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Evaluating barriers, enablers and opportunities for closing the loop through 'waste upcycling': A systematic literature review

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ABSTRACT

The United Nations Sustainable Development Goals aim to 'do more and better with less', with numerous calls to action arising from the business sector concerning the substantial reduction of targeted types of commercial and industrial waste. Emanating from the original work on closing material loops by McDonough and Braungardt in the 1990s, over the last two decades the concept of 'upcycling' has increased in popularity as a targeted intervention to reduce material and energy use in business processes. Essentially upcycling involves reusing, repairing, repurposing and upgrading waste material to avoid the conventional endpoint of 'disposal'. However, upcycling is still considered a niche practice and many business enterprises remain unclear as to how to use upcycling opportunities for better management of their waste. In this paper, the authors propose a Tiered Approach to Waste Upcycling for Business, as a strategic way for businesses to close the loop within their industrial processes and production chains. The paper comprises a systematic literature review of opportunities and barriers for enabling business enterprises to close the loop through waste upcycling. The review highlights the *ad hoc*, champion-based and highly variable use of upcycling practices and uncovers opportunities for more systematic and streamlined practices to produce value-added products from waste material. Synthesising the findings, the authors establish three tiers of 'macro', 'meso' and 'micro' barriers and enablers that businesses can consider identifying upcycling opportunities for managing their waste. The authors also discuss key benefits of upcycling including improved quality and life of material, creating jobs and influencing positive consumer behaviour. The authors conclude the benefits of a structured approach to considering circular economy opportunities, towards improved waste management that is better for the bottom line, people and planet. With regard to future research in the field, the authors define a set of key theoretical constructs relating to waste upcycling, that can facilitate innovation and investigations into applying ideas.

KEYWORDS

Upcycling, waste management, circular economy, tiered approach, enablers, barriers

INTRODUCTION

Current industrial and economic systems operate on a predominantly take-make-use-dispose model, wherein resources are extracted to make products that are become waste and are lost to landfills or incineration [1-3]. This unsustainable linear economic system puts pressure on natural resources, pollutes the environment, and creates significant economic and social impacts at local, regional, and global scales [4]. To address this, current approaches to increasing resource efficiency and sustainable manufacturing of products focus on circular economy principles [5, 6]. The term 'circular economy' refers to material flows in a closed loop system [7], characterised as a "design and business model [with] strategies that are slowing, closing, and narrowing resource loops" [8].

With clear negative impacts of waste accumulation, there are increasing calls for circular economy practices. It is well understood that circular economy approaches to business enterprises (referred to as 'businesses' herein) and project management can improve material flows as well as positively contribute to job creation, livelihood improvement, and waste management. Globally there are a number of stand-out examples of initiatives to promote such circular economy approaches. These include for example: GOLDEN [9], Climate-KIC (Europe) [10], US Circular Economy Program (USA) [11], Low Carbon Green Growth Roadmap for Asia and the Pacific (Asia-Pacific) [12], and the Blue Economy Co-operative Research Centre (Australia) [13].

Upcycling is recognised as one of the most sustainable waste management options in the circular economy [14]. 'Upcycling' has emerged as a targeted intervention to reduce material and energy use in business processes through reusing, repairing, repurposing and upgrading waste material in a creative way [15-17]. It has been increasingly recognized as a promising means of transitioning towards a circular economy. However, upcycling is still considered as a niche practice and it remains unclear for many businesses as to how exactly to use upcycling for better management of waste and promotion of sustainable production and consumption [14]. This paper, therefore, aims to provide insights for business enterprises to identify the challenges and uncover opportunities for better, streamlined practices to produce value-added products from waste.

There is still relatively limited research on enablers and barriers to upcycling in business enterprises, despite a large body of research on upcycling and related technologies in various disciplines ranging from design, textile and clothing, architecture, engineering and business management in leading journals such as the *Journal of Cleaner Production* (Impact Factor 6.39) and *The Journal of Resources, Conservation and Recycling* (Impact Factor 7.04) [15, 18-20]. Within this context, the authors have drawn on 85 papers spanning the last two decades, to address this research gap and establish a novel action framework for business to efficiently engage in upcycling practices. Specifically, the study was guided by the following two research questions:

1. How can waste upcycling practices enable businesses to close the loop?
2. What barriers and opportunities influence business engagement in such practices?

In the following section a detailed methodology is provided regarding the literature review and thematic analysis undertaken. The paper then considers definitions and characteristics of waste upcycling (*What?*), the ecosystem of business upcycling operators (*Who?*), key benefits in waste upcycling (*Why?*) and industrial processes, enablers and barriers for upcycling in business (*How?*). Research findings from this literature review provide a timely contribution to understanding what enables business to use waste materials in production processes. The authors present a tiered approach to

waste upcycling that can guide actions to close the loop within business processes and production chains.

THEORETICAL BACKGROUND

Progress toward circular economy and sustainable development has become increasingly important around the world in recent years [21], which is due in part to changing consumer attitudes and behaviours [15]. There is also a growing consciousness of sustainable production and consumption practices [20]. In this context, upcycling has been considered a sustainable approach in a number of fields including environmental management, engineering, technology, design and business [17].

