TRANSITIONING TO THE CIRCULAR ECONOMY THROUGH DIFFERENT BUSINESS MODELS:

LESSONS FOR, AND FROM, AUSTRALIAN CHEESE MANUFACTURERS

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BRIEFING PAPER

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1 Executive Summary

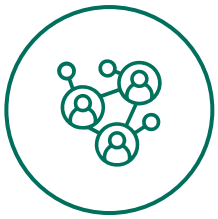
Cheese 'whey' is a liquid by-product from cheese manufacturing. There is a significant amount of whey generated for every tonne of cheese produced (75-90% of the mass), there are many uses for it (including in human food products), yet it is one of the largest sources of food loss and waste (FLW) in the Australian dairy sector, and Australia more generally.

This research evaluates the incentives, barriers and enablers of circular business model (CBM) adoption within the Australian cheese manufacturing sector.

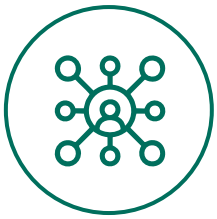
Four CBMs are considered in this research:

IN-HOUSE (IH)
A firm changes internal processes to repurpose waste in-house.

THIRD-PARTY (TP)
A third-party firm is engaged (+/- payment) and subsequently repurposes waste.



JOINT VENTURE (JV)
A firm partners/ invests with similar firms to collectively repurpose waste.



FOCAL COMPANY (FC)
A firm repurposing waste, accepts the waste material from other similar firms.

The dairy sector is well-placed to have minimal FLW, given the availability of technologies that can repurpose the by-product (a.k.a. 'Upcycled'[1]) that would contribute to the overall reduction of FLW and maintain a high-level of resource circularity.

This research finds the lack of clear incentives, persistent and unique barriers, and the general absence of conditions that enable adoption (e.g., easily identifiable benefits to profit, risk, etc.) have resulted in relatively low adoption rates. This research also highlights several areas where there is a gap between 'perceived' and 'actual' barriers—for instance, distance to potential partners being a highly cited issue, but data revealing the median distance is 1.1km.

Based on the research findings, this briefing paper suggest recommendations to improve both the supply-side and demand-side conditions to drive change in whey repurposing.

[1] 'Upcycled foods use ingredients that otherwise would not have gone to human consumption, are procured and produced using verifiable supply chains, and have a positive impact on the environment.' [1]

Supply-side recommendations for key stakeholders:

1. Better access to information about the benefits and risks of whey repurposing and circular business models, including mapping potential partners and seeing case studies of successful examples.
2. Better guidelines to overcome regulatory hurdles (e.g., food safety compliance, alcohol taxation).
3. Supply-side subsidies and/or incentives to improve the commercial viability of whey-based products, such as de-risking and/or (co-)investment in cold chain, storage, or processing infrastructure.
4. Improve transparency and access to inputs for Upcycling (e.g., cultures used for fermentation to create high value products such as whey-based alcohol).
5. Develop and promote integrated decision support tools to enable businesses to identify most suitable management practices and business models (incorporating financial, risk, environmental indicators).
6. Research & development (including funding or incentives) into small-scale place-based processing technologies to make more accessible smaller operations (e.g., whey pasteurisation and concentration whey to improve transporting logistics).
7. Establishing focal company projects to leverage the existing processing infrastructure (e.g., with large cheese manufacturers such as Bega Group, Saputo Dairy Australia and Fonterra Co-op).
8. Establishing joint venture projects to get the economies of scale for new processing infrastructure.

Demand-side recommendations for key stakeholders:

1. Supporting new market entrants (e.g., start-ups) whose business model is focused on Upcycling whey.
2. Explore the value proposition of Upcycled labelling to inform as part of a broader consumer campaign about purchasing behaviour consequences.
3. Promoting the benefits of whey-based products (e.g., environmental benefits) and community benefits from regional development opportunities.
4. Individuals and businesses (e.g., retailers) change shopping behaviour/procurement policies to purchase whey-based product equivalents.
5. Individuals and businesses (e.g., retailers) establish new expectations/procurement policies about cheese products and FLW management to incentivise desirable whey management practices.

Dealing with FLW is a complex, ever-evolving issue, with no single solution. This research sheds light on the under-recognised but persistent challenge of whey waste, which is the result of failures in markets, government policies, and social licenses to generate optimal outcomes. Other sectors can learn from the dairy sector, which has had relatively high levels of investment in research and development into processing technologies for several decades. Exploring different business models, improving incentives, and clearly identifiable benefits are needed.

2 Background

Australia generates 7.6 million tonnes of FLW each year, half of which occurs before food reaches consumers [2]. In response, Australian governments, private firms, industry bodies and civil society have committed to Sustainable Development Goal (SDG) 12.3, aiming to halve FLW by 2030.

The dairy sector significantly contributes to Australia's overall FLW, accounting for an estimated 14.9% of the total [2]. Accounting for approximately half of this waste is whey, a by-product of cheesemaking [3].

Whey is the liquid that remains after milk is curdled and strained during cheese and yoghurt production. As with raw milk (comprised of 87% water), whey is predominantly comprised of water (94%), but it contains around half of the nutrients in raw milk (mostly lactose, with some protein and minerals). It accounts for up to 90% of its mass. Partly owing to it being mostly comprised of water—which makes it energy-intensive to extract components and transport—whey is often treated as waste or diverted to low-value uses (e.g., irrigated onto pastures). However, there are numerous opportunities for businesses of all sizes to transform this by-product into high-value food products, as shown in Figure 1.

It is common for protein and lactose powders to be extracted from whey to be used in food manufacturing including ice cream, baked goods, infant formula and health foods. The global whey protein market was estimated to be AU$16.2 billion in 2022 and is expected to experience a 7.9% compounded annual growth rate between 2022 and 2027 [4]. Some manufacturers extract high-value nutrient components like Lactoferrin, which has been researched to aid the treatment of long-COVID symptoms [5].

Also, consumers can purchase alcohol (e.g., beer, vodka, gin and espresso liquor) made from whey derived from cow, goat, sheep and camel milk. Interestingly, some whey-based alcohol emits fewer greenhouse gases and uses less water than traditional brews (e.g., from grain) [6].

Despite all these opportunities, whey waste is one of the largest sources of FLW in the dairy sector. Each year, approximately 350 million litres of whey is wasted in Australia, leading to significant social, environmental and economic impacts [3]. This has significant negative consequences (see Figure 2).


2611
2615
2686

Whey generation and repurposing / Upcycling options

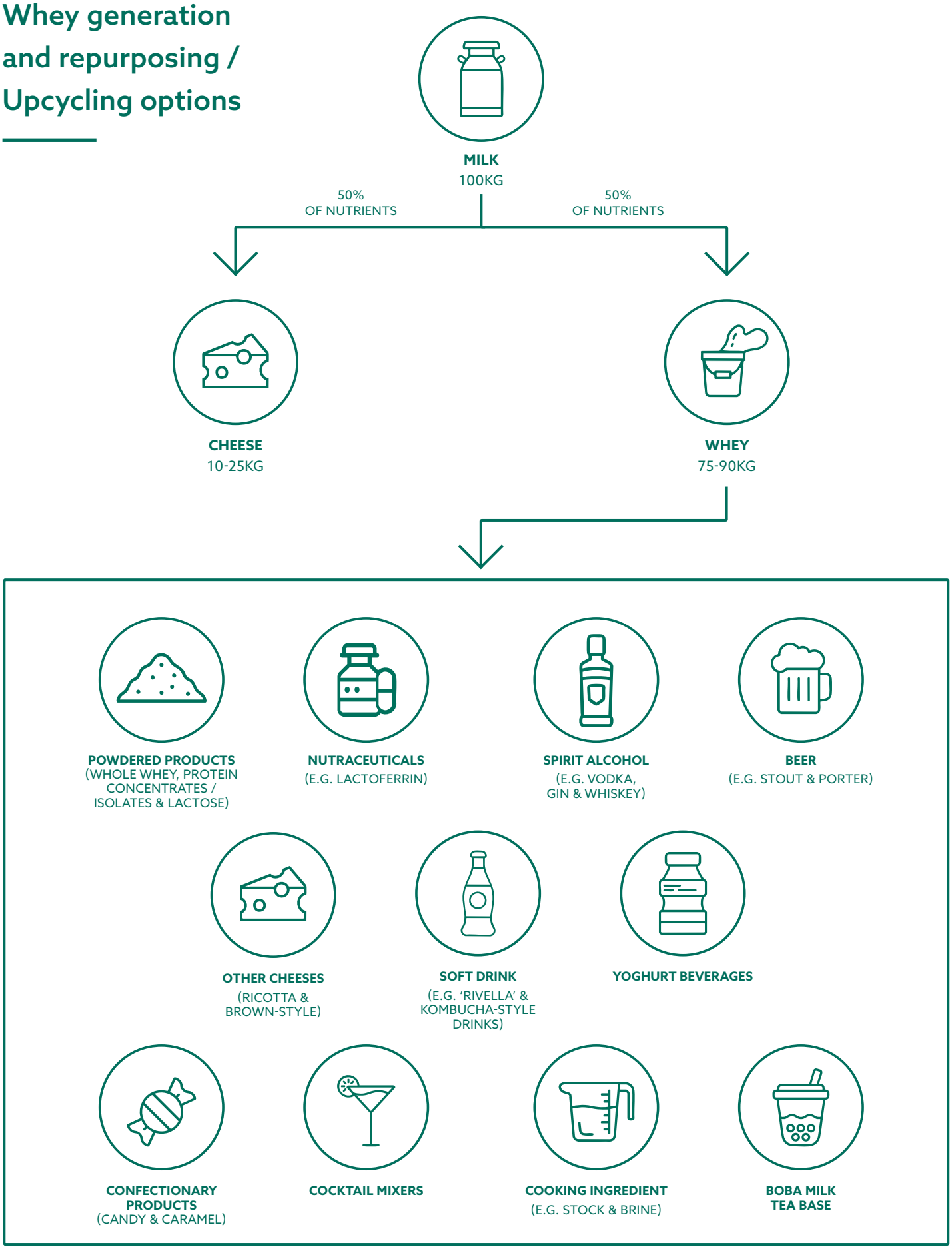


Figure 1. Whey generation and repurposing/Upcycling options.

