Multi-Mine Circular Resource Recovery Facility

A Prospectus for a Collaborative Approach to Resource Circularity in Queensland's Bowen Basin

ACKNOWLEDGEMENT

We acknowledge the first and continuing custodians of the countries and the grounds upon which we collectively work, create, live and dream.

We pay respect to Aboriginal and Torres Strait Islander cultures, and to Elders past and present. We recognise the unique and enduring relationship that exists between Indigenous Peoples and their traditional territories, and welcome their deep knowledge and participation in the circular economy. An understanding of interconnectedness and continual regeneration has long informed Indigenous cultures, and the opportunity exists for all organisations to benefit from an Indigenous understanding of living systems, the passing down of knowledge through communities and the key elements of circular economy practice.

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EXECUTIVE SUMMARY

Project overview

This project leveraged robust context-based analysis to identify high-priority material streams across the Bowen Basin mining sector and appropriate circular economy opportunities that could be implemented in a common-user facility to target these material streams while generating local value for key materials that are being wasted today.

Using a combination of stakeholder engagement, site-specific data, and detailed impact modelling, **10 materials were selected,** including timber pallets, bulk bags, food waste, diesel particulate filters (DPFs), scrap metal, cardboard, pipes, intermediate bulk containers (IBCs), off-the-road (OTR) surface mining tyres, and construction materials.

For each material, we evaluated current practices, estimated waste volumes, and environmental impacts. A total of **23 circular solutions were analysed** (several per target material), supported by life cycle assessments, techno-economic analysis and material processing experts. **Site suitability and enabling conditions were also assessed** to inform appropriate site locations.

The findings were consolidated into a strategic prospectus for a Multi-Mine circular Resource Recovery Facility, outlining key opportunities, delivery pathways, and investment considerations.

The prospectus development also presents a replicable methodology for common-user resource circulation facilities shared amongst multiple operators in an area.

~110,180 tonnes of wasted materials could be recovered or diverted from landfill per year

Each tonne recovered means one less extracted, saving emissions & preserving resources.

UP TO ~**$4.7 BILLION** IN 10 YEAR NET-PRESENT VALUE COULD BE REALISED

THE VALUE OF CIRCULARITY

A guiding framework for business and government

A Circular Economy is a new economic model, promising to deliver broad scale impact reduction while delivering regenerative value.

It is based in three, globally accepted principles:

1. Eliminate waste and pollution (considers waste a design flaw)
2. Circulate products and resources at their highest value, for longer
3. Regenerate natural and social systems

$26 billion in GDP each year by 2035

Circularity empowers a crucial system's perspective, revealing where the mining sector can unlock its potential for total value creation (environmental, social, and economic).

ENVIRONMENTAL

Circularity can address **45%** of greenhouse gas emissions

CO_2

You don't become circular for circular's sake.

You enact circularity because it addresses GHG emissions, biodiversity loss, waste, etc.

SOCIAL

3x Job creation from circular initiatives (CSIRO)

Circularity elevates communities.

Tapping into local skills and programs, and creating resilient localised economies.

ECONOMIC

Public equity funds with a circular focus permored **5%** Better than their benchmarks

Circularity is outperforming the market.

Demonstrating better and more resilient returns than non-circular investments.

VALORISING ALUMINIUM BY-PRODUCTS

Cross-sector circular collaboration to use aluminium by-products for soil regeneration

Rio Tinto collaborated with all five municipal governments and local blueberry growers on a circular economy project to find a valuable application for anhydrite waste coming from their Saguenay - Lac-Saint-Jean aluminium operation in Canada.

The collaboration found that anhydrite contains calcium and sulphur - important nutrients for crops. They developed products from their anhydrite that are used in a number of agricultural applications such as fertiliser for local blueberry producers.

Rio Tinto is continuing to collaborate with the Canadian Government and local businesses to explore circular opportunities for their many waste streams, such as anhydrite as a gypsum alternative and in the paper industry. Today, ~85% of waste material (excluding bauxite residue) created by their Saguenay – Lac-Saint-Jean aluminium operations is now used to make new products.

This site also became the first in the industry to be certified by the Aluminium Stewardship Initiative for producing "responsible" aluminium (which includes low carbon emissions to high standards on biodiversity, indigenous people's rights and water management).

RioTinto Québec CFIA Canadian Food Inspection Agency FONDS DE RELANCE 02

MULTI-MINE CIRCULAR RESOURCE RECOVERY FACILITY

Unlocking total resource value through collaborative practice

INTRODUCTION

Multi-Mine Circular Resource Recovery Facility

Below ground, nature aggregated vast quantities of resources such as copper, metallurgical coal, bauxite, and more - geological inheritances built up over millions of years. Yet above ground, those aggregated resources are being split across dozens of disaggregated operators, each managing their patch in isolation. In Queensland's Bowen Basin, home to Australia's largest steelmaking coal reserve, 58 active mine sites extract the same materials, use the same equipment, generate the same by-products, and face the same waste challenges. But instead of working together, these mines often act alone. The result? A deeply fragmented system where valuable materials are buried instead of recovered, infrastructure is duplicated, and circular opportunities are lost.

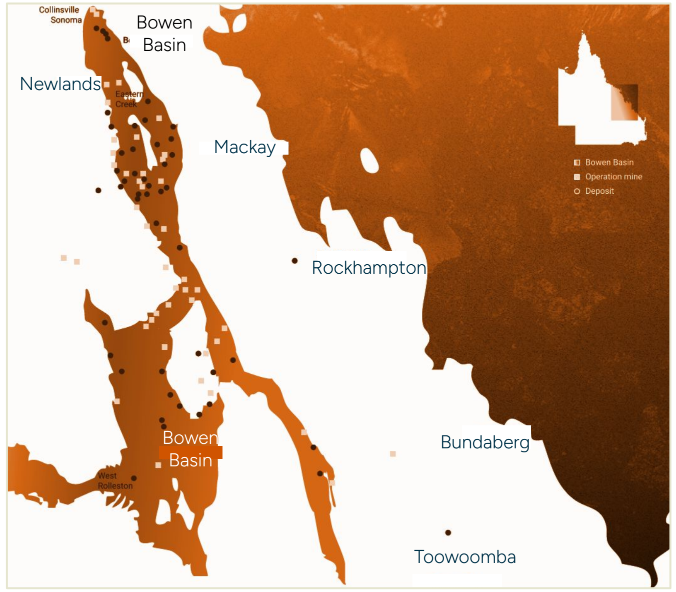
This report presents an alternative model: a whole-of-region, collaborative approach to resource recovery. The Multi-Mine Circular Resource Recovery Facility proposed is a common-user facility which would house circular solutions identified for materials that are wasted across operators in the Bowen Basin region.

To develop this prospectus, Coreo mapped material flows in and out of mines in the Bowen Basin, surveyed current recovery gaps & existing regional capabilities, identified circular, context-based solutions, and analysed these in partnership with the University of Queensland Sustainable Minerals Institute (UQ SMI). This prospectus was built off of the Bowen Basin context but offers a replicable methodology that can be applied across regions.

Each year, 58 mines produce:

137 million tonnes of metallurgical coal

~110,180 tonnes of wasted materials
(≈ two Brisbane Story Bridges)

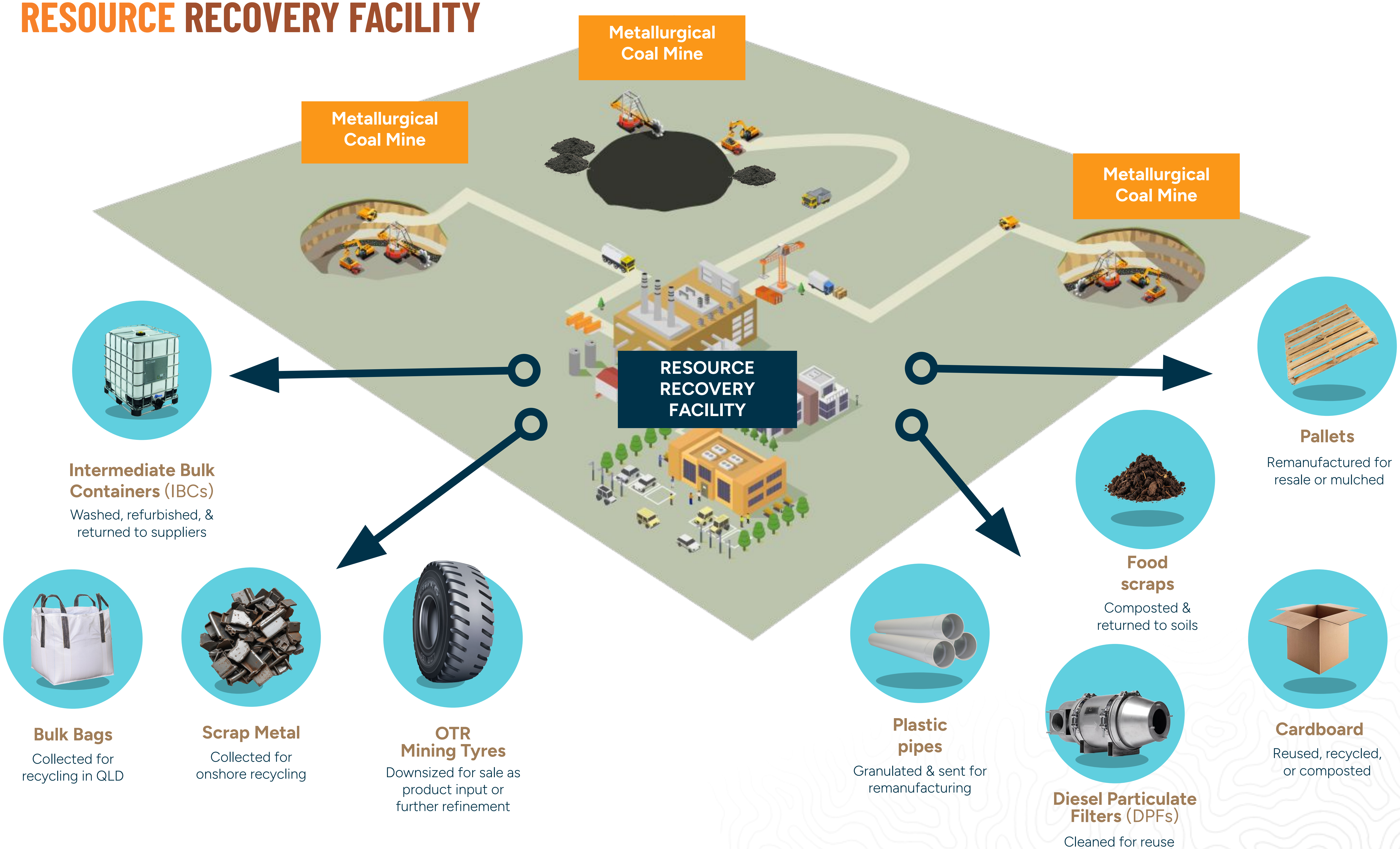


From vermicomposting food scraps to remanufacturing pallets and devulcanising off-the-road tyres, the Multi-Mine Circular Resource Recovery Facility charts a new course for the resources sector: one that understands where to compete and where it makes sense to collaborate to maximise economic, environmental & social value.

We're all digging in the same dirt - doesn't our shared geological inheritance deserve a shared systems solution?

THE VISION

MULTI-MINE CIRCULAR RESOURCE RECOVERY FACILITY



SOLUTIONS OVERVIEW TABLE

MATERIAL TYPE	SOLUTION	ON/OFF -SITE	END PRODUCT	10-YEAR NET PRESENT VALUE (NPV)	EMISSIONS TO 10-YEAR NPV RATIO	NOTES
TIMBER PALLETS	**T1:** Remanufacturing through repair & rebuilding	ON	Refurbished pallets	$41,667.283	$626k/t CO_2e	Recommended as a hybrid model to prioritise reuse & repair with mulching of residues / damaged timber.
	T2: Mulching of untreated pallets for site rehabilitation or local agriculture	ON	Mulching	$52,462,746	$1608k/t CO_2e	
BULK BAGS	**BB1:** Sorting, washing & redistribution for reuse	ON	Reused bulk bags	$273,489	$146k/t CO_2e	Recommended as a hybrid model to prioritise bag reuse where feasible and recycling unusable units.
	BB2: Recycling via Big Bag Recovery Program	OFF	Plastic pellets	$737,823	$364k/t CO_2e	
FOOD & ORGANIC MATTER	**F1:** Regional vermicomposting (Mackay) (with CB4)	OFF	Compost	$5,199,705	240k/t CO_2e	Existing provider (AusCan Worms) has expressed interest in servicing region.
	F2: On-site vermicomposting (with CB2)	ON	Compost	$2,002,005	$182k/t CO_2e	Solution enables operators to reuse by-products onsite for rehabilitation and soil amendments. By-product testing and storage may be required to support this model.
	F3: On-site biodigestion	ON	Greywater & fertiliser	$7,255,466	$685k/t CO_2e	As above. By-product testing, storage and greywater systems may be required to support this model.
SCRAP METAL	**SM1:** Site cleanup & sorting of legacy stockpiles	ON	Recycled metals	$889,347	$34k/t CO_2e	Recommended as a hybrid model to address legacy metals and establishing recovery pathways for stockpiled and future excess metals.
	SM2: Aggregation & supply to local recyclers	OFF	Recycled metals	$135,835,316	$775k/t CO_2e	
CARD BOARD	**CB1:** Reuse in local industry	ON	Reused boxes	$27,844,049	$1756k/t CO_2e	Solution requires central collection points at Multi-Mine facility for community or local businesses.
	CB2: Recycling into new corrugated cardboard	OFF	Recycled cardboard	$21,842,058	$128/t CO_2e	Recommended as a hybrid model (CB1, CB2, & CB3 or CB4) to prioritise reuse, recovery and recycling.
	CB3: On-site vermicomposting (with F2)	ON	Compost	$21,870,558	$582k/t CO_2e	Cardboard can typically only account for 10-20% of composting feedstock (technology dependent).
	CB4: Off-site vermicomposting (with F1)	OFF	Compost	$22,393,738	$356k/t CO_2e	
DPFs	**DPF1:** DPF cleaning	ON	Maintained DPF units	$3,376,104,452	$810k/t CO_2e	Recommended as a hybrid model to prioritise DPF maintenance and unit life extension where feasible and recovering precious metals. DPF precious metal recovery will be dependent on condition and material content of aftermarket components.
	DPF2: Collection for off-site recycling	OFF	Recovered materials	$730,516,665	$84k/t CO_2e	
PVC PIPES	**P1:** On-site pelletisation	ON	Recycled plastic	$58,961,021	$608k/t CO_2e	Solution requires accurate plastic pipe sorting to ensure efficient recycling by type. Can be further supported by on-site granulators to reduce volume size for transport.
	P2: Collection by manufacturer for recycling	OFF	Plastic pellets	$2,874,061	$116k/t CO_2e	Solution is suitable for all plastic types (PVC, PE), however PIPA-certified providers may be type dependent.
IBCs	**IBC1:** On-site reconditioning for reuse	ON	Refurbished IBCs	$58,327,345	$616k/t CO_2e	Efficient wash down areas are required to ensure correct drainage and cleaning of IBCs prior to refurbishment.
	IBC2: Off-site reconditioning for reuse & recycling	OFF	Refurbished IBCs / Recycled components	$13,868,922	$78k/t CO_2e	Recommended as a hybrid model (IBC1, IBC2) to prioritise IBC reuse where feasible and recycling unusable units.
OTR TYRES	**OTR1:** Crumb rubber into roads	ON	Rubber crumb, recovered steel, energy	$21,152,187	$10k/t CO_2e	OTR1 & OTR2 are near-term implementation opportunities, and a required as a first step to OTR3 & OTR4. While expensive technologies like pyrolysis are often explored to address tyres, primary processing options also represent viable end products. The list of end products presented is not exhaustive, other viable products include concrete safety barriers, permeable pavements or rail mats.
	OTR2: Buffings, granules & crumb rubber for local manufacturing	ON	As above - localised recovery	$20,979,687	$10k/t CO_2e	
	OTR3: Pyrolysis - carbon black into conveyor belt or retread manufacturing	ON	Carbon black	$37,027,122	$11k/t CO_2e	There is no silver bullet for addressing the enormous quantities of used tyres generated per year. As such, a hybrid approach of all solutions is recommended. To mitigate risks associated with pyrolysis & devulcanisation, investment should only proceed alongside partnerships with tyre, conveyor belt, or retread manufacturers to secure offtake markets and reduce the risk of project failure.
	OTR4: Devulcanisation - rubber mix to conveyor belt or retreat manufacturers	ON	Rubber mix	$14,393,361	$4k/t CO_2e	

METHODOLOGY

Overview

METHODOLOGY

Overview

This project followed a structured, evidence-based approach to identify priority materials and circular opportunities, leveraging both quantitative & qualitative insights to inform the design of a common-user Multi-Mine Resource Recovery Facility in the Bowen Basin.

To identify target materials by type and quantity, material flow data was analysed from multiple Basin mine sites. This data was averaged and scaled to reflect broader use across the Bowen Basin.

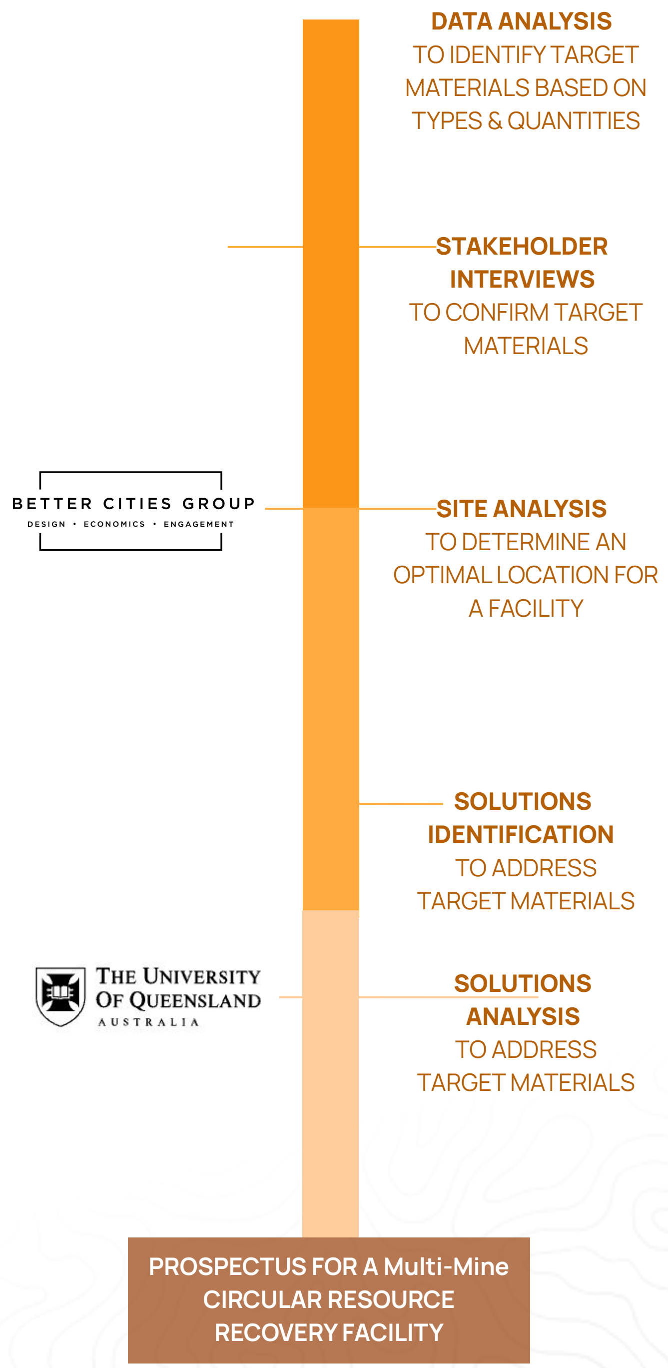
Consultations were conducted with key stakeholders to confirm target materials and uncover factors that influence material management.

Better Cities Group conducted a comprehensive site analysis to evaluate strategically located facility options capable of supporting a regional circular economy network. Sites were selected to enable optimised logistics and scalable, long-term resource recovery operations.

Solutions for recovery, reuse, and recycling of identified target materials were developed in collaboration with key stakeholders and subject matter experts.

The University of Queensland Sustainable Minerals Institute evaluated each material solution for its environmental, economic, and social impact using a life cycle assessment and techno-economic analysis.