Upcycling is often referred to as 'cradle-to-cradle', as it seeks to close the loop [22]. The term was coined from the seminal publication on ecologically intelligent design, Cradle to Cradle: Remaking the way we make things [23]. It is a process in which materials that become obsolete after their intended use, are converted into products of higher quality and/or value in a second life [24]. By extending the useful lifetime of products and materials, upcycling directly contributes to circular economy and promotes sustainable production and consumption [1, 2, 25]. These outcomes will enable businesses to contribute to the United Nations Sustainable Development Goal 12 on responsible consumption and production [26]. Reducing the amount of new material inputs reduces extraction of raw materials, improves resource efficiency and therefore ultimately reduces carbon emissions related to materials and energy consumption [27]. As such, upcycling has the potential to drive the transition from a linear economy towards a circular economy with benefits for local people, the environment and a resilient local economy in times of global financial instability.

In this transition to a circular economy, a fundamental requirement is the involvement of all stakeholders and their capacity to co-share knowledge and skills. Upcycling brings together and connects a diverse group of stakeholders including craft professionals, hobbyists, artists, makers, entrepreneurs, industries and consumers [14, 28]. Researchers [29, 30] report that individuals and industries engage in upcycling to create positive change or benefit for the environment, due to emotional attachment, economic and/or social benefit. It was noted that identifying these important stakeholder relationships will help upcycling entrepreneurs in recognizing prospective collaborations and benefits for both the entrepreneurs and consumers [31].

Upcycling has been practiced among many micro and small-scale businesses and is largely considered as a niche practice [32]. However, with the increasing concern for environment (resource scarcity) and economic benefits of using low-cost waste materials many businesses are starting to see 'upcycling' as a business opportunity [16]. Entrepreneurs could use low-cost waste material to create value-added products and sell them at high prices considering their aesthetic and environmental value. Previous authors suggest three long term interventions to help scale up upcycling; incentives for upcycling businesses, incentives for upcycling initiatives, research and curriculum enrichment [17]. They further propose market-based incentives such as tax reductions for upcycled products and special grants or customized loans for upcycling businesses [17].

The consumer pressures for sustainability are rising, therefore products must become more sustainable to help them stay competitive in the market [27, 29, 33]. Technology also plays a significant role in this. With new technology developments, converting waste materials into value-added products has become more efficient and accessible to many.

People are digitally engaged and are increasingly aware of sustainability issues. According to a previous study, 72 per cent of millennials are willing to pay extra for sustainable products [34]. They are becoming sustainability-conscious and are willing to demonstrate this publicly through their purchasing habits [35]. Today, consumer perception is shifting toward "*good for people and good for planet*". As consumers' demand for environmentally sound products increases, upcycling could be the new industrial revolution [36].

Upcycling holds a key role in the transition from a linear to circular economy. This transition aims to slow, close and narrow resource loops by designing out waste, and keeping resources in use for as long as possible by cycling them back into production processes. A fully circular economy would be characterised by zero waste going into landfill and minimal use of virgin materials [8]. For this to be sustainable, products and resources at their end of life must be recycled to a quality equal or greater than the original product. By adding value to products at their end of life, upcycling closes resource loops in a way that ensures the same resources can continue along with these loops indefinitely [15-17]. Downcycling on the other hand, does not close resource loops as effectively and would result in more virgin materials required for high-quality products. Closing resource loops through upcycling requires businesses and consumers to consider waste as resources, to promote creative innovation and to support upcycling initiatives. Businesses participating in waste upcycling practices are an important part of the transition to a more circular economy through helping to close resource loops [37, 38].

METHOD

This paper canvasses key literature in the upcycling domain focusing on waste management. A five-phased structured literature review [39] was deemed appropriate due to its transparency and reproducibility (Figure 1), as described in the following paragraphs.

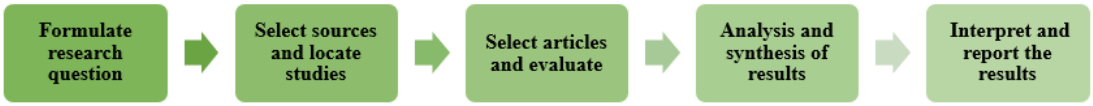

Figure 1: Five phases of the systematic literature review process [39]

An initial search was conducted using Google Scholar to define the scope and research question. The main searches were conducted in four databases including Science-Direct, ProQuest Central, Web of Science and Google Scholar. The initial scoping was focused on 'waste upcycling' (i.e.: reusing, repairing, repurposing and upgrading waste material) in small and medium-sized enterprises. Due to the limited literature found, the criteria were expanded to upcycling applications of small (less than 20 employees), medium (20-200 employees) and large scale (more than 200 employees). A summary of the literature screening is summarised in Figure 2 and described in the following paragraphs.

