Exploring Barriers and Drivers to the Implementation of Circular Economy Practices in the Mining Industry

Abstract

The circular economy is a widely discussed topic in the field of Eco-industrial initiatives and environmentally responsive economies. The current economic and industrial model which is termed as the produce-use-dispose model is a linear model in which the resources are lost forever after their utilization; a waste of resources as well as money. In addition to economic impact, it creates immense pressure on the environment while disposing of the waste products. For this reason, scholars are trying to find an effective solution to this problem by ensuring the re-utilization of resources. The economic concept of the circular economy ensures the recycling and utilization of resources and closes the resource loop. In a world of reducing and often scarce natural resources, the recycling and utilization of resources increase the opportunities for economic growth– this is especially important given the rising demand for natural resources in emerging economies – exacerbated by the low-carbon transition. This study encompasses these ideas and explores the barriers, drivers and triggers of the circular economy transition for the mining industry. In this paper, authors review several circular economy initiatives taken by mining industries. The paper aims to demonstrate some common themes across three big mining companies with the help of content analysis; and evaluates the identified barriers, drivers and triggers of these circular economy initiatives. The authors argue that the mining industry might capitalize on the learning of other industries in relation to CE, enabling timely advancement of circular economy initiatives.

Keywords: Circular economy, Mining industry, Extraction industry, Barriers of circular economy, Drivers of circular economy

1. Introduction

Whilst globalisation gives both a larger market and increased competition, the companies' supply chains have become more complex and critical than before (Sheffi, 2018). The rate of worldwide consumption has increased eight times over several decades, and it is expected that the resource use globally will increase three times more until 2050 (Lucas, 2014) – with much of this increase occurring in emerging economies. The effect of population growth, and the subsequent increase in consumption challenges the environment, overall society, and the depletion of scarce resources. Global factors such as the transition to a low-carbon economy will be a key factor for increasing the demand for various resources – especially mineral resources such as steel, aluminium and lithium. Much of this demand is going to arise in emerging economies with over 70% of new renewable energy capacity projected to be built in non-OECD countries in 2050 under a scenario that takes the world to 2 degrees of warming by the end of the century (IEA, 2017).

The resource consumption of the linear model follows the take-make-consume-dispose pattern. Companies are facing a range of challenges such as global competition, raising awareness regarding environmental issues, and global business warfare. In addition, limited resources are also causing a vulnerable situation for these companies. Companies operating multiple business sectors have to rethink and design their business model to ensure it is responsive to these challenges. In this context, the concept of the circular economy can support the economic players to face the challenges and ensure economic growth (Lambert *et al*., 2001; Drohomeretski *et al.*, 2014; Sajan and Sridharan, 2015; Vijayvargy *et al*., 2017; Baz *et al.,* 2018). The link between circular economy and policy & technology issues have been explored and gaining popularity as an area of research (Mangla *et al*., 2018; Kazancoglu et al., 2020; Upadhyay *et al.,* 2021a; Upadhyay *et al*., 2021b).

Therefore, the concept of the circular economy is quite clear: It looks beyond the typical produce-use-waste concept and shifts to the recycle model (Terziovski, and Samson, 2009). That is why; it ensures economic growth and provides a solution to 'resource crunch' by facilitating re-using and re-consumption that is imperative for economic excellence (Ghisellini et al., 2016; Upadhyay et al, 2020). At the same time, the circular economy also ensures socio-economic and environmental excellence through the re-consumption of resources and reducing the decomposition of waste products in the environment (Andrews, 2015). Circular economy minimizes the utilization of intact resources by reducing loops of resources and reconnects them with range nodes (Lieder and Rashid 2016; Witjes and Lozano, 2016). However, the focus of the circular economy is to establish a recycle-production-use industry so that the waste products can be transformed into usable products (Park et al. 2010; Tukker 2013; Urbinati et al. 2017; Jakhar et al., 2019). The circular economy is a widely discussed topic in the field of eco-industrial initiatives and environmentally responsive economies. Research has shown that Circular Business Models are strategically linked with other management areas (Kumar et al., 2016; Wang et al., 2017; Govindan and Soleimani, 2017; Upadhyay et al., 2019 Jaeger and Upadhyay, 2020).