This work formed the basis of a Prospectus for the Multi-Mine Circular Resource Recovery Facility presented in this report.



METHODOLOGY DETAIL

PHASE 1 DATA ANALYSIS

Purpose: To identify target materials based on common types and quantities.
Description: This phase involved examining waste generation data across several mine sites in the Bowen Basin. Material volumes were averaged across the studied operational sites and scaled to metallurgical coal production levels to maintain data anonymity. Data was first scaled up to the combined production of five sites (49.2 Million tonnes per annum (Mtpa)) to provide a localised understanding, and then to all 58 sites in the region (137 Mtpa) for a comprehensive Basin-wide perspective.

PHASE 2 STAKEHOLDER INTERVIEWS

Purpose: To confirm target materials.
Description: Following the data analysis, in-depth interviews and consultations with key stakeholders such as mine operators, waste contractors, and local government representatives were conducted to validate the identified target material streams, and uncover operational, contractual, or behavioural nuances that affect material flows. This phase ensured that the materials prioritised for circular solutions are grounded in practical realities and aligned with stakeholder needs and constraints.

PHASE 3 SITE ANALYSIS

Purpose: To determine an optimal location for a facility.
Description: Utilising heat mapping to identify catchment areas within a 25km radius of a maximum number of operating sites, and to towns & transport routes, followed by multi-criteria analysis to compare a shortlist of possible sites. Stakeholder consultation was also conducted in this phase to identify possible sites within the catchment areas. Then, a multi-criteria analysis was applied to six identified sites, evaluate potential facility locations based on factors like logistics, zoning, ownership, existing infrastructure, and regional accessibility.

PHASE 4 SOLUTIONS IDENTIFICATION

Purpose: To address target materials.
Description: This phase involved the development of potential solutions for the recovery, reuse, and/or recycling of each target material drawing from best practice case studies, local capabilities, and insights from stakeholder interviews. Solutions were tailored to the unique characteristics of the area and regional capabilities. Solutions identified vary from on-site recovery infrastructure, reverse logistics models, product stewardship schemes, or partnerships with local processors nearby.

PHASE 5 SOLUTIONS ANALYSIS

Purpose: To evaluate and compare solutions identified to address target materials.

Description: Each proposed solution was assessed for its environmental, economic, and social impact using a combination of life cycle assessment (LCA) and techno-economic analysis. Factors such as carbon emissions, net present value, and job creation were evaluated to help prioritise a set of recommended solutions.

The boundary of this assessment concluded at the point of material recovery at the Multi-Mine Facility due to this equipment and energy requirements may be the same for some solutions due to their processes

Assumptions made during this analysis can be found in the **Appendix** to this report.

Life Cycle Assessment (LCA)

The LCA component quantified greenhouse gas emissions (measured in tonnes CO_2e per year) for each recovery pathway including:

Scope 1 captured direct emissions from on-site processing

Scope 2 accounted for indirect emissions from energy use, and

Scope 3 covered value chain emissions, including transport and the embodied impacts of materials.

Techno-economic analysis

Each proposed solution was evaluated for its economic feasibility and value-generation potential. The analysis incorporated a range of cost estimates across infrastructure, materials, transport, and labour to determine an average cost per functional output. Established service providers were engaged to provide indicative process flows and associated costs for solutions. Where data was limited, informed assumptions were applied to maintain consistency and comparability.

The assessment included:

- **Net Present Value** (NPV) calculated over 10-year and 20-year project lifespans
- **Capital Expenditure** (CAPEX) and Annual **Operational Expenditure** (OPEX)
- **Annual revenue potential** for service providers
- An **emissions-to-NPV ratio**, serving as a Sustainability Performance Index (NPV-10YR k/tCO_2$e).

RESULTS

Materials, solutions, & analysis

RESULTS

Overview

Through a staged process of data analysis, stakeholder engagement, site assessment, and circular economy solutions co-design, ten priority material streams were analysed across mine sites in the Bowen Basin. These priority materials were selected based on their volume, current disposal practices (including landfill and stockpiling), interest in recovery by operators & other local stakeholders, and the potential for high-impact circular recovery.

Included for each material:

- A snapshot of current management practices;
- Estimated volumes across multiple mine sites;
- A set of tailored circular recovery solutions;
- Lifecycle and techno-economic analysis of solutions.

This section outlines the material-specific solutions that underpin the prospectus for a common-user Multi-Mine resource recovery facility.

The ten priority materials identified include a mix of organics, packaging, regulated waste, and operational inputs:

Timber pallets discarded after single use despite being suitable for reuse, mulching, or remanufacturing.

Bulk bags made from woven polypropylene, currently landfilled but structurally reusable or recyclable.

Food and organic matter, a high-moisture, emissions-intensive stream with composting or biodigestion potential.

Diesel particulate filters (DPFs), a regulated waste stream containing valuable recoverable metals.

Scrap metal (often steel - made from the very commodities that are produced in the Bowen Basin!), partially recovered but often contaminated or stockpiled, with missed value and safety risks.

Cardboard boxes, common across packaging chains but often contaminated, undermining recycling potential.

Plastic pipes, stockpiled or landfilled despite being technically recyclable or reusable.

Intermediate Bulk Containers (IBCs), bulky and often discarded, yet suitable for reconditioning or materials recovery.

Off-the-road (OTR) surface mining tyres, the heaviest waste stream by volume, currently buried with less than 2% recovery despite high material value.

TIMBER PALLETS

Timber pallets are flat, platform-like structures, designed to support goods during storage and transport, allowing for easy lifting and movement by forklifts or pallet jacks. They are a crucial component of logistics and supply chains worldwide.

TIMBER PALLETS

What is happening to them today?

Once used or damaged, timber pallets are often discarded.

Thousands of pallets are chewed through across the Basin each year, often forgotten after a single-use and destined for landfill. This places additional pressure to harvest more trees, convert more land, and release more greenhouse gas emissions from commercial timber production.

Not only is this bad practice, it's a circular opportunity waiting to realise untapped value.

CURRENT IMPACT

~16,371 tonnes of timber pallets used per year across 58 sites in the Bowen Basin = **467,743 individual timber pallets.**

This usage results in an estimated **22,919 tonnes of embodied CO_2e emissions.**

*Based on an emission factor of 49 kg CO_2e per pallet.

How much is there?

Mine site annual usage (t)	Material utilised (t) per unit (Mt) of production per annum		
(from 3 sites)	per one Mtpa	per 49.2 Mtpa	in the Bowen Basin
457.67	119.5	5,879	16,371

Mine sites can use hundreds of timber pallets every year, with generation rates varying from 250 - 1350 tonnes per year, representing an average timber pallet usage of approximately 457 tonnes per year. If we scale this up to the average timber pallets usage across the whole Basin, that equates to 16,371 tonnes of timber pallets used per year.

PROPOSED SOLUTIONS FOR TIMBER PALLETS

Two recovery solutions were analysed for timber pallets, addressing both intact and damaged materials.

These pathways include reuse, and remanufacturing, followed by mulching to achieve full material recovery.

VALUE POTENTIAL

UP TO 16,371 TONNES OF TIMBER PALLET WASTE TO LANDFILL DIVERTED PER YEAR IN THE BOWEN BASIN

10 YEAR NPV RANGE: **$41M - $52M**

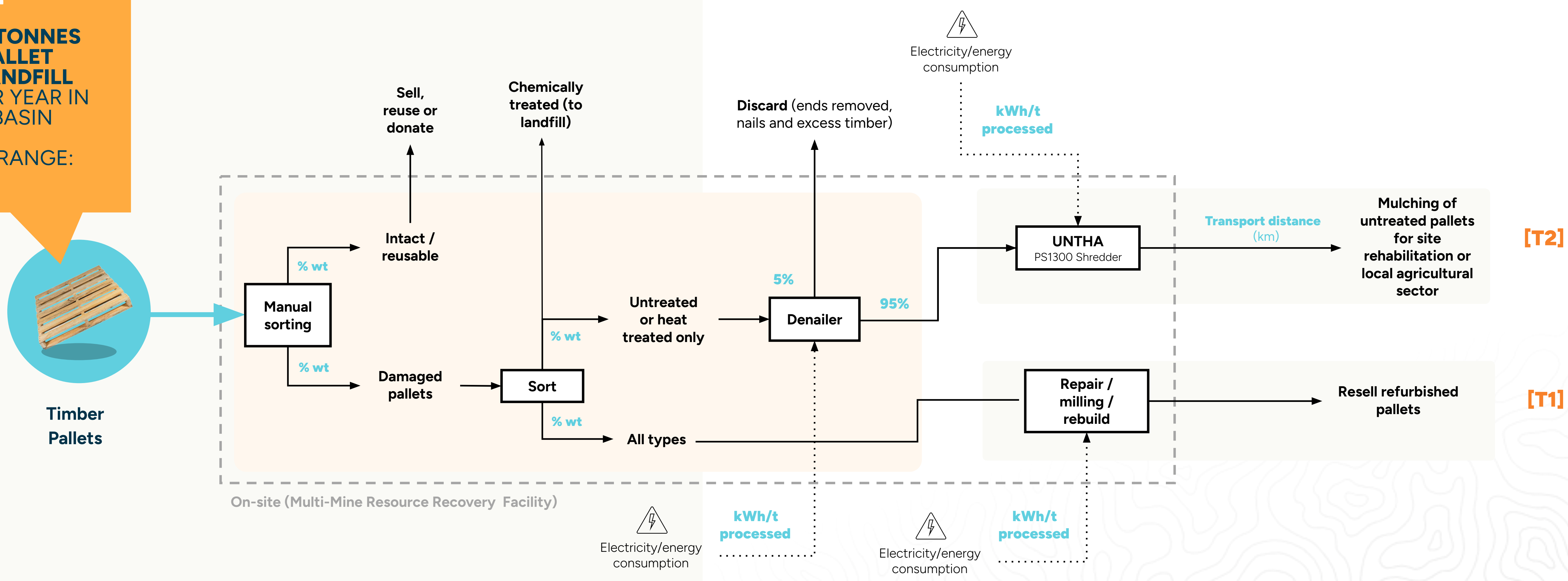
END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO NPV-10 YR RATIO
NEW PALLETS	$52,462,746	$1608k/t CO_2e
MULCH	$41,667,283	$626k/t CO_2e

T1: Remanufacturing through repair & rebuilding

Damaged pallets can be refurbished by dismantling, sorting, and reassembling components into new or hybrid pallets. Performed on-site with basic workshop equipment, this process reduces reliance on virgin timber and diverts waste from landfill. Rebuilt pallets can be used in mining operations or sold into secondary markets.

T2: Mulching of untreated pallets for site rehabilitation or local agriculture sector

Heavily damaged pallets made of timber are processed into mulch for use in landscaping or mine site rehabilitation applications. After de-nailing to remove hardware, the pallets are shredded using equipment. The mulch can be applied on disturbed land to support erosion control and revegetation. While heat-treated pallets are accepted, chemically treated pallets are excluded due to chemical contamination concerns.



ANALYSIS OF SOLUTIONS FOR TIMBER PALLETS

Two circular recovery pathways were assessed for timber pallets; T1: Remanufacturing through repair and rebuilding and T2: Mulching for site rehabilitation. Both options are low-risk, commercially viable, and suitable for near-term implementation.

Remanufacturing (**T1**) delivers the strongest economic return, with a 10-year Net Present Value (NPV) of $52M, low upfront costs ($45K CAPEX), and a high-value product ($342 per tonne). By repairing and rebuilding pallets on-site, this approach avoids virgin timber use and emissions (49 kg CO_2e per pallet) while supporting local repair jobs and reducing procurement costs.

Mulching (**T2**) is a complementary solution for damaged or untreated pallets, generating a 10-year NPV of $41M. T2 has slightly lower CAPEX of $34K compared to T1 but higher OPEX ($170K). This solution plays an important role in mine rehabilitation, improving soil structure, microbial activity, and erosion control.

Together, these solutions offer a practical, scalable dual-pathway: prioritising remanufacturing for high-value recovery, while mulching residuals to ensure full material use and zero waste to landfill.

	T1: Remanufacturing through Repair & Rebuilding	T2: Mulching of untreated pallets for site rehabilitation or local sectors
10 year NPV	$ 52,462,746	$ 41,667,283
Total CAPEX	$ 45,000	$ 34,751
OPEX per year	$ 157,018	$ 170,247
Annual revenue for service provider	$ 6,957,011	$ 5,570,851
Emissions to 10 Year NPV ratio	$ 1608k/t CO_2e	$ 626k/t CO_2e
Risk Profile	LOW	LOW
Feasible time frame to get up and running	**Short term - technology is commercially available**	**Short term - technology is commercially available**
End product	New pallets	Mulch
$ value of end product (p/t)	~$ 342	~$ 500
Environmental value	Avoids 49 kg CO2e for every new timber pallet displaced	Mulch-amended soils can host up to 383 distinct microbial taxa, boosting plant growth, carbon retention, and greenhouse gas mitigation
Social value	Generates regional employment through repair and refurbishment activities, particularly in logistics, warehousing, and light manufacturing.	Supports local land rehabilitation and agriculture efforts by providing a low-cost, carbon-rich soil amendment.

BULK BAGS

Bulk bags are an essential component of mining operations within the Bowen Basin, primarily used to transport and store stone dust used for passive explosion barriers to suppress the shock and risk of further ignition during explosions. Bulk bags are opaque bags typically made from woven fabric polypropylene.

BULK BAGS

What is happening to them today?

When properly managed, bags can have a long service life and can be reused where no sign of degradation is evident.

Unfortunately, due to their polymer make-up, there are limited pathways to manage bulk bags - meaning they are often left to degrade in landfills, or stockpiled without a clear disposal or reuse plan. With thousands used across the region annually, this contributes to a significant volume of avoidable plastic 'waste'. Durable and consistent in form, and relatively clean post-use, they are an excellent candidate for recovery, repurposing, or recycling with existing in-State programs.

CURRENT IMPACT

Each year, approximately **5,116 tonnes of bulk bags** are utilised across the 58 sites in the Bowen Basin - equating to around **4.43 million individual bulk bags.**

This high quantity of bulk bag use and production, results in an estimated **7,521 tonnes of CO_2e emissions.**

How much is there?

Mine site annual usage (t)	Material utilised (t) per unit/s (Mt) of production per annum		
(from 1 site)	per one Mtpa	per 49.2 Mtpa	In the Bowen Basin
143	37.34	1,837.13	5,116.58

At a typical site in the Bowen Basin, an estimated 76,380 bulk bags of various sizes are used annually. With the average weight of an empty bulk bag being 1.875 kg, this equates to approximately 143 tonnes of bulk bags used per site each year. When normalised to production output, this represents around 37.34 tonnes of bulk bags per million tonnes of production (Mtpa). Scaling this figure across an average of five mining sites, the estimated bulk bag usage increases to 1,837 tonnes per year, most of which is assumed to be sent to landfill. At the scale of the entire Bowen Basin, this amounts to approximately 5,116 tonnes of bulk bags wasted annually, highlighting a significant opportunity for improved material management across the sector.

PROPOSED SOLUTIONS FOR BULK BAGS

Two solutions were developed to manage bulk bags made from woven polypropylene,

focusing on reuse where possible and downstream recycling for damaged units.

VALUE POTENTIAL

UP TO 5,116 TONNES OF BULK BAG WASTE TO LANDFILL DIVERTED PER YEAR IN THE BOWEN BASIN

10 YEAR NPV RANGE: **$273k - $737k**

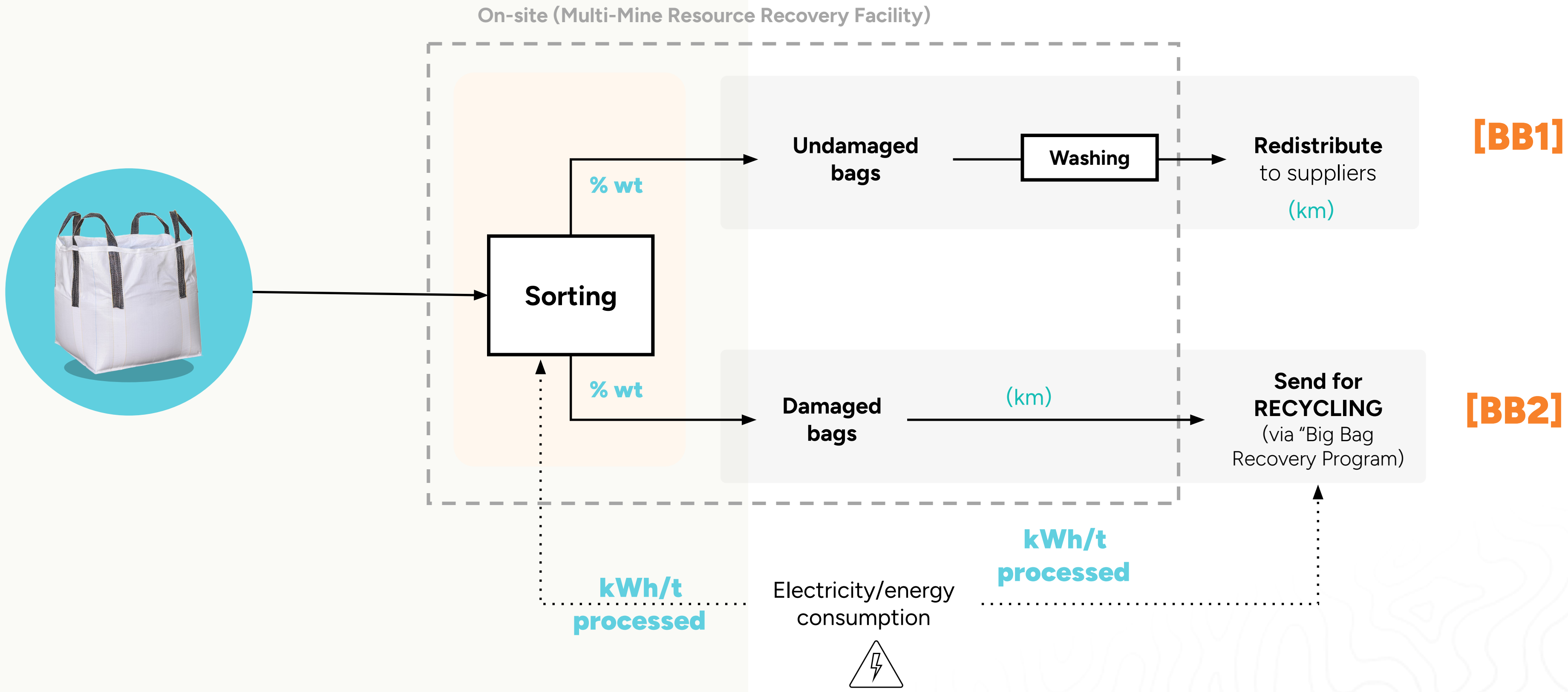
END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO NPV-10 YR RATIO
BULK BAGS	$ 273,489	$146k/t CO_2e
PELLETS	$ 737,826	$364k/t CO_2e

BB1: Sorting, Washing, and Redistribution

Reusable bags (those with Safety-Factors 6:1 or 8:1) are identified through visual inspection, cleaned, and returned to suppliers or operators. This simple on-site process supports extended packaging life cycles and reduces procurement costs.

BB2: Recycling of Damaged Bags via Big Bag Recovery Program

Damaged, contaminated, and Safety-Factor 5:1 bulk bags are compacted and sent off-site for recycling through programs such as the Big Bag Recovery initiative in QLD. This route ensures that polypropylene materials are returned to the circular economy as raw material inputs.



ANALYSIS OF SOLUTIONS FOR BULK BAGS

Two recovery pathways were evaluated for managing woven polypropylene bulk bags used in mining operations; BB1: Reuse via Sorting, Washing, and Redistribution, and BB2: Recycling through the Big Bag Recovery Program.

BB1 targets reusable bulk bags (typically rated at Safety Factor 6:1 or 8:1). These can be visually inspected, washed, and reintroduced into supply chains for multiple use cycles. With low CAPEX ($5K) and moderate risk, this solution is quickly deployable using existing on-site infrastructure. It delivers an estimated $107,409 in annual revenue (consistent with BB2), a 10-year NPV of $272,489 and supports reduced procurement demand while minimising material waste.