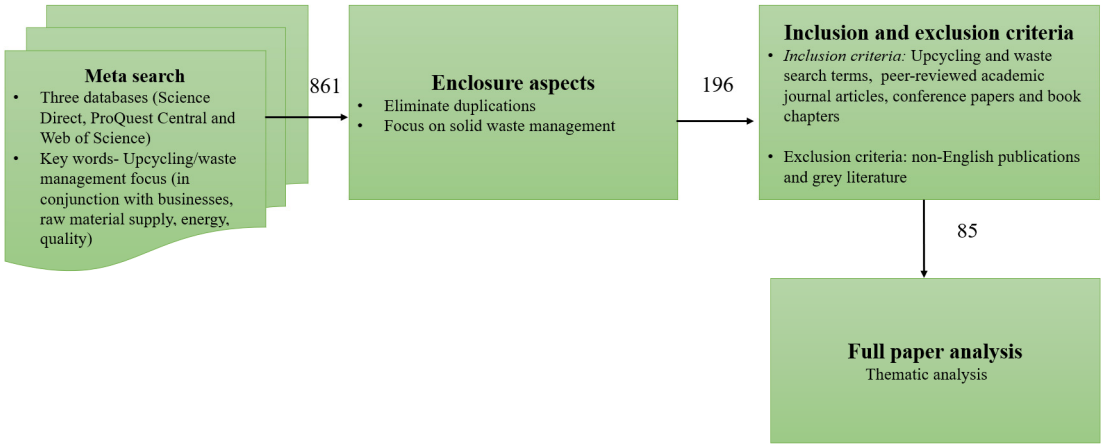

Figure 2: Screening of key literature (Adapted from [40])

A meta-search was conducted to reflect on literature from 2000-2020 using the key words of waste upcycling (in conjunction with energy, material supply, quality), resulting in 861 articles. The duplicates were removed and most relevant research for waste upcycling were considered. Finally, after applying the inclusion and exclusion criteria 85 publications were selected for the review. The context-intervention-mechanism-outcome (C-I-M-O) framework [41, 42] was used for this stage to identify the inclusion and exclusion criteria for the study. A backward review process was conducted, going back to relevant citations of the extracted articles to determine preceding articles related to the scope of the review. A forward review then identified subsequent articles that cited the extracted articles, which were within the review theme, to access the relatively extensive amount of literature [43].

The search terms were created considering the phenomena needing exploration (see the introduction for the two key questions driving the study). Inclusion criteria required publications to be related to waste upcycling, noting that metal ion upcycling and nanoparticles synthesis were not within the scope [44-46]. It also included publication types to be peer-reviewed including journal articles, conference papers, book chapters. Exclusion criteria included eliminating any industry reports and magazines and non-English publications.

Given that the purpose of this research was to deliver a synthesized review of how waste upcycling can enable businesses to close the loop, the pre-codification scheme was based on the fundamental questions of *what*, *why*, *who* and *how* (see introduction) for understanding the applications of waste upcycling. This was consistent with previous similar meta-literature review papers [14] which created a base to investigate common themes reported in waste upcycling concepts.

THEMATIC FINDINGS AND DISCUSSION

The thematic findings of the structured literature review were categorized under the key themes of: 1) Definitions and characteristics of waste upcycling (*What?*); 2) Business enterprises in upcycling (*Who?*); 3) Key benefits of waste upcycling (*Why?*); 4) Industrial processes, Enablers and barriers for upcycling in business enterprises (*How?*). These themes are discussed in detail in the following sections.

Definitions and characteristics of waste upcycling

The literature review identified that the term 'upcycling' has varied definitions and practices, as summarised in Table 1.

Table 1: Summary of upcycling definitions

Upcycling Definitions	References
"Transformation of waste into valuable products".	[18] [22] p.1
"An approach to develop a crafted, individual and possibly unique product requiring (often) manual intervention"	[53]p.6
"A process in which used materials are converted into something of higher value and/or quality in their second life".	[14] p.28
"The creation and creative modification of products by utilizing used materials in order to make a higher quality and better value product than the compositional elements".	[14] p.114
"An umbrella concept incorporating 'creative' forms of repair, reuse, repurpose, refurbishment, upgrade, remanufacture, and recycling".	[17] p.2

Inspired by the evolvement of the waste upcycling definitions, the authors provide a synthesised definition here, of upcycling as a *transformation of waste material into a value-added product through unique, creative crafting methods*.

Suitable materials and tools are key ingredients to produce a high quality upcycled product. Table 2 provides examples of different waste materials and upcycled products that could be created using these wastes, with the relevant literature cited accordingly.

Table 2: Examples of products from upcycled waste material

Waste material	Products	References
Food and Organic waste	Beverage, whey protein, fish food, oil, compost	[51, 54, 55]
Plastics (Drinks bottles, cups, plastic bags, and packaging material, plastic films)	Lighting, and decorative home interior products	[15, 56-61]
Cardboard (Boxes, heavy duty cardboard tubes)	Building materials	[15, 57, 62]
Clothing and textile waste	Upcycled fashion products, jewellery, ladies handbags, office stationery	[16, 35, 48, 49, 52, 63-66]
Glass (Glass bottles)	Construction materials	[15, 67]
Metal (Tin cans)	Sculpture	[56, 60, 67]
E-waste (Old circuit boards)	Jewellery	[15, 68, 69]
Wood	Furniture	[16, 47, 60]
Construction and demolition waste	Urbanite for patios and walkways	[70, 71]

Upcycling can be practiced using simple tools and skills. However, high quality products often require specialist skills and equipment. Product longevity is considered an important criterion to produce high quality, well designed upcycled objects that will last [15]. Achieving connectivity between a wide range of materials and objects can become a challenge in upcycling waste materials into non-structural building materials [15].

Business enterprises in upcycling

Reviewed articles highlighted the involvement of a diverse group of stakeholders in upcycling. A majority of reviewed papers focused on individuals, micro-small and medium sized-businesses working on upcycling processes [16]. These micro and small-sized businesses represented a variety of sectors: food and organic products; plastics; cardboard; clothing and textile waste; glass; metal; e-waste; and wood as indicated in Table 2. Examples of each of these business categories are discussed in the following sections.

