used with micronised uPVC recyclate to extrude a profile for new product being developed by Think Fencing for market. The pellet to uPVC blend was trialled at 10 percent, 20 percent and 30 percent additive in a trial lab and the outcomes were reported by the company to be promising.

A further trial micronized the pellets in order to get a better dispersion within the blend.

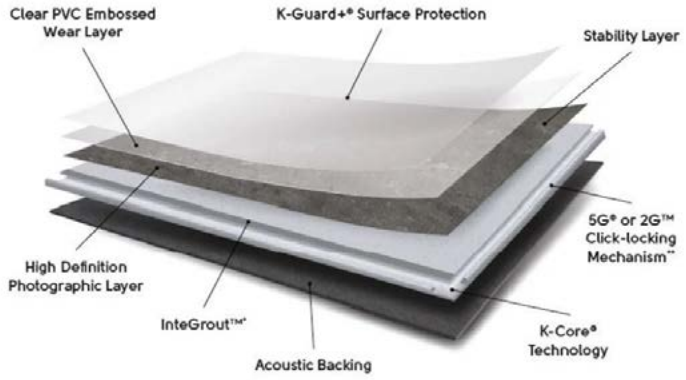
A larger scale trial using approximately one tonne of granulated LVT material was being prepared to be undertaken at the time of publishing this report

Separation Trial

PVC Separation is a process being developed in Australia to separate composite materials to improve recycling. The process involves adding solvent and a catalyst to the vinyl flooring products to separate PVC from calcium carbonate and other components.

The company received samples of four brands of Hybrid or rigid core floor tile products.

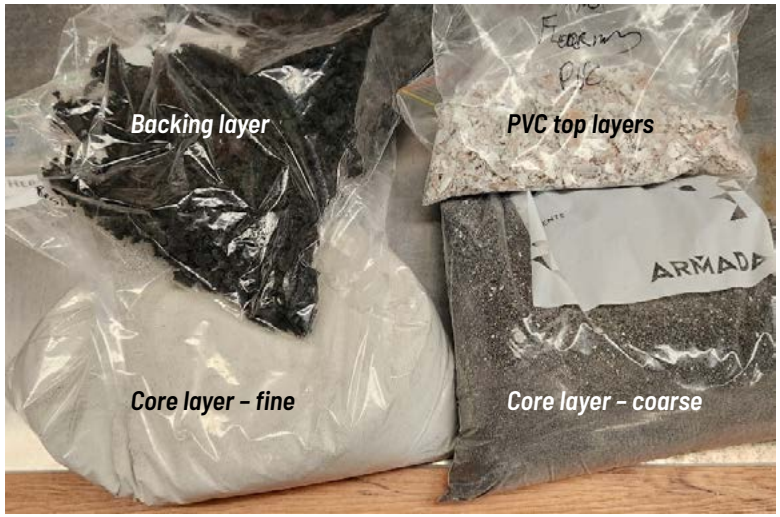
Figure 19: Example of composition of Hybrid Tile (Source: Karndean Flooring)



The task was to show how successful the PVC Separation process worked. The separated components were sent to an independent laboratory to identify and confirm the proportion of target materials and contamination.

Each brand sample was separated into components using the solvent-catalyst process (see image below) and the materials sent to an external laboratory for analysis of the cross-contamination of the recyclates from one layer to another. The key layers of interest are the top polymer wear and film layers and the rigid core layer (separated into coarse and fine particles). An additional output is a resinous substance potentially derived from the adhesives and plasticisers in the product. This will also be analysed. The separated backing materials, which may be IXPE[33], other polymers or cork, are not being examined at this stage.

The results were not available at the time of this publication; however, it is expected they will indicate whether this separation process is effective at producing relatively 'clean' recyclate streams, improving the opportunity for downstream reprocessing.



33 IXPE is an irradiation cross-linked polyolefin material.

Waste Recovery Trials: Designing the Process

The purpose of these trials was to model through in-field try-outs a proposed waste recovery system for resilient flooring installation (off-cut) waste and optimise the logistics and operations process.

