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Evaluating barriers, enablers and opportunities for closing the loop through ‘waste upcycling’

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ABSTRACT

The United Nations Sustainable Development Goals (UN SDGs) aim to ‘*do more and better with less*’, with and 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 as niche practice and remains unclear for many business enterprises on how exactly to use upcycling for better management of waste. Within this context, this 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. The authors draw on a variety of multidisciplinary resources to establish an emergent framework that shows how in successfully addressing these barriers and amplifying the enablers, would create sustainable outcomes. The findings also describe key benefits of upcycling including improved quality and life of material, creating jobs and influencing positive consumer behaviour. The authors propose that business enterprises could rapidly contribute to the circular economy through adopting upcycling practices to keep resources in the material cycle for a longer period of time.

Keywords: Upcycling, SMEs, waste management, circular economy

1. INTRODUCTION

Current industrial and economic systems operate on a predominantly take-make-use-dispose model, where resources are extracted to make products that are used only for a short period after which the materials become waste and are lost to landfills or incineration [1, 2]. This unsustainable linear economic system puts pressure on resources, pollutes the environment, and creates significant economic and social impacts at local, regional, and global scales. To address this, current approaches to increasing resource efficiency and sustainable manufacturing of products focus on circular economy principles [3]. Circular economy represent the material flow in a closed loop system [4] and this economic model can be characterised as a “design and business model strategies that are slowing, closing, and narrowing resource loops”[5,p.309]. As negative impacts of a linear economy and waste accumulation are increasingly felt throughout the world, the social and economic interests for circular economy are high. 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 jobs creation, livelihood improvement, and waste management [6]. Globally there are a number of stand-out examples of initiatives to promote such circular economy approaches. These include for example GOLDEN [7], Climate-KIC (Europe)[8], US Circular Economy Program (USA)[9], Low Carbon Green Growth Roadmap for Asia and the Pacific (Asia-Pacific)[10], and the Blue Economy Co-operative Research Centre (Australia)[11].

Upcycling is recognised as one of the most sustainable waste management options in the circular economy [12]. ‘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 [13-15]. 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 business enterprises as to how exactly to use upcycling for better management of waste and promotion of sustainable production and consumption [12]. 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.

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) [13, 16-18], there is still relatively limited research on enablers and barriers to upcycling in business enterprises. Within this context, the authors draw on a more than 50 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. Within this context, the study was guided by the following two research questions:

1. *How can the concept of ‘waste upcycling’ enable businesses to close the loop?*
2. *What barriers and challenges exist for businesses to engage in waste upcycling practices?*

In the following section a detailed methodology is provided with regard to 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 enablers and barriers for upcycling in business (*How?*). The authors also describe key benefits of upcycling, spanning improved

quality and life of material, job creation and the opportunity to positive influence consumer behaviour. Research findings from this literature review provide a timely contribution to understanding what enables business to creatively use waste materials in production processes, thereby reducing the consumption of materials and energy. The findings, including an emergent conceptual framework, are also important in addressing barriers that still inhibit businesses engaging in upcycling.

2. METHOD

This paper presents key literature in the upcycling domain specifically focusing on waste management. A five-phased structured literature review approach adopted to support the review [19] was deemed appropriate due to its transparency and reproducibility. It is illustrated in Figure 1 and described in the following paragraphs.

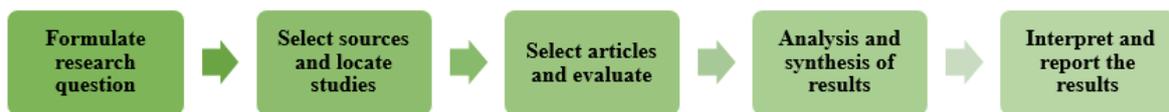


Figure 1: Five key steps of the systematic literature review process [19]

An initial search on Google Scholar was conducted to define the scope and research question and the main searches were conducted in three databases including Science-Direct, ProQuest Central and Web of Science. Though 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, medium and large scale.

The distillation of articles is summarised in Figure 2. A meta-search was conducted to reflect on literature from 2000-2020 using the key words of waste upcycling which resulted 817 articles (ProQuest 296, Science direct 368 Web of science 153). Then the duplicates were removed and most relevant research for waste upcycling were considered. Finally, after applying the inclusion and exclusion criteria 51 publications were selected for the review. The C-I-M-O context-intervention-mechanism-outcome [20] framework 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. This was followed by a forward review to determine subsequent articles which cited the extracted articles that are within the review theme, to access the relatively extensive amount of literature (Webster & Watson, 2002).