Researchers have determined pathways to develop marketable food and organic products by upcycling waste material into value-added products such as beverage, whey protein, fish food, oil, compost. For example, pomace which would be otherwise

discarded as waste material can produce a high-quality organic functional food supplement [51]. Enhanced food products have gained popularity in the food industry for example previous research demonstrates the use of the barley spent grain to enrich semolina which would then be used to produce dry pasta. Those upcycled food products have proven to be high in nutritional value and have minimal impact on the sensory values of the cooked pasta [54]. Another major application in the brewing industry is emphasized as the biogas production from by-products from the brewing process [55]. A link between industries such as food and fashion was pointed out by researchers who inferred that extracted starches from germinated food grains (waste material) and showed its applicability as a thickener in textile printing [66]. Clothing and textile upcycling has opened up a variety of opportunities to many business including redesigned and repurposed clothes, accessories for ladies, handbags, lady's purses and office stationery [63, 72, 73]. The process outcomes of upcycling waste material such as textiles and wood were further validated through causal loop diagrams [16].

Converting plastic waste such as drinks bottles, cups, plastic bags, and packaging material into value-added products has uncovered significant opportunities for micro-small-medium sized enterprises. These value-added products include lighting, and decorative home interior products [15]. The value of these products can be enhanced by augmenting other waste material such as cardboard and glass [15]. These types of creative upcycling revealed the potential for reconnecting people with material and establish communities of '*making*'. Eco-artists use this type of craft-based recycling with waste plastic and cans to create decorative home interior products [56]. Metal has comparatively high value as a re-usable/ recyclable waste material and the integration of different know-how has proven to advocate for creative innovation that can be applied to a variety of products including sculptures.

Waste materials such as polystyrene, disposable crockery, woodchips, molten rock powder and kaolin, steel plates and glass have been used to develop upcycled products [67]. Another study demonstrated an example of an upcycled café as a research hub to attract people to share their ideas on upcycling [15]. Designers and engineers play an important role in promoting upcycling by developing better quality products. The above-mentioned practices can be a step towards more sustainable craft practice and have indicated to go beyond individual practice. The contemporary 'Maker Movement' which includes craft professionals, hobbyists, eco-artists, makers and designers, who have become small entrepreneurs in niche markets play a key role in the continuation of the upcycling practices [14, 73]. Most of these grassroots level entrepreneurs improve their designs through self-taught practical skills developed by experimenting with different materials, techniques and colour combinations [56]. Upcycling is a social innovation process, which can be a vehicle for marginalized groups, e.g. prisoners, migrants, elderly people or unemployed youth to become change agents [22, 74].

Through the above analysis of examples, it was identified that upcycling has broader applications that permeate into multiple business sectors. However, there are key factors that need to be considered when engaging in an upcycling business. These include the type of material, preservation techniques, functionality and aesthetic value. Types of material could be attributed to the original colour, texture and look of it. Preservation techniques describe the methods that need to be employed to ensure the durability of the value-added product. The functionality described a whole new function the upcycled product would perform. The aesthetic value explains the right touch of creativity that should go in as a key ingredient to maintain the character of the product [60]. The next section delineates the key benefits of upcycling for businesses.

Industrial processes related to upcycling

For upcycling business to operate efficiently, it is critical to consider the quality of the raw material (i.e. waste resource), energy requirements for the conversion process and the quality of the upcycled end product. This section examines the industrial processes underpinning the upcycling operations in terms of raw materials, energy and quality standards. Evaluating the quality requirements of the raw material (i.e.: waste resource) for upcycling involves addressing their quality and adequate quantity of supply [16]. The energy requirement for upcycling refers to the change in the energy requirements of industrial processes using waste resources as opposed to virgin materials. Ensuring the quality of the final product includes assessment and management of risks to the safety and quality of final products which is used to establish requirements, rules, and constraints for upcycling production that controls the quality of products and ensures consumer safety.

Upcycling businesses require waste resource sources to deliver with a certain level of quality and quantity reliability. Challenges securing adequate sources of waste resources with predictable and consistent quantity is often a barrier for many organisations [16]. For example, upcycling in the fashion industry is highly dependent on the availability of waste fabric material. A study into the differences between standard fashion design and production processes and those of upcycling found that while standard design processes have the flexibility to source fabric after the product has been designed, upcycling processes require fabric sourcing to occur before any designing due to the irregularity of waste fabric availability [75]. Another study discussed the bespoke creation of unique designs by using remnant high-quality fabric form couture garments [73]. Secondly, the brewery by-product of spent grains is a high-protein resource that is often used as an agricultural feed supplement with consistent quality and quantity of supply for a reliable price particularly from large-scale breweries [76, 77]. Thirdly, regulations and safety standards in the construction industry create challenges for the approval of non-standard (waste resource) materials [15]. One method of mitigating the unpredictability of waste resource streams is for businesses to form an Industry Ecology partnership where one company's by-product is sold directly to another organization for upcycling in a collaborative and mutually beneficial agreement [78, 79]. Partnerships with large-scale companies can help maintain a steadier flow of waste resources [16]. The securing of waste resources with adequate quality and quantity has specific challenges within each industry and product. However, there is limited research addressing the specific industries and products that this barrier affects, which highlights future opportunities for academic research which will then give industries evidence-based avenues for development.