On a more business model focused study, sharing economy, a system that facilitates exchange between individuals or organizations with the aim of increasing efficiency and optimization of the under-utilized resources is among the emerging business models (Munoz and Kohen, 2017; Upadhyay, 2020). In essence, their research reveals some of the business models that adopt a sharing platform, and those included the crowd-base tech model which facilitates a high level of peer-to-peer interactions and matching offers and requirements; collaborative consumption which heavily depends on the underutilized resources and maximizing their utilization; Business crowd models that include spreading the cost of equipment over several organizations to maximize its productivity; and spaced-based sharing models that deal more with physical space sharing and use of equipment minimizing the cost to all users and maximizing value for the space owner (Munoz and Kohen, 2017; Kumar et al, 2019).

Mining is a crucial part of the economies and societies of many countries around the world, with mineral rents contributing 0.5% of global GDP (World Bank, 2020), and between 4 and 7% of greenhouse gas emissions (Delevingne et al, 2020). In many emerging economies the importance of the mining sector is bigger with mineral rents in Brazil almost four times the global average, with South Africa higher still and Chile twenty-three times higher. In developing countries, the importance of this sector is even higher with mineral rents accounting for 29% in Mongolia and 22% in Eritrea (World Bank, 2020).

Whilst a global shift to a circular economy would seem to invalidate the need for such an industry, in fact, this is not necessarily the case (as discussed in the section below). Given this scale of economic importance, and environmental damage, understanding the role that the sector can play in transitioning the world to a circular economy, and how the concepts associated with circular economy can be adopted within the sector, is vital in helping to facilitate a low-carbon transition across the world. A first step in this process is to understand the extent to which circular economy concepts have been acknowledged, adopted and communicated by large-scale mining firms. This would allow an understanding of how far these concepts have permeated, and where barriers and opportunities may exist for deepening understanding and implementation of the concepts. This paper undertakes such an exercise via an examination of the sustainability reports of major mining firms for signs of explicit or implicit acknowledgement and adoption of the concepts and processes relating to the circular economy. The analysis highlights that there is little explicit acknowledgement amongst these firms, although this has started to change in recent years. There has, however, been greater acknowledgement and adoption of some of the underlying processes behind the circular economy, such as recycling, both in communication and in practice. This implies that steps forward have been made in transitioning the mining sector towards a circular economy, especially regarding the underlying concepts, although more progress is required.

Section 2 examines the literature that examines the future role of the mining industry within a low-carbon economy, and a circular economy. Section 3 outlines the methods and results of a content analysis of the sustainability reports of large-scale mining companies focusing on concepts associated with the circular economy. Section 4 discusses performance data from large mining companies relevant to the circular economy. Section 5 discusses key findings and conclusions.

2. Future demand for mining from the low-carbon economy

The future energy system is predicted to be radically different from the one in place around the world today. Recent reports by the Intergovernmental Panel on Climate Change (IPCC) and the (International Energy Agency) IEA (IPCC, 2018; IEA, 2017) state that in order to mitigate against the impacts of climate change a radically different low-carbon economy must be created within the next 30 years. The transition will require the deployment of a huge range of infrastructure, capital equipment and machinery across a range of sectors – often fundamentally different from existing technologies. For example, by 2040 the IEA predicts that a total of over 3,000 Giga Watts (GW) of wind turbines and 3,400 GW of solar PV panels need to be installed to keep temperature rises at under 2^{o}C, increasing from 563 GW and 486 GW in 2018 respectively (IRENA, 2019).