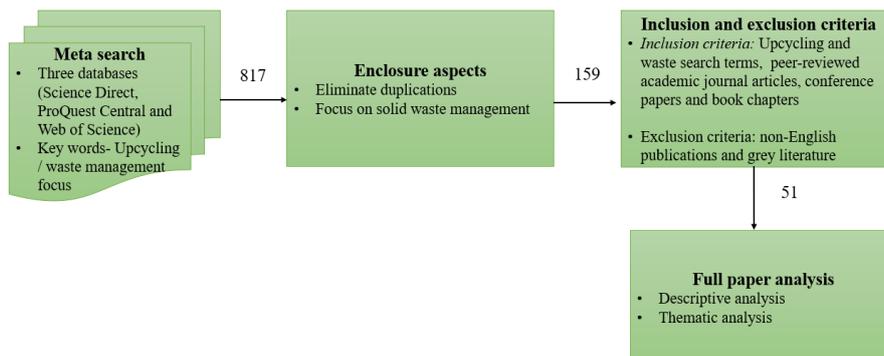


Figure 2: Screening of key literature (Adapted from [21])

The search terms were created considering the phenomena needing exploration (see the introduction for the two key questions driving the study). The inclusion criteria consisted of the content of the publications which should be related to waste upcycle (note: metal ion upcycling, nanoparticles synthesis was not within the scope), and the publication types to be peer-reviewed including journal articles, conference papers, book chapters. Exclusion criteria were to eliminate any industry reports and magazines and non-English publications.

Given that the purpose of this research was to deliver a synthesized review of how can waste upcycling 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 [12] which created a base to investigate common themes reported in waste upcycling concepts.

3. DESCRIPTIVE FINDINGS

The descriptive analysis describes the research trends over the last two decades, context (geographic distribution), types of methods and publication outlets. Figure 3 summarises the number of publications chronologically over the period since 2001. There is an increasing trend on articles from 2014 onwards highlighting that this concept is still its infancy and the opportunities to further investigate this phenomenon.

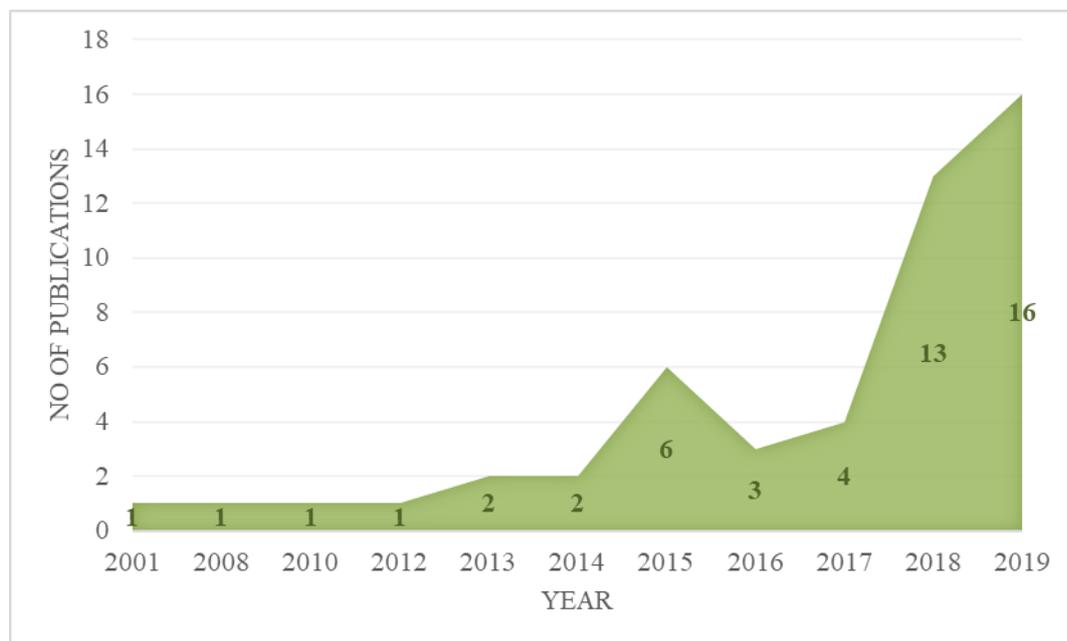


Figure 3: Articles published vs year

Figure 4 portrays the demographic distribution and number of the articles by the first authors. It is evident that a majority of the literature was recorded in the United Kingdom (n=17) and then in Italy (n=4) and Germany (n=3). Malaysia, India, Brazil, China, Indonesia, Singapore and Turkey. This is a good indication that the research findings were also likely to be applied to industries in these countries.