In principle, upcycling reduces energy requirements by simply adding value to existing products [16]. It was established that scaling up of upcycling could increase energy efficiency but there is limited evidence showing comparisons to the energy efficiency of production using virgin materials [16]. No studies were found that compare the energy consumption of a production processes using waste resources as opposed to virgin materials. This important comparison is a gap in the current academic literature which is an opportunity for further research that will help organizations understand the energy requirements of upcycling processes.

The risk assessment process and requirements for quality control and consumer safety will vary greatly between industries and products. Product quality has been a major concern for upcycling in the food and agricultural industry, demonstrated by the high

proportion of upcycled product quality literature addressing this field [80]. National-based agricultural and manufacturing standards for product purity and food safety standards will help ensure consumer safety in the food industry. In the case of berry pomace as an upcycled byproduct of a black currant juice production, the food quality standards of the original process contribute to the chain of evidence supporting consumer safety of berry pomace [51]. However, there is limited academic research specifically addressing product quality in terms of consumer safety. An investigation into the nutritional quality and textural characteristics of ready-to-eat snacks upcycled from brewer's spent grain found that product quality including protein digestibility was affected by a number of production conditions such as feed moisture, feed rate and temperature profile [81]. A different study of the dry pasta upcycled from brewer's spent grain included analysis of cooking quality, nutritional profile, yellow index, sensory quality, and enrichment but did not include any specific food standards or consumer safety test results [54]. Research into upcycled textile products [66, 82, 83] uses colour strength, tonal variation, and other indicators to test the quality of garments upcycled using natural dyes and extracted starches from germinated food grains as a thickener. The fear of product failure and unclear product quality can result in a lack of community confidence for upcycled products [16]. Ensuring product quality and communicating this clearly with consumers are important considerations for organisations promoting upcycled products.

More research is required to address key industry and consumer concerns regarding the quality requirements of waste material for upcycling, the energy requirements of upcycling and ensuring the quality of final products. Simplified lifecycle assessment tools and Material Flow cost accounting tools (which model material flows, energy use and quality control) can both be used to compare an organisation's standard production processes against different upcycling opportunities [15, 79, 84]. Key concerns regarding industrial process chains need to be addressed for each industry and each upcycled product.

Key benefits of waste upcycling

Waste upcycling has demonstrated a range of benefits for the society, environment and economy. During the last decade, upcycling has gained prominence, driven by a growing concern for the environment, resource scarcity, high volumes of waste generation [85] and an increasing number of individuals and businesses entering the Maker Movement [30]. Most importantly it has been established that upcycling practices embeds into a circular economic strategy and enables the shift from the take-make-dispose linear system to a more restorative and regenerative closed-loop system [1]. Within this system, the lifetimes of materials and products will be extended and energy consumption and greenhouse gas emissions will be reduced [17]. For instance, this includes how upcycling can reduce the production of new textiles from virgin materials and hence reduce the use of water, energy and chemicals in the production process are explained [20]. In principle, upcycling increases the material efficiency, slows material flows and thereby reduces the need to extract raw materials or purchase new products contributing to environmental sustainability and optimizing the use of limited resources [19, 86].

Apart from the environmental and ecological advantages which can be brought about by creative transformation of waste, there are many socio-economic benefits of upcycling [20]. Upcycling-based businesses can be financially sustainable. It creates more job

opportunities for disadvantaged people and monetary savings that would have been used for purchasing new materials or products [17]. Upcycling also provides socio-cultural and psychological benefits such as a sense of community, a renewed sense of pride and fulfilment, new knowledge and skills and sense of empowerment [15]. It enables individuals, businesses and communities to share resources and skills and trade waste within the local economy [20]. The power behind upcycling activities is centered on the cultural framings used by people as they engage with different 'waste' objects.

Upcycling business models coupled with value proposition and innovation can promote sustainability and develop better connections between entrepreneurs, the upcycled products and consumer engagement in the transition to a more circular economy [31]. Researchers have argued that upcycled products shift purchase behaviour, a change that is stimulated by consumer desire for the personal, social and ethical benefits of their buying decisions [65]. This change in consumer attitudes and perceptions about 'waste' and the potential for creative reuse of materials could encourage people to see waste through a different lens [16] and engage in individual upcycling. Home-based upcycling could be a means of creating awareness and encouraging sustainable waste management at source [24]. Upcycling can be a rewarding experience in which something pleasing and useful is produced that carries the authentic and personal touch of the creator, which makes the product unique [24, 87].

Enablers, barriers and opportunities for upcycling in business enterprises

Findings revealed fifteen key barriers to waste upcycling practices in business enterprises as shown in Table 3, under the three categories of macro, meso and micro barriers. Macro– barriers consists of perceived structural, legal, regulatory and economic external conditions that are beyond the influence of individual enterprise [88]. Meso-barriers focus on local institutional factors and influences, as well as community issues that often describe the parameters of product manufacturing [88]. Micro-barriers describe day-to-day practice and attributes or characteristics of individual enterprise and their practice environments that affect how products are manufactured. Similar categorization of enablers and barriers have been established in previous research in other scientific fields [88].