Wind turbines, electric vehicles, solar panels and distributed transmission grids require different, and crucially more, metals and minerals (such as Neodymium, Indium, Lithium and Cobalt) than the fossil-fuel based technologies that they replace. There is emerging literature examining the future demand requirements of the low-carbon transition. The World Bank (2017) projects future rates of growth for a range of metals from energy technologies up to 2050, highlighting especially large increases in metals such as Lithium, Aluminium, Copper and Manganese. This work builds on previous work (Moss, 2013) that highlights the criticality of a range of minerals for the low-carbon transition. In a more recent study Tokimatsu et al (2017), used a cost-minimising energy model to highlight that there was a potential cause for concern about metal requirements and availability for the deployment of Solar PV, Nuclear and Electric Vehicles. In a similar study, Deetman et al (2018) focused on the demand for five metals: copper, tantalum, neodymium, cobalt and lithium in electricity production, cars and electronic appliances. They used a metal content estimate along with a dynamic stock model to show that total demand for copper, neodymium and tantalum could increase by 2 to 3 times by 2050, while lithium and cobalt demand could increase by 20 to 30 times.

These large scale increases in final demand for minerals needs to be considered in the context of uncertainty over the scale of unexploited resources for some of these minerals. For example, Sverdrup et al, (2017) use an integrated WORLD and Hubbert's model to assess the future supply for a range of metals, highlighting that demand for most metals is predicted to peak within the next 40 years, especially for copper, zinc and nickel – all crucial to the low-carbon transition. Mudd & Jowitt (2018) on the other hand present a more optimistic picture for reserves, highlighting strong growth in the known mineral resources – discussing that the key factors governing the availability of resources are social, environmental and economic rather than geological or physical resource depletion. This view is supported by Rotzer & Schmidt (2018) who discuss that declining ore grades that are sometimes seen as an indicator of resource exhaustion, should be read as the result of increasing demand and improved extraction technology-implying increased profitability for lower ore grades.

What is less controversial is the negative social and environmental impacts of mineral extraction, whether through large-scale mining or artisanal and small-scale mining (ASM). Large-scale mining can contribute to deforestation, directly and indirectly (Sonter et al, 2017), water pollution (Liu et al, 2019), turbidity

(Rudorff et al, 2018; Jones et al, 2019), local air pollution (Serbula et al, 2017) and loss of biodiversity (Sonter et al, 2018). ASM has also been associated with impacts on tropical forests (Dezécache et al 2017; Kalamandeen et al, 2018) and water pollution (especially through its use of mercury) (Lobo, et al 2016; Esdaile & Chalker, 2018; Afrifa et al 2018). Social impacts include crime (James & Smith, 2017), and prostitution (Kolala & Bwalya Umar, 2019).

Given these issues, there may be environmental and social advantages to move beyond primary extraction towards increasing rates of recycling and re-use – and moving production systems to closed-loop systems. There are, however, significant difficulties and limitations to moving fully to a model whereby mineral extraction is redundant (Fellner et al, 2017). Two key areas of challenge exist: availability of suitable material; and the inappropriateness of recycled material for some particular applications.

The lack of availability of suitable material can serve as a key challenge to the adoption of a fully circular economy in the case where demand for new metals, minerals or materials outstrips the availability of the same materials at the end-of-life. This is the case when demand is increasing rapidly, as is likely to be the case with a range of metals involved in the low-carbon transition (as discussed above). This issue has been highlighted as a key issue in Fellner et al, (2017) and Buchner et al (2017). In the latter paper, the authors examine a particular case study of Austria, focusing on aluminium. The paper highlights that the country would be dependent on imports of scrap aluminium to meet the demand for secondary production.

The issue can be further highlighted by examining two current recycling rates: end-of-life recycling (EOL) and Recycled Content (RC). The first of these gives the percentage of metals that are recovered and recycled at the end of their life. If all metals are recovered and recycled, then this would be 100%. Recycled content refers to how much-recycled material occurs in new products. If all of the new products come from recycled material (a fully closed-loop system) then this rate would be 100%. If all material in new products comes from primary extraction the rates would be 0%.