The trials aimed to assess:

- The efficacy of waste separation by product type
- The degree of contamination of waste collected
- Quantities of recovered material relative to area of flooring laid and waste generated
- Education and training requirements for installers
- Processes for tracking, measuring and reporting the waste
- The ease of stakeholder engagement
- Costs and potential savings for key stakeholders, including logistics costs
- Feedback from stakeholders on the process
- Incentives and drivers to encourage changes in waste recovery behaviour

A waste recovery process, nick-named *'Bag it, Box it, Book it'*, was designed based on learnings from successful practices of existing schemes and finalised through consultation with stakeholders. This included:

- Collection receptacles designed to minimise freight costs and use minimal, recyclable/reusable packaging materials.
- Avoiding the cost and logistics requirements of delivering empty receptacles to collection sites and assessing the benefits of reusable containers that can be returned to the site versus single-use containers.
- Working with strategically locating recyclers to minimize freight costs and avoid having all materials transported to one central location.
- Identifying the possibility of reverse logistics/backloading, preferable to a separate freight service.
- Addressing the issue of stockpiling by implementing regular collections, particularly in regional areas where cost-benefit analysis is necessary.

For the trials, ResiLoop elected to work with GMK Logistics, a key player in the movement of rolled floor products who already services much of the industry. Stillages needed to be hired given the short-term nature of the trials, and Cevol Industries, who operate in all the trial states, was contracted to supply them.

Across the commercial and residential sectors, the majority of flooring sub-contractors take back waste to contractors' premises, where it is either disposed of at the contractor's own expense, stored, or returned to a supplier. ResiLoop therefore proposes that waste be returned to collection points at contractors' and retailers' depots/warehouses. From there, in the trial, the waste would be collected and delivered to GMK's nearest depot for consolidation and inspection.

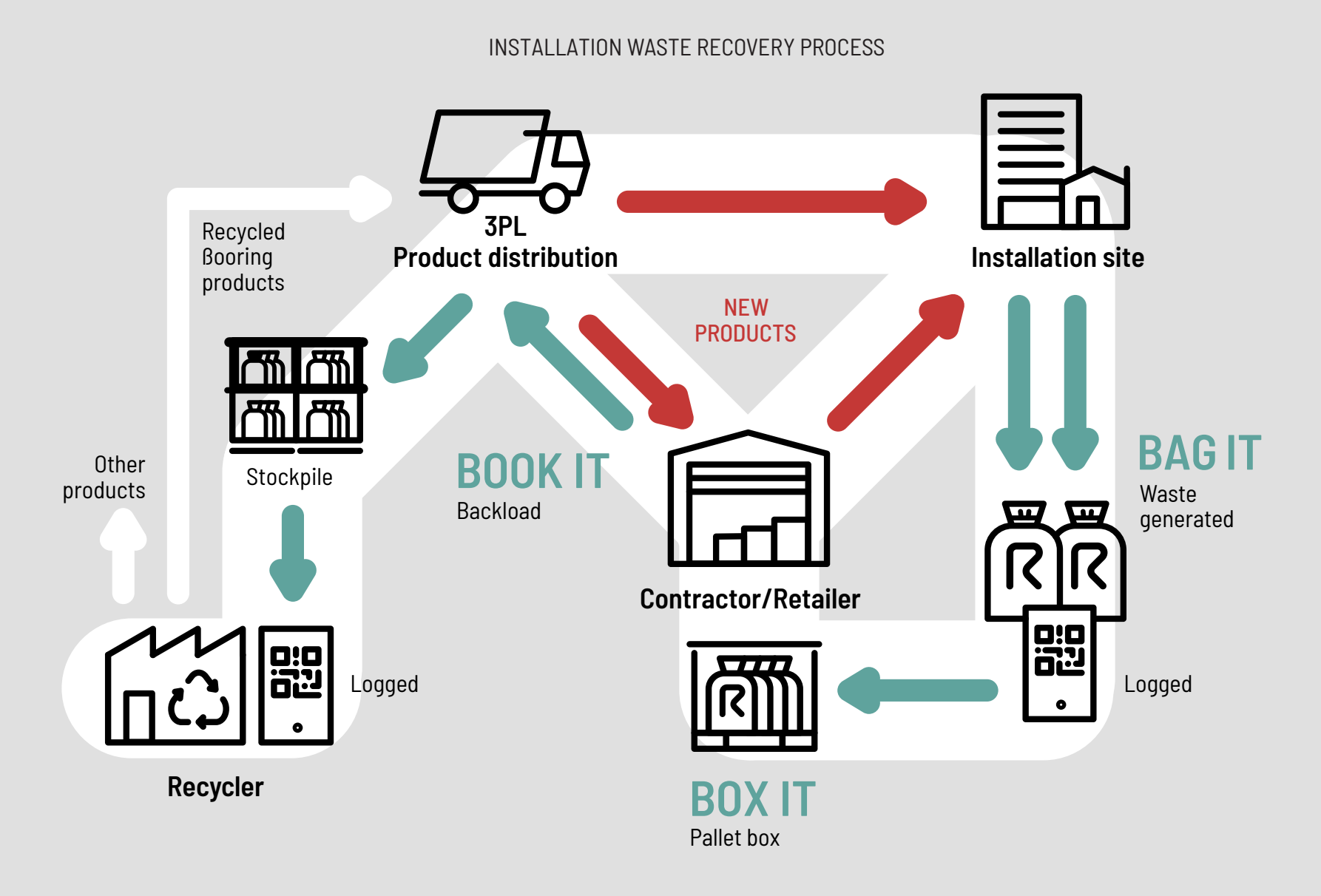
Currently, resilient flooring waste is generally combined with other waste and disposed of as comingled Commercial and Industrial (C&I) waste by contractors. To optimise value, collecting product types separately is preferred, so a clear and easy method of separating resilient flooring waste is essential to adherence to the scheme. ResiLoop developed three colour coded bag labels corresponding to flooring type so that contractors could readily collect the relevant flooring waste. These labels include disallowed materials for clarity.