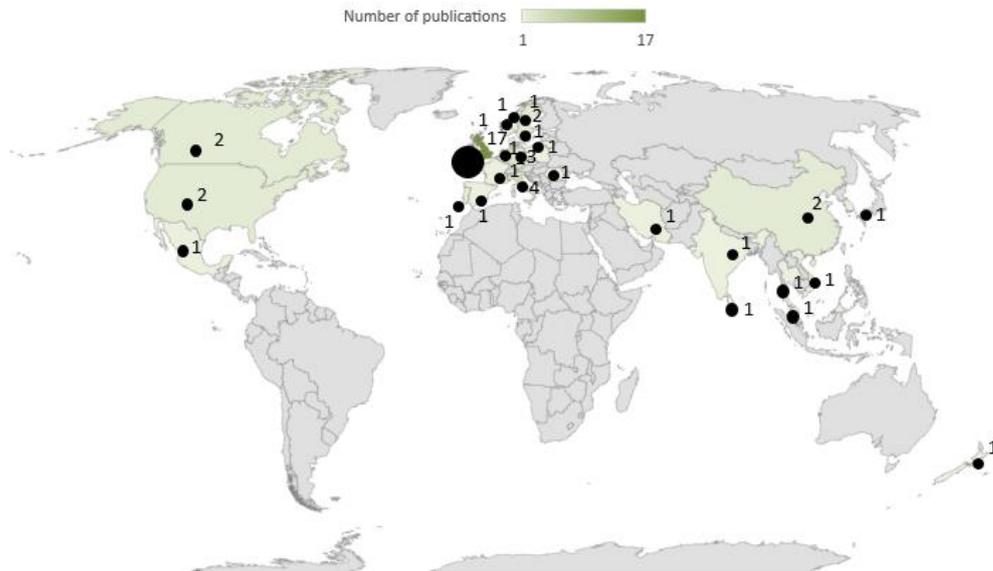


Figure 4: Geographic distribution of research conducted on waste upcycling (by first author)

Of the 51 articles selected for review, 71% (n=36) were journal articles, 21% (n=11) were book chapters and 8% (n=4) were conference papers (Figure 5). Out of 36 journal articles, 8 were published in *Journal of Cleaner Production*. *The Journal of Resources, Conservation and Recycling* had published 3 articles. This provides an indication of suitable outlets to publish waste upcycling related articles.