There is little data that shows consistent global estimates for these two rates across a range of metals. The most important piece of work in this area was conducted in 2011 and separately published as a report and a journal article (UNEP, 2011; Graedel et al, 2011). Data for a selected group of metals is shown in Table1. This data highlights two key features of current recycling data – first that end-of-life recycling rates vary massively both across metals, but also across different uses for metals. This is because different products are recycled at different levels of efficiency, and at different rates across the world, and also because the nature and structure of some products mean that it is, at least economically, impractical to recycle the metals involved in the product. The second feature highlighted is that recycled content rates are dramatically lower than end-of-life rates, across the board, due in part, to increases in demand outstripping the availability of scrap material to be input into recycling processes. Even if recycling could improve whereby all material was captured at the end of its life and EOL rates go to 100%, if demand rates keep increasing, and the ratio of end-of-life to recycled content rates remains the same, there would still be demand for materials from primary production, i.e., extraction via mining.

Table1: Selected end-of-life and recycled content recycling rates (Source: UNEP, 2011)

Metal	**End-of-life recycling rates**	**Recycled content rates**
Iron	52-90	28-52
Nickel	57-63	29-41
Aluminium	42-70	34-36
Zinc	19-60	18-27
Lead	52-95	51-63
Silver	30-97	20-32
Gold	15-96	29-31

This effect is exacerbated by the inappropriateness of using recycled material in some applications. For example, a major future source of demand for Cobalt stems from its use in Lithium-ion batteries, predicted to be a major player in the moves to electric vehicles. However, the Cobalt used in such batteries needs to be extremely pure – and extracting such purity of metals from a stream of mixed metals that arises from recycling processes is extremely expensive (Bomgardner & Scott, 2018). This limits the use of recycled cobalt in such technologies. The more that such a phenomenon occurs across established or emerging technologies then the harder it will be to move fully away from mineral extraction to a fully closed-loop economy.

The interaction of mining and the circular economy has been examined by a small, but growing set of literature. Applying CE principles to the mine-level was examined by Lèbre et al, (2017) who developed a framework for conserving non-renewable resources within mining activity. Zhao et al, (2012), in an early paper on the topic, examined an example of the coal mining industry to discuss the establishment of a circular economy system at an enterprise level. Liu et al, (2019) examined a similar question regarding the circular economy in the Chinese coal mining industry, but from an empirical perspective. The business opportunities from embracing circular economy concepts within the mining industry were examined in Kinnunen & Kaksonen (2019) – with a focus on increasing the value from tailings in the industry. A similar theme of creating value and reducing the liability from mining waste through the embracing of circular economy concepts were examined by Tayebi-Khorami et al, (2019). Careddu (2019) has examined the potential for embracing circular economy concepts within the stone mining sector. The business advantages of first-mover advantage to Brazilian firms using metallic natural resources were discussed in Jabbour et al (2020) – highlighting the opportunities, challenges and barriers for the theory and practice of operations management for the sharing economy. Although this emerging literature has started to examine some of the key concepts linking mining and the circular economy, what is lacking is an assessment of how far and fast these concepts are being adopted by the key global players within the mining sector – a key focus of this paper.

Any progression towards circular economy including recycle and reuse within the mining sector is likely to continue to minimise its environmental footprint, whether related to greenhouse gas emissions, water or other forms of waste – and moving toward circular economy contexts and closed-loop solutions, in at least part of the production processes, such as the use of water. In this context understanding how far and fast the mining sector has embraced the overall concept and the details of the circular economy. The remainder of the paper sets out to examine this question through content analysis and analysis of data from mining companies.

3. Content Analysis

To understand the extent to which circular-economy or closed-loop thinking has permeated the mining industry, a content analysis of the Sustainability Reports of three major mining companies was undertaken. Sustainability Reports have become a mainstream tool of major mining companies to outline their commitment and approach to various forms of sustainable development and environmental management, as well as a vehicle for communicating data on the firm’s performance outside financial metrics. For those major mining companies that are members of the International Council on Mining and Metals (ICMM) there are guidelines in place for the nature, form, structure and contents of Sustainability Reports (ICMM, 2010). They have become a useful tool in the literature to analyse companies, countries and industries approaches to sustainable development (e.g. Huang & Wang, 2010; Roca & Searcy, 2012; Boiral, 2013; Landrum & Ohsowski, 2018; Laing et al, 2019). The purpose of these reports was outlined by ICMM, (2010) as:

"A sustainability report should provide a balanced and reasonable representation of the sustainability performance of a reporting organization – including both positive and negative contributions."[1]

Three major mining companies were selected for the content analysis: Anglo-American (AA), BHP Billiton (BHP) and Rio Tinto (RT). These three companies represent three of the five biggest mining companies by revenue in the world, they are also diversified across products and countries and therefore represent a snapshot of the large-scale mining industry. It should be noted that the mining industry is highly diversified and therefore findings from this analysis cannot be applied to medium or small-scale components of the industry.