BB2 addresses non-reusable or damaged bags (often rated 5:1), which can be compacted and transported to an operational Big Bag Recovery facility in Toowoomba, Queensland. Here, bags are processed into plastic pellets valued at $650-800 per tonne, with an associated CO_2e reduction of 1.47 kg per kg recycled. The approach is low risk, has no CAPEX, a
low OPEX of $11,858 and supports the circular plastics economy. It also creates 74 full-time equivalent (FTE) jobs at the recycling facility.

While both pathways yield similar economic returns, their strengths lie in different points of the value chain. A hybrid model is recommended: reuse bags wherever safe and feasible and suppliers are willing to take back, and recycle the remainder to ensure full diversion from landfill. Together, they offer a practical, short-term implementation opportunity that supports emissions reduction, material recovery, and job creation, all with minimal infrastructure barriers.

	BB1: Sorting, Washing, and Redistribution for reuse	BB2: Recycling of Damaged Bags via Big Bag Recovery Program
10 year NPV	$ 272,489	$ 737,823
Total CAPEX	$ 5,000	-
OPEX per year	$ 71,344	$ 11,858
Annual revenue for service provider	$ 107,409	$107,409
Emissions to 10 Year NPV ratio	$146k/t CO_2e	$364k/t CO_2e
Risk Profile	MEDIUM	LOW
Feasible time frame to get up and running	**Short term - no major infrastructure requirement**	**Short term - Big Bag Recovery program facility in Queensland is operational and able to receive bulk bags for recycling**
End product	Bulk bag (reused)	Pelletised plastic
Economic value of end product	~ $10-100/tonne (size and condition dependent)	~$650-800 per tonne
Environmental value	Avoids 0.637 kg CO2e for every plastic woven bag displaced	Every kilogram of plastic recycled equates to 1.4678 kgs of CO2e reduction.
Social value	Enables on-site employment opportunities through inspection, sorting, cleaning, and redistribution tasks.	74 FTE created at the Big Bag Recycling Facility in Toowoomba

FOOD & ORGANIC MATTER

This solution is targeted at food scraps generated from accommodation camps, canteen, and kitchens. These organic streams are nutrient-rich materials which can be returned to soils.

FOOD & ORGANIC MATTER

What is happening to it today?

In the Bowen Basin, food and organic waste is typically co-disposed with general waste and sent to landfill.

Despite its high value as a resource for compost or bioenergy, the remoteness of many mine sites limits access to organics processing infrastructure. There is limited separation at the source, and where composting is technically feasible, it is usually not operationalised due to regulatory, logistical, or contractual constraints with existing waste contractors.

CURRENT IMPACT

Each year, approximately **3,792 tonnes of food and organics** are discarded across the 58 sites in the Bowen Basin.

The decomposition of this quantity of food and organics in landfills can result in an estimated **7,963 tonnes of CO_2e emissions** annually.

*Based on an emission factor of 2.1 t CO_2e per t.

How much is there?

Mine site annual usage (t)	Material utilised (t) per unit (Mt) of production per annum		
(from 2 sites)	per one Mtpa	per 49.2 Mtpa	In the Bowen Basin
106	27.68	1,362	3,792

Mine sites generate hundreds of tonnes of food waste every year from on-site accommodation facilities. For example, two Queensland mine sites were found to have sent an average of 106 tonnes of food waste to landfill annually. When normalised to production output, this equates to approximately 27.68 tonnes of food waste per million tonnes. Extrapolating this figure across the average annual production of five mine sites, wasted food amounts to approximately 1,362 tonnes per year. For the entire Bowen Basin, this represents an estimated 3,792 tonnes of food wasted on an annual basis.

PROPOSED SOLUTIONS FOR FOOD & ORGANIC MATTER

Three recovery options were analysed for food and organic matter, recognising the high moisture content and biological value of these streams.

VALUE POTENTIAL

UP TO 3,792 FOOD WASTE TO LANDFILL DIVERTED PER YEAR IN THE BOWEN BASIN

10 YEAR NPV RANGE: **$2M - $7.2M**

Option	END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO NPV-10 YR RATIO
F1	COMPOST	$ 5,199,705	$340k/t CO_2e
F2	COMPOST	$ 2,002,005	$182k/t CO_2e
F3	GREYWATER & FERTILISER	$ 7,255,466	$685k/t CO_2e

F1: Regional Vermicomposting (Mackay)

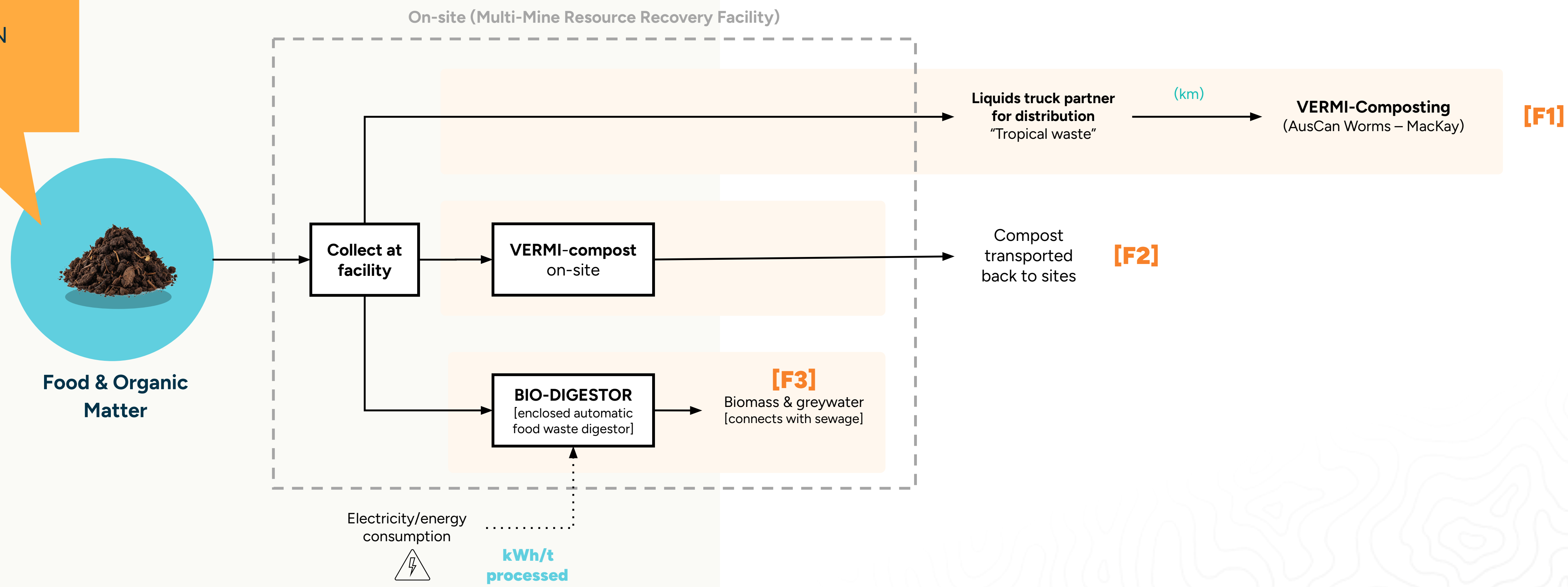
F1 is an offsite solution for food scraps explored a partnership with an existing facility in Mackay that leverages vermicomposting (with worms) to decompose organic matter into a compost product. In this model, scraps would be transported in a liquids truck to Mackay for processing. The existing provider (AusCan Worms) has expressed interest in servicing food scraps from camps.

F2: On-site Vermicomposting

Large scale worm farm on-site at the facility (refer to Wormtech example). This model would enable operators to reuse compost products themselves.

F3: On-site Biodigestion

F3 explores the use of LFC digestion units to address food scraps from sites & camps. These units produce greywater that can be used for irrigation as well as a biomass residue that can be applied to soils as a fertiliser. Food scraps would be segregated on operator sites and transported to the facility for processing.



ANALYSIS OF SOLUTIONS FOR FOOD & ORGANIC MATTER

Three low-risk recovery options were evaluated to manage food and organic waste, all requiring similar changes to camp operations (notably, source separation and staff training). The key differences lie in infrastructure needs, capital costs, logistics, and onsite versus offsite handling. All solutions would require segregation of food scraps on operator sites. All solutions achieve similar annual revenues (~$1M).

F1: Regional vermicomposting (Off-site, Mackay) provides the most immediately implementable pathway. It leverages an existing facility with capacity and interest, requires no capital investment, and achieves a moderate 10-year NPV ($5.1M) compared to F3. This model externalises processing while delivering strong environmental returns through compost production and landfill diversion.

F2: On-site vermicomposting delivers similar outcomes but retains compost on-site for direct use in landscaping or rehabilitation. With low CAPEX ($1.5K), highest OPEX ($804K) and the lowest NPV ($2M), this option suits sites with space and operational support for managing a decentralised system. It reduces reliance on external transport but introduces light infrastructure and ongoing site-level responsibilities.

F3: On-site biodigestion introduces a more technical solution, converting food waste into greywater which can be used in landscaping and wetting applications, and fertiliser-grade biomass. While it supports water reuse and soil improvement, it carries the highest capital cost ($35K), lowest OPEX ($77K) and offers the highest economic return (NPV $7.2M).

	F1: Regional Vermicomposting (Mackay)	F2: On-site Vermicomposting	F3: On-site Biodigestion
10 year NPV	$ 5,199,705	$ 2,002,005	$ 7,255,466
Total CAPEX	-	$ 1,500	$ 35,000
OPEX per year	$347,686	$ 804,002	$ 77,105
Annual revenue for service provider	$ 1,021,253	$ 1,063,465	$ 1,021,253
Emissions to 10 Year NPV ratio	$ 240k/t CO_2e	$ 182k/t CO_2e	$ 685k/t CO_2e
Risk Profile	LOW	LOW	LOW
Feasible time frame to get up and running	**Short term - existing facility & interested service provider. Will require change in operational practices at mine camps.**	**Mid term - requirement of infrastructure installation and in-camp practice changes**	**Mid term - requirement of infrastructure installation and in-camp practice changes**
End product	Compost	Compost	Greywater & fertiliser
Economic value of end product	~$50 - $150 per tonne (dependent on quality)		
Environmental value	Avoidance of methane emissions in landfill & compost-amended soils can host up to 383 distinct microbial taxa, boosting plant growth, carbon retention, and greenhouse gas mitigation		Greywater can displace freshwater use for non-critical purposes, such as
Social value	Supports existing local business	Provides low-cost inputs for regeneration efforts, offering opportunities for employee & community involvement	No major social value return (approximately 1 FTE)

DIESEL PARTICULATE FILTERS

Diesel Particulate Filters (DPFs) are critical emission control devices installed in diesel-powered mining equipment. They capture and store soot and other particulate matter from exhaust gases, significantly reducing harmful emissions. DPFs are essential for ensuring compliance with stringent environmental regulations and for protecting the health and safety of workers, especially in confined environments like underground mines.

DIESEL PARTICULATE FILTERS

What is happening to it today?

In the Bowen Basin, DPFs are integral to mining operations, particularly in underground settings where diesel-powered machinery is prevalent.

DPFs require regular maintenance, including regeneration processes to burn off accumulated soot. However, challenges such as harsh operating conditions, inconsistent maintenance practices, and limited access to specialised cleaning services can lead to premature clogging or failure of DPFs. When DPFs become saturated or damaged, they are often removed and replaced instead of cleaned. Due to the lack of local recycling infrastructure and the complexity of recovering valuable metals from used filters, many spent DPFs are stockpiled or disposed of as regulated waste.

CURRENT IMPACT

Each year, approximately **22,035 tonnes of DPFs are discarded across the 58 sites in the Bowen Basin** - the estimated equivalent of approximately 489,668* individual DPFs.

DPFs are resource-intensive to produce and when landfilled, can leach heavy metals and hazardous residues into surrounding environments.

*Individual DPF size and weight dependent

The types of vehicles that use DPFs on mine sites include:
Caterpillar or Hastings Deering heavy plant such as loaders, graders and shotcrete machines.

How much is there?

Mine site annual usage (t)	Material utilised (t) per unit (Mt) of production per annum		
(from 3 sites)	per one Mtpa	per 49.2 Mtpa	in the Bowen Basin
616	160.84	7,913	22,035

Mine sites consume large quantities of DPFs each year to maintain the safe and efficient operation of heavy equipment. Some machinery requires DPF replacement as frequently as once a week, with several sites reporting usage of 4 to 8 pallets of DPFs weekly. Data from three Queensland mine sites indicates this results in an average of 616 tonnes of DPFs per year.

When normalised to production output, this equates to approximately 160.84 tonnes of wasted DPFs per million tonnes of production. Scaling this figure to represent average annual production across five mine sites, wasted DPFs are estimated at 7,913 tonnes per year. At a Bowen Basin-wide level, this grows to an estimated 22,035 tonnes of DPFs and associated precious materials being discarded annually

END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO NPV-10 YR RATIO
MAINTAINED DPF UNITS	$ 3,376,104,452	$810k/t CO_2e
RECOVERED METALS	$ 730,516,665	$84k/t CO_2e

This significant NPV is based on indicative market pricing provided by established providers that charge between $1100 - $1880 to clean one DPF unit.

PROPOSED SOLUTIONS FOR DIESEL PARTICULATE FILTERS

Two recovery options were analysed for DPFs, focused on maintaining DPFs in use and recovering the value of components when no longer usable.

VALUE POTENTIAL

UP TO 22,035 TONNES OF DPF WASTE TO LANDFILL DIVERTED PER YEAR IN THE BOWEN BASIN

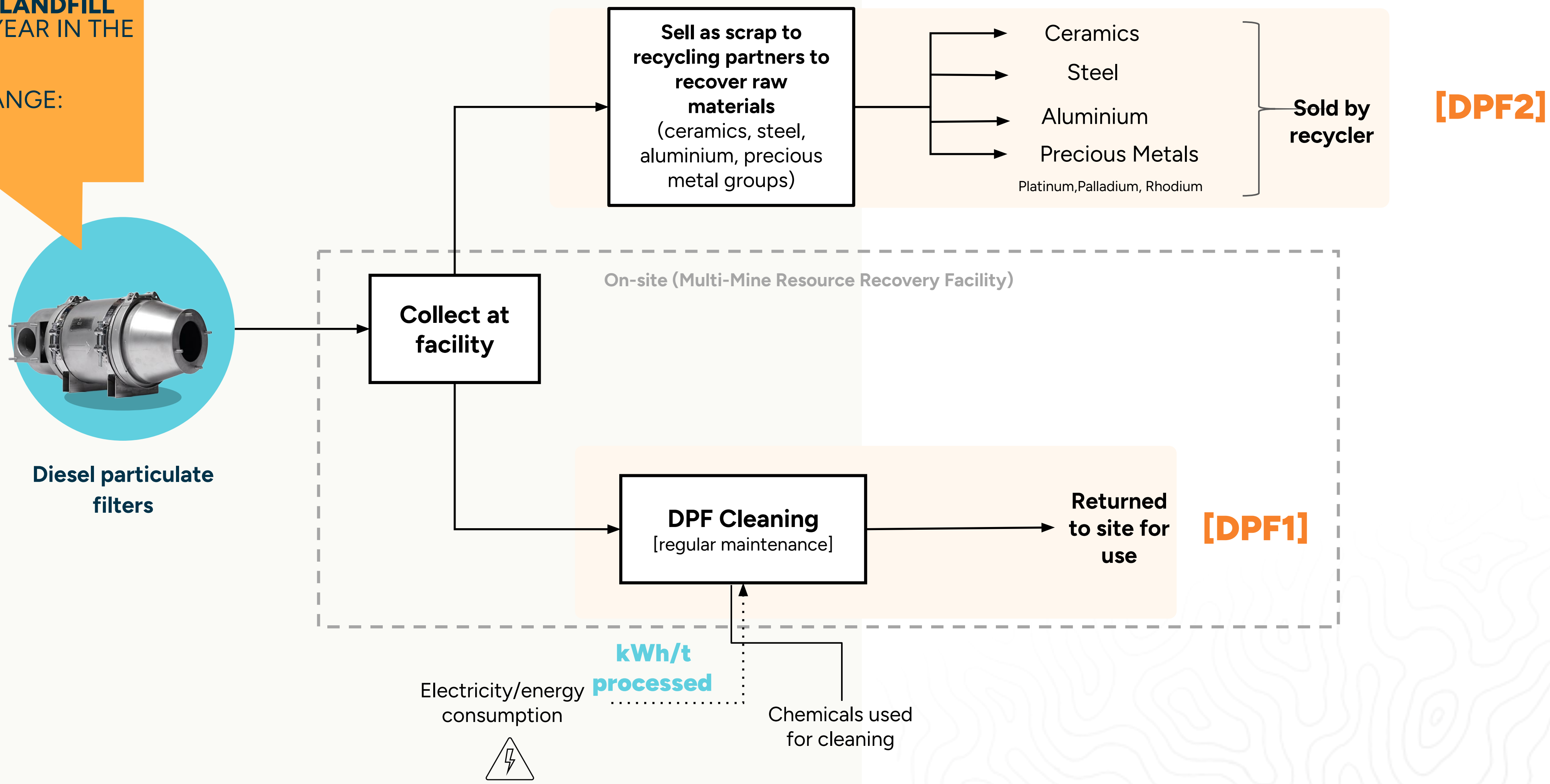
10 YEAR NPV RANGE: **$730M - $3.3B**

DPF1: DPF Cleaning

DPF1 offers a pathway for operational DPFs that can be maintained and refurbished, extending their lifespan and keeping them in circulation longer. The cleaning and refurbishment process typically involves ultrasonic and flash jet cleaning technologies, often supported by metal-compatible detergents, to restore DPFs to high performance standards.

DPF2: Collection for off-site recycling

DPF2 provides an off-site recycling solution for DPF components, including ceramics, steel, and precious metals (Platinum, Palladium and Rhodium). DPFs that have reached the end of their lifespan and can no longer be maintained or repaired, can be collected and transported to the Multi-Mine facility for storage and on-selling to recyclers such as OzzyMetals to enable the recovery of raw materials.



ANALYSIS OF SOLUTIONS FOR DIESEL PARTICULATE FILTERS

Two low-risk pathways were assessed to address DPF wastage across mining operations in the Bowen Basin.

Both options support a circular approach but differ in infrastructure requirements, capital investment and potential to retain material value through component recycling or extended operational life.

DPF1: This solution supports circularity through maintenance rather than material recovery. This option has a shorter implementation timeline, either through the installation of on-site cleaning infrastructure or through partnership with an established solution provider. This solution generates significant 10-year NPV ($3.3B) and revenue ($438M) due to low CAPEX ($25K) and annual OPEX ($1.6M). These figures were based on indicative market pricing of DPF cleaning where established providers quoted $1100 - $1880 per unit depending on size. This solution can support significantly reduced waste volumes and can preserve the embodied carbon within DPF components.

DPF2: This solution targets DPFs that have reached the end of their usable life and can no longer be cleaned or maintained. With a 10-year NPV of $730M, this model delivers high environmental value through the recovery of critical materials including platinum group metals, steel, aluminium, and ceramics. It requires a short-term setup through established providers therefore requires no CAPEX and is supported by a low OPEX of $184,276.

By implementing **both DPF1 and DPF2** together, mining operations can address the full lifecycle of DPFS, retaining functional units in use for longer and responsibly recovering critical materials at end-of-life. This two-pronged approach maximises circularity, reduces front-end costs and emissions.

	DPF1: Cleaning DPFs for lifespan extension	DPF2: Recycling DPF components
10 year NPV	$ 3,376,104,452	$ 730,516,665
Total CAPEX	$ 25,265	N/A
OPEX per year	$ 1,689,427	$ 184,276
Annual revenue for service provider	$ 438,913,671	$ 94,789,527
Emissions to 10 Year NPV ratio	$ 810k/t CO_2e	$ 84k/t CO_2e
Risk Profile	LOW	LOW
Feasible time frame to get up and running	**Short term - requirement of cleaning infrastructure installation or partnership with cleaning offtake partner such as Australian DPF Centre.**	**Short term - established recycling pathways through offtake partner such as OzzyMetals.**
Economic value of end product	N/A	Condition and market price dependent.
Environmental value of end product	High environmental value by prolonging unit lifespans and reducing frequency of new unit procurement, manufacturing and associated material extraction.	High environmental value through recovery of materials and reduces residue leaching into environment.
Social value	Low to moderate social value through the support of specialised cleaning jobs and promotion of on-site operational reuse practices.	Moderate social value through the support of specialised recycling jobs and promotes social license to operate through responsible waste stewardship.