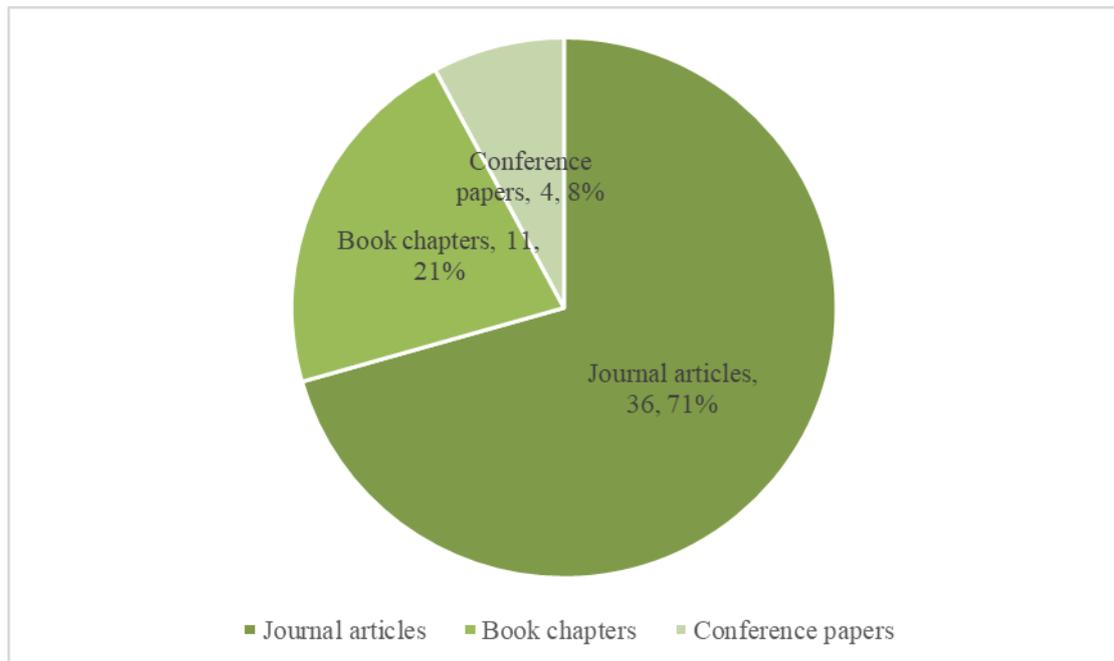


Figure 5: Research outlet types

4. THEMATIC FINDINGS AND DISCUSSION

The thematic findings of the structured literature review were categorized under 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) Enablers and barriers for upcycling in business enterprises (*How?*). These themes are discussed in detail in the following sections.

4.1 Definitions and characteristics of waste upcycling

Upcycling is a term with varied definitions and practices. 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]. Table 1 provides a summary of the definitions elicited from the reviewed articles.

Table 1: Summary of upcycling definitions

Upcycling Definitions	References
“Transformation of waste into valuable products”.	[16] [22] p. 1
“An approach to develop a crafted, individual and possibly unique product requiring (often) manual intervention”	[24]p.6
“A process in which used materials are converted into something of higher value and/or quality in their second life”.	[12] 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”.	[12] p.114
“An umbrella concept incorporating ‘creative’ forms of repair, reuse, repurpose, refurbishment, upgrade, remanufacture, and recycling”.	[15] 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 crafted 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	[25-27]
Plastics (Drinks bottles, cups, plastic bags, and packaging material)	Lighting, and decorative home interior products	[13, 28, 29]
Cardboard (Boxes, heavy duty cardboard tubes)	Building materials	[13, 29]
Clothing and textile waste	Upcycled fashion products, jewelry	[14, 30-34]
Glass (Glass bottles)	Construction materials	[13, 35]
Metal (Tin cans)	Sculpture	[28, 35, 36]
E-waste (Old circuit boards)	Jewelry	[13, 37]
Wood	Furniture	[14, 36]

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 [13]. Achieving connectivity between a wide range of materials and objects can become a challenge in upcycling waste materials into non-structural building materials [13].

4.2 Business enterprises in upcycling

Reviewed articles highlight the involvement of a diverse group of stakeholders in upcycling. A majority of reviewed papers focused on individuals, micro-businesses and SMEs working on upcycling processes [14]. For instance, [28] has focused on upcycling practices by individuals in the UK. [13] has used an upcycled café (U café) as a research hub to attract people to share their ideas on upcycling. Designers and engineers play an important role in promoting upcycling by developing better quality products. The contemporary Maker Movement which includes craft professionals, hobbyists, eco-artists and designers, who have become small entrepreneurs in niche markets play a key role in continuation of the upcycling practices [12]. Most of these grassroots level entrepreneurs improve their designs through self-taught practical skills developed by experimenting with different materials, techniques and color combinations [28]. Upcycling is a social innovation process. It can develop marginalized groups, e.g. prisoners, emigrants, elderly people or unemployed youth to become change agents [22].

4.3 Key benefits of waste upcycling

Waste upcycling has demonstrated a range of benefits the society, environment and economy. Most importantly it has been established that upcycling practices embeds into a circular economic strategy and enables to shift from the take-make-dispose, linear system to a more restorative and regenerative close loop system. Within this system the material life cycle will be extended and energy consumption and greenhouse gas emissions will be reduced [15]. Upcycling create more job opportunities for disadvantaged people and also provides sociocultural and psychological benefits such as a sense of community, learning, being empowered and saving money that would have been used for purchasing new material [21]. Upcycled products also catalyzes purchase behavior and is stimulated by consumer desire for the personal, social and ethical benefits of their buying decisions [32].

4.4 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 and that are beyond the influence of individual enterprise. Meso-barriers focus on local institutional factors and influences, as well as community issues that often describe the parameters of product manufacturing. 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 categorisation of enablers and barriers have been established in previous research in other scientific fields [38].