AA is a multinational company, headquartered in the UK and South Africa. It has operations across all continents and is the world's largest producer of platinum. It also produces copper, diamonds, coal, iron ore and nickel. It has over 64,000 employees. It currently has 67 active operations across developed countries, emerging economies and the developing world with the majority in Southern Africa but also operations in Brazil. It had a total revenue of over US$31 billion in 2019.[2]

BHP is a British-Australian company headquartered in Melbourne. It is the world's largest mining company, and at times has been Australia's largest by revenue. It is a major producer of coal, copper, iron ore, petroleum and potash. It has 23 major operating sites producing minerals worldwide with a large number of operations in South Africa, but also Brazil and Chile. It has revenues of over US$36 billion in 2019 with a workforce of approximately 72,000.

RT is a British-Australian company with headquarters in London and Melbourne. It is one of the world's major producers of aluminium, iron ore, copper, uranium, coal and diamonds. It is also involved in the refining of bauxite and iron ore. It has over 45 operations worldwide, with the majority in Australia but also operations in Brazil and South Africa, with over 45,000 employees. It has revenue of over US$40 billion in 2018 with profits of almost US$5 billion.

Content analysis is a methodological technique that emerged from communication research – it draws on symbolic qualities of data to make inference regarding the behaviour of the object of study, whether individuals, firms or groups (Krippendorf, 1989). The technique has been defined as "a technique for objective, systematic and quantitative description of the manifest content of communication" (Berelson, 1952). Content analysis may be either conceptual or relational. The former identifies the existence and frequency of concepts in a text; while the latter examines the relations among concepts in a text. This analysis follows the former approach that was also adopted in Metaxas & Tsavdardou (2013) in a paper on a similar theme.

Content analysis has been used to analyse a number of different questions in relation to the mining industry including the implementation of corporate sustainability activities via analysis of sustainability reports (Fuisz-Kehrbach, 2015), the implementation of the triple bottom line (Laing et al, 2019) and the effectiveness of mining engineering programs (Kansake et al, 2019). It has also been used to examine the reliability of social and environmental disclosures of companies (Milne & Adler, 1999), and the corporate and social responsibility in the metallurgy sector in Greece (Metaxas & Tsavdaridou, 2013).

Conceptual content analysis was used to examine the sustainability reports for the three firms for instances of two features: the Circular Economy and the related concept of recycling which forms a crucial role in any move to a circular economy but is more likely to be mainstream to the sustainability

[1] ICMM (2010) pp. 7
[2] Data from: https://www.angloamerican.com/investors/financial-results-centre/key-financial-information

of mining companies. These two features were identified to help understand two aspects of the acknowledgement and adoption of the principles of circular economy by large mining companies. The first feature was chosen to identify the explicit adoption of the concept of circular economy. The second feature represents an implicit adoption of some of the key features of a move towards a circular economy – such as recycling. Two key hypotheses underpin the analysis. The first is that full acknowledgement of the need to move towards a circular economy will be characterised by explicit use of the term. Earlier acceptance of the need to move to a circular economy would be characterised by mere implicit adoption of the concept. It is anticipated that implicit adoption would be a precursor to explicit acknowledgement of the concept.

The content analysis followed a two-stage process. The first stage was a word-count of the sustainability reports conducted for two terms: the first was 'circular' – representing the circular economy – and the explicit acknowledgement of the concept. Although there was a chance the term could be used in other contexts this was deemed to be unlikely. The second term searched for was 'recycl' – this was used to capture the use of recycle or recycling in the Reports and the implicit adoption of practices related to the circular economy.