Figure 20: Example colour-coded bag labels

As contractors and retailers often bear the cost of disposing of returned waste to landfill, a benefit of participation in the process would be to lower or avoid this cost.

An overview of the proposed process for the field trials is detailed below.

Figure 21: Proposed 'Bag it, Box it, Book it' process



Trials of the process were conducted in early 2023 across Victoria, Queensland and New South Wales under the coordination of Circular Design Thinking (CDT). Trial partners included two major retailers, three commercial floor laying contractors and logistics providers.

Table 10: Waste recovery trial partners

Commercial Contractors	Retail Groups	Logistics
Floor 91	Carpet Court	Cevol
Icon Flooring	Flooring Xtra	GMK
True Floors		

Each partner was issued with transparent, labelled bags measuring 1.5m by 1.0m in size. They attended a training session prior to conducting collection trials from installation jobs being performed over the trial period. The short timeframe for the trials due to the NPSIF grant timeline was a major challenge. Nevertheless, these trials provided valuable feedback on the process as well as data on recovery and logistics costs and potential waste volumes.

Key Results from Waste Recovery Trials

1. Waste successfully separated by Product Type

Waste collected from residential and commercial job sites was accurately separated and bagged by product type. Commercial sector installers are likely to know the products they are installing (LVT, HO or non-textile HE) and therefore to bag them correctly.

A number of floor-layers are already familiar with the recovery of carpet underlay waste and the ResiLoop system was not seen as significantly different. However, all underlay is collected as one product whereas ResiLoop requires source-separation by product (LVT, HO, HE).

Feedback from the trial reported that the collection bags were suitable due to their ease of use and handling.as installers worked. The installers were able to move the bags while working, whichassisted in successfully keeping product wastes separate. The ResiLoop process also eliminated the need for installers to take the waste over to site skips, which are often located some distance away and inconvenient to access.