Consequences of whey waste in Australia

Whey

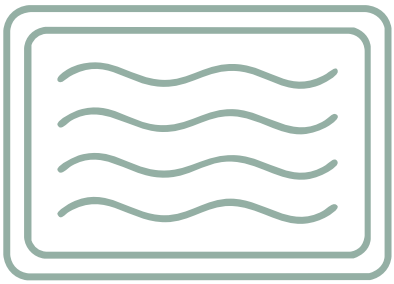
is over **100 X** more polluting than **Sewage**[7, 8]

Economic loss

of whey waste costs manufacturers annually

$578 million[3]

Whey waste contains enough water to fill



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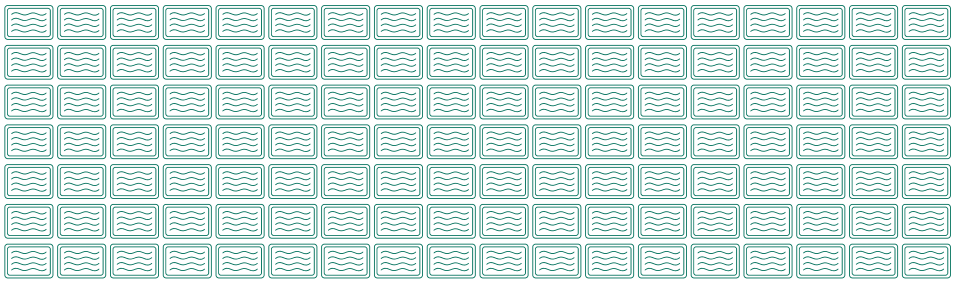


OLYMPIC SWIMMING POOLS[9]

315 000 000 litres

Equivalent greenhouse gas emissions to to the annual energy usage of:

[10]

113,169 homes

or the emissions from 206,537 petrol cars[2] (867.8GT CO_2e)

Nutrient loss includes enough lactose, protein, and minerals to fill 790 semi-trailer trucks.

[9]

790

(21,000 tonnes dry weight)

Ties up additional, yet unmeasured, upstream agricultural inputs that are ultimately wasted:

WATER (cattle drinking water and irrigation of pasture and crops)

LAND

FERTILISERS

[2] See: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results

Figure 2. Consequences of whey waste in Australia.

3 About the sector

In Australia, 43% of national milk supply (8.1 billion litres p.a.) contributes to cheese production [11]. At the time of the study, 132 firms were manufacturing cheese products from cow, goat, sheep, and camel milk. The industry is characterised by a few large manufacturers (2.1% of firms), several medium (8.5%) and many small manufacturers (89.4%) that are mainly concentrated in the south-east of Australia (see Figure 3). There are at least ten cheese manufacturers that also produce high-value whey products based on publicly available information (i.e., business websites and reports).

The sector features a diverse range of business models, from vertically or horizontally integrated firms to those with varying product portfolios, from exclusive cheese production to broader dairy and non-dairy offerings. Additionally, the industry is characterised by complex relationships between firms. For instance, Bega Group holds an exclusive licensing agreement with Fonterra Co-op Group for the marketing and distribution of Bega-branded products[3], while Saputo Dairy Australia engages in multiple joint ventures to share processing infrastructure[4].

Australian manufacturers produce 58,000 tonnes p.a. of whey powder, with half exported to Asia [11], and health supplements such as Lactoferrin [12]. Large and mid-scale manufacturers in Australia produce whey powdered products such as whole whey powder, concentrates, and protein isolates. There is also a small but growing market for whey-based alcohol such as gin, vodka and beer, which is produced by small artisanal distilleries (e.g., Hartshorn in Tasmania) and industrial-scale producers (e.g., Asahi-owned 'Vodka O' in Melbourne).

These product options are achieved through a variety a range of technology options, such as cooling, pasteurisation, concentration (spray dryers, reverse-osmosis), fractionation (microfiltration, ultrafiltration, nanofiltration, chromatography) and fermentation [13].

As is evidenced by the findings of this research (below), **there are different technology, market and business model options currently in operation in this sector, largely viable across all scales of production, that contribute to the highest levels of circularity (i.e., keeping food as food)**. Though, how these are achieved from a technical and commercial perspective are not widely publicised, hindering widespread adoption.

[3] See: https://begagroup.com.au/student-resources/

[4] See: https://www.saputodairyaustralia.com.au/en/our-products/joint-ventures

132 Cheese manufacturers in Australia

Production scale*

- Large (>25 kt p.a.): 2.1%
- Medium (10-25 kt p.a.): 8.5%
- Small (<10 kt p.a.): 89.4%

*Production scale based on annual kilotonnes of finished cheese products

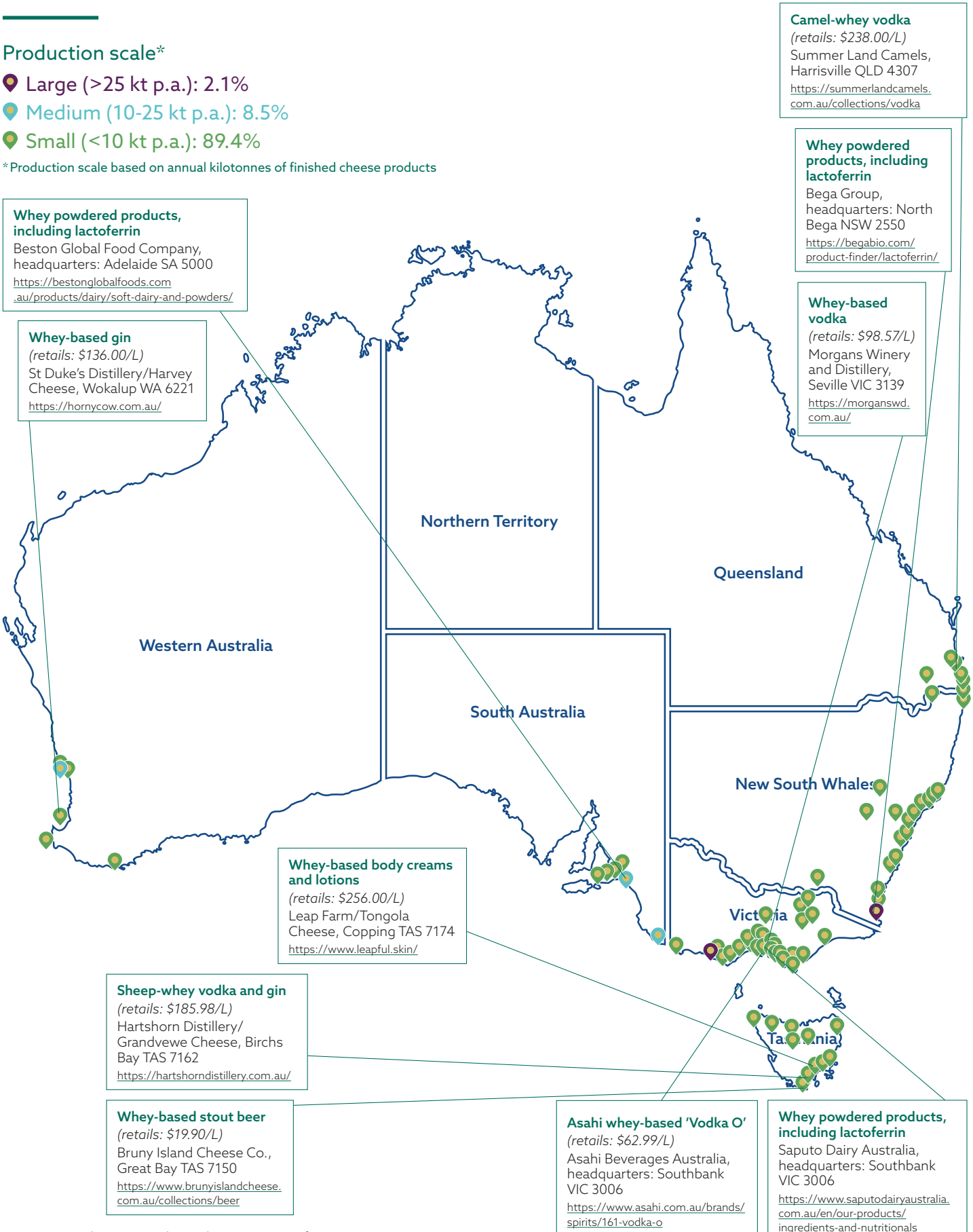


Figure 3. The Australian cheese manufacturing sector and examples of whey-based products.

*Information based on a review of all manufacturers' websites and is not limited to the study sample. Price (in AUD) information retrieved: 12 March 2024

3.1 | Dairy Sector Action Plan

In 2023, Dairy Australia, in collaboration with End Food Waste Australia (formerly Stop Food Waste Australia) and the Australian Dairy Products Federation, published the *Dairy Sector Food Waste Action Plan* [3], estimating dairy FLW to be 708,104 tonnes p.a. with 50% generated by manufacturing by-products.

There is, approximately, 350,000 tonnes of annual whey waste, which the Australian dairy sectors aims to halve by 2030. This suggests an annual reduction of 175,000 tonnes of whey waste.

The Dairy Sector Action Plan categorises management practices (end destinations) contributing to national FLW reduction targets. It emphasises the importance of 'moving up' the Food Waste Hierarchy to ensure that as much food as possible is consumed by people. The hierarchy prioritises the following:

1. **Reduction** – Avoiding FLW, such as spoilage of surplus stock.
2. **Repurposing** – Upcycling food materials into other human food products.
3. **Redistribution** – Donating surplus food to charities.
4. **Reuse** – Using food materials, like whey, as animal feed (though less preferred than the above options).

These practices contribute to the **prevention of FLW** and the target of halving it by 2030, aligned with **SDG12.3**[5]. The green tiers in Figure 4 represent these preferred actions.

Although reduction is typically the most desirable option, unavoidable by-products like whey cannot be completely eliminated. Common practices such as reusing whey as animal feed (e.g., for pigs) are beneficial but not as high-priority as repurposing whey into new human food products. Actions that **Recycle** or **Recover** resources will likely be important options for some firms, but as these do not contribute to the prevention of FLW, this research paid less attention on these end destinations.

The most critical factor within this framework is the ultimate end destination of the food material. For instance, diverting whey from sewage to compost (classified as 'recycling') does not count toward SDG12.3 targets. Similarly, while processes such as cooling, concentrating, or pasteurising whey may enable new product creation, these actions only contribute to SDG12.3 if the whey is ultimately consumed by humans or animals.

As part of the Dairy Sector Action Plan, ten actions were identified to address dairy FLW, two of which directly address whey:

- Monitor dairy food waste across the supply chain and establish industry working group.
- Assess commercial feasibility of diverting excess whey to third-party processors in regional networks for conversion to value-added products.

[5] While terminology describing actions within different end destinations varies between authors/reports (e.g., distinctions between 'prevention,' 'reduction,' or 'reuse'), this document uses terms consistent with the Australian context for clarity, following End Food Waste Australia [14] and Dairy Australia [3].