Reports from 2014 onwards were searched for these two terms – for AA and RT this represented five reports, whilst for BHP the 2019 report was also available and thus there were six observations. The results of the analysis are shown in Table 2 and 3.

The second stage of the content analysis involved delving into the particular uses of the terms to put their use into context.

Table 2: Instances of the term 'circular' in Sustainability Reports

	AA	RT	BHP
2019			0
2018	2	1	0
2017	0	0	0
2016	1	0	0
2015	0	0	0
2014	0	0	0

Table 3: Instances of the term 'recycl' in Sustainability Reports

	AA	RT	BHP
2019	NA	NA	8
2018	14	12	3
2017	18	7	4
2016	17	9	7
2015	11	14	4
2014	13	25	9

Table 2 shows that across the three companies the term circular was used just four times, and none at all before 2016. The lack of use of the term before 2016 reflects the overall trend in the use of circular economy – for example, the peak use of the search term 'circular economy' in Google over the last five years occurred in February 2020, with the level of search activity prior to 2016 at a third or a quarter of that level.[3]

The lack of the term in the Reports can be read as the lack of attention, recognition and policies within these three companies relating to the circular economy. Indeed, the term has not been used in any of the BHP reports.

AA's 2018 report did spell out that the company was moving towards embracing the concept highlighting that:

"We are, for example, introducing 'circular economy' thinking. The circular economy is regenerative and restorative by design: durable goods are able to be repaired (rather than replaced) and biological materials returned to the biosphere without being contaminated. Our aim is to have the lowest possible impact on human health and the environment."[4]

This highlights that although there are no other mentions of the term circular outside this statement there has been some movement towards the acknowledgement of the concept by the company.

Rio Tinto also uses the term in their 2018 report highlighting that:

"We believe there are three key elements to consider in the transition [to a low-carbon economy]*: – A shift away from fossil fuels and desire for higher energy efficiencies – Increased electrification of transportation and industrial processes – A stronger focus on material reuse and recycling, i.e., the circular economy"*[5]

This was the only reference to the circular economy in the whole report – and again highlights that, similar to AA, there has been an acknowledgement of the concept, but limited use of the term beyond that.

In contrast, the term 'recycl' – either in reference to recycle or recycling occurred much more frequently throughout the reports – although there is no trend of increasing use of the term in any of the three companies' reports. In fact, the highest use of the term in RT reports occurred in 2014, whilst for AA it happened in 2017. The prevalence of the term in the BHP reports was markedly lower than in the other two companies.

Across the three companies, there were similarities and differences in how the terms were used. Across all companies, the focus was on the use of recycled water in their production process. AA also focused on detailed specifics of other components, such as tyre recycling and an aim to achieve zero waste to landfill. BHP used the term mainly to express overall aims including:

"BHP encourages the responsible design, use, reuse, recycling and disposal of our products throughout our value chain, in line with the ICMM Sustainable Development Framework."[6]

RT tended to use the term to address individual issues relating to water, or mineral waste. For example, in their 2018 report they discuss:

"Our main types of waste are mineral waste such as waste rock, slag and tailings, and non-mineral waste such as used oil and office waste. It is not always possible to reuse or recycle waste, so we build

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[3] Data from Google Trends, available at: https://trends.google.com/trends/explore?date=today%205-y&q=circular%20economy

[4] AA (2018) pp.42

[5] RT (2018) pp.56

[6] BHP (2019) pp.16

facilities to manage it in ways that minimise adverse environmental and community impact, disposal costs and future liabilities"[7]

The analysis highlights that there has been very limited explicit adoption of the concept of the circular economy amongst large-scale mining firms. Only limited mention has been made of the term in the companies' sustainability reports, and there is no indication that the term has become mainstream in the vernacular of the industry. However, there is greater use of the terms and concepts associated with the implicit adoption and acknowledgement of some of the processes underlying the move to a circular economy, such as recycling. This highlights that potentially the concepts underlying the circular economy concept are being adopted at an operational level within these mining companies, but the broad explicit concept has not yet made it into mainstream communications or the boardroom. To examine this idea further, in the next section data underlying these processes emerging from the companies has been examined.