Some installers may collect in their own receptacle; however, this requires decanting into the correctly labelled ResiLoop bag before going into the stillage at the Collection Point (unless product-designated stillages are maintained at each depot).

It was found that some collection bags slit from product corners, although they didn't break. A potential problem may also arise of bags being overfilled, particularly the LVT bags as LVT is a heavier product. This may result in bags being too heavy for safe manual handling. Alternative bags might be reusable "IKEA-style" woven polypropylene bags with handles.

Collected and bagged installation waste

2. Collected waste was uncontaminated

Visual inspection of the bags of resilient materials revealed that they contained virtually no contamination by foreign materials. A small piece of cardboard and adhesive on some product was noted. The reason for glue on installation waste is a consequence of not following best practice installation guidelines, which is where installers dry lay the space, trim the material without adhesive, before then fixing the floor. However, many installers glue the space, lay material and then trim the edges,resulting in some offcuts with adhesive residue.

Two bags of carpet offcut were collected in ResiLoop bags and submitted to the trial from the residential sector. These were readily identifiable given the transparent collection bags and could be removed before transport to the consolidation point/recycler. However, it may be harder to spot other types of non-targeted resilient flooring. Ideally the bags need to be inspected at the Collection Point before being added to the waste aggregation receptacle (stillage/bulk bag etc).

3. Installation waste generation rates

644 kg waste was collected for approximately 2,500 sqm of flooring laid, suggesting a waste generateion rate of 5.4 percent. Unfortunately, there was insufficient data collected on each site's waste generation by product type, except for one commercial site which calculated a 7.4 percent wastage rate.

This aligns with ResiLoop estimates of an average installation waste rate of 7.1 percent across product categories.

Once filled with waste material, the bags used for collection tended to weigh between 16 and 21 kg. The waste material was found to be reasonably well condensed in the bags.

According to one contractor's estimation, each installer would typically use one clear collection bag every 2–3 days. This could equate to a total of 60 bags a week for their company.

With sheet flooring product, the roll ends can potentially generate large quantities of 'waste' material. To send these roll ends to a recycler, they need the cores removed by the contractor before being transported in stillages (approx. 2 tonnes/stillage). However, it is common for smaller roll ends to be put in C&D waste stream bins on job sites. ResiLoop will need to explore how these materials can efficiently be collected and sent to a recycler.

4. Changing existing trade behaviours requires education and training

Retailer and contractor participants preferred to instruct their sub-contracted installers about the process 'on the job'. Off-site training and education is not likely to be feasible or acceptable to industry. It was relayed to us that as installers are paid by the floor area laid, a system to collect the waste generated must be very easy to implement and come at no additional cost to them.

ResiLoop will need to provide very clear, short, and easy to follow instructions that can go out with the collection bags (or be printed on the bags)

Results were better in the commercial sector where contractors have more control over the job/installation and are in a better position to require installers to follow the process.

In recruiting retail stores' participation, ResiLoop will need to know they meet certain volumes of resilient sales versus timber and carpet, to make it worthwhile.

Ideally, education about ResiLoop could be introduced into the flooring technical trade certified training program; however, it is necessary to recognise that two thirds of floor layers are reportedly not certified.

Recommendation arising from the trials

Tracking, measuring and reporting the waste provides feedback loops and incentivises performance