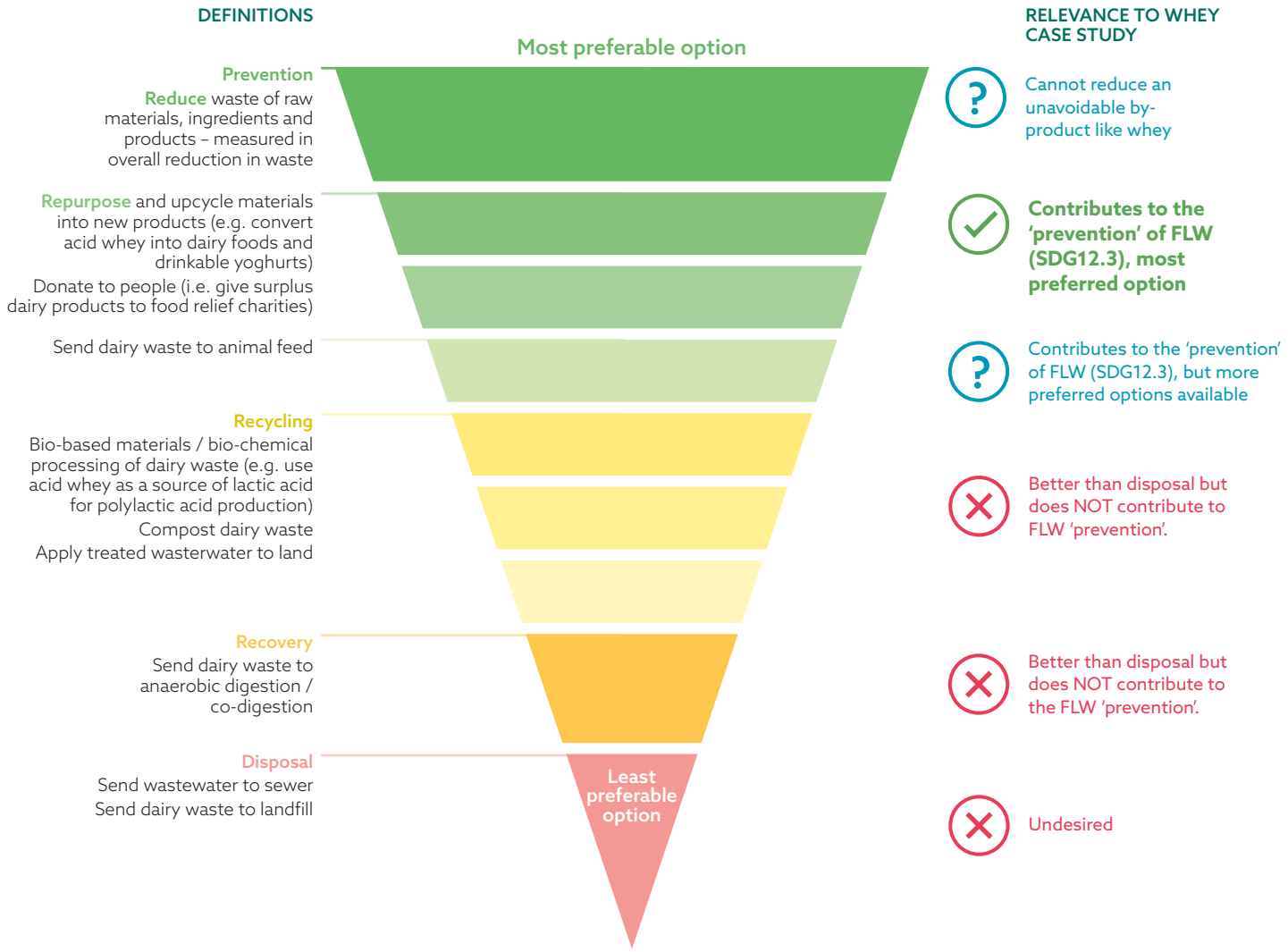


Figure 4. Preferred management practices/end destinations for all dairy FLW according to the Australian dairy sector's adaptation of the Food Waste Hierarchy, and an assessment of whey's most preferred option.

4 Research scope

With the sectoral objectives in mind, this research aimed to understand how we can move firms up the Food Waste Hierarchy, preferably repurposing whey into human food products. This includes different CBMs that achieve the same outcome.

This research evaluated the incentives, barriers and enablers of CBM adoption within the Australian cheese manufacturing sector.

Figure 5 illustrates the conceptual approach of this research. While whey is also generated from yoghurt, this research focused on cheese whey only[6].

[6] This was due to several reasons, including: there being a higher volume of whey generated from every tonne of finished product compared to yoghurt, it was identified as a more substantial issue from a national FLW perspective, and there are more processing options available for cheese whey compared to yoghurt-derived acid whey, which presents greater technical challenges. While acid whey is also generated from certain cheese products, sweet whey—which is also prevalent in cheese manufacturing—offers more viable processing and repurposing options. This is discussed more in the next section.

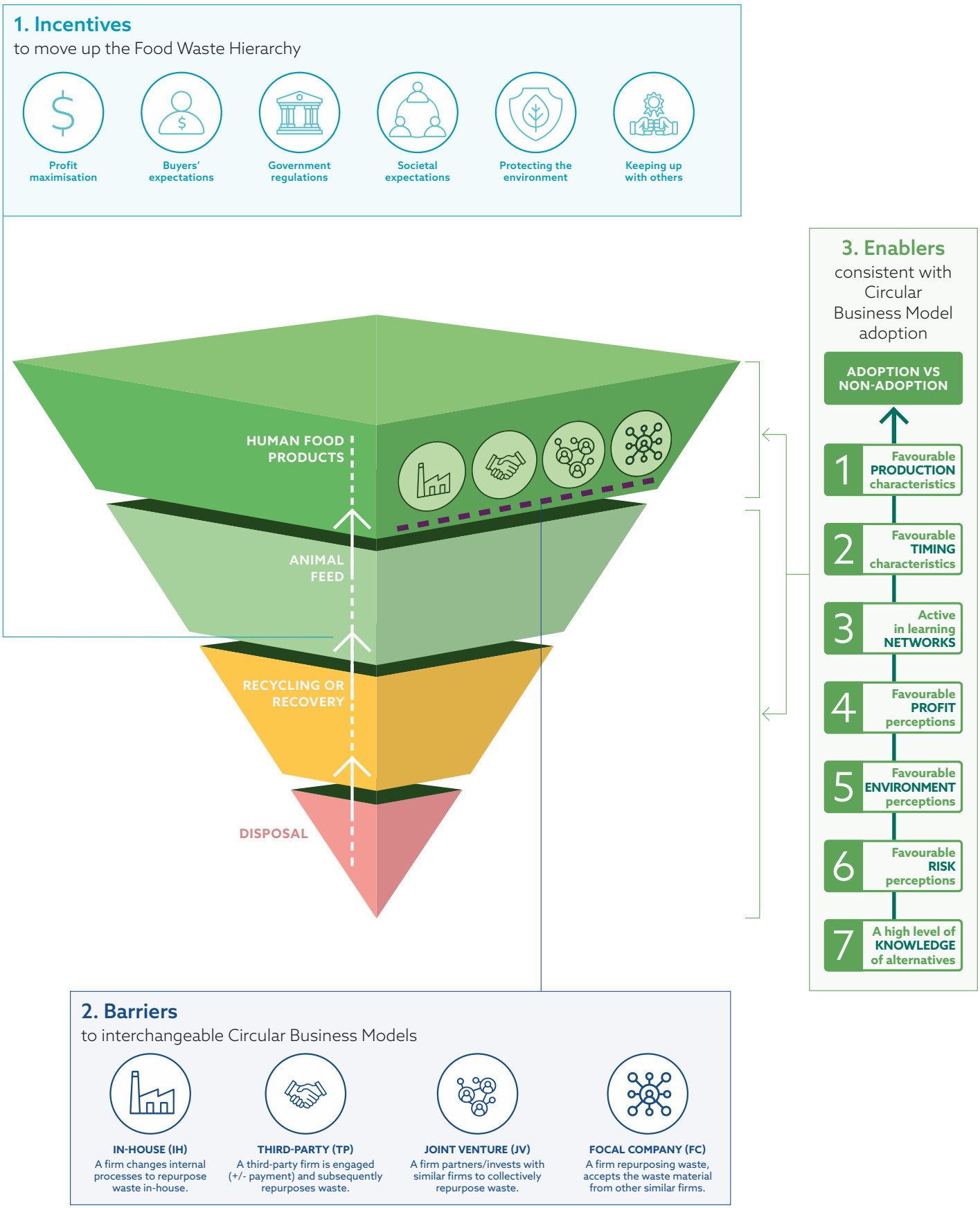


Figure 5. Conceptual approach and scope of the research analysis.

5 Method

- Semi-structured interviews with Australian cheese manufacturers between November 2022 and June 2023.
- 43 interviews from 42 firms (a change of ownership occurred, and the new owner participated in an interview).
- The final sample accounted for 31% of firms and was nationally representative for production scale and states.
- Topics covered:
  - Business and production characteristics
  - Food loss and waste management (including whey)
  - Business operating environment
  - Decision support tools.
- Interviews recordings were transcribed for detailed analysis.
- Due to ethics and privacy requirements, the identity of individuals participants and firms cannot be disclosed. However, where possible, general information is provided.

6 Research findings

6.1 | Current behaviour

The study found a diverse range of whey management practices across different scales of cheese manufacturers. The awareness of alternative options for repurposing whey into high-value products was high, with all participants knowing at least one repurposing method for whey (Table 1). This study also observed novel uses of acid whey (see box below).

The study revealed that whey repurposing behaviours were spread across several categories, such as using whey for human food products (e.g., ricotta, powdered products, alcohol) and for animal feed or recycling/recovery processes like paddock irrigation. Disposal of whey in wastewater was also prevalent, especially among mid- to small-scale producers. While larger manufacturers predominantly repurpose whey into human food products, mid-and small-scale manufacturers can also achieve this outcome.

Acid whey

Acid whey, which is generated from particular cheese production methods like mozzarella, is a particular challenge for repurposing due to the effect on the nutrient components (e.g., denaturing of proteins). However, two participants reported repurposing acid whey into food products.

The first produced whole whey powders and protein concentrates. The second was making cheese to generate a primary whey. This was made into ricotta, resulting in an 'exhausted' acid whey. This was subsequently fermented into alcohol. While there is some scientific information about acid whey transformation [15, 16], there is limited publicly available information detailing how these two examples can be achieved.

Table 1. Current management and awareness of practices of whey based on the number of firms (n=42).

Category	Management practice	Firms that implement practices	Firms that are aware of the practices	Firms that are aware of at least one human food product use
Human food products	Ricotta (from whey)	23.8%	61.9%	100.0%
	Powdered products	9.5%	83.3%	
	Alcohol products	9.5%	81.0%	
	Other human consumption[1]	7.1%	59.5%	
Animal feed	Livestock feed	42.9%	92.9%	
Recycling or recovery	Anaerobic Digestion	2.4%	28.6%	
	Compost	4.8%	9.5%	
	Paddock irrigation	35.7%	69.0%	
	Other products for sale[2]	2.4%	21.4%	
Disposal	Wastewater	35.7%	69.0%	

[1] Includes making non-fermented beverage products, confectionaries, selling to food service as cooking stocks, cocktails, etc.

[2] Includes skin care products and paint.