Table 3: A summary of key barriers from literature

Barriers type	Details	References
Macro-barriers	Lack of policy and regulation systems,	[37]
	Lack of funding schemes and incentives	[12]
	Existing stringent standards focused on conventional construction materials and techniques, making use of non-standard materials difficult	[13]

	Political powerlessness and instability	[37]
	Negative attitudes toward using waste as a raw material	[14, 15]
	Limited financial resources	[14, 15]
Meso-barriers	Socio-psychological factors such as approval from others	[15]
	The lack of unified and generally acceptable standards affects the operation and development of the recycling industry	[18]
	Lack of consumer awareness and knowledge	[18, 32]
	Lack of knowledge and clarity on upcycling opportunities (limited skills, imagination, inspiration and information)	[12, 18, 28, 39]
Micro-barriers	Absence of resources (money, men, machines and space)	[39-43]
	Poor quality of upcycled products, product composition complexity, and lack of transparency of material ownership	[39]
	Marketing one off upcycled products are challenging	[13, 44]
	High price of the upcycled product	[41, 43]
	Contamination interactions limits the application of the upcycled objects	[13]

Through evaluation it was evident that most of the barriers are affecting the business enterprises at a micro level and these can be attributed to individual factors such as resources, time, skills, and quality of raw materials.

Overall the industrial practitioners from business enterprises have identified waste upcycling as a business opportunity to transform waste material and the following section detailing the enablers are presented, drawn from the thematic analysis. Table 4 presents thirteen enablers under the three categories of macro, meso and micro enablers. Macro-enablers consists of perceived structural, legal, regulatory and economic external conditions and that could influence individual enterprise from the external environment. 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.

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	[32]
	Better mobilization of resources and knowledge	[45]
	Promote circular spirits and capacity building for entrepreneurs	[41]
Meso-enablers	Facilitate community awareness and support	[32]
	Networks for social innovation and encouraging more people to engage in upcycling	[15, 40]
	Use of material flow accounting to show the created value	[25]
	Strengthening system-level waste solutions and social awareness	[45]
	Advocate reuse over recycling	[14]
Micro-enablers	Provide design guide for upcycling with less time, efforts and money	[12]
	Shift in cultural perceptions	[13]
	Optimise freely available material and bio-inspired procedures	[12, 28]
	Improve material provision	[40]
	Train employees and suppliers and experiment development of new products	[30]
	Promote reverse logistics	[41]
	Take ownership, selling the uniqueness the story behind the product	[12, 28]

It is clear that there are micro-enablers are driven by key factors such as shift in cultural perceptions, improved material provision, assigning ownership to entrepreneurs and building capacity in business enterprises. Synthesising the key literature from 51 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]	Waste materials lasts even longer in the respire cycle reducing the burden on virgin material [21]	Increased profit through the aesthetic values and uniqueness to the design [12]
Opportunity to demonstrate leadership in sustainable business practice [46]	Leveraging sustainability-oriented innovation for waste valorisation [35]	Stimulates entrepreneurship, supporting the culture of prosumerism [6]
Socioeconomic regeneration by co-creating shared value [46]	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 [14]	Ability to create future goods and services that is consistent with sustainable development goals [9]	Enables more sustainable consumer behaviour [14]

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.

4.5 Emergent framework on barriers, enablers and opportunities for waste upcycling

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 (Figure 6). On the left-hand side of the framework the links between the macro, meso and micro barriers are presented, where:

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

The boxes attached to each of the cogs bring forward the content discussed in the Table 3 and 4 at each of the three levels (i.e.: macro, meso, micro). This illustration assumes moving forward (progressing the closed-loop economy agenda) is clockwise, and reversing perverse incentives and challenges is anti-clockwise. Starting with the left-hand side, from the macro-barriers, the framework shows how they then turn the cogs of the meso and micro, perpetuating the limitations of the system and stalling efforts to engage in closed-loop economy business. 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. 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. The boxes at the bottom of the framework highlights the economic, environmental and social opportunities are drawn from the Table 5.

4.5.1 Macro- meso- micro barrier links

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 type of macro-meso and micro barriers are then having cumulative effects on implementing upcycling practices.

4.5.2 Macro- meso- micro enabler links

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.