4. Data analysis

The second stage of analysis undertaken to understand how far issues of the circular economy and recycling have pervaded, not just the narrative of mining companies, but also their actions, involved the analysis of data on processes themselves emanating from the sustainability reports. The focus in this component was whether implicit adoption of practices relating to the circular economy can be observed in actions by the companies. In order to understand this process reported data from the Sustainability Reports on issues of recycling were extracted.

For AA, reported data was on hazardous and non-hazardous waste to landfill (Figure 1). The aim here would be to reduce such waste, either through waste reduction efforts or through efficiency in production – both vital components of the move to a circular economy. Over the last five years, there has been no discernible downward trend in the hazardous waste heading to landfill. However, there is a general downward trend in non-hazardous waste – especially from the peak in 2015.

BHP report data on water recycling and re-use – matching their overall priority in the use of recycling in their Sustainability Reports in figure 2. The company's use of recycled and reused water has increased 55% in the last five years, representing a major increase in the adoption of some of the key concepts of the circular economy within one of the key business processes.

[7] RT (2018) pp. 20

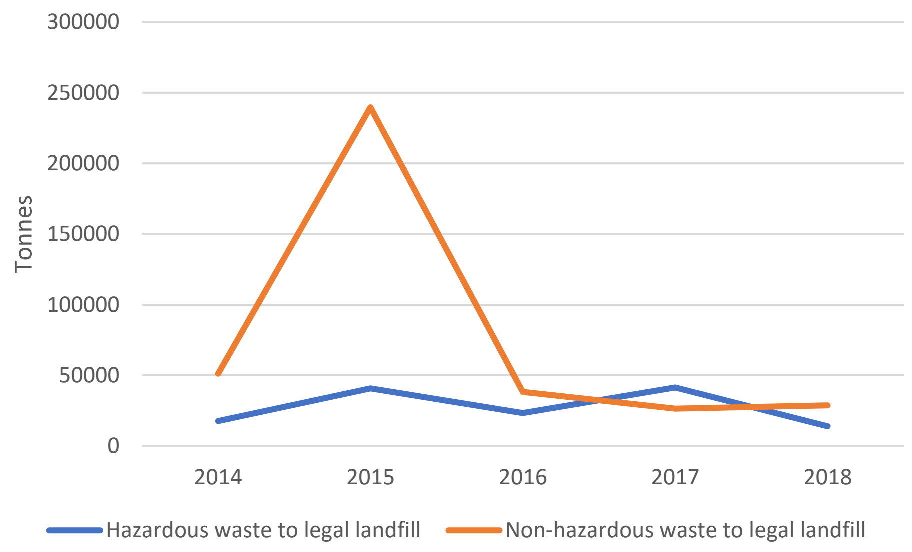

Figure 1: AA reported hazardous and non-hazardous waste to legal landfill Source: AA (2018)