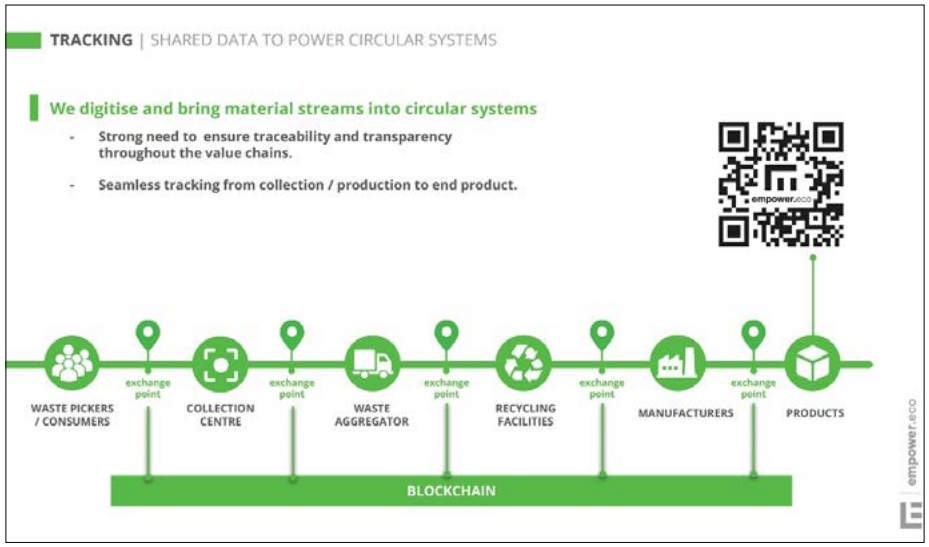
The timeframe for the trial was too short to develop a digital process to track, measure and report. However, GMK Logistics were able to weigh returned stillages containing bags and track their movement through their digital system.

A simple to use digital tracking system is required to log information about collected bags from installer to recycler.

CDT investigated digital solutions to link all the participating organisations in the flooring value chain and track movement, providing trusted data and complete visibility of the full journey.

CDT identified Empower.eco as a suitable solution using blockchain technology that:

- Can link the flooring value chain and helps track from Installation Site to Collection Centre (retailer/contractor) to Aggregator (3PL Warehousing) to Recycling Facilities to the manufacturing facility to the Products. With this solution, all partner organisations in the value chain could digitally receipt the material, send material from one partner to another and process the material within their organisation. For example, the recyclers can easily track their flooring — from receiving flooring off-cuts to processing it into granulated recycled material.
- Using Collectors' and Collection Points' unique ID numbers will ensure that only scheme members can log collected waste into the system.
- Can enable production of Product Passports so that brands can show consumers the full provenance of all the recycled material in their products. With a quick scan, a customer can see the full journey — including photographs. They can track the product from say an installation site through the recycling and manufacturing process all the way to the shelf.
- The proposed solution is easy to onboard partner organisations and offers a dashboard and monitoring of supply chain and tracked materials and tracking reports, showing the origin and journey of materials, tied to immutable tracking data.
- It facilitates documentation of collection and recycling data that can be used for Carbon Credits as well as scheme reporting.



It is recommended that the solution is trialled with participating organisations to further refine the solution technically and commercially to the flooring industry and ResiLoop's purpose in Australia.

An on-boarding process will improve results

'Onboarding' of participants should be conducted in a staggered approach where each organisation will need to meet certain requirements and training before commencing.

It was suggested that as installers go frequently to accessory product suppliers like MJS, FIS, QEP, these depots might be convenient as additional waste drop off points. It was recommended we explore engaging them, potentially offering them an incentive (and zero waste cost) for acting as collection points.

In the Residential sector, the two retail companies volunteered at head office and nominated stores to participate. The franchisees were therefore not necessarily self-nominating and the level of interest in engaging was varied; some stores did not participate at all in the trials.

Some retail stores claimed not to do sufficient resilient flooring (compared to carpet and timber) to justify the effort of educating installers etc. Engaging the Residential sector may need a different approach to ensure that retail stores are committed and meet certain criteria to ensure they are adequately resourced to participate.

Costs and Savings

The trial, due to the short time frame available, incurred higher than would be expected logistics costs due to small quantities of material collected in the time frame, a small order run of collection bags, the use of labels on bags rather than printing, and the need to hire stillages for Collection Points rather than purchase reusable/recyclable boxes or bags that can be delivered more efficiently and cost effectively, and do not require transporting and returning empty.

The cost per tonne of waste collected in the trials was over $2000/tonne.