Macro barriers for upcycling include lack of availability of materials, outdated policies and legislation that fail to value upcycling, lack of funding, and financial difficulties [16]. Researchers suggest that providing incentives, funding opportunities and financial support for upcycling businesses from the government could help to address these barriers [14]. Lack of availability of good quality materials and current standards that focus only on conventional materials and techniques also hinders upcycling. This leads to upcycling non-standard materials difficult especially in building and construction sector [15]. The politicization and political powerlessness have led to poor enforcement of policy and regulations in many developing countries discouraging small-sized upcycling businesses [68]. It was emphasized that a lack of supportive government policies and standards hinders the growth of the upcycling industry. The lack of incentives to repurpose waste materials motivates industries to get rid of the wastes by dumping or landfilling instead of directing them for value addition [20, 89].

Table 3: A summary of key barriers from literature

Barriers type	Details	References
Macro-barriers	Lack of policy and regulation systems,	[68]
	Lack of funding schemes and incentives	[14]
	Existing stringent standards focused on conventional construction materials and techniques, making use of non-standard materials difficult	[15]
	Political powerlessness and instability	[68]
Meso-barriers	Negative attitudes toward using waste as a raw material	[16, 17]
	Limited financial resources	[16, 17]
	Socio-psychological factors such as approval from others	[17]
	The lack of unified and generally acceptable standards affects the operation and development of the recycling industry	[20]
	Lack of consumer awareness and knowledge	[16, 20, 65]
Micro-barriers	Lack of knowledge and clarity on upcycling opportunities (limited skills, imagination, inspiration and information	[14, 20, 56, 90]
	Absence of resources (money, men, machines and space)	[30, 38, 90-93]
	Poor quality of upcycled products, product composition complexity, and lack of transparency of material ownership	[16, 90]
	Marketing one off upcycled products are challenging	[15, 94]
	High price of the upcycled product	[38, 92]
	Contamination interactions limit the application of the upcycled objects	[15]

Many industries that generate waste materials ideal for upcycling are not aware of opportunities to donate these wastes to upcycling businesses. Furthermore, there is limited and *ad hoc* legislative support from local councils to collect and use discarded materials making it difficult for upcycling businesses to openly access waste [20]. Provision of financial support from the government for leasing and renting of space and to scale-up the operations are important. However, such financial facilities are often not given to small-sized businesses [68].

There is a significant correlation between consumer awareness and attitudes to recycling and upcycling [20, 65]. A lack of consumer awareness and knowledge leads to negative market demand for upcycled products. This could also lead to a negative perception of used materials, final product quality and price in upcycled products from the general public [17]. A lack of quality protocols and standards for upcycling is another barrier faced by the upcycling industries. Thus, for some consumers, upcycled products have close associations with poor quality, reduced durability and low cost-effectiveness [16].

The review highlighted that most barriers are affecting business enterprises at a micro level attributed to individual factors such as resources, time, skills, and quality of raw materials [93]. Previous work [14, 20, 56] highlights that self-doubt about the marketability of upcycled products and a lack of knowledge and clarity on upcycling opportunities are challenges for design up-cyclers. Another research [90] identifies poor quality of upcycled products, product composition complexity, and lack of transparency of material ownership as barriers to upcycling. Finding clean waste materials, compatibility of the materials with the quality of the end-product and responsible sourcing needed to be considered when sourcing waste materials for upcycling [15]. Maintaining quality is a significant challenge in upcycling due to the inherited nature of varied materials and product quality. The lack of affordable machinery, technological skills and knowledge of manufacturing processes and design protocols further hinder the upcycling sector [38, 91, 92].

Overall the industrial practitioners from business enterprises have identified waste upcycling as a business opportunity to transform waste material [95]. Table 4 presents fifteen enablers under the three categories of macro, meso and micro enablers. Macro–enablers consists of perceived structural, legal, regulatory and economic external conditions that could influence individual enterprise from the external environment.

Table 4: A summary of key enablers for waste upcycling elicited from literature

Enabler types	Details	References
Macro-enablers	Provide support for waste upcycling education, endorsements, resource hubs	[65, 96]
	Better mobilization of resources and knowledge	[97] [86]
	Promote circular spirits and capacity building for entrepreneurs	[38, 98]
Meso-enablers	Facilitate community awareness and support	[65]
	Networks for social innovation and encouraging more people to engage in upcycling	[17, 30, 98]
	Use of material flow accounting to show the created value	[51]
	Strengthening system-level waste solutions and social awareness	[97, 99]
	Advocate reuse over recycling	[16]
	Provide design guide for upcycling with less time, efforts and money	[14]
Micro-enablers	Shift in cultural perceptions	[15, 100]
	Optimise freely available material and bio-inspired procedures	[14, 56]
	Improve material provision	[30]
	Train employees and suppliers and experiment development of new products	[30]
	Promote reverse logistics	[38]
	Take ownership, selling the uniqueness the story behind the product	[14, 56, 99, 101]

Meso-enablers focus on local institutional factors and influences, as well as community factors that often drives the upcycled product manufacturing processes. Micro-enablers describe day-to-day practice and attributes or characteristics of individual enterprise and their practice environments that influence how products are manufactured.

The key enablers identified from literature have been proven to be effective in their relative locations, wider application of these approaches will facilitate a more rapid and expansive transition to waste upcycling. Macro enablers for upcycling include education and knowledge sharing, discovering resource sharing partnerships and promoting of circular-inspired entrepreneurs [102]. Researchers suggest that interdisciplinary collaboration and the mobilization of resources and knowledge can enable the generation of new upcycled product ideas for businesses [97]. Previous work recommends standardising customer-facing sustainability rating language in the fashion industry as way to promote upcycled products through education and endorsements [65, 103]. Entrepreneurs of small-sized businesses have the valuable opportunity to adopt circular business models that are considered more 'radical' and may feature products offered as services or in sharing platforms. Promoting and supporting circular-inspired entrepreneurs enables the growth of small upcycling businesses to make a bigger impact [38]. Creating education, resource sharing and support programs can enable businesses with a waste upcycling focus to thrive [75].