As shown in Table 2, most whey (based on tonnage) is processed into human food products (mainly powdered products), which is disproportionately driven by the small number of very large producers whose scale is far larger than the others (between 10-10,000 times larger). This means the largest producers are not the source of the current whey waste issue, and efforts are needed on the mid- to small producers. It is also for this reason (i.e., significant skewing caused by the largest firms) we focus on the predominant practice at the firm level rather than the total mass for much of this research. Interestingly, while most firms use the whey as animal feed (33%), there is almost three times the tonnes of whey that can be diverted from disposal (19,008 vs 59,714 tonnes p.a.).

Figure 6 shows most participants (54.8%) had not yet taken significant steps to adopt a business model that repurposed whey, with the remainder at varying stages of exploration and implementation.

Table 2. Summary of the total mass of liquid whey and firms' predominant management practice, broken down by production scale and business model (n=42).

	Human food products	Animal feed	Recycling or recovery	Disposal	Total
Total mass of liquid whey from all study participants (tonnes p.a.)	1,069,061	19,008	12,566	59,714	1,160,349
Breakdown of firms' predominant practice[1]					
Production scale (tonnes p.a.)[2]					
≥ 100,000	7.1%	0.0%	0.0%	0.0%	7.1%
10,000 – 100,000	0.0%	0.0%	0.0%	4.8%	4.8%
1,000 – 10,000	2.4%	11.9%	4.8%	11.9%	31.0%
100 – 1,000	0.0%	9.5%	9.5%	9.5%	28.6%
10 – 100	2.4%	11.9%	9.5%	2.4%	26.2%
< 10	2.4%	0.0%	0.0%	0.0%	2.4%
Total	14.3%	33.3%	23.8%	28.6%	100.0%
Business model					
In-house	9.5%	11.9%	21.4%	0.0%	42.9%
Third party	2.4%	21.4%	2.4%	28.6%	54.8%
Joint venture	2.4%	0.0%	0.0%	0.0%	2.4%
Focal company	0.0%	0.0%	0.0%	0.0%	0.0%
Total	14.3%	33.3%	23.8%	28.6%	100.0%

[1] Based on where >50% of liquid whey ends up.

[2] Production scale based on liquid milk processed into cheese products.

Predominant practice according to Food Waste Hierarchy

% of firms that currently send >50% of whey to end destination
Height (not area) of tiers are to scale of %.

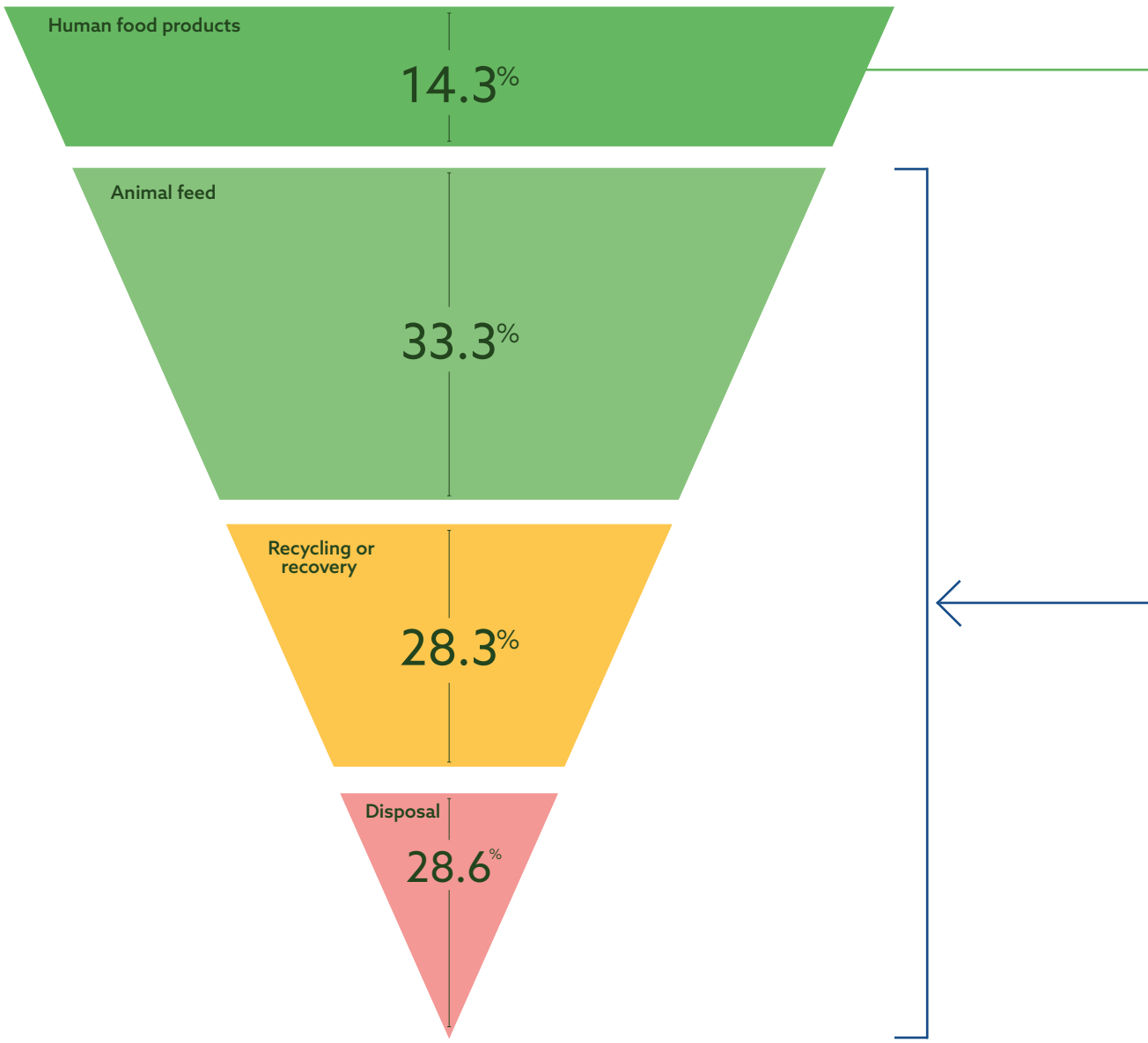
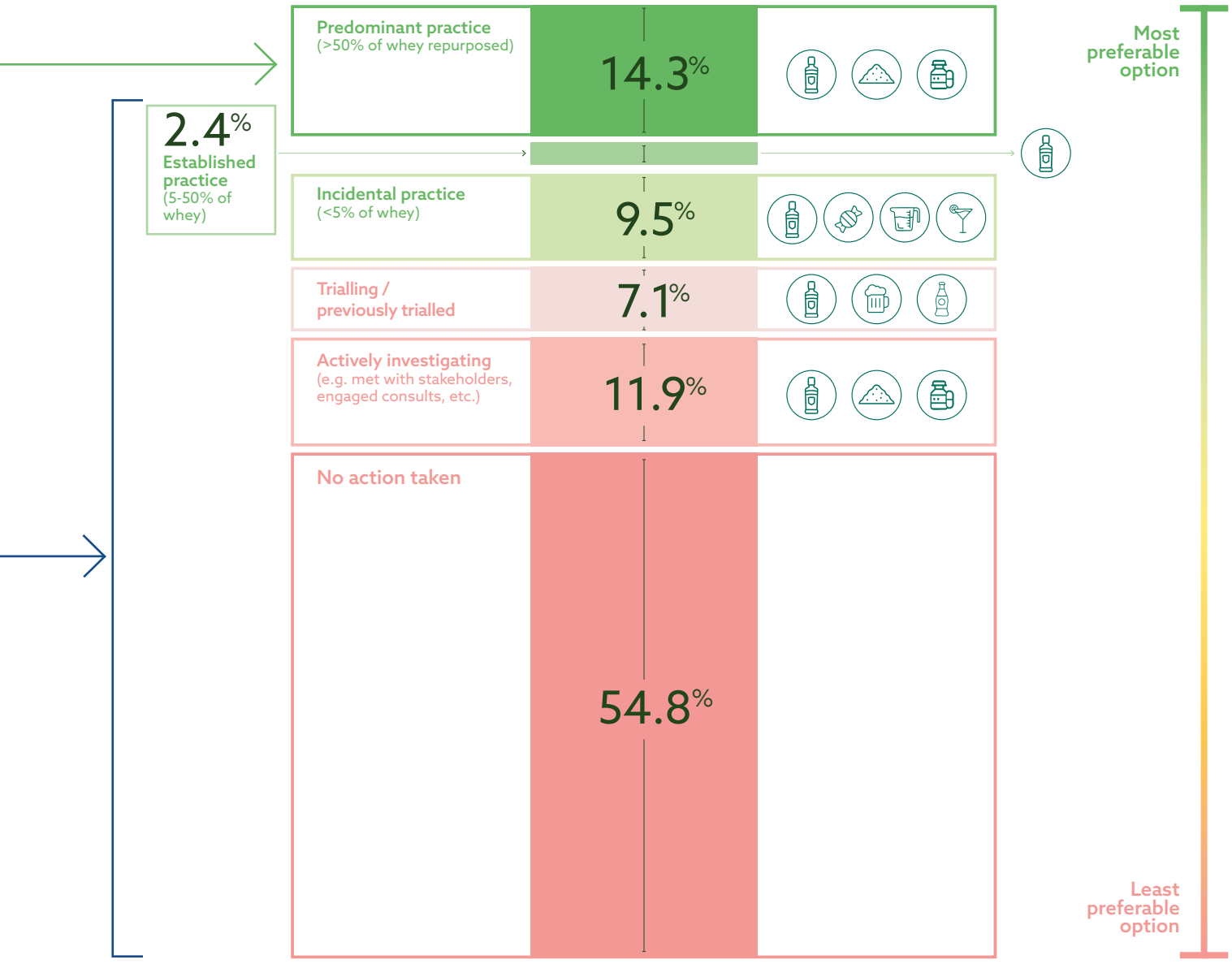


Figure 6. Summary of different dimensions of current whey management behaviour, including according to the alignment with the Food Waste Hierarchy (left) and the extent of adoption of repurposing whey into human food products (n = 42).

Extent of adoption of whey repurposing into human food products

% of firms, based on adoption category.



ICON LEGEND

SPIRIT ALCOHOL · POWDERED PRODUCTS · NUTRACEUTICALS · BEER · SOFT DRINK · CONFECTIONARY · COOKING INGREDIENT · COCKTAIL MIXER

6.2 | Incentives

In general, firms are incentivised to change behaviour based on a range of monetary and non-monetary factors. These profit drivers, coercive forces or normative pressures (values and social norms), or following the behaviour of others.
This research assessed the relative importance of motivators to incentivise firms to 'move up' the Food Waste Hierarchy. This included: profit maximisation, buyers' expectations, government regulations, social expectations, valuing environmental protection, and keeping up with industry practices.