It was estimated that stillages would hold approximately 250–300 kg of collected material. Hiring and moving stillages is expensive for the relative weight of materials collected. It was therefore recommended that the collected bags be decanted into single product-defined bulk bags (LVT, HO, HE) at Collection Points, stored on pallets or in stillages which allow the bulk bags to be lifted by forklift for transportation. Bulk bags are common, re-useable and recyclable bags in the plastics manufacturing sector. They can be reused by recyclers for product category granulate or pellets etc.

Example of Collection Point stillage, courtesy of Floor 91.

Switching to reusable/recyclable bulk bags or pallet boxes and transporting direct from Collection Points to Recyclers will significantly lower the costs. It was estimated that the costs could be in the order of $230–240/tonne. However, transport distance to the recycler will be the major factor in determining logistics costs.

Retailers and contractors currently pay for their own waste disposal ranging from $130 – $170 per skip bin or $130 – $450 per tonne. Major contractors have skips (containing all wastes) emptied twice a week. Removing some of the waste stream via ResiLoop will reduce their costs.

Installers usually do not pay to dispose of waste but bring it back to depots or have the capability to dispose of it at the installation site via supplied skip bins.

Key Challenges

The waste recovery trials identified the following challenges need to be addressed:

- Introducing new processes to a well-established trade process that is potentially seen as disrupting their current workflow
- Ensuring installers were recruited effectively by participating contractors and retail stores to the trial
- Identifying the most suitable, cost-effective collection point storage options (stillages vs bags vs boxes) and freight services

Recommendations

The following recommendations were established to guide following trials:

- Prioritise engaging large commercial sector contracting businesses as they may have better controls over waste collection, storage and installer behaviours.
- Select retail store participants where the volume of resilient flooring sold is significant in their business mix, and their installation sub-contractors are committed to the process.
- Explore recruiting Accessory Product Suppliers as Collection Points for residential installers.
- Develop clear, concise instruction material for installers
- Trial reusable PP collection bags instead of clear plastic bags
- Trial decanting collected offcuts into bulk bags at the Collection Points.
- Trial an easy-to-use digital tracking system to log collections and materials.
- Identify freight providers to transport direct from Collection Points to Recyclers.

Environmental, Health & Safety Risk Assessment

A desktop assessment of the potential risks in handling, managing and disposing of the waste material was completed by independent specialists to:

- Identify relevant health, safety and environment regulatory requirements for the collection, transport and storage of resilient flooring waste.
- Identify any necessary licensing requirements.
- Identify hazards and evaluate risks in the collection, transport and storage of resilient flooring waste from the point of recovery by installers on site to receipt of waste by recyclers
- Identify appropriate control measures to protect the environment, property and people against risks to health and safety arising from handling the waste
- Identify any differences in approach for installation waste ('clean') compared to end-of-life waste (up to 30 years old) which may contain legacy additives such as lead-based heat stabilisers and phthalate plasticisers.

This helps inform ResiLoop and those involved in the program, including construction firms, specifiers, industry and broader stakeholders.

The task required assessment across environmental, safety and compliance risks and a matrix was designed to cover a range of these aspects. In general, risks defined as high, very high or extreme present unacceptable levels of risk and must be acted on immediately to mitigate these risks.

Impacts identified as having low or medium risks are acceptable, however existing control measures need to be monitored for their ongoing effectiveness and further, long-term controls are to be developed for the impacts with a medium risk to reduce the risk level to low.

The risk assessment process identified three aspects where there was a residual risk rating of high, all related to potential for stockpiling of material on a site due to inability to dispose of materials and/or disruption to recycling. A further five aspects were rated as having a residual risk rating of Medium (High).

Controls have been recommended to be implemented to demonstrate management of all these risks.

GLOSSARY

ACCC: the Australian Competition and Consumer Commission

ARFA: the Australian Resilient Flooring Association, the peak body representing the sector.

Brand owner: a company that owns and manages a brand that is part of the resilient flooring supply chain.

Contractor: the person or company that provides services to clients under a contract or agreement. In the context of the ResiLoop project, contractors may be involved in the supply and installation or removal of resilient floorcoverings.