SCRAP METAL

Scrap metal includes a broad range of materials generated during construction, operations, and decommissioning activities. This encompasses structural steel offcuts, damaged plant components, wire and mesh, brackets, piping, and redundant equipment. The majority is ferrous (e.g. steel, iron), though non-ferrous metals like copper, aluminium, and brass are also present in lower volumes. These materials carry significant embodied energy and commercial value when recovered cleanly.

SCRAP METAL

What is happening to it today?

Scrap metal is one of the more actively recovered streams in the Bowen Basin, with many sites engaging local or regional scrap merchants for resale. However, on closer inspection, recovery is far from optimised.

Metal is often co-collected with other bulky or demolition waste, leading to cross-contamination that significantly reduces resale value. Contaminants like residual oil, paint, and embedded fixtures are common.

In many cases, separation is performed only after significant accumulation, with metals stored in informal or unmanaged stockpiles onsite - some of which remain for years due to limited backhaul logistics or market volatility. These stockpiles not only represent lost revenue and space inefficiencies but also introduce health, safety, and environmental risks if not properly managed.

CURRENT IMPACT

Each year, an estimated **49,040 tonnes of scrap metal,** primarily steel, is generated across the 58 mine sites in the Bowen Basin. Much of this metal ends up in landfill, despite being the very material these mine sites are actively extracting metallurgical coal to produce.

This usage results in an estimated **142,216 tonnes of embodied CO_2e emissions.***

*Based on a hot rolled structural steel emission factor of 2.9 kg CO_2e per kg.

Moreover, once metals leave sites, there is limited transparency over where they go or whether they are recycled into high-value applications. Without robust traceability or verified end-markets, the actual circularity performance of scrap metal remains unclear.

How much is there?

Mine site annual usage (t)	Material utilised (t) per unit (Mt) of production per annum		
(from 2 sites)	per one Mtpa	per 49.2 Mtpa	In the Bowen Basin
1,317	1357.96	17,612	49,040

Mine sites generate hundreds to thousands of tonnes of scrap metal per year, with significant amounts stockpiled and limited recovery or recycling taking place. For example, two Queensland mine sites generated an average of 1,317 tonnes of scrap metal in a single year, of which an estimated 795 tonnes (approximately 60%) was stockpiled. Only 522 tonnes were recovered. When normalised to production levels, the total annual usage equates to approximately 1,358 tonnes of scrap metal per million tonnes of production. Scaling this figure across the annual production of five mine sites, the volume of scrap metal generated rises to an estimated 17,612 tonnes per year. At the scale of Bowen Basin metallurgical coal production, this implies nearly 50,000 tonnes of scrap metal generated annually much of which may remain underutilised, representing a clear opportunity for improved recovery and circular resource practices.

PROPOSED SOLUTIONS FOR SCRAP METAL

Two solutions were considered for scrap metal intended to be implemented in succession, first focussing on legacy clean-up as a precursor to an ongoing operational solution.

VALUE POTENTIAL

UP TO 49, 040 TONNES OF METAL SCRAP TO LANDFILL DIVERTED PER YEAR IN THE BOWEN BASIN

10 YEAR NPV:
$889K - 135M

END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO NPV-10 YR RATIO
SCRAP STEEL	$889,347	$34k/t CO_2e

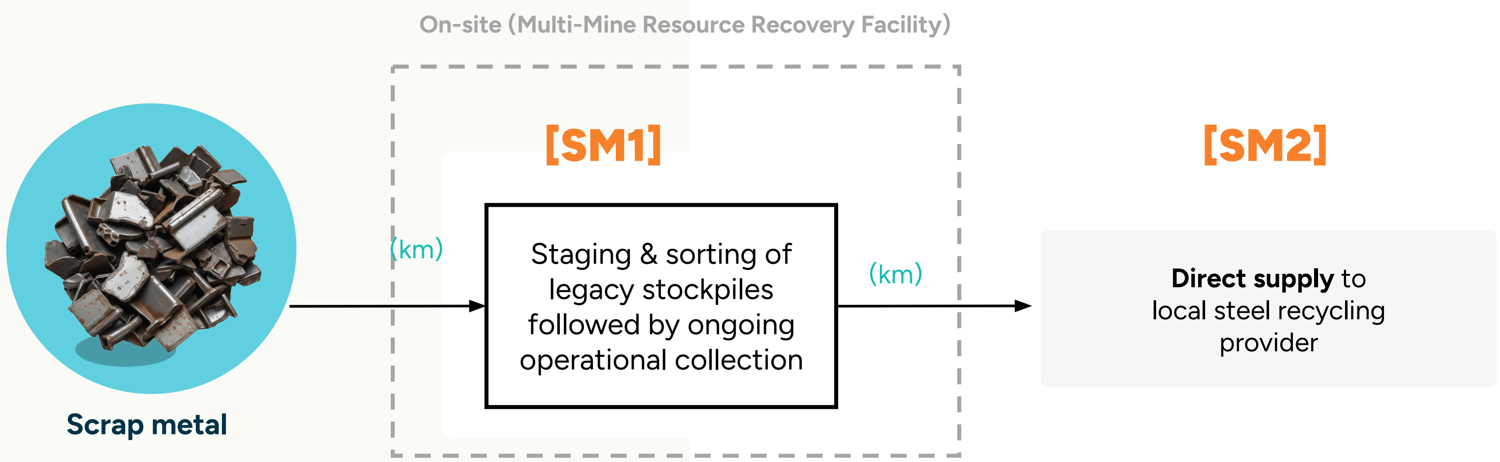
SM1: Site cleanup and sorting of legacy stockpiles

The first stage focuses on removing, sorting, and processing stockpiled legacy materials with a focus on scrap metal. In this initial stage, the Multi-Mine facility would serve as a staging area for sorting & processing of materials. This cleanup effort will improve site conditions and will marks as a first step in setting up an ongoing solution for full steel recovery from Basin sites.

END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO NPV-10 YR RATIO
SCRAP STEEL	$135,835,316	$775k/t CO_2e

SM2: Aggregation and direct supply to local steel recycling provider

Recovered metals are aggregated and transported to directly to manufacturers for recycling into new steel products. This route enables full circularity within Australia's steel supply chain. This option will continue following site cleanup of legacy stockpiles (SM1).



These solutions combined can generate a 10-year NPV of $136,835,316

ANALYSIS OF SOLUTIONS FOR SCRAP METAL

Scrap metal recovery is a clear, low-effort, high-return opportunity across Bowen Basin mine sites. Two solutions are proposed and intended to be implemented together:

SM1, which involves the cleanup and sorting of legacy stockpiles currently buried or left onsite, and SM2, which aggregates ongoing scrap for supply to domestic recyclers. The first stage (SM1) serves as both a clean-up effort and a practical foundation for future operations, improving site conditions, freeing up space, and recovering stockpiled materials. Established industry operators estimated this process would have a total CAPEX of $2M due to the logistics, labour resources and machinery required to audit, track, sort and aggregate stockpiles on site.

SM2 builds on the legacy solution by establishing a steady channel for recovered steel to flow into the local recycling market, requiring minimal infrastructure (relying mostly on on-site sorting) and generating strong returns (10-year NPV of $135.3M, $17.6M in annual revenue).

Together, these solutions offer a fast, low-risk pathway to recover value, reduce waste, and close the loop on steel; recycling the end products made from the Basin's own metallurgical coal instead of sending them to landfill.

	SM1: Site cleanup and sorting of legacy stockpiles	SM2: Aggregation and direct supply to local steel recycling provider
10 year NPV	$ 889,437	$ 135,835,316
Total CAPEX	$ 2,000,000	-
OPEX per year	$ 14,330	$ 20,507
Annual revenue for service provider	-	$ 17,611,802
Emissions to 10 Year NPV ratio	$ 34k/t CO_2e	$ 775k/t CO_2e
Risk Profile	LOW	LOW
Feasible time frame to get up and running	**Short term**	**Short term**
End product	Recycled metals	Recycled metals
Economic value of end product	Range of $1-3M scrap metal value stockpiled on site	$250 per tonne
Environmental value	Steel produced from recycled ferrous scrap can cut emissions by up to 70% compared to primary steel made from iron ore.	
Social value	Improves site safety, appearance, and employee wellbeing	Supports Australian manufacturing and local jobs

CARDBOARD BOXES

Cardboard is an essential packaging material for everything from equipment to consumables. It is generally clean, dry, and high in fibre content, making it a strong candidate for recycling - provided it is kept separate and uncontaminated.

CARDBOARD BOXES

What is happening to it today?

Onsite separation practices for cardboard vary significantly across Bowen Basin sites.

In many cases, cardboard is co-mingled with general waste or gets wet/contaminated, rendering it non-recyclable.

Where infrastructure exists, some cardboard is baled and sent off site for recycling, but distances to recovery facilities increase costs.

Opportunities for reuse (e.g. backloading to suppliers or local redistribution) are rarely explored.

CURRENT IMPACT

Australia consumes **4.9 Mt of cardboard & paper** annually, with around half landfilled.

Virgin cardboard production is water-intensive, drives deforestation & **generates more landfill emissions than food & organics.**

Recycling just one tonne of cardboard can prevent 0.6 t of CO_2 emissions.

How much is there?

While cardboard quantities were notably absent from the collated material flow data across Queensland mine sites, landfill waste audits conducted by local regional councils revealed substantial disposal of both clean and contaminated cardboard boxes. The mine site-level discrepancy is likely due to a common reporting focus on products themselves, rather than the packaging materials surrounding them. This mine site-level gap does not diminish the significance or environmental impact of cardboard packaging within the Basin network.

Have data on cardboard box usage at mine sites?
We would love to hear from you. Your insights can help strengthen the foundation for a Multi-Mine Resource Recovery Facility designed to deliver circular solutions across a broad range of material types.

END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO NPV-10 YR RATIO

PROPOSED SOLUTIONS FOR CARDBOARD BOXES

Four solutions were considered for cardboard boxes, focusing on its ability to be reused in good condition, and its inherent organic value.

VALUE POTENTIAL

10 YEAR NPV RANGE:
$ 21M - $27M

REUSABLE BOXES	$27,844,049	$1756k/t CO_2e

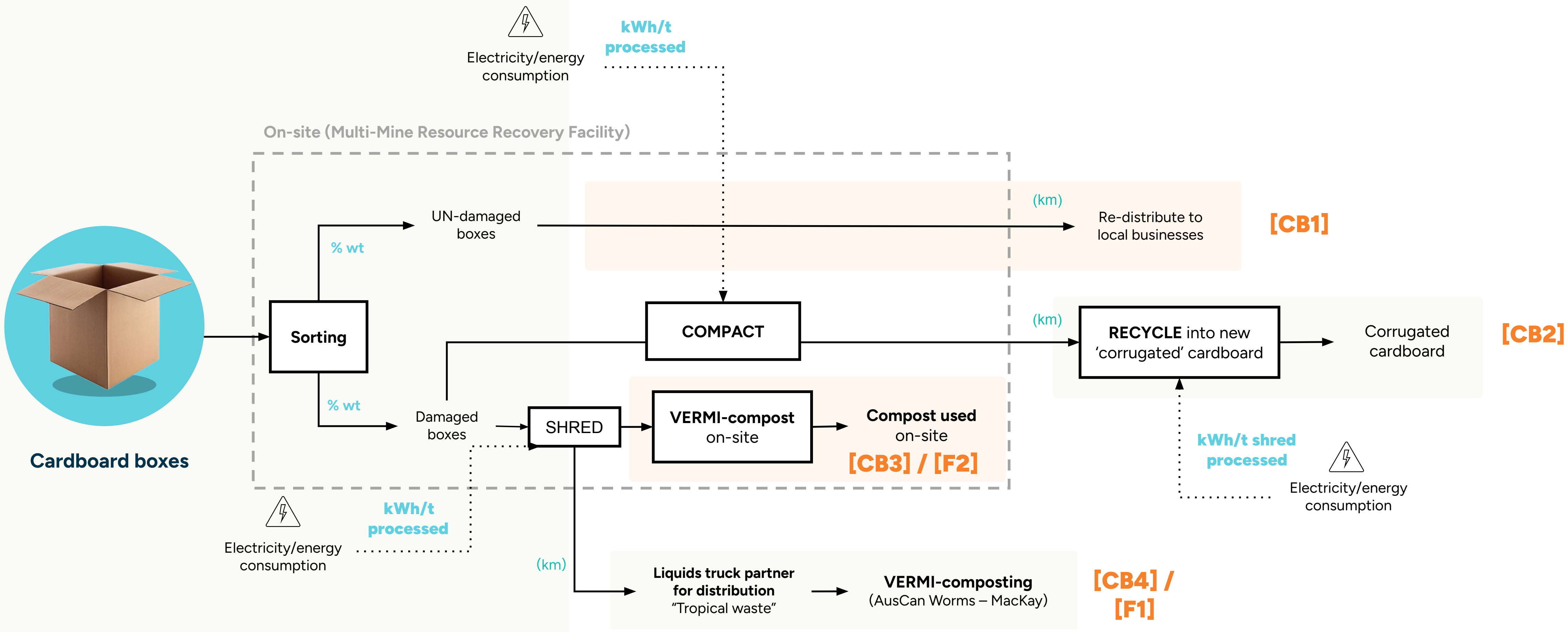
CB1: Reuse in local industry

Boxes in good condition can be set aside and made available to nearby businesses & communities, promoting packaging reuse in sectors like retail or agriculture.

RECYCLED CARDBOARD	$21,842,058	$128k/t CO_2e

CB2: Recycling into new corrugated cardboard

Damaged boxes would be collected and compacted at the facility for pulping and reprocessing into new packaging materials through existing local recycling programs.



COMPOST	$ 21, 870,558	$582k/t CO_2e

CB3: On-site vermicomposting (with F2)

Cardboard is shredded and added to food waste streams in on-site vermicomposting systems. It serves as a carbon-rich bulking agent in compost production. The by-products could then be used easily by operators for site rehabilitation.

COMPOST	$ 22,393,738	$356k/t CO_2e

CB4: Off-site vermicomposting (with F1)

Boxes could be sent down the same pathway as food scraps included in regional composting operations. This avoids contamination risks associated with onsite storage or mixed waste handling.

ANALYSIS OF SOLUTIONS FOR CARDBOARD BOXES

The four proposed solutions for cardboard; reuse, recycling, and two composting options are all low-risk, revenue-generating, and readily implementable, but differ in infrastructure needs, environmental value, and their position in the circular hierarchy. All solutions are projected to yield a similar annual revenue of approximately $3.7M.

Reuse (**CB1**) offers the greatest return (NPV $27.8M) with no CAPEX, low OPEX ($144K) and the fastest rollout, requiring only behaviour change on site. It also delivers the strongest environmental performance by avoiding the resource- and emissions-intensive pulp and paper production stage. Recycling (**CB2**), while still valuable (NPV $21.8), requires more infrastructure, has the highest CAPEX ($65K) and delivers more modest environmental savings, as recycled cardboard has a similar carbon footprint to virgin material.

The two composting options, on-site (**CB3**) and off-site (**CB4**) vermicomposting, have comparable economics and enable full recovery of contaminated or damaged cardboard, serving as a bulking agent for food waste streams.

Overall, there are many opportunities to better recover value from cardboard, a high volume material that is for the most part being wasted today.

	CB1: Reuse in local industry	CB2: Recycling into new corrugated cardboard	CB3: On-site vermicomposting (with F2)	CB4: Off-site vermicomposting (with F1)
10 year NPV	$ 27,844,049	$ 21,842,058	$ 21,870,558	$ 22,393,738
Total CAPEX	-	$ 65,000	$ 36,500	$ 35,000
OPEX per year	$ 144,068	$ 912,936	$ 898, 272	$ 845,376
Annual revenue for service provider	$ 3,750,000	$ 3,750,000	$ 3,843,000	$ 3,750,000
Emissions to 10 Year NPV ratio	$ 1756k/t CO_2e	$ 128k/t CO_2e	$ 582k/t CO_2e	$ 356k/t CO_2e
Risk Profile	LOW	LOW	LOW	LOW
Feasible time frame to get up and running	**Short term- no new infrastructure required, on site practice change required**	**Mid term - requirement of infrastructure installation & changes in onsite practices for correct segregation**		**Short term - existing facility & interested service provider. Will require change in operational practices**
End product	Undamaged boxes for reuse	New recycled cardboard	Compost	Compost
Economic value of end product	$ 750 per tonne	$ 150 per tonne	$ 500 per tonne	$ 500 per tonne
Environmental value	Reusing cardboard helps to displace the production of new cardboard, mainly ozone depletion, water use, and acidification, from pulp and papermaking.	Recycled cardboard displaces the need for new raw materials (though does not offer a much lower carbon footprint per kg than virgin cardboard)	Avoidance of methane emissions in landfill & compost-amended soils can host up to 383 distinct microbial taxa, boosting plant growth, carbon retention, and greenhouse gas mitigation	
Social value	Supports existing local business	Supports Australian manufacturing and local jobs	Provides low-cost inputs for regeneration efforts, offering opportunities for employee & community involvement	Supports existing local business

PLASTIC PIPES

Polyvinyl chloride (PVC), high density polyethylene (HDPE) and polyethylene (PE) pipes are used extensively across mine sites for water, slurry, drainage, and cable protection. They are durable and chemically resistant but challenging to recycle due to the presence of additives and contamination.

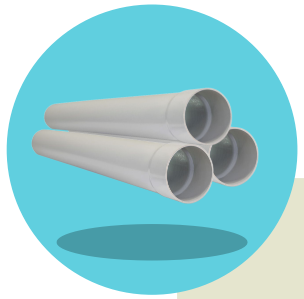
PLASTIC PIPES

What is happening to it today?

Plastic pipes are a critical part of mining infrastructure, commonly used for dewatering, slurry transport, water management, and ventilation systems.

The two primary materials used are Polyvinyl Chloride (PVC) and High-Density Polyethylene (HDPE/PE), depending on factors such as material compatibility, handling requirements, durability, and operating pressures.

While technically recyclable, end-of-life pipes are often stockpiled or landfilled in the Bowen Basin due to contamination, project transitions, unclear responsibilities, logistical challenges and a lack of coordinated recovery pathways.



CURRENT IMPACT

Each year, approximately **1,860 tonnes of PVC pipes** are discarded across the 58 sites in the Bowen Basin.

This usage results in an estimated **7,719 tonnes of embodied CO_2e emissions every year.***

*Based on an emission factor of 4.5kg CO_2e per kg or 9.7 kg CO_2e per m.

How much is there?

Mine site annual usage (t)	Material utilised (t) per unit (Mt) of production per annum		
(from 2 sites)	per one Mtpa	per 49.2 Mtpa	in the Bowen Basin
52	13.58	668	1,860

Mine sites consume thousands of PVC pipes each year, with large volumes either stockpiled or disposed to landfill. For instance, two Queensland mine sites sent an average of 52 tonnes of PVC pipe to landfill in a single year.When normalised to production output, this translates to approximately 13.58 tonnes of PVC waste per million tonnes of production. Scaling this figure to represent average production across five mine sites, the total rises to around 668 tonnes of PVC waste annually. At a Bowen Basin-wide level, this equates to an estimated 1,860 tonnes of PVC plastic discarded each year.

While the data indicated that PE pipes are utilised in smaller quantities on mine sites, industry experts anticipate PE quantities may equal or exceed that of PVC pipes. For example, one Queensland site replaces 10 kilometres of PE pipe on an annual basis, resulting in approximately 1 tonne of discarded material.

The circular solutions developed for PVC pipes can be readily adapted to a broader range of plastic types including PE - offering a valuable opportunity to address legacy and on-going plastic streams across the Bowen Basin.

END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO NPV-10 YR RATIO

PROPOSED SOLUTIONS FOR PLASTIC PIPES

Two solutions were considered for plastic pipes, with a focus on legacy clean-up and ongoing operational material flow.

For both solutions, PVC pipes are stockpiled, audited and sorted to determine whether they are suitable or unsuitable for reuse. Those identified as suitable will go on to be reused on site. Depending on their condition, suitable pipe lengths may be retained for non-critical applications such as temporary water transfer or drainage. These solutions can be applied to other plastic pipe types including PE.