Main findings

Profit, environmental protection, and government regulations are important but this varies, meaning firms have different motivators to change. Buyers and society are largely not concerned about whey waste, but some participants worry this could change in the coming years. Regulatory pressures differ across hierarchy levels, but there is no evidence they incentivise firms to 'move up' the hierarchy.
While there is variation present in the sector, the below points summarise some broader trends based on examples in the study sample:

- Firms at the top of the hierarchy, have invested the time and resources required repurpose whey. They are able to focus on their other goals, meaning their decision to change is largely affected by profit.
- Those that are feeding whey to animals (e.g., pigs, cattle, goats) are interested the potential benefits that can come with repurposing whey, but other government regulations create additional transactions costs to reaching the highest levels of the hierarchy – primarily in the form of food safety regulations and alcohol taxation. Dealing with these add complexity and cost which deter or delay firms to change.
- Primarily through irrigation onto pasture, firms that recycle or recover whey see little benefit to exploring alternative options, with one participant saying they would only change if they were forced to.
- Significant penalties exist in some jurisdictions for whey disposal, but some firms have no choice but to move 'sideways' due to a lack of information and the inability to access some technologies (e.g., cultures/yeasts for fermenting lactose into alcohol). One participant was paying $160,000 p.a. in non-compliance fees, but resorted to installing on-site treatment processing, which means it is still 'disposed' due to the inability to access technologies or partners in their current setup.

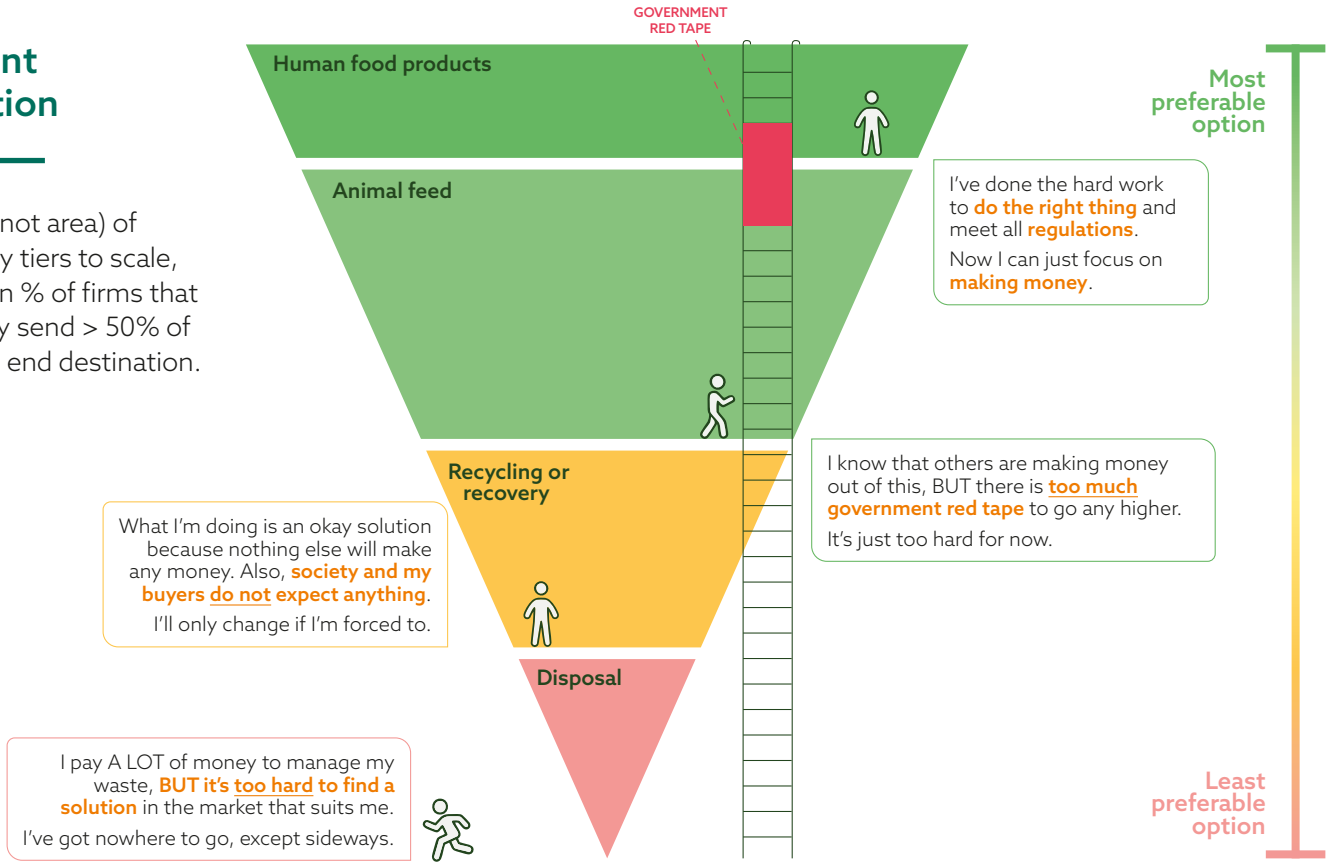
Findings suggest a failure of markets, governments, and social license to drive desirable outcomes. In order to move enough firms up the hierarchy by 2030, pathways to change will likely require simultaneously improving market conditions (information availability and access to technologies), driving demand for whey management practices and whey-based products, addressing government disincentives (navigating additional regulatory compliance).

For more detailed information see the working paper:

Hetherington, J., Loch, A., Juliano, P., Umberger, W. (2024). 'Exploring incentives to move up the Food Waste Hierarchy: a case study of the Australian cheese manufacturing sector', (Preprint). https://doi.org/10.21203/rs.3.rs-4215468/v

Current situation

Height (not area) of hierarchy tiers to scale, based on % of firms that currently send > 50% of whey to end destination.



Situation likely needed to halve food loss and waste by 2030

Height of tiers in this scenario are illustrative only but acknowledges the need to shift most firms up the hierarchy, ideally to human food products but at least to animal feed.

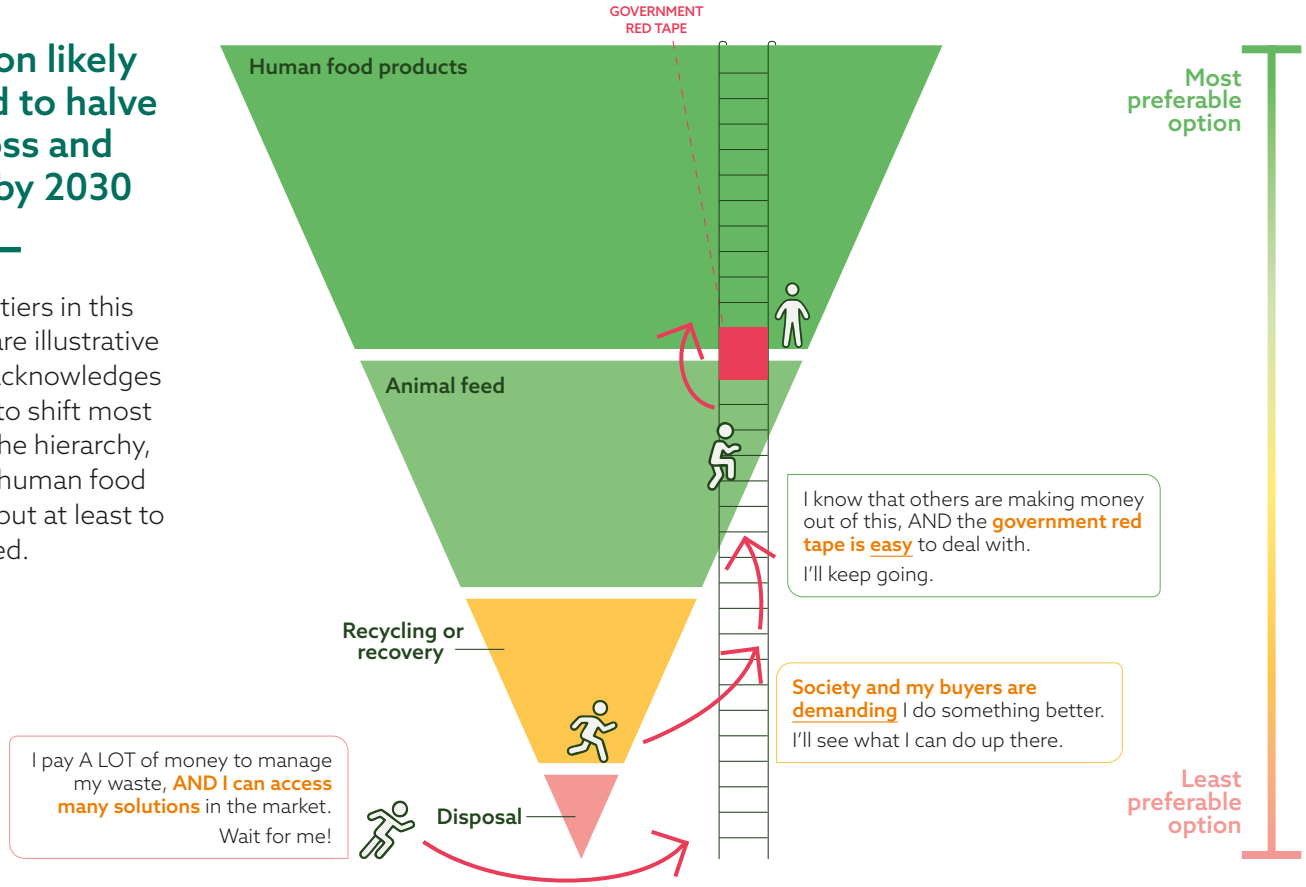


Figure 7. Incentives to move up the Food Waste Hierarchy.

6.3 | Barriers

Contributing to the Circular Economy can be achieved through different pathways, including where a waste-generating business changes to processing in-house (IH), engaging a third-party (TP) or starting a joint venture (JV). And as shown in Table 2, many businesses are already engaged in these arrangements currently, including to repurpose whey. Also, businesses that are already repurposing waste products, in theory, have the capacity to accept the waste of others to increase the throughput of the processes. These so-called 'focal companies' (FC) could act as sectoral leaders by accepting the whey from nearby cheesemakers to reduce overall waste, while also making additional profit margins from the additional throughput.

Internationally, FCs have historically led innovation and market penetration in the upcycled food sector due to their ability to focus their resources on building efficient supply chains to utilise upcycled ingredients (i.e., Upcycled Foods Inc and Renewalmill in the USA). These companies have seen major success from partnering with retailers on private-label product or as ingredient suppliers to other food manufacturers, removing the supply chain barriers for those companies and issues of economies of scale for waste producers. Processing in-house has also elicited some success in Europe and the USA, however, this is most effective where large food and beverage businesses create a spin-off company or brand (i.e., Foodfellows and Evergrain) [17].

As part of this research, cheese manufacturers were asked what was preventing these options. The figure below presents the ten most prevalent barriers to each of these approaches.

Main findings

As shown in Figure 8, illustrating the prevalent barriers to repurposing whey (the darker the box, the more prevalent), there were diverse issues, including internal financial (e.g., economies of scale), organisational (e.g., complexity or time requirements) and technological-related issues (e.g., incompatible with other equipment or not enough information detailed information). External issues were dominated by supply chain issues (e.g., lack of willing partners), with some market and institutional issues.