Distributor: a company that manufactures and/or distributes or sells resilient flooring products to retailers, commercial contractors, or specifiers.

Installation waste: the flooring waste generated during the installation process, such as offcuts or trimmings. This waste is more likely to be free from contaminants typically found in end-of-life waste, such as adhesives and legacy additives.

Installer: the person or company responsible for installing new floorcoverings.

Job site: the place at which resilient floorcovering waste is generated, either through the uplifting of end-of-first-life floors or as offcuts from the laying of new resilient floorcoverings.

Manufacturer: businesses or organisations that are engaged in local manufacturing of resilient floorcoverings or other products and supply these products to the domestic Australian market.

Pre-consumer waste: refers in ResiLoop to materials and products entering the waste stream prior to their intended use stage of the lifecycle and includes waste generated during the installation stage. Although this may not be consistent with how some standards and bodies define waste streams (where installation waste is included as 'post-consumer' waste), it helps us segment the waste stream based on product age (current market offering versus older end-of-life product).

Post-consumer waste:. ResiLoop refers to 'post-consumer' as material or products that have reached their intended end user, and which are no longer being used for their intended purpose.

Recycler: a business or organisation receiving ResiLoop material and processing it into a form (**Recyclate**) which can be used to replace virgin materials in the production process for new products.

Recyclate: the material produced from recycling a product.

Resilient floorcoverings (or flooring) refers to floorcoverings made from materials with some elasticity. This covers a range of products with varying compositions, including Luxury Vinyl Tiles (LVT), sheet vinyl, linoleum/ marmoleum, rubber, safety flooring, and hybrid/rigid core tiles.

ResiLoop is an initiative of ARFA, funded initially by a National Product Stewardship Investment Fund grant, to improve the design, recovery, reuse and recycling of resilient flooring consumed in Australia by developing a business case, supported by proof of concept, for a national product stewardship scheme for resilient floorcoverings, together with a roadmap for the national roll-out of the scheme in Australia.

Specifiers: A professional responsible for preparing detailed technical specifications and recommending product selections for construction projects.

Uplifted waste: waste generated when resilient floorcoverings are removed from a floor, such as at the end of their first life.

APPENDIX 1: DEFINITIONS OF TYPICAL RECYCLING/REPROCESSING TERMS

Term	Category	Description
Compound, Granules, Pellets	Material Presentation	Small pellets of 3-5mm that are used to manufacture products from plastics. The shape can vary in size depending on the machine used to cut the material. Produced as part of the extrusion process, in either the production of virgin plastics (new) or recycling plastics. Pellets are made to ensure consistent and continuous flow into the extrusion process for the product manufacturer.
Compounding	Recycling Process	Creating a highly specified plastic resin by taking multiple additives and/or materials and making them into one consistent pellet. To be used in manufacturing products that require certain technical properties to be met.
Converter	Manufacturing Process	Specialized operator capable of shaping plastics raw material to make a usable semi-finished or finished product*
Extruder	Equipment	Machine that takes plastic resin, regrinds or agglomerate, melts it down, filters out contaminations, removes gases and allows the dosing of colours or additives. It produces a refined resin that will move on to manufacturing or finished products directly such as Pipes, Profiles, Sheets, Tubes and more.
Filler	Materials	A mineral powder like Calcium Carbonate added to plastics to either reduce cost, change colour or create particular mechanical properties. In recycling, materials with filler may have less value and have limited markets compared to pure material.
Flake	Material Presentation	Plate-like regrind. The shape of regrind depends both on the plastics being processed and the manner of processing*
Floatation Tanks	Equipment	Because only pure PE & PP float in water, floatation tanks are used to separate contamination from plastics, ensuring a pure end product. It is possible to separate most polymers using water (eg., PET, PS, ABS, PA, POM etc), but it requires the water density to be altered with salt. For mixed polymer streams, often several floatation tanks, each with varying densities are required.
GF - Glass Filled	Materials	Glass filled plastics are produced to enhance the strength, rigidity, hardness or other technical requirements of the material, depending on what it will be used for. "GF30" means 30 percent glass filled. GF10, GF15, GF20, GF25, GF30 are most common, but it is possible to find up to GF50. For recycling, there are limited applications.
Granulation, Grinding, Regrinding	Recycling Process	The process of making regrind using a granulator.
Granulator	Equipment	Machine that cuts plastics into regrind of 6-14mm [Note: rPVC granules may be produced <5 mm]. It does this with a series of rotating and stationary blades that cut large plastic pieces down as they enter the machine. A screen at the bottom of the machine determines when the material can be vacuumed out and into big bags. The size of the holes in the screen determines the size of the regrind (eg. 10mm). The pieces will be continually grinded down by the blades until they reach this size. The smaller the size, the more times the material must be cut, which increases the amount of fines or powder produced.
Hot Washed, Hot Washing	Recycling Process	Plastic that has gone through a washline with at least one tank filled with hot water. This helps remove more contamination. Hot washed material is generally more clean and pure. It also means the feedstock was dirtier.
Installation waste	Materials	The offcut of material, or trim, that is wasted during the installation process
Jazz	Material Presentation	Common name given to mixed colour plastics. When reprocessed, jazz material (mixed colour) can only be made into dark grey or black products. Therefore, it is less valuable than natural or transparent.