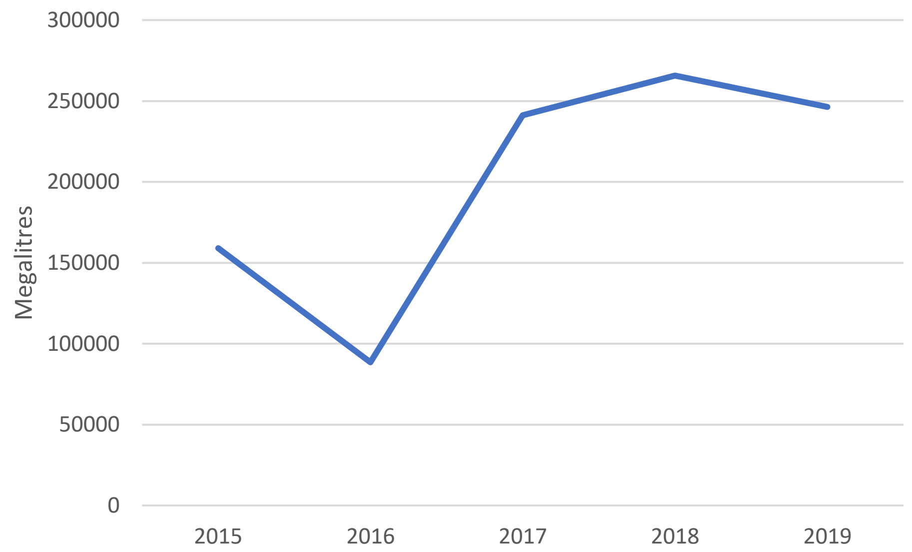

Figure 2: BHP Recycled and re-used water Source: BHP (2019)

The results of this analysis highlight a number of crucial findings that highlight the scale to which implicit adoption of the underlying processes behind a move to a circular economy has been adopted by large-scale mining companies. The first thing to note is that reporting of some of the key data underlying moves to a circular economy is being undertaken by large-scale mining firms, but this is not being done in a consistent fashion. Reporting on recycling of waste and water is happening; both crucial aspects of the adoption of circular economy practices in the mining industry. However, data from the companies fail to show any clear trend that these practices are resulting in higher levels of recycling, and reductions in waste. This highlights that although identification of the practices that underline a move to a circular economy may be becoming more mainstream in the mining industry, actually increasing these practices has not yet occurred on a large scale.

5. Discussion and Conclusion

In this research, the authors have explored barriers, drivers and triggers in the mining industry towards its transition to circular economy. The mining industry is one of the core industries in the primary sector. The method of extraction of minerals and processing has a huge impact on circular initiatives in the mining industry. This paper has examined the extent to which the explicit and implicit concepts that underpin the move to a circular economy have permeated large multi-national mining firms. Through content analysis of sustainability reports the paper has highlighted that explicit adoption of the term has been extremely limited, and while implicit mention of related processes such as recycling are present, there is less evidence that these processes have increased in either communication or practice.

The mining industry is perhaps one of the most challenging areas for CE because of the need for 'purity' in the materials that are extracted. There are many opportunities for further research into 'drivers' for change in processes and exploration of the 'triggers' that might encourage change. The emerging concern for global warming, phasing out of petrol and diesel cars/transport and lack of landfill availability may lead to potential changes in legislation for the mining industry that could help trigger moves towards the circular economy.

This is a crucial area for emerging economies because many of these countries, including Brazil, Chile, China and South Africa are on both sides of the coin – with relatively large economic dependence on mining and the extractive industries – but also demanding the products of the industry due to rapid investments in infrastructure and especially for the low-carbon transition. Moves towards CE in mining therefore have important economic and environmental implications for the mining industries in these countries – but could also impact on the industrial sectors and businesses demanding the minerals in these countries. Understanding the extent to which it is occurring, therefore, has important implications for environmental management, and also industrial policy across emerging economies.

Urban mining is an intriguing and interesting concept which is emerging nowadays. This urban mining concept should be structured within a circular economy model. Urban and Landfill mining is also another area of mining which should be explored in a circular economy model. Urban mining extends landfill mining to the process of reclaiming compounds and elements from any kind of anthropogenic emissions (Baccini and Brunner, 2012; Lederer et al., 2014). Urban mining has generally arisen in developed countries, such as Japan and understanding its potential and any barriers and challenges in emerging economies is an interesting area for future research.

The circular economy concept is still in its early stages in the mining industry as it is with most primary sectors. This research involved data from a small subset of large multinational mining firms involving publically reported information. A key limitation of this approach is, therefore, it represents the public image that these firms want to display. Generalisation of the findings of this work should, therefore, be made with caution, but it does open up avenues for future research to delve further into the question of how far and fast the concepts of the circular economy have been embraced by the mining industry, large and small, with a particular focus on adoption of the technologies and processes needed for the industry to move to a circular economy. The mining sector has a crucial role to play in the transition to a low-carbon economy, and embracing the move to a circular economy can help to reduce the negative impacts of its activities.

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