Some barriers were consistent across all CBMs, such as economies of scale and operational costs. Others are absent in one or two CBMs (e.g., capital costs in JV and competing priorities in TP), while some are unique (e.g., low or inconsistent demand in IH, payment expectations in TP, conflicting values or personalities in JV, and upstream product specifications in FC).

Findings indicate that:

- While IH models are technically and commercially feasible for all production scales (albeit by a small number of firms), it requires sufficient time and resources (e.g., capital) to make it happen.
- TP models can remove the time and resource requirements, provided there is agreement on compensation with the recipient—what is the value of a waste product?
- JVs could work for firms wanting to retain some of this value but lacking the volumes or capital. However, this requires clear leadership and transparent business plans.

– Utilising existing infrastructure of firms already repurposing by-products can be effective to addressing all of these other barriers but requires upstream firms meeting product specifications of the FC (e.g., nutrient composition, certification standards, hygiene requirements).

This highlights the necessity for diverse strategies to achieve SDG 12.3, as a one-size-fits-all approach is insufficient. Firms may need to partner with others for repurposing, and those already repurposing can enhance efforts by enabling others to repurpose waste, though multiple pathways also increase potential barriers.

For more detailed information see the full paper (open access):

Hetherington, J.B., Loch, A.J., Juliano, P., Umberger, W.J. (2024). 'Barriers to circular economy adoption are diverse and some are business-model specific: Evidence from the Australian cheese manufacturing sector', *Journal of Cleaner Production* 477, 143879. https://doi.org/10.1016/j.jclepro.2024.143879

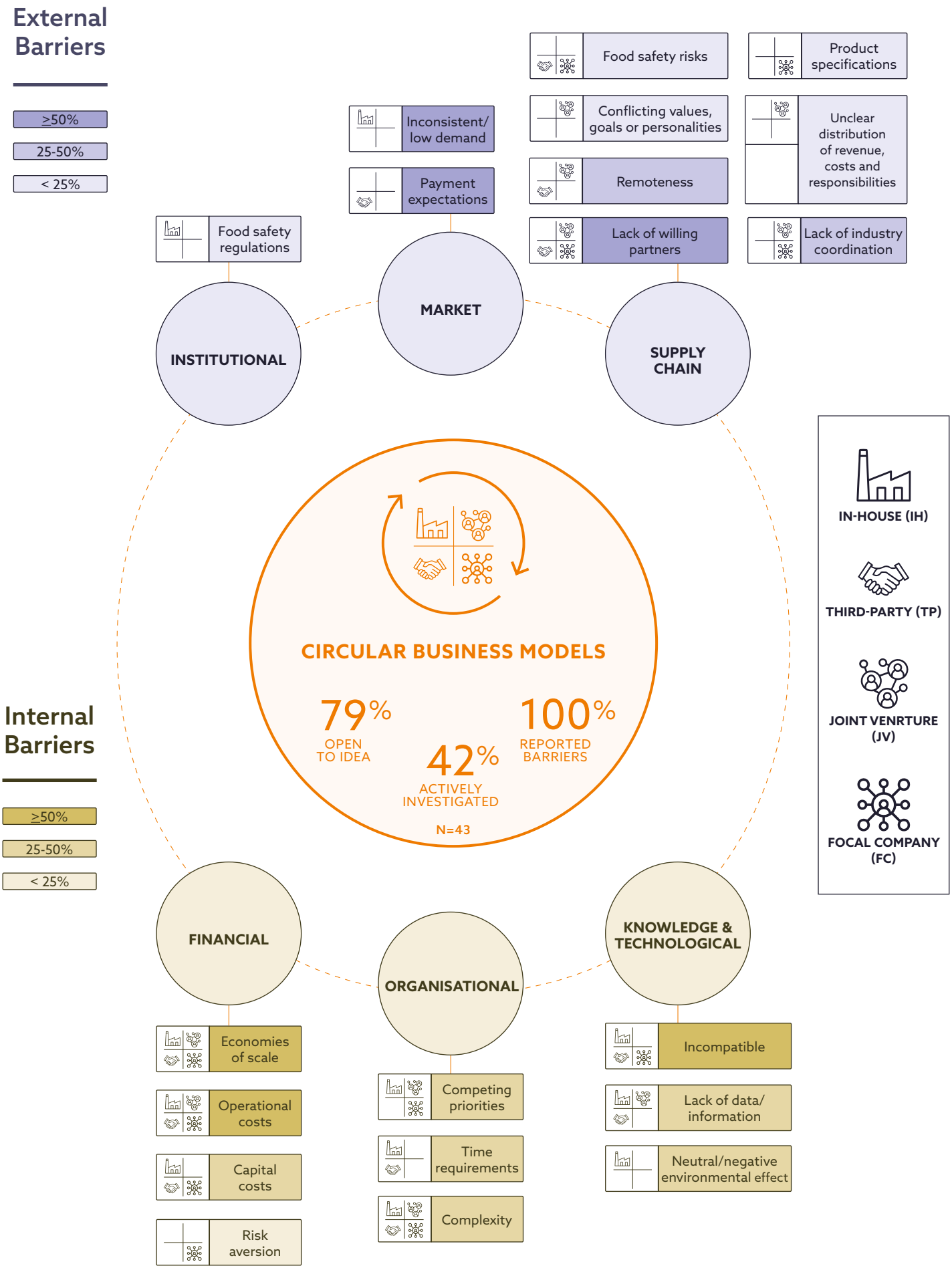


Figure 8. Prevalent barriers to interchangeable Circular Business Models. The icons identify which Circular Business Model faced the barrier.

6.4 | Enablers

The decision to adopt any innovation is based on a combination of factors relating to the decision maker (e.g., socio-economic factors, risk attitude, etc.), the innovation itself (e.g., profitability, environmental benefits, etc.) and the social context these fit within (e.g., the presence of learning networks). The culmination of these factors ultimately enables if, how much, and for how long, an innovation is adopted in population/sector.

Using CSIRO's Adoption and Diffusion Outcome Prediction Tool (ADOPT) [18] as a foundation to understand important conditions for adoption, the consistent combination of enablers of CBM adoption were evaluated, as were the combinations of conditions consistent with non-adoption.

Main findings

There are only two enabling 'recipes' consistent with CBM adoption, comprised of four core conditions:

- **Favourable production characteristics**—being a large producer or specialising in cheese products.
- **High engagement in learning networks**—active in industry groups or information seeking (e.g., engaging advisors).
- **Perceived profit benefits**—repurposing whey was a profitable option.
- **Comprehensive knowledge of CBM options**—A depth (technical detailed knowledge) and breadth (awareness of many options) of knowledge about whey repurposing options.

A fifth condition was present in both with either: the absence of favourable timing conditions (i.e., a long implementation timeframe or frequent financial shocks) or a perceived risk benefit (e.g., diversified income).

There were six consistent 'recipes' to non-adoption, comprised of a mixed configuration of mostly absent conditions. Notably, the absence of a perceived profit benefit was consistent across most non-adopter 'recipes' (see pathways 1-5 to non-adopters in Figure 9). Driving this is a mix between: there current practice having little to no operating costs (e.g., a pig farmer picks up the whey); or, based on their assessment, all repurposing options being not commercially viable.

However, perceiving a profit advantage was is not enough to lead to adoption, shown by a segment of firms that felt it could be profitable but there were other conditions absent affecting their adoption decision (see pathway 6 for non-adopters). For instance, relative to their current whey management practice, these firms felt there was a neutral or negative impact on risk from whey repurposing. This included over product diversification or increased regulatory scrutiny compared. They are also perceived no or neutral environmental benefits and did not have a high level of knowledge of repurposing options.

This means, being able to identify alternative management practices that are more profitable is needed in conjunction with other enablers to achieve adoption, such as perceived risk benefits and improved knowledge levels. This will need to consider a number of factors, including market dynamics, capital costs, other competing priorities and in-house capability.

The findings emphasise the importance of supporting this sector with information and tools to better assess their options from a profit, risk and environment perspective.

More detailed information available in the working paper:
Hetherington, J.B., Loch, A.J., Juliano, P. (2024). 'If there's a will, there's a 'whey' to achieve SDG12.3: realistic shifts to the perceived benefits to enable Circular Business Model adoption' (Available upon request).

Conditions consistent with Circular Business Model adoption (and non-adoption)

Repurposing/upcycling of the by-product cheese 'whey' in Australia

ESTIMATED ADOPTION OUTCOMES[1]

Business-as-usual scenario	Plausible scenario*
1%	50%
OF FIRMS AFTER 7 YEARS	OF FIRMS WITHIN 4-6 YEARS

* Assumes sector-wide improvements in perceived benefits (profit, environmental and risks) and observability of Circular Business Model options

[1] Based on modelling using the Adoption and Diffusion Outcome Prediction Tool (ADOPT)