VALUE POTENTIAL

UP TO 1,860 TONNES OF PVC PIPE TO LANDFILL DIVERTED
PER YEAR
IN THE BOWEN BASIN

10 YEAR NPV RANGE:
$2.8M - $58M

PELLETS	$ 58,961,021	$608k/t CO_2e

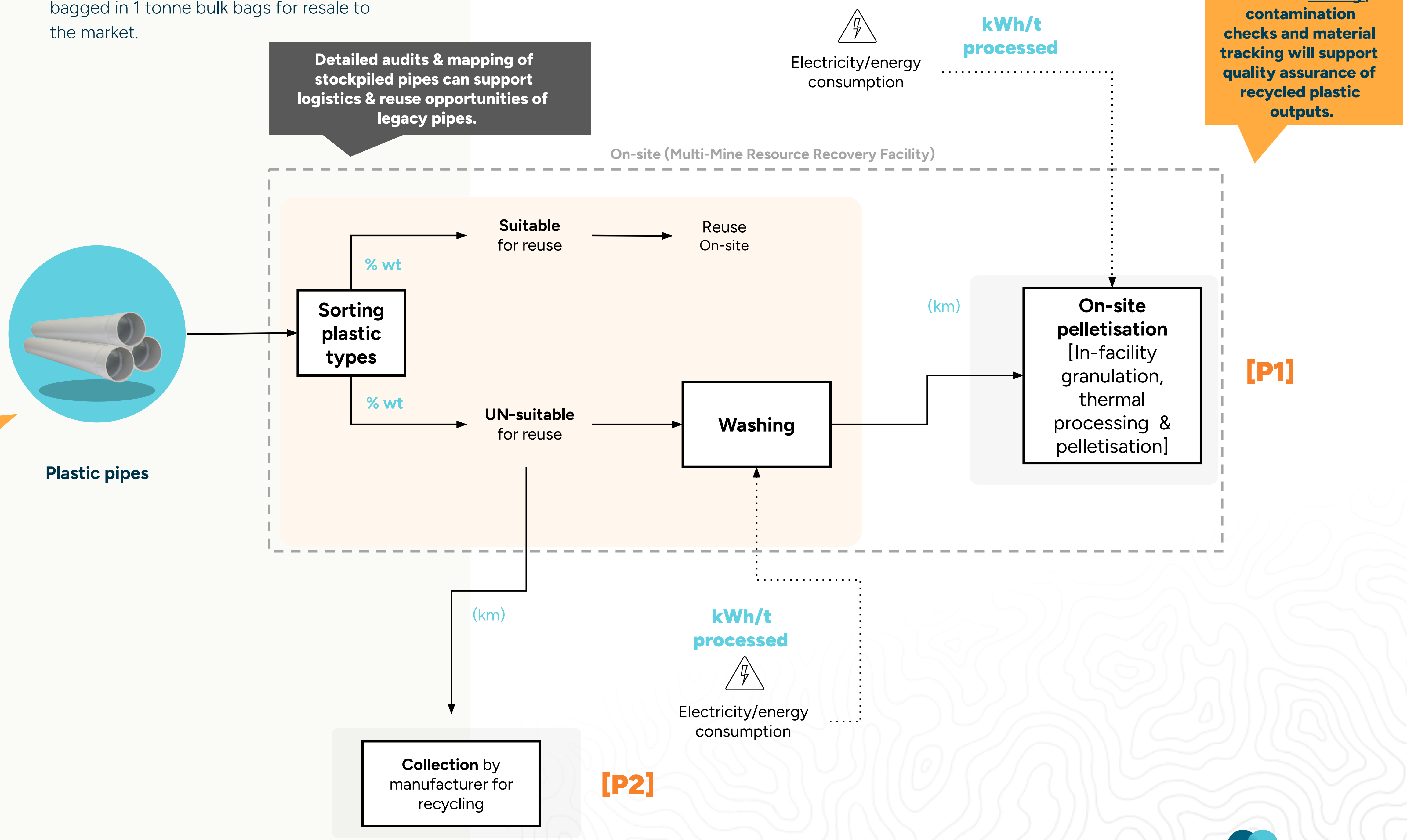
P1: On-site pelletisation

Pipes are collected and sorted by type and condition. Pipes unsuitable for reuse are washed and transported to the Multi-Mine facility where they undergo granulation, thermal processing (heating to 200-230°C and water-cooled extrusion), fine separation and pelletisation before being bagged in 1 tonne bulk bags for resale to the market.

PELLETS	$ 2,874,061	$116k/t CO_2e

P2: Collection by manufacturer for recycling

Granulated PVC is transported to a certified Plastics Industry Pipe Association of Australia (PIPA) manufacture partner for further testing, cleaning, and processing for future remanufacturing.



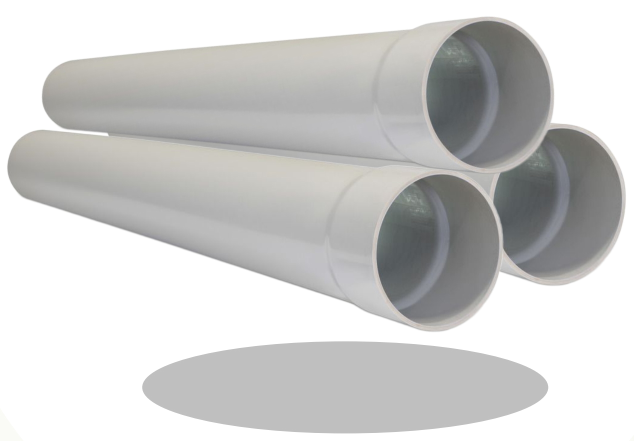
ANALYSIS OF SOLUTIONS FOR PLASTIC PIPES

Two viable recovery solutions were evaluated to manage un-reusable stockpiled and discarded PVC pipe.

Both solutions offer high environmental value by reducing pipe size prior to transportation as well as reducing reliance on virgin feedstock as well as associated extraction and production emissions.

P1: On-site pelletisation through the Multi-Mine facility enables direct processing of un-reusable PVC pipes into saleable pellets. With a 10-year NPV of $58.9M and moderate CAPEX ($425K) due to upfront infrastructure investment, this option retains value on-site with a projected $7.8M annual revenue and supports local job creation. However, this solution has a moderate risk as it requires higher operational oversight and annual higher OPEX ($291K) compared to established manufacturing pathway (P2).

P2: Collection by manufacturers delivers a streamlined pathway by aggregating cleaned and granulated pipe for direct offtake by PIPA-certified manufacturers for pelletisation and remanufacturing. This model achieves a NPV of $2.8M with no CAPEX and lower annual OPEX of $128K. However, this solution has a lower projected annual revenue of $500K compared to $7.8M for P1. This solution pathway leverages existing industrial capacity and enables faster implementation through established manufacturers.



	P1: On-site pelletisation	P2: Collection by manufacturer for recycling
10 year NPV	$ 58,961,021	$ 2,874,061
Total CAPEX	$ 425,265	-
OPEX per year	$ 291,679	$ 128,788
Annual revenue for service provider	$ 7,892,475	$ 500,992
Emissions to 10 Year NPV ratio	$ 608k/t CO_2e	$ 116k/t CO_2e
Risk Profile	MODERATE	LOW
Feasible time frame to get up and running	**Medium-term to install infrastructure and build capability**	**Short-term through existing manufacturer**
End product	Pellets for on-selling	N/A
Return per tonne of end product	~$650-800 per tonne	N/A
Environmental value	High due to reduced reliance on virgin plastic materials and associated extraction and production emissions	
Social value	Moderate due to local job creation and capability building in recycling	Moderate due to creating further value for established manufacturers using recycled inputs

INTERMEDIATE BULK CONTAINERS

IBCs are rigid, reusable containers used for the storage and transport of liquids and bulk materials, particularly chemicals and lubricants in mining operations. Typically made from high-density polyethylene (HDPE) encased in a steel cage, they have a volume capacity of around 1,000 litres.

INTERMEDIATE BULK CONTAINERS

What is happening to it today?

IBCs in the Bowen Basin are commonly used for operational fluids like diesel exhaust fluid, solvents, and cleaning chemicals.

While some are returned through supplier-led stewardship schemes, many are stored indefinitely or disposed of due to lack of viable return logistics. Cleaning and reuse is often avoided due to contamination risks, and most are not being reprocessed into high-value applications. In the absence of consistent reverse logistics, IBCs today are often treated as bulky waste and landfilled.

CURRENT IMPACT

Each year, approximately **357 tonnes of IBCs** are discarded across the 58 sites in the Bowen Basin.

This is the equivalent of 6,375 individual IBCs a year.

How much is there?

Mine site annual usage (t)	Material utilised (t) per unit (Mt) of production per annum		
(from 2 sites)	per one Mtpa	per 49.2 Mtpa	in the Bowen Basin
10	2.61	128	357

Mine sites utilise hundreds of IBCs every year, with a significant portion sent to landfill despite representing a strong opportunity for reuse and recovery. Analysis from Queensland sites found an average of 10 tonnes of IBCs landfilled per year. When normalised to production output, this figure represents an average of 2.61 tonnes of IBCs utilised per million tonnes of production. Based on the output of 5 Bowen Basin sites, this translates to an estimated 128 tonnes of IBCs wasted annually. Scaling up to Basin-wide production levels, the estimated total increases to 357 tonnes of IBCs each year - highlighting the need for improved recovery and reuse systems for IBCs.

END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO NPV-10 YR RATIO

PROPOSED SOLUTIONS FOR IBCs

Two solutions were considered for IBCs, focused on keeping IBCs in use through reconditioning.

For both solutions, IBCs will be drained, washed and sorted to determine whether they are damaged and suitable or unsuitable for reuse. Those identified as suitable will go on to be reused on site.

VALUE POTENTIAL

UP TO 357 TONNES OF IBC TO LANDFILL DIVERTED
PER YEAR IN THE BOWEN BASIN

10 YEAR NPV RANGE:
$13M-$58M

REUSABLE IBCS	$58,327,345	$615k/t CO_2e

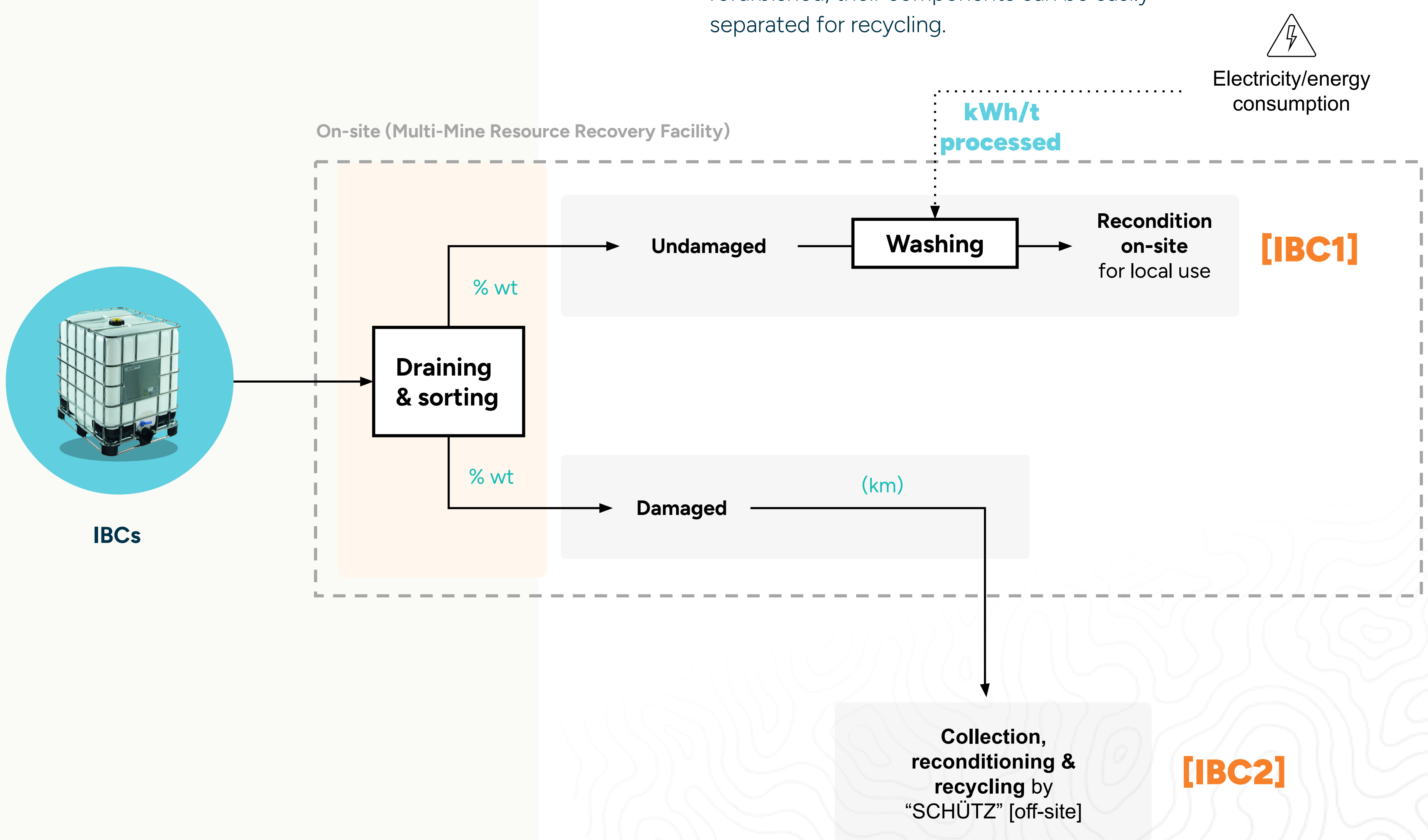
IBC1: On-site reconditioning for local use

Undamaged IBCs will be collected and transported to a laydown area at the Multi-Mine facility and be reconditioned for local use. Reconditioning involves inspecting and repairing components such as valves and cages as well as and pressure-testing for leaks to ensure safe reuse. Depending on condition, the process may include full cleaning, part replacement, or rebottling, followed by relabelling and certification for return to service.

REUSABLE IBCS	$13,868,922	$78k/t CO_2e

IBC2: Off-site reconditioning & recycling

Damaged IBCs will be collected and reconditioned off-site by a certified solution provider such as SCHÜTZ, using their closed-loop SCHÜTZ TICKET SERVICE. Similar to IBC1, this involves inspecting all components for structural and functional integrity as well as replacing damaged or contaminated parts. The outer steel cage may be retained if intact, while the inner container can be rebottled with a new high-spec HDPE liner. Each unit undergoes rigorous leak testing and quality assurance checks, before being relabelled and returned to service. Where IBCs cannot be refurbished, their components can be easily separated for recycling.



ANALYSIS OF SOLUTIONS FOR IBCs

Two low-risk pathways were assessed to IBC wastage across mining operations in the Basin.

Both options support the refurbishment and reuse of existing IBC materials to achieve high environmental value through landfill diversion and reduced virgin material reliance.

IBC1: This solution pathway focuses on reconditioning undamaged IBCs at the Multi-Mine facility for local reuse in mine sites. This process promotes regional job creation and offers high operational control. This pathway has a 10-year NPV of $58M with a low CAPEX ($11K) and moderate OPEX ($78K). The projected annual revenue from this solution is $7.6M. This option may also offer a lower emissions intensity due to lower transport requirements.

IBC2: This solution pathway involves collecting damaged IBCs for reconditioning by an established external partner such as SHÜTZ via their closed-loop ticket service. This pathway has a lower 10-year NPV of $13.8M compared to IBC1 and a higher annual OPEX of $703K. Reconditioned IBCs can hold high economic value per unit ($316-$603) through SHÜTZ. This model demands minimal operational involvement but may detract from local capability building and job creation. Where IBCs cannot be refurbished, their individual components can be separated and recycled through this solution pathway to maximise material recovery.

Adopting both IBC1 and IBC2 pathways enables mining operations to manage both damaged and undamaged IBCs - keeping viable containers in service onsite while redirecting damaged units into specialist reconditioning loops. Together, these solution pathways deliver strong economic returns, reduce landfill contributions and front-end procurement needs.

	IBC1: On-site reconditioning	IBC2: Off-site reconditioning
10 year NPV	$ 58,327,345	$ 13,868,922
Total CAPEX	$ 11,856	-
OPEX per year	$ 78,735	$ 703, 911
Annual revenue for service provider	$ 7,633,929	$ 2,500,000
Emissions to 10 Year NPV ratio	$ 615k/t CO_2e	$ 78k/t CO_2e
Risk Profile	LOW	
Feasible time frame to get up and running	**Short-term**	
End product	Reconditioned IBC	
Economic value of end product	$416 - $603 per reconditioned unit	
Environmental value	High due to reduced landfill contributions and reliance on virgin materials.	
Social value	Moderate due to promotion of regional job creation	Low due to responsible asset stewardship and associated social licence.

OFF THE ROAD MINING TYRES

As a high-volume, complex product that is very difficult to recover, off the road OTR) mining tyres have become a major focus for generators. As such, this prospectus conducted a deep dive on OTR mining tyres, a high-focus stream for the mining industry.

OFF THE ROAD MINING TYRES

A deep dive

OTR tyres represent the largest waste stream analysed for this prospectus across Bowen Basin mining operations, yet recovery remains negligible, with most tyres currently buried on site. Despite their size and regulatory complexity, these tyres contain high-value materials and are a current focus for industry, meaning they are a prime candidate for circular recovery at scale.

This section outlines the volume, challenges, and immediate opportunities associated with OTR tyre recovery, and proposes infrastructure-ready solutions to close the loop on this critical stream.

WHAT ARE OTR SURFACE MINING TYRES?

A combination of complex materials

9% Oils antidegradants, resins, curing agents & textile reinforcements

Improving adhesion & flexibility

27.3% Steel

Giving driving stability, strength, & rolling resistance

40.6% Natural & Synthetic Rubber

Giving high impact resistance & durability

23.1% Fillers Carbon black & silica

Improving tyre properties such as grip, rolling resistance, and mileage.

Once vulcanised, materials are very difficult to separate again

VULCANISATION

Heat binding the materials of the tyre

WHAT'S HAPPENING TO OTR SURFACE MINING TYRES TODAY?

Virtually all surface mining tyres in the Bowen Basin are stockpiled and then buried in mining pits.

Over 9,390 tonnes of OTR surface mining tyres are generated annually in Bowen Basin, almost all are stockpiled or buried in mine pits.

Disposal follows Queensland's Operational policy (ESR/2016/2380), which allows burial, but the current policy barely mentions the currently available and emerging resource recovery options.

New downsizing sites are popping up in and around the region, but only a tiny fraction (>2%) of these tyres currently get processed for resource recovery.

Also, let's be very clear: burial is not landfill.

Landfills follow strict rules i.e. liners, leachate collection, monitoring. In-pit burial at mines don't have these same standards. Although, there are rehabilitation requirements, it's not the same.

The environmental risks of burying tyres are largely unknown.

Is that a risk we're willing to take?

BOWEN BASIN OTR TYRE MINING POTENTIAL

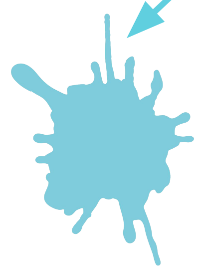
If the Bowen Basin were to recover all of these tyres . . .

9,390t of OTR surface mining tyres per year in the Bowen Basin Region

THE LOCAL BENEFIT COULD BE OVER **$6M** PER ANNUM

PRIMARY PROCESSING is about size reduction and steel recovery: shredding, granulation, and crumbing.

It is often the necessary first step for all recycling pathways.



2,265t of recovered steel

~$566,250
AT $250/t

If primary processed to crumb rubber (CR)

7,125t of CR

~$5.7Million
AT $800/t

Each tonne recovered means one less extracted, saving emissions & preserving resources.

What is the missed opportunity?

If the Bowen Basin were to recover all 9,390 tonnes, based on proportional estimates from Tyrecycle's national modelling, validated by UQSMI analysis from industry insights and Northern QLD - Analysis by Tyre Stewardship Australia (TSA), these tyres could become:

- 2,265 tonnes of recovered steel, worth ~$566,250 (at $250/t)
- 7,125 tonnes of crumb rubber is worth ~$46 million nationally, scaled down this is worth $5.1 million (at $800/t)
- $7.5 million in gate fees for recyclers

This could unlock:

- Over $5 million in investment in new primary processing infrastructure
- An estimated 20 new local jobs
- Significant environmental gains and stronger regional circular economy outcomes

Why isn't material circularity happening yet?