Meso enablers can be created through community education and engagement; and helping businesses design and implement waste solutions compatible with upcycling. Researchers have identified community misinformation surrounding the meaning of 'recycled' versus 'upcycled'. This is an opportunity to build community awareness and support by promoting upcycling as adding value [65, 98]. Other research has found that encouraging engagement in upcycling addresses the lack of consumer awareness and enables upcycling to become a more common activity [17, 30]. Advocating reuse over recycling within communities helps to slow and/or close material loops [16]. Another research [97] acknowledges that businesses often require collaborative research and support to develop innovative system-level waste solutions. Furthermore, design guides

help businesses redesign their products in preparation for easy repairing or upcycling [20]. Previous work recommends wider use of material flow accounting to model material efficiency, cost reduction and revenue generation to demonstrate upcycling benefits [51]. Creating a market for upcycled products requires community understanding and acceptance, and business communication and collaboration.

There are micro-enablers driven by key factors such as shift in cultural perceptions, improved material provision, assigning ownership to entrepreneurs and building capacity in business enterprises. Upcycling is currently a niche activity. Research indicates that addressing the negative cultural perceptions of creating value from waste is an important step to enable better acceptance of upcycled products [15]. Finding a reliable supply of used or waste materials enables businesses to expand production of upcycled products [30, 75]. A greater number of eco-artists and businesses are using discarded materials as it generates business opportunities including being able to optimise freely available material and bio-inspired procedures [14, 56]. Understanding new business opportunities and technical innovations may require some training for businesses. Another research [38] identifies reverse logistics as an enabling factor for businesses to retain the financial benefit of upcycling their old products into new ones. It was noted that a key feature of upcycled products which should be promoted is the unique story behind it [101]. This is particularly relevant in fashion and art industries [14, 56]. There are many enablers that businesses can capitalise on to implement waste upcycling.

Synthesising the key literature from 85 publications papers, Table 5 summarises emergent opportunities for waste upcycling categorises under social, environment and economic clusters.

Table 5: Emergent opportunities for waste upcycling (References as shown)

Social opportunities	Environmental opportunities	Economic opportunities
Creating employment [22, 75]	Waste materials lasts even longer in the respire cycle reducing the burden on virgin material [21,104]	Increased profit through the aesthetic values and uniqueness to the design [14, 99, 100]
Opportunity to demonstrate leadership in sustainable business practice [37]	Leveraging sustainability-oriented innovation for waste valorisation [10]	Stimulates entrepreneurship, supporting the culture of prosumerism [6, 75]
Socioeconomic regeneration by co-creating shared value [37, 100]	Ability to use biomimicry approaches [30]	Facilitate economic diversification and can exploit Niche market opportunity [29]
Collaboration among academic institutions, which could be set up through joint-funding schemes [16]	Ability to create future goods and services that is consistent with sustainable development goals [9,104]	Enables more sustainable consumer behaviour [16, 96]

Previous waste upcycling efforts have created opportunities for people to be socially responsible, inclusive and equitable, and use waste material to develop economically viable, environmentally sustainable and competitive businesses.

Emergent Waste Upcycling Framework for Business

Based on the three categories of enablers and three categories of barriers derived from reviewed literature the authors propose an emergent framework on barriers, enablers and opportunities for waste upcycling. This is presented in Figure 3 and discussed in the following paragraphs.

This illustration assumes moving forward (progressing the closed-loop economy agenda) is clockwise, and reversing perverse incentives and challenges is anti-clockwise.

The aim is to progress towards the boxes at the bottom of the framework, which highlight the economic, environmental and social opportunities drawn from Table 5.

In order to enable these opportunities, the micro, meso and macro barriers and enablers must be addressed in ways that build momentum, where:

- 'Macro' refers to perceived structural, legal, regulatory and economic external conditions and that are beyond the influence of individual enterprise [61]
- 'Meso' refers to local institutional factors and influences, as well as community issues that often describe the parameters of product manufacturing [61]
- 'Micro' refers to day-to-day practices and attributes or characteristics of individual enterprise and their practice environments that affect how products are manufactured [61]