Term	Category	Description
Mechanical recycling	Recycling Process	Processing of plastics waste into secondary raw material or products without significantly changing the chemical structure of the material*
Micronising	Recycling Process	Process by which a plastics material is ground into a fine powder*
Pallet Box	Packaging	Cardboard box capable of holding up to 1.2MT. Often used in plastics manufacturing. Can also be made from plastic
Post-consumer	Materials	Material generated by the end-users of products, that has fulfilled its intended purpose or can no longer be used (including material returned from within the distribution chain)* The material lifted off floors ('uplifted') when the commercial or residential building owner renovates or demolishes
Recovered material	Materials	Plastics material that has been separated, diverted or removed from the solid-waste stream in order to be recycled or used to substitute virgin raw materials*
Recovery	Recycling Process	Processing of plastics waste material for the original purpose or for other purposes, including energy recovery
Regrind, Flakes, Crush	Material Presentation	Hard plastics cut into small pieces (6-14mm) using a granulation machine (or granulator). This is done to densify the material for weight, consistent feeding into an extruder (to make pellets) or for more effective washing if the material is dirty. Some regrinds can be used directly in the production of products. Shredded and/or granulated recovered plastics material in the form of free-flowing material*
Recyclate	Materials	Plastics material resulting from the recycling of plastics waste. The terms "plastics secondary raw material", "recycled plastics" and "regenerate" are sometimes used synonymously*
Recycled Resin	Materials	Recycled plastics that have been extruded into a resin or pellet. Always of lower quality than virgin and cheaper, unless markets have an unusually high demand for recycled material.

Term	Category	Description
Shredder	Equipment	Machine that cuts large plastic pieces into rough shred of 20-60mm. It does this with a series of small blades or knives attached to a rotor and stationary blades. A screen at the bottom of the machine determines the size of the shred (such as 30mm) and the plastics will be continually cut until they can pass through the screen. This is a rough process designed to reduce the size of the material prior to washing or making regrind. Most frequently used for materials that are big and bulky.
Shredding	Recycling Process	Any mechanical process by which plastics waste is fragmented into irregular pieces of any dimension or shape. Shredding usually signifies the tearing or cutting of materials that cannot be crushed by fragmentation methods applicable to brittle materials, as typically carried out in a hammer mill*
Stillage	Equipment	A rack, cage or pallet for holding goods off the floor or separating goods in transit.
Zig Zag, Air Flow, Air Classifier	Recycling Process	Machine that removes dust and paper labels from plastic regrinds during the recycling process. It is called a zig zag because the material falls down a tall metal box shaped in a zig-zag form. There is a strong airflow going up to blow dust in the opposite direction of the material. Zig-zag shape means the material will hit several metal plates on the way down, dispersing the regrind to allow the dust to come free.

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