Stakeholder consultation and desktop review identified three key barriers:

1. **Absence of a well-designed, nationally regulated product stewardship scheme.**
2. **Legal and preferred practice of burying OTR surface mining tyres on-site.**
3. **Limited local market demand for products made from recycled tyres.**

TYRE PRIMARY PROCESSING IN AUSTRALIA

What's already happening?
The current primary processors in Queensland (as of June 2025)

Four TSA accredited operators already exist in QLD for OTR primary processing

Four steps to primary processing of OTR tyres

All of these facilities' size reduces the tyres, some end up in landfills after being shredded, and some are downsized, with a small proportion being crumb for local reuse.

Today, these pathways are unable to scale due to limited feedstock (mining tyres from mine sites). Meanwhile, demand for processing services exceeds local demand for the resulting products, meaning that many are exported rather than being recovered and put back into new products in-State or in-Country.

The Multi-Mine facility could serve as a consolidation hub or include a primary processing line to downsize OTR surface mining tyres, supporting their efficient management and enabling the sale of processed materials into various applications across QLD. The latter is the vision for the options presented in the following pages.

PROPOSED SOLUTIONS FOR OTR SURFACE MINING TYRES

Since the tyre-derived product is being sold, the emissions calculated apply only to the transport of the tyres and the primary processing stage, which is consistent across both of these solutions.

END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO REVENUE RATIO
CRUMB RUBBER	NPV AFTER 10 YEARS $21,152,187	$ 10k/t CO_2e
BUFFINGS	NPV AFTER 10 YEARS $20,979,687	$ 10k/t CO_2e

OTR1: Local roads: crumb rubber sold to local road manufacturers

End-of-life OTR surface mining tyres are reverse-logistics transported from the mines to the site, where they undergo primary processing into crumb rubber for use by road manufacturers. The crumb rubber is then incorporated into local and state road construction.

OTR2: Local manufacturing: buffings, granules, and crumb rubber sold to local businesses for use in flooring and underlay

End-of-life OTR surface mining tyres are reverse-logistics transported from the mines to the site, where they undergo primary processing into crumb rubber, granules or buffer to be sold to local manufacturers. The tyre-derived products become acoustic underlay and sports surface underlay.

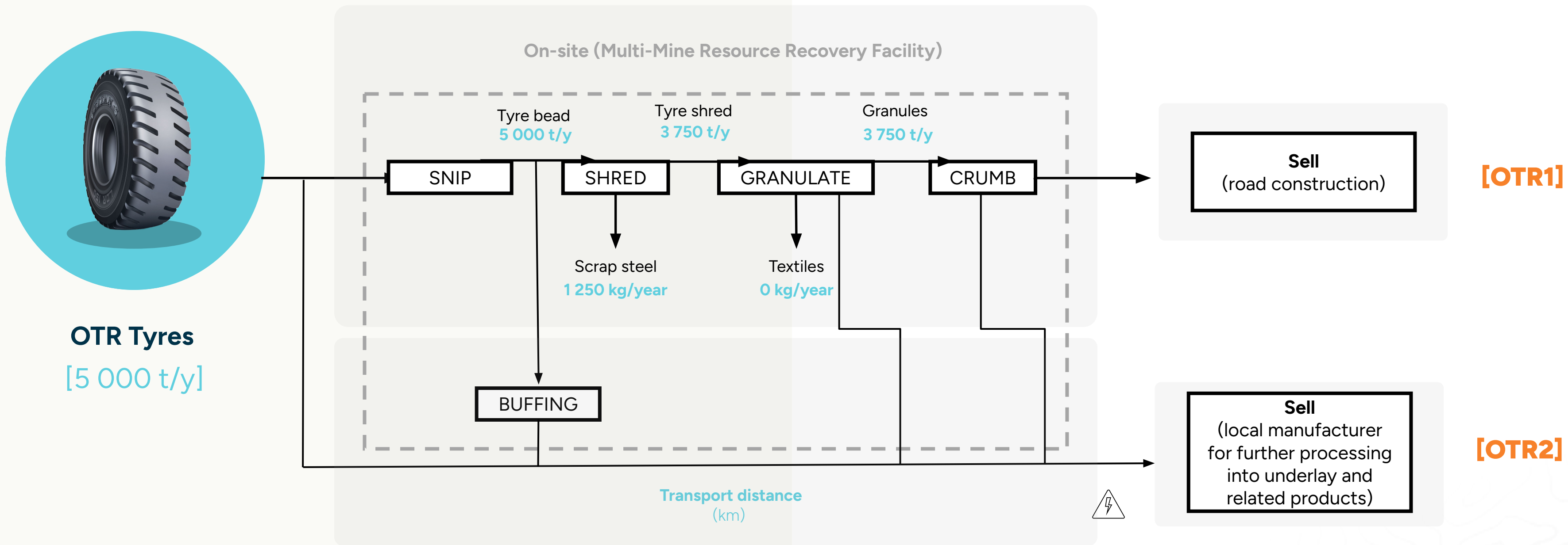
VALUE POTENTIAL

UP TO 9,390 TONNES OF OTR TYRES TO LANDFILL DIVERTED PER YEAR IN THE BOWEN BASIN

10 YEAR NPV RANGE: **$20M-$21M**

OTR1 & OTR2

Both viable primary processing solutions and form the basis of OT3 & OTR4



PROPOSED SOLUTIONS FOR OTR SURFACE MINING TYRES

Tyre Derived Polymer (TDP) is a building block for rubber manufacturers. Its composition reflects that of the original feedstock - OTR surface mining tyres - resulting in a high rubber content.

Devulcanisation preferentially breaks Sulfur-Sulfur (S-S) and Sulfur-Carbon (S-C) bonds, leaving Carbon-Carbon (C-C) bonds largely untouched. This creates a higher quality (less degraded) recycled product, allowing for higher load levels and better properties in the final product.

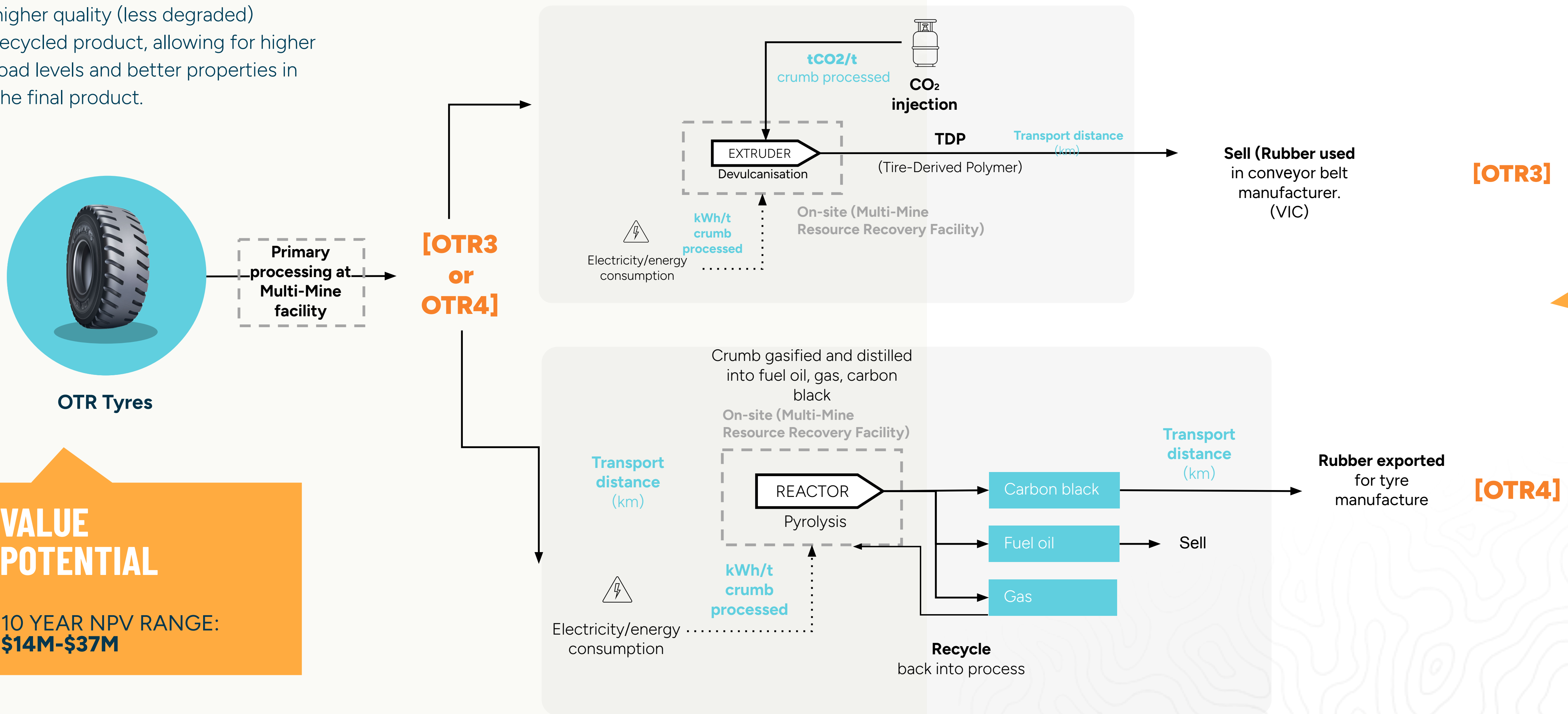
END PRODUCT	NPV AFTER 10 YEARS	EMISSIONS TO NPV-10 YR RATIO
CARBON BLACK	NPV AFTER 10 YEARS $37,027,122	$ 11k/t CO_2e
RUBBER MIX	NPV AFTER 10 YEARS $14,393,361	$4k/t CO_2e

OTR3: Pyrolysis carbon - recovered carbon black into conveyor belt or retread manufacturing

End-of-life OTR surface mining tyres are reverse-logistics transported from the mines to a the site, where they undergo primary processing into crumb rubber which is then onsold to a pyrolysis processing plant.

OTR4: Devulcanisation - crumb rubber processed to a rubber mix

End-of-life OTR surface mining tyres are reverse-logistics transported from the mines to the Multi-Mine site, where they undergo primary processing into crumb rubber. The output then undergoes devulcanisation to form tyre derived polymer (TDP) which can be on-sold to retread and conveyor belt manufacturers.



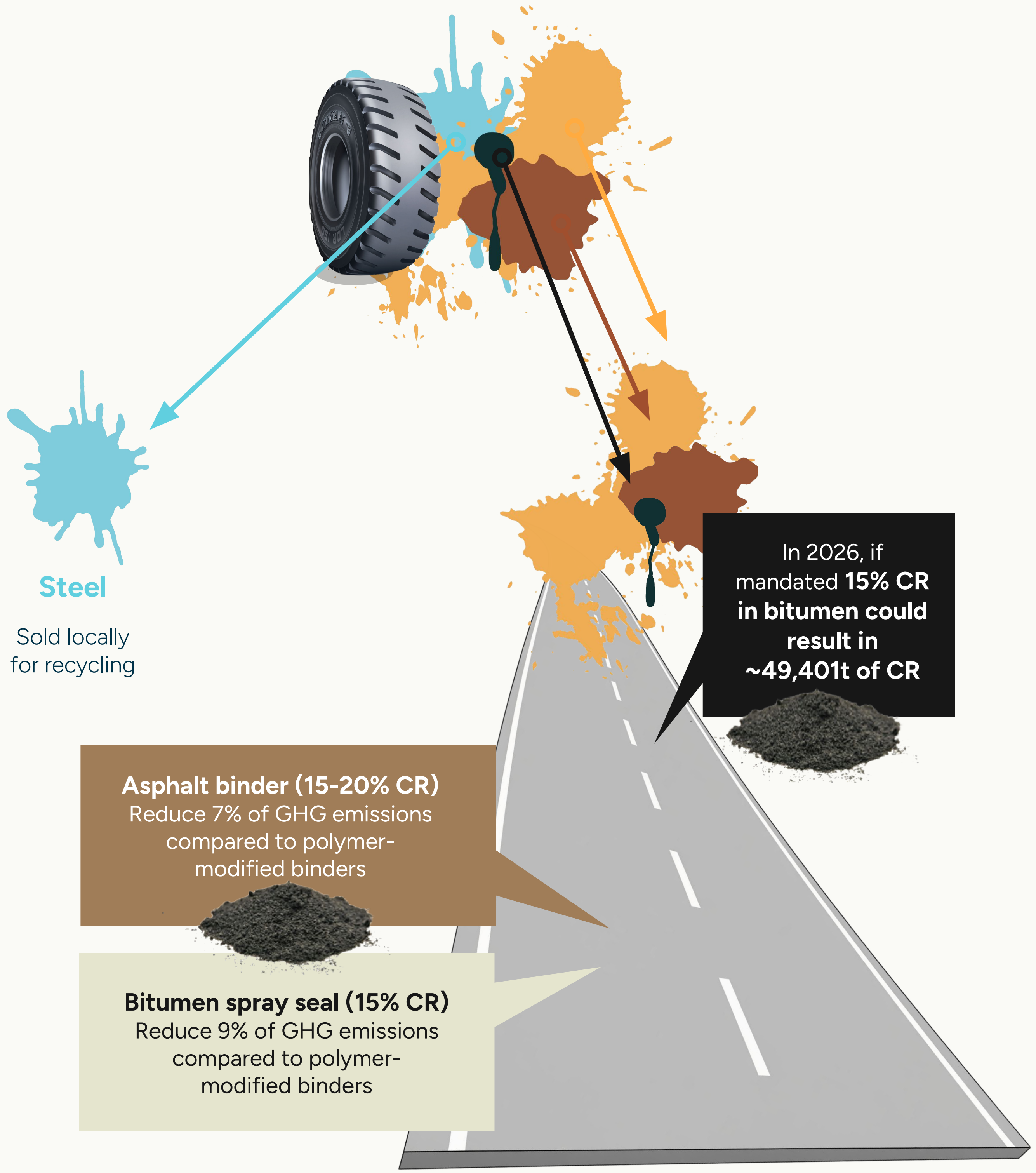
VALUE POTENTIAL

10 YEAR NPV RANGE:
$14M-$37M

OTR3 & OTR4

Post primary processing, OTR3 & OTR4 offer viable solutions to further process materials into refined products.

OTR 1:
CRUMB RUBBER IN ROADS



Source Tyre Stewardship Australia

Using crumb rubber in asphalt and spray seals isn't new.

Victoria's been doing it since the '70s - their standard specifications set parameters for how crumb rubber is used in most rural and regional Victorian roads.

Boral, supported by various industry bodies, in 2025 launched Australia's first crumbed rubber asphalt bitumen surfacing derived from OTR surface mining tyres, after a successful trial in the Sunshine Coast. A trial by BHP applied recovered OTR surface mining tyres in resurfacing works along the Peak Downs Highway in the Bowen Basin.

The pilot showcased a viable reuse pathway and the potential for coordinated action between OTR surface mining tyre users, councils, and road manufacturers in the region.

While this option may not absorb all of the OTR surface mining tyres generated in the Bowen Basin, it can support necessary investment into additional infrastructure, such as downsizing and adaptations to road mixing or laying equipment.

Plus, it brings big community benefits: tougher roads needing less maintenance, equating to long-term cost savings.

End Product	Crumb Rubber is used as a binder in all roads in QLD at the highest possible percentage.
Abated Virgin Material	Synthetic polymer binders, fossil fuel derived materials.
Necessary Infrastructure Investment	Based on stakeholder input, supplier quotes, and literature, the estimated capital cost for a primary processing plant is $3.96 - $6 million. This includes key equipment (snipper, shredder, granulator, crumb grinder), installation, conveyors, and infrastructure.
Value Potential	• This solution is projected to deliver a 10 year NPV of $29.9 M and $51.2M over 20 years. Although the project requires substantial upfront and ongoing costs, the anticipated revenues outweigh these investments.. • Roads using crumb rubber-modified asphalt require 30% fewer maintenance interventions than conventional roads, reducing long-term repair costs for regional councils and road authorities. • Life Cycle Assessments (LCA) by TSA show up to 30% fewer CO_2 emissions when compared to conventional bitumen over the road's lifetime. • Crumb rubber modified (CRM) binder is cost-comparable to other polymer-modified bitumen (PMB) options, offers lower lifetime costs than conventional bitumen
Considerations	• The strong smell of heated crumb rubber mix is often flagged by workers. While it poses no health risk, it's important to manage perceptions on-site. • As the mixture is more elastic and thicker, equipment updates are required. • CRM binder can have a short shelf life, so good planning is essential, and mobile mixing equipment may be necessary.
Recyclability of end product	**High.** Studies found no major issues with CRM binder roads being recycled into new roads (i.e used as reclaimed asphalt pavement).

OTR 2:
BUFFINGS & GRANULES IN FLOORING & UNDERLAY

Acoustic Underlay

Underlay for indoor or outdoor sports surfaces & gyms

OTR surface mining tyres could be transformed into various products for local use, if they aren't buried and are appropriately valued.

Recycled tyre products are already being used in QLD manufacturing, but it is unknown what quantity of these are made from Australian or international recycled tyres.

Buffings are high-elastomer shavings taken from tyre treads using a buffing machine. They are used to manufacture acoustic underlay, gym tiles, car interiors, and rubber matting.

These materials could be underfoot of athletes and spectators at the 2032 Olympic and Paralympic Games in Brisbane. Showcasing QLD recycled products on a global stage.

They are free from steel and textile contamination, making them well-suited for manufacturing. Therefore, the Multi-Mine facility could include a buffing machine and a primary processing site.

As retreading of OTR surface mining tyres isn't yet common in QLD, investment in buffing equipment has been limited. This could change in time. Introducing this step could speed up processing, improve recycling efficiency, and supply valuable material to local manufacturers. Thereby, reducing the reliance on imported recycled content.

End Product	Granules, buffings, or crumb rubber are combined with polyurethane glue to create indoor sport surfaces, rubber underlay for construction, or rubber mats.
Abated Virgin Material	Polymer materials: Virgin rubber ethylene propylene diene monomer (EPDM), thermoplastic vulcanisates, thermoplastic granules Imported recycled rubber materials.
Necessary Infrastructure Investment	Based on stakeholder input, supplier quotes, and literature, the estimated capital cost for a primary processing plant is $3.96 - $6 million. This includes key equipment (snipper, shredder, granulator, crumb grinder), installation, conveyors, and infrastructure. If a buffing machine was to also be invested in this cost would increase.
Value Potential	• This solution is expected to result in a similar NPV as OTR1. However, the inclusion of buffing machines may slightly increase costs, potentially resulting in a reduction in overall NPV compared to the previous solution. • Local jobs in both primary processing and local manufacturing. • If a buffing machine were invested in, there could be an increase in the volume of OTR surface mining tyres able to be processed in the region.
Considerations	• Health concerns about recycled materials are valid, but research shows tyre-derived products pose minimal risk when proper safeguards are in place. • However, products that are not bound together (such as crumb rubber in artificial turf fields) can pose a pollution risk if the surface is not appropriately managed.
Recyclability of end product	**Possible.** The material can be shredded and reused in the base impact layers application. However, due to the use of polyurethane glue, recycling may be difficult.