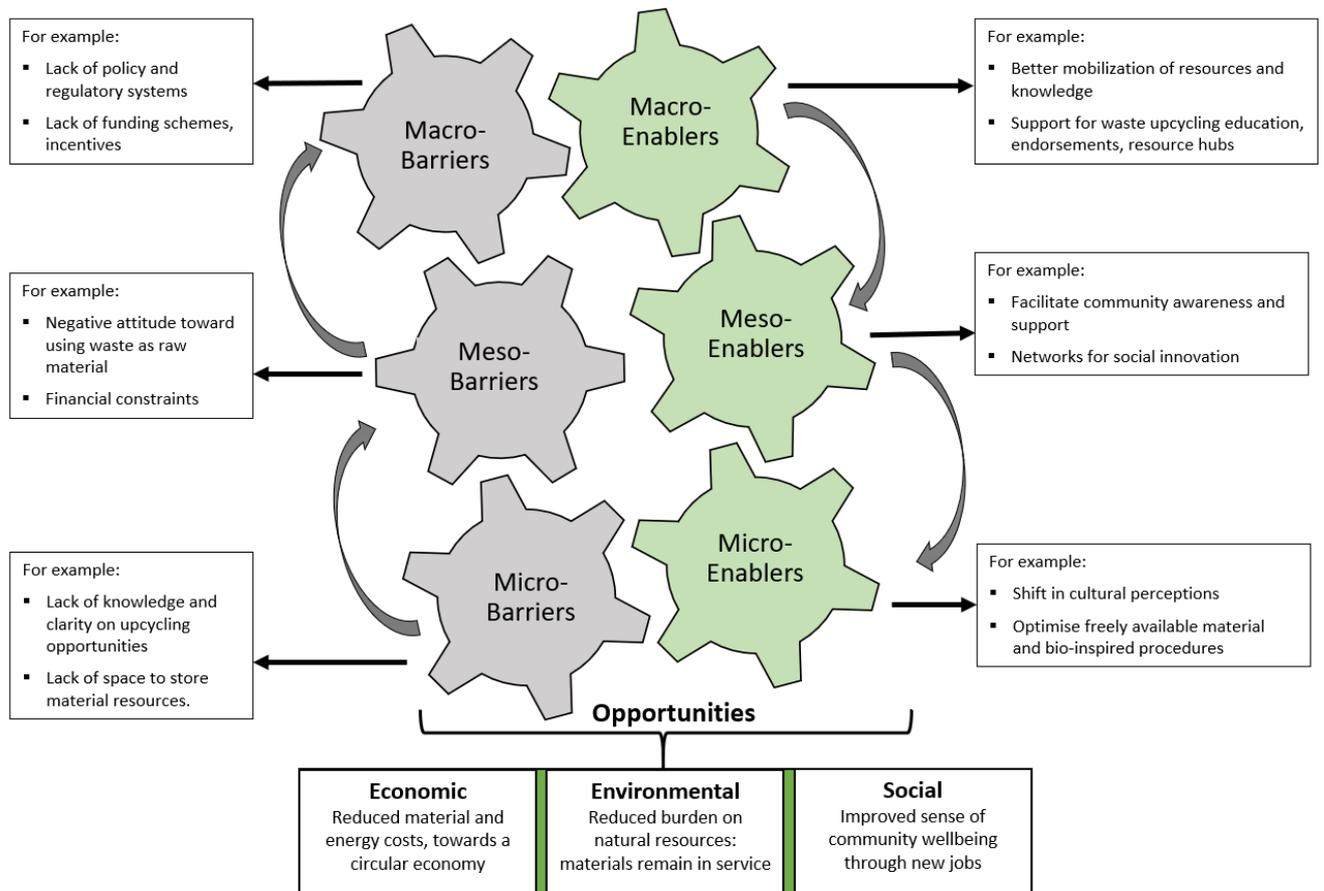


Figure 6: Emergent framework on barriers, enablers and opportunities for waste upcycling

The conceptual model shows how in successfully addressing these barriers and amplifying the enablers would create sustainable outcomes. These outcomes span economic, social and environmental opportunities such as reducing costs on material and energy, reducing burden on natural resources and creating a sense of community through new job opportunities.

5. CONCLUSIONS

Findings of this research contribute to the understanding of waste upcycling through key findings obtained from the reviewed studies, describing key benefits of upcycling including improved quality and life of material, creating jobs and influencing positive consumer behaviour. It is concluded that the current persistent context of *ad hoc*, *variable*, *champion-based* waste upcycling practices require more targeted mechanisms to mainstream this practice among business enterprises. The authors' thematic findings have been distilled into

an emergent framework on barriers, enablers and opportunities for waste upcycling. This framework concisely presents the macro, meso and micro level barriers faced by business enterprises. Furthermore, it shows how in successfully addressing these barriers and amplifying the enablers would enable business enterprises to achieve sustainable outcomes. 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.

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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