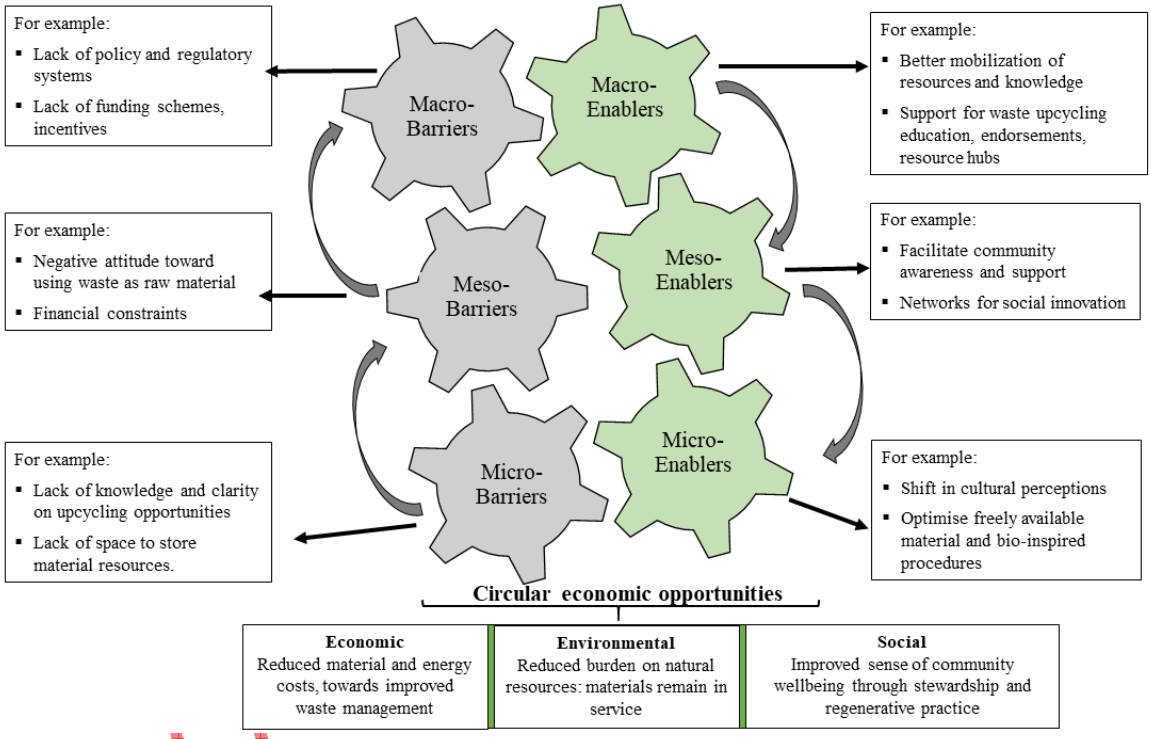

Figure 3: The Tiered Approach to Waste Upcycling for Business

On the sides of the framework, examples of the links between the macro, meso and micro barriers are presented. These are drawn from the content discussed in Table 3 and 4 at each of the three levels. The relationship between the enablers and barriers, at each level of macro, meso and micro the gears of either system can influence the other. It is therefore important to focus on the enablers so that they work on the barriers, in effect reversing the barriers influence.

Starting with the left-hand side, from the macro-barriers, the framework shows how they then negatively gear the cogs of the meso and micro, perpetuating the limitations of the system and stalling efforts to engage in closed-loop economy business. Macro-barriers such as lack of policy and regulatory systems and lack of funding schemes have an impact on community level meso-barriers related to financial constraints. Negative attitudes toward using waste as raw material influences lack of clarity about upcycling opportunities. These types of macro-meso-micro barriers are then having cumulative effects on implementing upcycling practices.

Conversely, the right-hand side of the framework presents the potential for the macro-enablers to positively gear the meso and micro enablers, supporting new and existing initiatives into closed-loop practices. Macro-enablers such as better support for waste upcycling education, endorsements, resource hubs and better mobilization of resources and knowledge would amplify meso-enablers such as community awareness and strengthen with skills and knowledge toward social innovation. These meso-enablers will then influence a shift in cultural perceptions in the day-to-day practices of businesses and leverage the freely available waste material and create unique, bio-inspired products.

The framework conceptually shows how successfully addressing the barriers and amplifying the enablers can create sustainable outcomes. These outcomes span economic, social and environmental opportunities such as reducing costs of material and energy, reducing the requirement for natural resources and creating a sense of community wellbeing through stewardship and regenerative practice.

CONCLUSIONS

The authors established a Tiered Approach to Waste Upcycling that can guide actions to close the loop within business processes and production chains. This framework concisely presents the macro, meso and micro barriers and enablers that businesses can consider identifying upcycling opportunities for managing their waste. Furthermore, it shows how in successfully addressing these barriers and amplifying the enablers would enable business enterprises to achieve outcomes better for the bottom line, people and planet. It can be used to immediately explore opportunities for leveraging links as business opportunities, providing practical pathways for contributing to a circular economic system. Businesses could rapidly contribute to the circular economy through adopting upcycling practices to keep resources in the material cycle for longer and manufacturing high-quality, value-added products.

Regarding the limitations of this study, the authors acknowledge the drawbacks of the SLR methodology [39], especially those concerning the literature sampling criteria and analysis. Moreover, extensive empirical research is required to test and validate the enablers and barriers framework. Future research could undertake deeper investigations using frameworks such as socio-technological systems, and institutional theory to establish how enablers and barriers inform future opportunities for industry and government practitioners to mainstream upcycled-based social creative business. This would further explain the complex interactions between people and technology. With regard to future research and publications in the field, the authors have defined a set of key theoretical constructs relating to waste upcycling, that can enable industry uptake of ideas and innovations. Deeper examination of social networks, expectations, learning and specific market strategies to advance the business agendas could be suggested as key next steps to evaluate the feasibility of a upcycled-based businesses.

This paper has immediate implications for applying upcycling within businesses and communicating these efforts within the larger circular economy dialogue and incentive schemes. It also has implications for business and academia globally, acknowledging the gaps in the literature which highlight potential lack of activity in application and/or reflection on the activities underway.

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