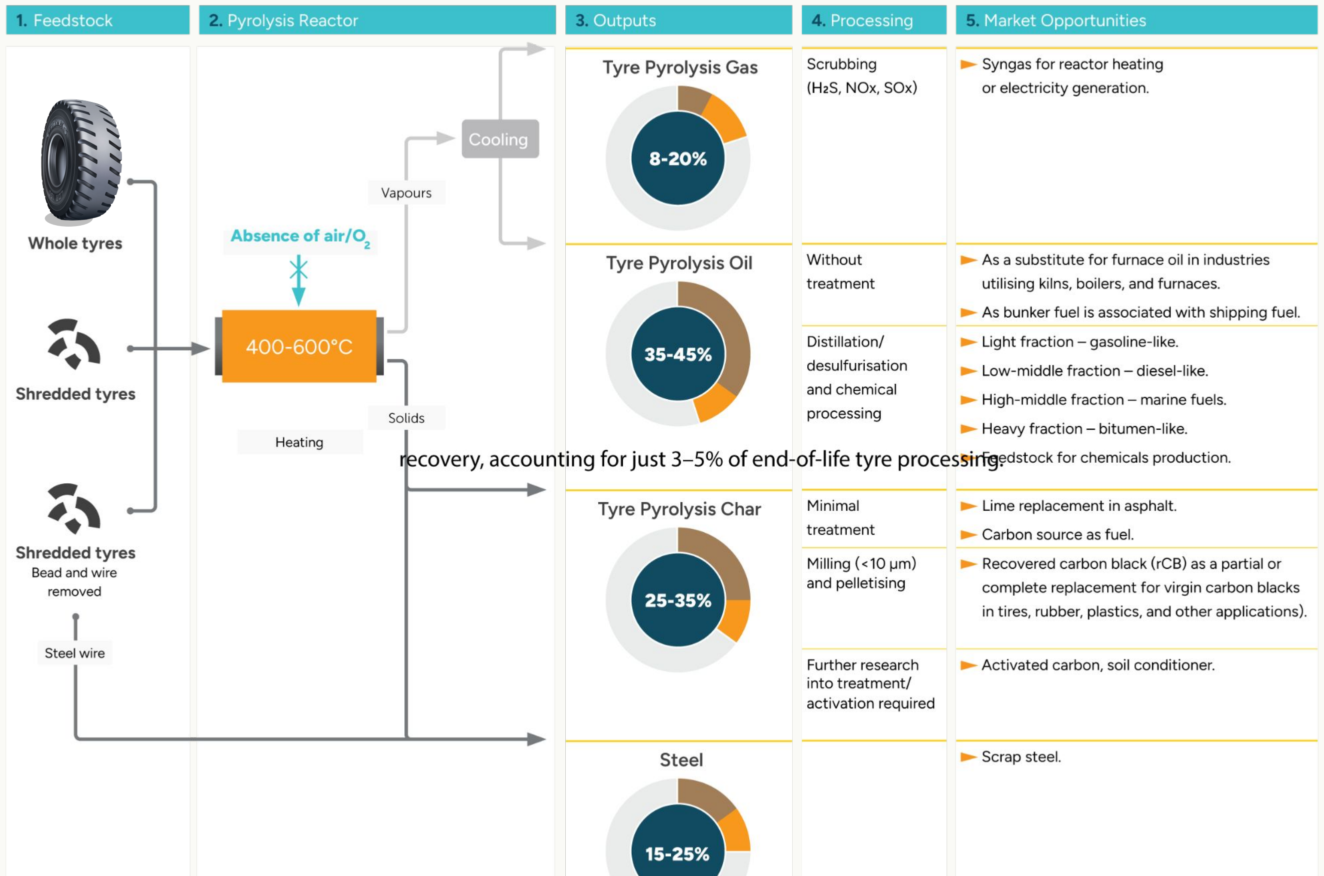
OTR 3: PYROLYSIS
CARBON BLACK INTO CONVEYOR BELT OR RETREAD MANUFACTURING

Pyrolysis involves heating tyres or downsized components in the absence of oxygen to generate oil, gas, and carbon char.

As illustrated below, the process is technically complex, and the nature and value of market opportunities depend heavily on the specific technology and configuration used.

Pyrolysis is attracting global investment but remains a minor player in tyre recovery, accounting for just 3–5% of end-of-life tyre processing.

In Europe, companies like CIRCTEC and Enviro have formed partnerships with tyre manufacturers to commercialise outputs. Kal Tire's Chilean plant processes five 63-inch tyres daily, producing 8,000 kg of pyrolysis carbon black, 6,500 litres of oil, and 4,000 kg of steel for retread and conveyor belt applications.



recovery, accounting for just 3–5% of end-of-life tyre processing.

Image credit- Tyre Stewardship Australia

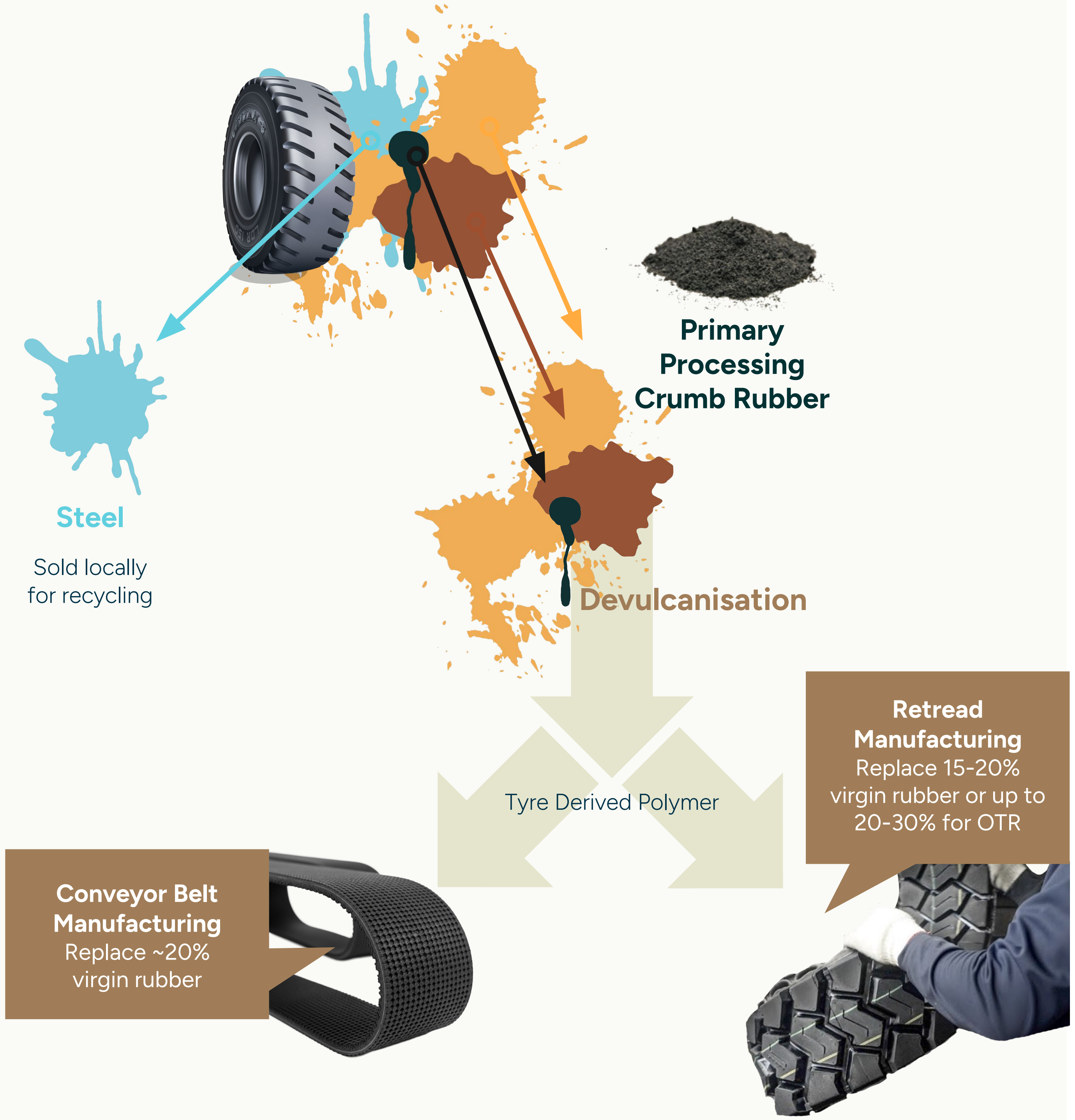
In Australia, stakeholders remain wary of pyrolysis due to a legacy of publicly unsuccessful commercial attempts. Entyre Limited (formerly Pearl Global) entered voluntary administration in 2024, despite raising $7.9 million and receiving $800,000 in QLD government support. Novum Energy also failed to commercialise its model, even after commitments from major mining players in the Bowen Basin region, with tyres instead redirected to shredding and crumbing.

The opportunity lies in designing systems that support product consistency and pathways to higher-value outcomes, led by material purchasers. Some advocate for refinery-led models focused on oil recovery, shifting the emphasis from material circularity to energy recovery. Others are exploring controlled feedstocks, such as specific tread compounds.

Given the high technical requirements, for the Multi-Mine site, primary processing would be the focus, with the buffings, crumb, or granules sold to a pyrolysis specialist. With the pyrolysis plant co-located with a retread or conveyor belt manufacturing site to enable necessary testing and refinement of the technology.

End Products	A pyrolysis plant that focused on producing Tyre Pyrolysis Char for further refinement into recovered carbon black (rCB). rCB can be used as a part replacement of some of the lower grades of carbon black (N500, N600, N700 series) that can be used to partially substitute for carbon black used in conveyor belt manufacturing.
Abated virgin material	Lower-grade carbon black, manufactured from fossil fuels.
Value Potential	• Able to significantly value add if rCB is the focus of the system. • rCB market value is approximately $1,000 per tonne, which compares to a current virgin carbon black price of approximately $2,200 per tonne, resulting in an approximately 50% reduction in cost.
Considerations	• Pyrolysis requires a high upfront investment and at least two years to reach steady productivity, delaying profitability. Therefore, rCB may cost more than virgin carbon black due to pricier feedstock and lower initial yields, making rCB-conveyor belts more expensive at first. • Onshore market demand for rCB is limited due to a lack of domestic tyre manufacturing, with a potential need to export to ensure offtake markets. • Multiple pyrolysis technologies with inconsistent end product quality, so careful selection and due diligence are essential for success. • Under the current legislative framework, processing of the products of pyrolysis may require additional such as ERA 7 – chemical manufacturing, incurring additional fees and requirements.
Recyclability of end product	**High.** Tyres or conveyor belts made with rCB can be resource recovered in similar pathways.

OTR 4: DEVULCANIZATION RUBBER MIX TO CONVEYOR BELT OR RETREAT MANUFACTURERS



Devulcanisation is the selective breakdown of the cross linked sulfur bonds without further breakdown of the rest of the polymer network.

Essentially, this technology can take a downsized tyre crumb into a rubber mix (called, tyre-derived polymer), which can be used as an input into various manufacturing applications.

This isn't theoretical. Internationally, Tyromer have commercialised the process with major tyre, conveyor belt, and retreading brands.

Currently, Tyromer has operational facilities in Canada, the US, India, and the EU. In Port Hedland (WA), the East-West Pilbara Rubber Recycling is setting up a devulcanisation facility with the capacity to process 12,000t of OTR tyres annually, backed by federal support. Bringing this technology to the Bowen Basin could help establish material circularity for mining tyres and unlock new regional opportunities.

End Product	Devulcanised rubber (tyre-derived polymer) for use in conveyor belt or retread manufacturing.
Abated virgin material	Rubber mix (natural rubber, synthetic rubber, silica and carbon black)
Necessary Infrastructure Investment	A standard devulcanisation machine for 4,000t per year is approximately $4.47 million, + additional costs for primary processing. Multi-line operations could be set up to increase scale. Together with the primary processing investment, this solution will require a total capital investment ranging between $8.11 and $11.1 million.
Value Potential	• The estimated Net Present Value (NPV) of this solution is $47.28 million over 10 years and $82.19 million over 20 years. • Local manufacturers could use Australian tyre-derived polymer instead of imported rubber mixes. • A new advanced manufacturing industry to produce high-value recycled materials, contributing to jobs and growth in a remote area.
Considerations	• **Lagging legislation can create approval delays and increase set-up costs.** • **Currently, no retreading of OTR surface mining tyres means this market is not yet available in Australia.** • **Require a high degree of collaboration, including industry co-investment to de-risk capital costs and ensure the quality of the tyre-derived polymer matches the expectations of the conveyor belt and retread manufacturers.**
Recyclability of end product	**High.** However, recycling of tyres with tyre-derived polymer is not extensively researched, given the emerging nature of the technology, however, these materials, like all used tyres, could go through downsizing and then through similar processes.

ANALYSIS FOR OTR SURFACE MINING TYRES

Based on the analysis of the four solutions, it is recommended that . . .

All primary processing pathways (OTR1 and OTR2) are near-term implementation opportunities representing a necessary first step before OTR 3 & 4 are possible. It represents a near-term solution to manage the volume of tyres, with future investment directed toward pyrolysis or devulcanisation.

For primary processing, a buffing machine should be prioritised given the local demand for high-value derived materials.

To mitigate risks associated with pyrolysis and devulcanisation, investment should only proceed alongside partnerships with tyre, conveyor belt, or retread manufacturers to secure offtake markets and reduce the risk of project failure.

All options offer local jobs, value added materials and viable pathways for this material.

This list of solutions for OTR mining tyres in this prospectus is not exhaustive. Other viable uses include crumb rubber in concrete safety barriers, permeable pavements or rail mats. Given the scale of the issue, there is sufficient crumb rubber to support all of these products.

	OTR1 - CRUMB RUBBER SOLD FOR USE IN ROADS	OTR 2 - CRUMB RUBBER, TYRE DERIVED MATERIAL ETC, SOLD INTO LOCAL MANUFACTURING	OTR 3 - PYROLYSIS OF RUBBER	OTR 4 - DEVULCANIZATION OF RUBBER
Number of Potential Jobs	20 FTE	20 FTE	20 FTE	24 FTE (20 for Primary Processing) + ~4 for Devulcanisation
Capacity (volume)	Low	Medium	High	High
Risk Profile	**Low**	**Low**	**Medium - High**	**Medium - High**
Feasible time frame to get up and running	**Short - already existing technology and existing offtake routes.**	**Short - already existing technology and existing offtake routes.**	**Long - already existing technology internationally, however, domestic offtake routes to be determined.**	**Long - already existing technology internationally, however, domestic offtake routes to be determined.**
Infrastructure investment	Medium	Medium	High (if consider the cost of establishing domestic Pyrolysis site)	High
Value of end product	Low	Low	HIgh	High
Recyclability of End product	Yes	Yes	Yes	Yes

ACTION PLAN FOR OTR SURFACE MINING TYRES

It will be up to various stakeholders to work creatively to support initiatives.

The solution to resource recovery and full valuation of tyres will likely involve implementing more than one initiative.
Below is a plan of action to get the tyre rolling.

Topic	Stakeholder(s)	Current Practice / Standard	Recommendation	Rationale
Product Stewardship	Federal Government (DCCEEW)	Voluntary, industry-led scheme	Transition to a fully regulated scheme, informed by the experience of recyclers and collectors, without delay	International best practice shows higher recovery and circularity outcomes under regulated schemes. As the North Queensland Regional Organisation of Councils noted, voluntary schemes allow poor practices to persist and burden government.
Transparency & Traceability	Mining Organisations	Isolated efforts for recycling and verification	Require the use of TSA-accredited recyclers/collectors and foreign end market verification	TSA accreditation ensures higher environmental standards and transparency, thereby reducing risk.
Collaboration	Mining Organisations	Small pilots with limited funding	Participate in TSA forums, share learnings from pilots and engage local providers	Increases opportunity for collaboration, access to best practice, and supports scalable solutions.
Disposal	QLD DES & Dept. of Resources / Mining Organisations	Burial permitted; no clear phase-out plan	Provide a timeline to ban onsite disposal	Provides regulatory certainty, reduces burial reliance, and creates a level playing field
Disposal in Mine Planning	Mining Organisations	Tyres buried or stockpiled	Publicly commit to phasing out burial and include tyre recovery in mine plans and contracts	Aligns with resource recovery goals and enables long-term system change
Local Roads	TMR & Local Councils	Suboptimal crumb rubber uptake; technical notes downplay use	Demand the highest viable crumb rubber content; update technical notes to reflect national best practice (e.g. VicRoads, WA Main Roads)	Supports investment, boosts recycling, and lowers long-term road costs
Local Manufacturing & Procurement	QLD Govt. / TSA / 2032 Brisbane Olympics & Paralympics	Imported content common and data on local recycled content unclear	Require recycled rubber origin disclosure in procurement; support national traceability framework; prioritise Australian recycled rubber in Brisbane 2032 procurement	Drives demand, improves data confidence, scales local markets

SITE ANALYSIS

A methodology for determining a suitable site location for common user facilities in industrial areas

SITE ANALYSIS

Overview

To enable the development of a shared, regionally integrated circular facility, a structured methodology was applied to identify a suitable site within the Bowen Basin. This analysis, delivered by Better Cities Group, was designed to be replicable, scalable, and responsive to the unique spatial and industrial context of the region.

Sites were shortlisted through a staged process, beginning with the identification of high-potential locations based on spatial proximity to mines, existing infrastructure, and zoning suitability. This was followed by a multi-criteria analysis assessing land size, transport access, industrial zoning, proximity to workforce and mine clusters, availability of essential services, and tenure conditions

Stakeholder input, particularly from logistics providers, regional operators, and infrastructure owners, further refined the assessment by highlighting co-location opportunities, existing facility synergies, and future transport efficiencies (e.g. via the Walkerston Bypass and potential rail connections).

This section presents the outcomes of the site assessment, identifying viable locations for a Multi-Mine resource recovery facility and establishing a decision-making framework that can inform site identification for shared facilities in a region.

SITE ANALYSIS

Methodology

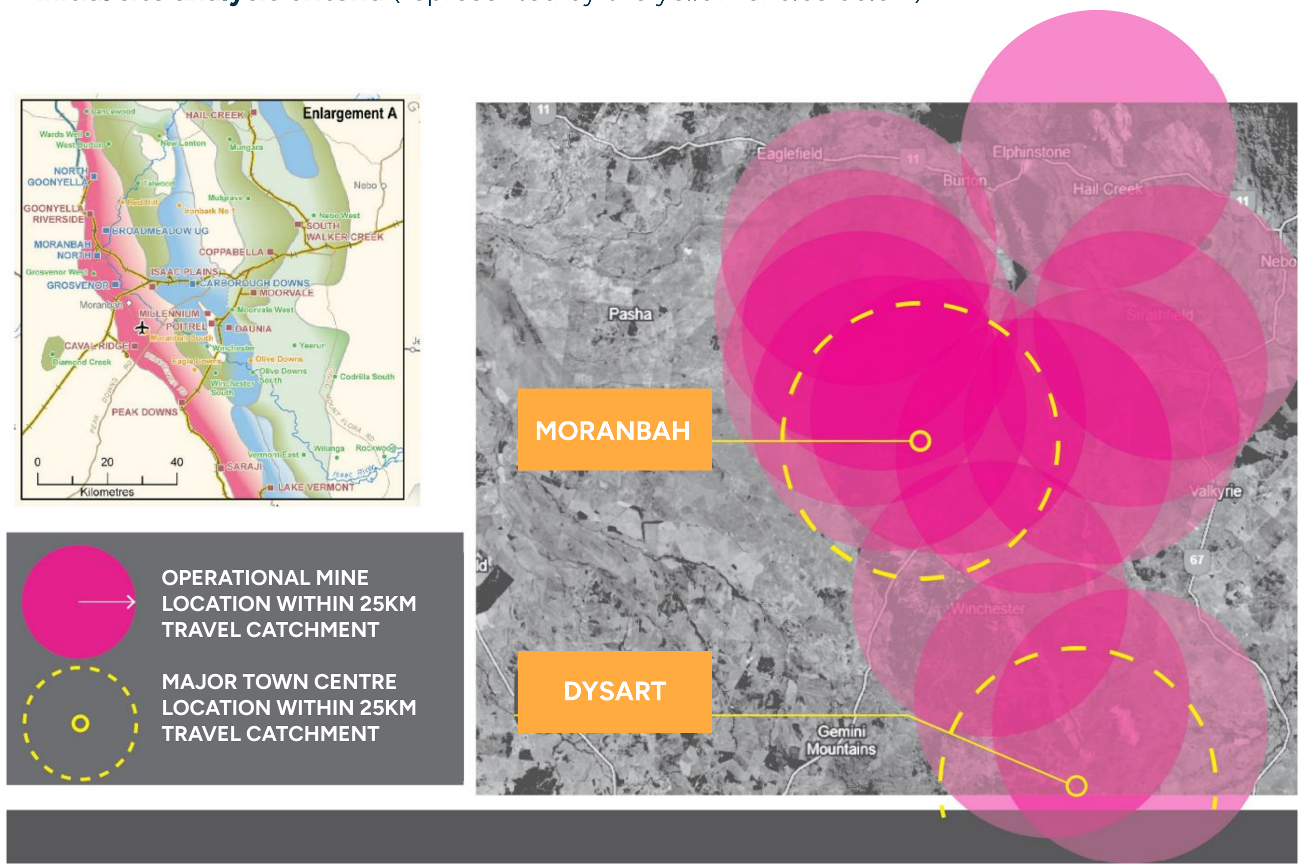
1. CATCHMENT HEAT MAPPING

The project team conducted an initial heat mapping exercise to identify catchment areas that to fulfill initial criteria developed (whilst a GIS sieve analysis could have been adopted, the scale of the project site would have reduced the efficiency of this process).