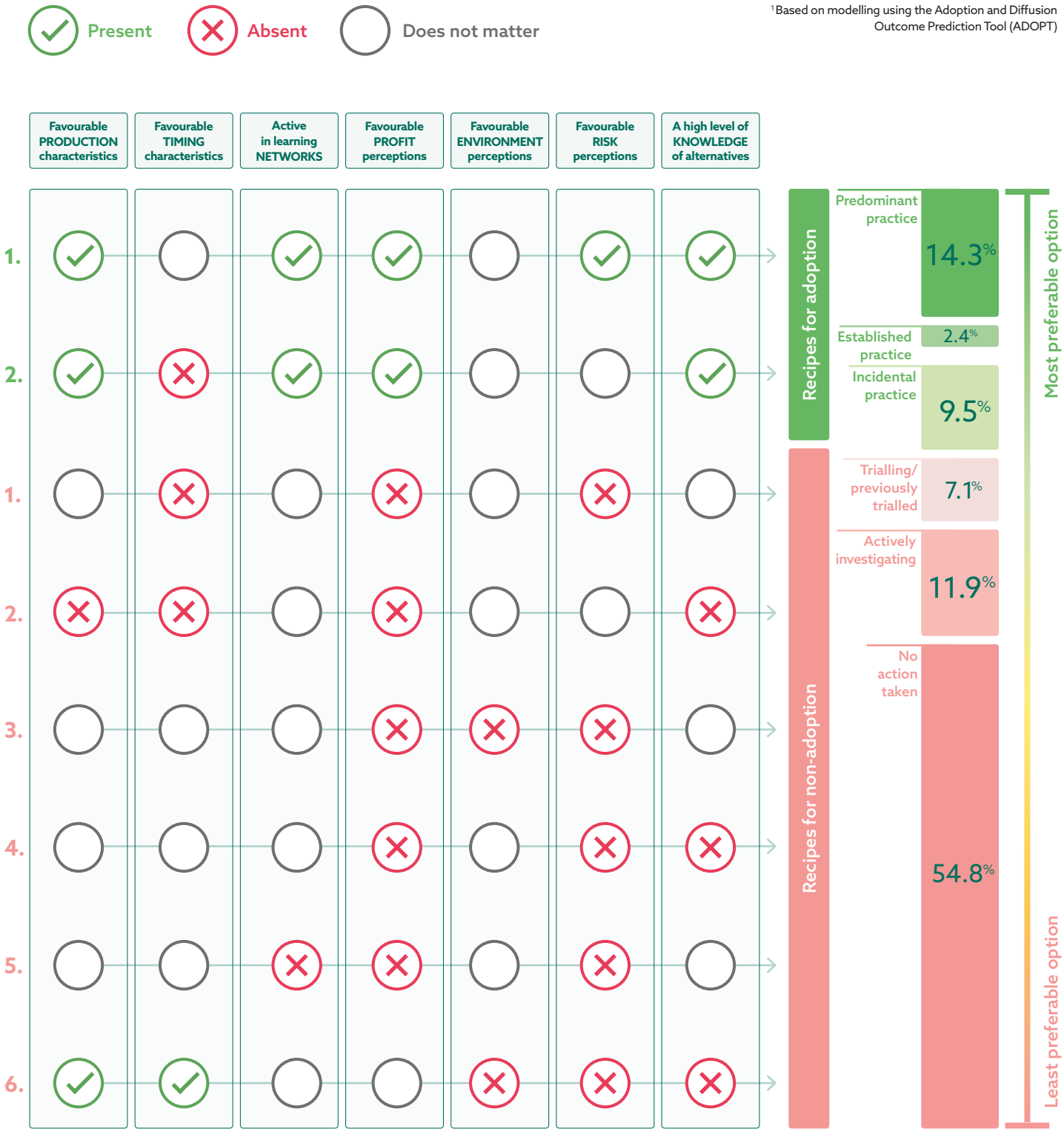


Figure 9. Conditions consistently present/absent with Circular Business Model adoption and non-adoption.

6.5 | Adoption potential

Total mass

If all the firms in the study sample (accounting for 31% of the sector) redirected the whey currently destined for end uses that contribute to 'food waste' (e.g., recycling, recovery, or disposal) to human food products (totalling 72,280 tonnes p.a.), this would account for 41% of the Australian dairy sector's SDG 12.3 target. Additionally, while not directly contributing to this goal, another 19,007 tonnes p.a. could be repurposed into higher-value products.

Willingness to change to a circular business model

The willingness to explore Circular Economy approaches increase markedly when all four CBM options are considered (79%), compared to IH approaches alone (33%).

Proximity to partners

Distance was often cited as a major issue, yet we showed that over half of cheesemakers had potential partner—like other cheesemakers, distillers or brewers—within 1.1 km. This suggests a gap between 'perceived' and 'actual' barriers to adopting these business models.

Rate of adoption

Using information about the current industry trends and of CBM adopters (which provides a reference point of what is achievable), including the general attitudes towards whey repurposing options, adoption rates are estimated using ADOPT[7] under 'business-as-usual' and 'plausible' scenarios. Projections suggest that without change, CBM adoption will remain minimal (1%), but with realistic shifts in the attitudes towards whey repurposing (i.e., improved profit, risk, and environmental outcomes) and the improved ability to see working examples[8], it is plausible adoption could raise to 50% within 4-6 years (86-96% in 10-13 years), which is in line with the 2030 timeframe. While there are always risks with forward projections, the emphasis is on the high rate of change that can be achieved.

It is feasible to achieve rapid adoption of CBMs, especially if proactive efforts to include collaborative business models are included. These should pre-empt prevalent barriers to these different approaches and improve the incentives to move-up the Food Waste Hierarchy. This would further motivate firms to look for and identify options that improve profit, risk, and environmental outcomes.

[7] Available here: https://adopt.csiro.au/Login.aspx

[8] These 'plausible' shifts include shifting attitudes to whey repurposing: from '*a large profit disadvantage*' to '*moderate profit advantage*'; from '*a small environmental disadvantage*' to '*large environmental advantage*'; from '*no risk benefit*' to '*moderate risk reduction*'; and from '*difficult to observe*' to '*moderately observable*'.

Willingness to consider changing to a Circular Business Model

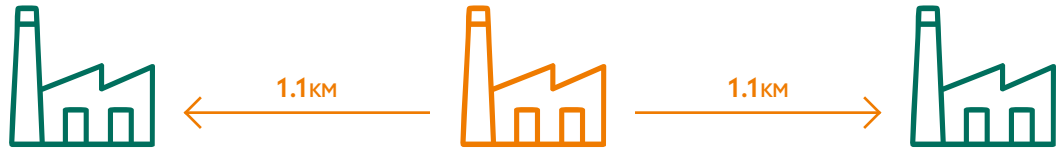
IN-HOUSE CBMs are possible for all scales of production BUT the firm needs **dedicate sufficient time** and resources.

THIRD-PARTY CBMs can solve this, BUT some firms **will want to be paid** because there is now greater 'value' in the by-product.

JOINT VENTURES CBMs allow firms to retain some of this value BUT needs someone willing to the **leadership role and finding equitable business plans**.

FOCAL COMPANIES CBMs utilise existing infrastructure BUT this requires all upstream firms **meeting product specifications**.

Median distance to nearest potential partner



Potential adoption rate

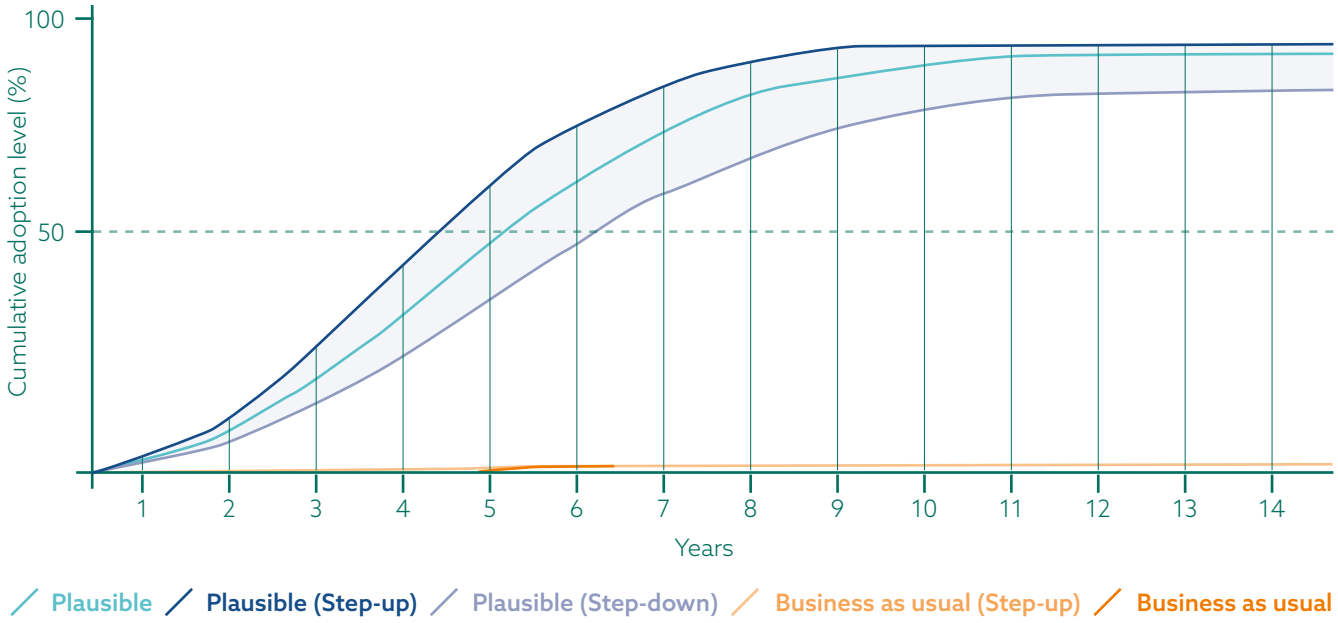


Figure 10. Adoption potential by exploring circular business models within the Australian dairy sector.

7 Implications and recommendations

This research suggests that the concurrent lack of clear incentives, persistent and unique barriers and absence of enablers is underlying the generally low adoption of Upcycling in the Australian cheese manufacturing sector. However, there is potential for widespread change in a relatively short amount of time, especially if collaborative efforts, such as FC, TP arrangements and JVs are supported.

In this sector, there have been efforts to facilitate JV (e.g., in South Australia [19]), with limited success to achieving the desired behaviour change. The Dairy Sector Action Plan, which was published after this study's interviews were conducted, provides a contemporary framework and roadmap to halving FLW in the Australian dairy sector, with a focus on establishing industry working groups and assessing the feasibility of diverting waste to third-party processors. The research findings support these proposed actions. The findings here identify areas to prioritise as part of this strategy, especially reducing the gap between 'perceived' and 'actual' barriers.

We suggest that companies that are already repurposing whey (i.e., potential 'focal companies') should be brought to the table, to leverage their existing processing capacity and help the industry as-a-whole reach its goal. This should include the major manufacturers like Bega Cheese, Fonterra, Saputo, who already have complex inter-firm arrangements (noted the section About the sector). Companies like Asahi that produce whey-based vodka ('Vodka O') should be invited to participate too given the established product lines and markets. Mapping CM facilities and potential partners (other CMs, distillers and brewers) also would facilitate discussions about collaboration opportunities. Low-cost set-ups could expedite the transition toward circularity in the dairy sector.

Low-cost solutions

One small-scale cheese maker was in a partnership with a local distiller, who would drop off a collection tanker for they whey with the starter culture already inside. Once the whey was pumped into the collection tank, the fermentation process would begin, and the distiller would collect the tanker several days later. This approach negated the need for the cheese maker to invest in specific collection and cooling infrastructure, which was prohibitive to most participants. In this case, the distiller bore the cost of transportation.

A general observation about the previous efforts to address whey waste, is the focus on improving supply-side conditions of markets that whey repurposing. That is, improving technologies to make value chains more efficient, improved information sharing, or reducing risks. What this research has highlighted is the need to focus on improving demand-side conditions, which aims to improve

incentives for upstream firms to change (in this case cheese manufacturers), including through contracting and vertical coordination. This has been used to consider other agricultural and resource market issues (e.g., water markets and agricultural development) [20, 21]. The demand-side of whey repurposing could be affected through two intertwined value chains—i.e., cheese products and whey-based products. Consumers and customers of these products could drive change through their choices. We recommend future efforts pay attention to both supply-side[9] and demand-side[10] initiatives.

Internationally, the Upcycled Food Association has developed a certification scheme for products that are rescued from lower stages of the Food Waste Hierarchy and repurposed into new food, cosmetic/personal care for pet food products [1]. This scheme could act as an incentive to move products up the hierarchy if businesses are able to leverage Environmental Social and Governance (ESG) benefits from supporting waste reduction across their supply chains. Education is required across the food industry to demonstrate the ESG and emissions reduction (Scope 3) benefits to food manufacturers who could purchase Upcycled whey as an input ingredient into their products.