The following two criteria were adopted to enable the high-level, first-cut assessment:

- Operational mine location within 25km radius
- Major town center within 25km radius

The first-cut assessment identified two catchment areas that fulfilled the initial site analysis criteria (represented by the yellow circles below):



Heat mapping 25km catchments of mines to Moranbah and Dysart (Better Cities Group)

2. LOCAL STAKEHOLDER CONSULTATION

After the first-cut assessment, the project team consulted three local stakeholders to identify specific sites within the identified catchment areas.

This phase provided invaluable input to ground our final options in the Basin context, identifying specific sites based on key local insights, such as high-travel transport corridors for materials management, upcoming relevant infrastructure construction, and available vacant land.

The stakeholder consultation process resulted in six options that were then analysed further with a multi-criteria analysis to select an ideal site.

Option	Site	Address	Rationale
1	Rail Corridor and Goonyella Road site	282 Goonyella Road MORANBAH QLD 4744	**Proximity to similar business such as the Moranbah Waste Management Facility.** Quality access with road and rail. Moranbah is a major service town for several coal mines in the Bowen Basin, one of Australia's largest coal - producing regions. Some of the key mines near Moranbah include Peak Downs Mine (one of Australia's biggest coal mines, producing high- quality hard coking coal) Moranbah North Coal Mine (a large underground longwall operation producing premium low- volatile hard coking coal, and Goonyella Mine (a significant coal mine in the region, exporting coal for steel production).
2	Moranbah Waste Management Facility	Waste Management Facility 1 Thorpe Street MORANBAH QLD 4744	**Co-location with complementary activities and existing infrastructure and operations.** Moranbah is a major service town for several coal mines in the Bowen Basin, one of Australia's largest coal - producing regions. Some of key mines near Moranbah include Peak Downs Mine (one of Australia's biggest coal mines, producing high-quality hard coking coal) Moranbah North Coal Mine (a large underground longwall operation producing premium low -volatile hard coking coal, and Goonyella Mine (a significant coal mine in the region, exporting coal for steel production).
3	Corner of Moranbah Access and Railway Station Road	186 Long Pocket Road MORANBAH QLD 4744	**Proximity to similar activities with Sims Metal and JJ Richards.** Ten minutes from the middle of Moranbah. Moranbah is a major service town for several coal mines in the Bowen Basin, one of Australia's largest coal - producing regions. Some of key mines near Moranbah include Peak Downs Mine (one of Australia's biggest coal mines, producing high-quality hard coking coal) Moranbah North Coal Mine (a large underground longwall operation producing premium low -volatile hard coking coal, and Goonyella Mine (a significant coal mine in the region, exporting coal for steel production).
4	Dysart Waste Management Facility	Waste Management Facility 7145 Dysart Clermont Road DYSART QLD 4745	**Co-location with complementary activities and existing infrastructure and operations.** Waste material brought to site. Dysart is a key service town for several coal mines in the Bowen Basin, one of Australia's largest coal-producing regions. Some of the mines near Dysart include Saraji Mine (an open pit metallurgical coal mine operated by BHP Mitsubishi Alliance (BMA) and Dysart East Coal Project (managed by Bengal Coal, this project is located about seven kilometres east of Dysart).
5	Dysart Middlemount Road site	Queen Elizabeth Drive DYSART QLD 4745	**Co-located with industrial uses with multiple frontages for access.** Dysart is a key service town for several coal mines in the Bowen Basin, one of Australia's largest coal-producing regions. Some of the mines near Dysart include Saraji Mine (an open-pit metallurgical coal mine operated by BHP Mitsubishi Alliance (BMA) and Dysart East Coal Project (managed by Bengal Coal, this project is located about seven kilometres east of Dysart).
6	Clermont Industrial Site	Industrial Road CLERMONT QLD 4721	**Co-location with complementary activities and existing infrastructure and operations.** Clermont services several mines in Central Queensland, including Clermont Open Cut, which is located 12 kilometres from the town of Clermont. This mine produces high-quality thermal coal for export and transports coal via an overland conveyor to stockpile and rail loading facilities at the nearby Blair Athol mine before shipping it out through Dalrymple Bay Coal Terminal.

SITE ANALYSIS

Methodology - cont'd

3. MULTI CRITERIA ANALYSIS SCORING

The project team then conducted a multi-criteria analysis using seven criteria.

The following seven criteria were applied to the six options identified in step 2:

1. Size: 5Ha+
2. Zoning: Industrial, Special Purpose Zoned or rural
3. Transport access (considering reinforced roads designed for heavy transport vehicles)
4. Proximity to towns (workforce stays in the towns, some are drive-in-drive out)
5. Proximity to maximum number of mine sites (colocation)
6. Servicing: power, gas, water etc.
7. Buffers & setbacks to sensitive adjacent land uses
8. Tenure: Ownership or land use intention

For each criteria, values were assigned for high (3), medium (2), and low (1) scores.

Full multi-criteria analysis scoring detail below:

Scoring	Size	Zoning	Access	Proximity to town	Proximity to mines	Servicing	Buffers	Tenure
3	20 Ha+	Industrial / Industrial investigation	Highway, multiple frontages	5 km	30 minutes	Services in 5 km proximity	No buffer issues to sensitive receptors	Freehold
2	10 - 20 Ha	Rural	Highway	10 km	1 hour	Services in 10 km proximity	Some buffer issues to sensitive receptors	Leasehold or licence
1	5 - 10 Ha	Other	Local road	20 km +	1 hour +	Services in 20 km proximity	Significant buffer issues to sensitive receptors	Reserve

Multi-criteria analysis results:

Option	Site	Address	Size	Zoning	Access	Proximity to town	Proximity to mines	Servicing	Buffers	Tenure
1	Rail Corridor & Goonyella Rd site	282 Goonyella Rd Moranbah QLD 4744	3	3	2	3	3	3	3	1
2	Moranbah Waste Management Facility	1 Thorpe St Moranbah QLD 4744	1	3	2	3	3	3	3	2
3	Cnr of Moranbah Access & Railway Station Rd	186 Long Pocket Rd Moranbah QLD 4744	3	2	3	3	3	2	3	3
4	Dysart Waste Management Facility	7145 Dysart Clermont Rd Dysart QLD 4745	1	3	3	3	3	2	3	3
5	Dysart Middlemount Rd site	Queen Elizabeth Drive Dysart 4745	1	3	3	3	3	3	1	3
6	Clermont Industrial site	Industrial Road Clermont QLD 4721	2	3	3	3	3	3	3	3

Key findings:
- There are many sites appropriately zoned, with good access, no buffer issues and located to complementary uses.
- Operational model selected affects site selection
- There is existing appetite for existing operators to support this opportunity.

Note on a replicable model for site selection for common-user facilities in industrial regions:

This assessment demonstrates an easy, efficient, and replicable process for evidence-based site selection of common user facilities in industrial regions. Using catchment heat mapping, local stakeholder consultation, and multi-criteria analysis, a project team can identify sites that will maximise returns for the most amount of operators in a region.

CONCLUSION

This prospectus presents a clear, evidence-based case for a shared circular infrastructure solution in the Bowen Basin.

With strong material volumes, high-value recovery opportunities, and shovel-ready solutions backed by local interest and site feasibility, the groundwork is complete.

What's now required is coordinated investment to translate this opportunity into action; shifting the region from fragmented disposal to integrated, commercially viable recovery at scale.

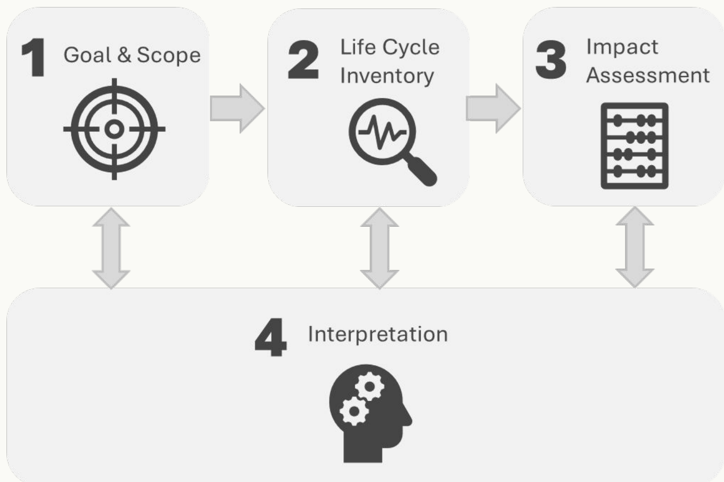
APPENDIX

ANALYSIS METHODOLOGY & ASSUMPTIONS

APPENDIX ANALYSIS METHODOLOGY & ASSUMPTIONS

This study followed the principles and framework outlined in ISO 14040 and 14044 for Life Cycle Assessment (LCA), and incorporates techno-economic analysis (TEA) to assess the environmental and economic performance of various waste management solutions for mining-related waste streams.
According to these standards, four main steps are to be followed to conduct an LCA study, including:

- **Stage 1:** Goal and scope definition
- **Stage 2:** Life cycle inventory (LCI)
- **Stage 3:** Life cycle impact assessment (LCIA)
- **Stage 4:** Interpretation of results



STAGE 1: GOAL & SCOPE

The goal of the study was to assess the environmental impact, specifically the global warming impact (CO_2e emissions), of multiple waste handling solutions across nine different waste streams commonly found on mine sites. For each solution, layouts were first developed to understand the material flow, operational steps, and infrastructure requirements. These layouts informed the system boundaries and functional units for each scenario. The scope of the study is described under the system boundaries, functional units, assumptions and data source(s).

- **System boundaries:** This defines which processes are to be included or excluded from the analysis. For this study, the system boundaries are defined according to each waste solutions unique scope, including upstream (e.g., transport from mine sites), core processing, and certain downstream stages. Thus, a "gate-to-gate" boundary.
- **Functional units:** The functional unit (FU) of an LCA defines the reference stream to which all inputs and outputs will be related to, and also provides a basis for comparison. The functional unit was defined per unit of waste processed to allow comparability between options (however, the 'last' product within the defined system boundary was also selected as a FU if a recycled version of the waste material was produced, in order to compare the results with the virgin material).
- **Data sources for emission factors (EFs):** Given the diversity of waste streams and processes, emission factors were drawn from multiple sources, including peer-reviewed literature, government databases, industry reports, and proprietary tools where appropriate.

STAGE 2: LIFE CYCLE INVENTORY (LCI)

The LCI involves compiling an inventory of all flows into and out of the system. Flow diagrams of all the processes were completed to visualise and map out all the input and output streams within a process. After all relevant inputs and outputs was established, data for all these streams were collected. Data collection included data for the following parameters:

- **Material compositions**
- **Mass flow rates**
- **Energy usages** (electricity, other fuels)
- **Transport distances** between mine sites and treatment/recovery facilities
- **Emission factors** for energy and material use (Scope 1, 2, and 3)
- **Cost data** including capital, operational, and maintenance costs

Ideally, site-specific data ('primary data') must be obtained, but in most cases, this was not available. Where data gaps existed, assumptions were made based on expert judgment or published estimates ('secondary data').

STAGE 3: LIFE CYCLE IMPACT ASSESSMENT (LCIA)

The LCIA involves using the inventory data to evaluate the potential environmental impact of the product system under review. In terms of impact categories, this LCA study only evaluated the global warming potential (GWP), expressed in CO_2e. This was assessed across 3 different scopes:

- **Scope 1 emissions** (direct emissions from fuel use, on-site combustion, etc.)
- **Scope 2 emissions** (indirect emissions from electricity and other purchased energy)
- **Scope 3 emissions** (upstream and downstream emissions from materials, transport, waste disposal, etc.)

Total life cycle emissions were calculated based on the defined system boundaries and inventory data for each solution.

TECHNO-ECONOMIC ASSESSMENT (TEA)

The TEA was conducted in parallel with the LCA to assess the economic performance of each solution. The following components were considered:

- **Capital expenditure (CAPEX):** Once-off costs associated with installation, infrastructure, or equipment procurement.
- **Operational expenditure (OPEX):** Recurring costs, including electricity and fuel use, water consumption, labour, maintenance, and transport.
- **Revenue streams:** Where applicable, revenue was included from recovered materials, saleable byproducts, and, most significantly (in most cases), the recycling 'gate fee' received..

Net present value (NPV) was calculated over 10-year and 20-year periods.

STAGE 4: INTERPRETATION

The final stage of the LCA process is where the results of the LCIA are analysed and interpreted, such that an overall understanding can be achieved over the full system, and should be conducted throughout the process. Based on the results, the specific issues can be identified. Emissions and costs were analysed and compared, either by comparing with virgin material manufacturing, comparing the different options, or considering the avoided emissions.
To compare the environmental and economic attractiveness of each waste management solution, a "Sustainability Performance Index (SPI) was introduced, and can be defined as:

$$SPI = \frac{NPV_{10}/1000}{Total\ CO_2\ per\ year}$$

This indicator reflects the economic return in relation to emissions emitted, allowing for a normalised comparison of options, where higher values indicate greater economic benefit with lower environmental burden.

ASSUMPTIONS AND LIMITATIONS

Assumptions were made throughout the LCA study for simplification purposes, and are listed below:

GENERAL ASSUMPTIONS

- No landfill emissions will be accounted for (for current disposal method), unless stated otherwise
- Assume equal amounts of waste material comes from all 5 mine sites
- Trucks for transporting waste from mine sites are 20-t diesel road transport trucks (except for OTRs)
- For all transport, only the applicable trips will be accounted for (no return)
- Auxiliary energy requirements are not taken into consideration, unless stated otherwise
- All electricity is from the national electricity grid, and state-specific emission factors will be used (or national, if not available), unless stated otherwise
- For all international transport, road transport will be used to Brisbane port, and then from Brisbane port to export country port via maritime shipping
- There is a viable market for the products produced during the proposed solutions
- No maintenance work / replacements of parts was considered for this LCA, unless stated otherwise
- For the TEA, annual maintenance cost on equipment will be assumed to be 5-10% of CAPEX cost
- For LCA (emissions) and TEA (cost) calculations, only significant equipment/activities are considered
- No sorting processes use electricity, but only manual labour
- Recycling gate fee assumed as $500-$1000 per tonne waste material, for all waste materials
- Service provider fee assumed as $200-$300 per tonne waste material, for all waste materials

OTR ASSUMPTIONS

- Crumb rubber contains all rubber, carbon black and other
- All steel in OTR ends up in scrap steel to be recycled, i.e., 100% recovery
- Primary processing uses electricity, diesel and LPG as energy source
- For crumbing being used in road construction, crumb be transported to Townsville to an asphalt mixing plant
- The devulcanisation process uses no chemical solvents, devulcanization chemicals, or additives
- TDP is the only product from the devulcanisation process, and mass is equal to shred/crumb feed (1:1)
- The conveyor manufacturer is West Footscray, Victoria
- Tires manufacturer is PT Gajah Tunggal Tbk in Jakarta, Indonesia
- Buffings and crumb rubber are equal in cost

BULK BAGS ASSUMPTIONS

- Bulk bags consist of 100% polypropylene
- Empty bulk bags weighs approximately 1.875 kg
- Ratio between damaged vs undamaged pallets: 30% damaged, 70% undamaged
- Electric energy consumption for washing = 10 kWh per tonne bags
- Water consumption for washing = 200 L water per tonne bags
- Undamaged bags are transported (= 200 km)
- Damaged bags are transported to 'Big Bag Recovery' facility, Toowoomba (= 1000 km)
- Electric power consumption for recycling = 30 kWh per tonne bags

TIMBER PALLETS ASSUMPTIONS

- Mass of standard wooden pellet is 10-30kg (i.e., assume average = 20 kg)
- All pallet forklifts will be solar powered (no diesel usage)
- Ratio between intact vs damaged pallets: 40% intact, 60% damaged
- During denailing, 5% of the pallet weight is removed
- Ratio between treated vs untreated pallets: 50% of damaged pallets are treated, 50% are untreated
- Treated' pallets refers to a heat treatment or methyl bromide pesticide
- Electric energy consumption of denailer (MPB Automatic Denailing machine) = 20 kWh / tonne pallets
- Electric power consumption for chipper (UNTHA PS1300 Shredder) = 18 kW / tonne pallets
- Operational availability of the chipper (UNTHA PS1300 Shredder) = 66%
- Throughput of chipper (UNTHA PS1300 Shredder) = 30 pallets / hour
- Electric energy consumption of rebuilding of pallets = 7.1 kWh / tonne pallets
- Natural gas consumption of rebuilding of pallets = 0.497 L / tonne pallets
- Transport distance from Multi-Mine to Auscan Worms, MacKay = 200 km
- Electric energy consumption for composting (loaders, sprayers, de-packaging, etc.) = 10 kWh / t waste
- Water consumption for composting = 10 L water per tonne waste
- Inoculant consumption for composting = 0.1 L inoculant per m^3 waste
- Food waste density is 193 - 211 kg/m^3 (i.e., assume average = 200 kg/m^3)
- 30-50% of waste will be converted to compost (i.e., assume average = 40%)
- Intact waste pallets are sold at $10-$16 per pallet

FOOD/ORGANIC MATTER ASSUMPTIONS

- Transport distance from Multi-Mine to Auscan Worms, MacKay = 200 km
- Electric energy consumption for composting (loaders, sprayers, de-packaging, etc.) = 10 kWh / t waste
- Water consumption for composting = 10 L water per tonne waste
- Inoculant consumption for composting = 0.1 L inoculant per m3 waste
- Food waste density is 193 - 211 kg/m3 (i.e., assume average = 200 kg/m3)
- 30-50% of waste will be converted to compost (i.e., assume average = 40%)
- Bio-digester size used: LFC-1000 (since the total feed per day would be around 3000 kg)
- Electric energy consumption for bio-digester = 29 kWh / tonne waste
- Water consumption for bio-digester = 10 L / tonne waste
- Capex for VERMIcomposting is low since most equipment will be hired (i.e., OPEX)

SCRAP METAL ASSUMPTIONS

- Scrap metal will be transported to the closest BlueScope location, Port Kembla facility (NSW)

DPFS ASSUMPTIONS

- DPFs weights range from 15-50 kg
- Recycle plant by Ozzy Metals (= 1 000 km)
- Electric energy consumption for recycle plant = 100 kWh / tonne DPFs
- DPF Cleaning uses Flash-JET cleaning equipment
- Water consumption for DPF Cleaning = 10 L / tonne DPF

Assumptions and limitations

Assumptions were made throughout the LCA study for simplification purposes, and are listed below:

CARDBOARD BOXES ASSUMPTIONS

- Ratio between damaged vs undamaged boxes: 70% damaged, 30% undamaged
- Undamaged boxes transported to local businesses (= 100 km)
- Electric energy consumption for compacting process = 5 kWh / tonne boxes
- Visy Recycling Material Recovery Facility is in Rocklea: 36 Suscatand St, Rocklea, QLD, 4106, Australia
- Electric energy consumption for recycling plant = 10 kWh / tonne boxes
- Transport distance from Multi-Mine to Auscan Worms, MacKay = 200 km
- Electric energy consumption for composting (loaders, sprayers, de-packaging, etc.) = 10 kWh / t waste
- Water consumption for composting = 10 L water per tonne waste
- Inoculant consumption for composting = 0.1 L inoculant per m^3 waste
- Food waste density is 193 - 211 kg/m^3 (i.e., assume average = 200 kg/m^3)
- 30-50% of waste will be converted to compost (i.e., assume average = 40%)

PVC ASSUMPTIONS

- Pipes composition: 40% PVC, 60% HDPE
- Ratio between damaged vs undamaged boxes: 70% damaged, 30% undamaged
- Electric energy consumption for washing, granulating, pelletising = 20, 30, and 200 kWh / tonne pipes
- Water consumption for composting = 100 L water per tonne pipes
- Pipes transported to manufacturer in Queensland for recycling (= 1000 km)
- Washing equipment will be similar to Flash-JET (DPF cleaning)

IBCS ASSUMPTIONS

- IBCs composition: 28% HDPE container, 72% steel cage (tot wt = 56 kg per IBC)
- Ratio between damaged vs undamaged IBCs: 70% damaged, 30% undamaged
- Electric power consumption for draining & washing = 11 kW
- Washing equipment can wash 6 IBCs per hour

THANK YOU

If you are interested in learning more or contributing data to widen our dataset, please reach out to hello@coreo.com.au

"Alone we can do so little; together we can do so much."

- Helen Keller

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