Specific recommendations arising from this research are provided in Table 3 in terms of potential initiatives, grouped by supply-side and demand-side initiatives. It should be acknowledged that many of the recommendations align directly with the goals of various government programs. In particular, the National Reconstruction Fund can provide finance in the form debt, equity and guarantees and has a priority around value-addition from agricultural industries. Likewise, there a various state-based initiatives, such as South Australia's Circular Economy Lead-Educate-Assist-Promote (LEAP) grants. This generally aligns with the priority to enabling design for environmental good, by greater incentives to design out waste through Upcycled food products would reduce the need virgin agricultural products.

Everyone has a role to support the transition, including policy makers, industry groups, individual companies and the general public to improve the supply-side and demand-side of whey repurposing.

[9] Supply-side initiatives: these are typically led by public agents, help producers overcome constraints to adoption, such as access to markets, information, liquidity, and risk.

[10] Demand-side initiatives: these are interventions typically led by private agents, such as entrepreneurs, businesses, and producer organisations. They can create incentives for upstream firms to change through contracting and vertical coordination in value chains.

Table 3. Recommendations arising from this research for improving supply-side and demand-side of whey repurposing.

		Relevant Circular Business Models				Relevant Stakeholders			
		In-house	Third party	Joint venture	Focal company	Policy makers	Industry groups	Individual businesses	General public
	Supply-side initiatives								
1.	Better access to information about the benefits and risks of whey repurposing and circular business models, including mapping potential partners and case studies of successful examples.	●	●	●	●	●	●		
2.	Better guidelines to overcome regulatory hurdles (e.g., food safety compliance, alcohol taxation[11]).	●	●	●		●	●		
3.	Supply-side subsidies and/or incentives to improve the commercial viability of whey-based products, such as de-risking and/or (co-)investment in cold chain, storage, or processing infrastructure.	●	●	●	●	● e.g. NRF			
4.	Improve transparency and access to inputs for Upcycling (e.g., cultures used for fermentation to create high value products such as whey-based alcohol).	●	●	●		●	●	● e.g. Input suppliers	
5.	Develop and promote integrated decision support tools to enable businesses to identify most suitable management practices and business models (incorporating financial, risk, environmental indicators).[12]	●	●	●	●	●	●	● e.g. Analytics companies	
6.	Research & development (including funding or incentives) into small-scale place-based processing technologies to make more accessible smaller operations (e.g., whey pasteurisation and concentration whey to improve transporting logistics).	●	●	●	●	● e.g. NRF	●	● e.g. Tetrapak	
7.	Establishing focal company projects to leverage the existing processing infrastructure (e.g., with large cheese manufacturers such as Bega Group, Saputo Dairy Australia and Fonterra Co-op).				●	● e.g. NRF	●	● e.g. large CM	
8.	Establishing joint venture projects to get the economies of scale for new processing infrastructure.			●		● e.g. NRF	●	● e.g. small to mid-scale CM	
	Demand-side initiatives								
9.	Supporting new market entrants (e.g., start-ups) whose business model is focused on Upcycling whey.		●			● e.g. NRF			
10.	Explore the value proposition of 'Upcycled' labelling to inform as part of a broader consumer campaign about purchasing behaviour consequences.	●	●	●	●	●	●	● e.g. CM	
11.	Promoting the benefits of whey-based products (e.g., environmental benefits) and community benefits from regional development opportunities.[13]	●	●	●	●	●	●	●	
12.	Individuals and businesses (e.g., retailers) change shopping behaviour/procurement policies to purchase whey-based product equivalents.	●	●	●	●			●	●
13.	Individuals and businesses (e.g., retailers) establish new expectations/procurement policies about cheese products and FLW management to incentivise desirable whey management practices.[14]	●	●	●				● e.g. Retailers	●

NRF = National Reconstruction Fund; CM = cheese manufacturer; FLW = food loss and waste

[11] A reported barrier to alcohol production was the tax implications. However, the Australian Tax Office advises '*eligible alcohol manufacturers can receive a full (100%) automatic remission of excise duty on alcoholic beverages they manufacture, up to a maximum of $350,000 per financial year*' (accessed 17 October 2024).

[12] Tools like DIRECT, economic models and Life Cycle Analysis softwares are examples of tools that can be integrated to inform businesses of their current costs and options for change.

[13] A public awareness campaign targeting purchasing of Upcycled food products could align with the Nation-wide Consumer Behaviour Change Campaign led by EFWA.

[14] There have been recent changes to important accreditation schemes for accessing international markets (e.g., EU) regarding the requirements to disclose FLW levels [22]. This makes cheese manufacturers disclose how much waste is generated.

8 Conclusions

Dealing with FLW is a complex, ever-evolving issue, with no single solution. This research sheds light on the under-recognised but persistent challenge of whey waste, which is the result of failures in markets, government policies, and social licenses to generate optimal outcomes.

While CBMs offer some promising solutions, they are not without their unique challenges. Joint ventures, for instance, can alleviate capital cost barriers, but there needs to be clear leadership and business plans. Despite these challenges, realistic shifts in the shifts of businesses regarding the profitability, environmental benefits, and risk reductions of whey repurposing can catalyse rapid CBM adoption. This will be achieved through better evidence-based information, demonstrating the actual net benefits of these options. Observing and promoting successful case studies could further encourage this transition.

Achieving SDG 12.3 in the dairy sector is a realistic goal by improving both the supply and demand sides of whey repurposing markets. By leveraging low-cost solutions, utilising existing infrastructure, and securing policy and industry support, adoption rates of circular models can increase significantly. Projections indicate that with these changes, widespread CBM adoption is feasible within the 2030 timeframe.

What can we learn from the dairy sector?

The dairy sector's whey waste problem mirrors broader issues of FLW in Australia. Finding options to improve the circularity of our food system could unlock economic benefits for the industry and enable us to produce more with less. This will require both different forms of collaboration and providing enough incentive for these businesses to push through some of the barriers and invest in these changes.

9 References

1. Upcycled Food Association (2020). *Upcycled Certification Standard (Version 1)*. Upcycled Food Association, Denver, USA. https://www.upcycledfood.org/the-standard
2. FIAL (2021). *The National Food Waste Strategy Feasibility Study–Final Report*. Food Innovation Australia Ltd (FIAL), Werribee, Australia. https://www.fial.com.au/sharing-knowledge/food-waste
3. Dairy Australia (2023). *Dairy sector food waste action plan*. Dairy Australia, Melbourne, Australia. https://www.dairyaustralia.com.au/manufacturing-support/manufacturing-sustainability/dairy-sector-food-waste-action-plan#:~:text=The%20Dairy%20Food%20Waste%20Action,across%20the%20dairy%20supply%20chain.
4. Technavio (2023). *Global Whey Protein Market 2023-2027*. Infiniti Research Limited.
5. Chang, R., T.B. Ng, and W.-Z. Sun (2020). *Lactoferrin as potential preventative and adjunct treatment for COVID-19*. International Journal of Antimicrobial Agents, 2020. **56**(3): p. 106118. https://www.doi.org/10.1016/j.ijantimicag.2020.106118
6. Risner, D., et al. (2018). *Fermentation and distillation of cheese whey: Carbon dioxide-equivalent emissions and water use in the production of whey spirits and white whiskey*. Journal of Dairy Science, 2018. **101**(4): p. 2963-2973. https://www.doi.org/10.3168/jds.2017-13774
7. Smithers, G.W. (2008). *Whey and whey proteins—From 'gutter-to-gold'*. International Dairy Journal, 2008. **18**(7): p. 695-704. https://www.doi.org/10.1016/j.idairyj.2008.03.008
8. Carvalho, F., A.R. Prazeres, and J. Rivas (2013). *Cheese whey wastewater: Characterization and treatment*. Science of The Total Environment, 2013. **445-446**: p. 385-396. https://www.doi.org/https://doi.org/10.1016/j.scitotenv.2012.12.038
9. Tsermoula, P., et al. (2021). *Whey – The waste-stream that became more valuable than the food product*. Trends in Food Science & Technology, 2021. **118**: p. 230-241. https://www.doi.org/10.1016/j.tifs.2021.08.025
10. EPA (2019). *Waste Reduction Model (WARM) Tool*. Environmental Protection Agency (EPA), Washington DC, USA. https://www.epa.gov/warm/versions-waste-reduction-model-warm#15
11. Dairy Australia (2023). *In Focus 2023*. Dairy Australia, Melbourne, Victoria.
12. Fahey, J. (2023). *Butter and Dairy Product Manufacturing in Australia*. IBISWorld. https://my.ibisworld.com/au/en/industry/C1133c/about
13. Tetra Pak (2015). *Chapter 15 – Whey Processing, in Dairy Processing Handbook*, G. Bylund, Editor, Tetra Pak: Pully, Switzerland.
14. SFWA (2021). *Stop Food Waste Australia: Strategic Plan*. Stop Food Waste Australia, Adelaide, Australia.
15. Zhao, G., et al. (2023). *Transforming acid whey into a resource by selective removal of lactic acid and galactose using optimized food-grade microorganisms*. Bioresource Technology, 2023. **387**: p. 129594. https://www.doi.org/10.1016/j.biortech.2023.129594
16. Rocha-Mendoza, D., et al. (2021). *Invited review: Acid whey trends and health benefits*. Journal of Dairy Science, 2021. **104**(2): p. 1262-1275. https://www.doi.org/10.3168/jds.2020-19038
17. Goodman-Smith, F. (2024). *Upcycled food* Winston Churchill Trust, Canberra, Australia. https://endfoodwaste.com.au/wp-content/uploads/2024/04/UpcycledFood_ChurchillReport2024_FINAL.pdf
18. Kuehne, G., et al. (2017). *Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy*. Agricultural Systems, 2017. **156**: p. 115-125. https://www.doi.org/10.1016/j.agsy.2017.06.007
19. Hauser, J. (2017). *Analysis of South Australia whey processing options*. Xcheque, Australia. https://www.greenindustries.sa.gov.au/__media_downloads/176945/SA%20Whey%20Processing%20Options%20-%20ExecSumm.pdf
20. de Janvry, A. and E. Sadoulet (2020). *Using agriculture for development: Supply – and demand-side approaches*. World Development, 2020. **133**: p. 105003. https://www.doi.org/10.1016/j.worlddev.2020.105003
21. Loch, A., D. Adamson, and N.P. Dumbrell (2020). *The Fifth Stage in Water Management: Policy Lessons for Water Governance*. Water Resources Research, 2020. **56**(5): p. e2019WR026714. https://www.doi.org/10.1029/2019WR026714
22. FSSC (2023). *FSSC 22000 Guidance Document: Food Loss and Waste*. FSSC, The Netherlands. https://www.fssc.com/wp-content/uploads/2023/03/Guidance-Document-Food-Loss-and-Waste-V6-1.pdf

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