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Mining as a temporary land use: A global stocktake of post-mining transitions and repurposing

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ABSTRACT

Post-mining land use and associated economies have become a priority issue in mine lifecycle planning amongst many major companies. Ensuring the post-mining landscape is returned to a safe and stable condition is usually the first order priority in mine closure, though achieving this is often a challenge. The drive for industry to do more than rehabilitation is also growing. One of the many drivers for this expectation is the scale of mines, with many mining leases occupying thousands of hectares. Some of this land may be used for other purposes with relatively little intervention. For the mine footprint itself, it is often not possible or feasible to return the landscape to the prior condition, although creative repurposing of mine features and elements of mine infrastructure may be an option. At the same time, these large-scale mines employ hundreds, sometimes thousands of people and consideration of economic transitions for mining workforces, notably local dependant populations, is increasingly expected of industry post closure, as employment is often positioned at the "heart" of development. In this article, we reframe mining as a temporary land use. This approach positions post-mining land use as intrinsic to the mine lifecycle, including the planning and operational phases. We developed a global database of repurposing cases building on the S&P Global Market Intelligence database, relevant literature and other publicly available information. We provide an overview of the findings and the themes to emerge from this global repurposing database of 141 cases. Our findings include: our general observations on the research process; an analysis of the most common repurposing land uses; factors influencing repurposing, including factors internal and external to the company; initial observations about industry approaches to repurposing. Finally, we argue that reconceptualising mine 'closure' and the associated mining legacies is an essential operational shift the extractives industry, notably the major companies, will need to make to keep pace with societal and local community expectation.

1. Introduction

Post-mining land use and associated economies have become a priority issue in mine lifecycle planning for many major operators. Ensuring the post-mining landscape is returned to a safe and stable condition is usually the first order priority in mine closure, though achieving this is a challenge in many contexts (Laurence 2006; Limpitlaw and Briel 2014). The drive for industry to do more than bio-physical rehabilitation is also growing (Fordham et al., Blackwell; Owen and Kemp 2018; Zvarivadza 2018). One of the many drivers for this expectation is the scale of mines, with many mining leases occupying thousands of hectares (Werner et al., 2020). Some of this land may be used for other purposes with relatively little intervention. For the mine footprint itself, it is often not possible or feasible to return the landscape to the prior condition, although creative repurposing of mine features and elements of mine infrastructure may be an option (Pearman 2009). At the same time, these large-scale mines employ hundreds, sometimes thousands, of people and consideration of "economic transitions" (Bainton and Holcombe 2018) for mining workforces, notably local dependant populations, is increasingly expected of industry post closure, as employment is often positioned at the "heart" of development (Betcherman and Rama 2017).

There has been a convergence between the establishment of mine closure regulations from the 1970s to the 1990s in many jurisdictions globally and the development of major industrial scale mines that will subsequently need to follow these closure requirements. Applying innovative approaches to such large-scale closures offers opportunity for industry to leave positive legacies. Indeed, the term "repurposing", as

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used in this paper, is a relatively recent addition to this mining lexicon. However, we recognise that large-scale mining rarely changes the geography of the mine-impacted areas in ways that make these places more attractive to alternative forms of economic development in the future (Mitchell and O'Neill 2016). This is notably the case in mining regions where there are cumulative industrial scale impacts over vast areas (Kretschmann 2020; Kirsch 2014).

The topicality of this issue is evident with several recent initiatives. These include the ICMM's recent revision of the *Integrated Mine Closure: Good Practice Guide*, which now incorporates a "screening tool" for repurposing activities and advocates incorporating sustainable development considerations (e.g. environment, economic, and social impacts) into mine closure planning from the outset of mine development (ICMM 2019). Likewise, the 2019 mine closure conference (in Perth, Western Australia), had for the first time, a specific workshop session on Repurposing, entitled "Reimagine. Repurpose. Relinquish." with over 35 workshop participants from across the world. Also in Western Australia, a *Framework for Developing Mine Site Completion Criteria* has been developed (Young et al., 2019). Though its focus is the environmental aspects of closure there is one mention of repurposing, which suggests the nascence of addressing the social aspects of mine closure in Australia.[1]

Corporate attention to the topic is also beginning to be reflected in the structure of mining companies and corporate policies. One major global mining company has renamed their operations that have ceased production as "assets" rather than "legacies". Presumably this is to encourage a similarly entrepreneurial approach to their management, as for operational assets (Keenan 2020). Another major company has reframed community engagement planning and programming related to closure as "social transition". We view these changes as the mining industry taking on increasing responsibility for the social impacts of mine closure, reflecting societal and, in some jurisdictions, regulatory expectations. Given the tendency for mining companies to avoid closure responsibilities and externalise social risks, or to develop mine-closure plans with an incomplete understanding of the real costs of closure (Bainton and Holcombe 2018), this incremental shift is positive. As we discuss in this article though, there are few examples of mining companies leading successful transitions to alternative economies by repurposing and re-imagining the post-mining landscape.

We developed a global database of repurposing cases building on the Standard and Poors (S&P) Global Market Intelligence database, relevant literature and other publicly available information. This article provides an overview of the findings and the themes which emerged from this global repurposing database of 141 cases. Our findings include: our general observations on the research process; an analysis of the most common repurposing land uses; factors influencing repurposing, including factors internal and external to the company; initial observations about industry approaches to repurposing. Finally, we argue that reconceptualising mine 'closure' and the associated mining legacies is an essential operational shift the extractives industry, notably the major companies, will need to make to keep pace with societal and local community expectation.

1.1. Method

This paper condenses some of the key findings and ideas from a larger project report from the Social Aspects of Mine Closure Research Consortium (https://www.mineclosure.net/) of the Sustainable Minerals Institute's Centre for Social Responsibility in Mining, at The University of Queensland. The aim of the project was to provide an overview of the 'state of play' of post-mining transitions, and identify future research and policy directions that encompass a breadth of options for repurposed mining landscapes, infrastructure and economic linkages. We were able to document 141 cases in total in the repurposing database.

Our initial selection of cases gave us a quantitative indication of the scale of this task. The S&P Global Market Intelligence Platform is a database of global mining industry activities. It includes data on over 35,000 mining properties globally, and enables analysis by data categories including country, company, development stage and commodity. We began with this platform as it is the largest general database of mining properties that we had access to. We selected all cases in the S&P database with a 'development stage' of 'closed'. This returned around 1800 records. Within this set, a further category – 'activity status' - indicated the last activity recorded at each operation. The significant majority of cases (1719) were 'inactive', 21 were in 'care and maintenance' and 49 were in 'rehabilitation, while other categories included 'under litigation'. One operation was categorised as 'relinquished'. Of note, regions such as the Middle East, Africa and parts of Europe have very little coverage in the S&P database. Approximately 73% of the S&P sample are from ten countries, with the significant majority from the USA, followed by China, Australia, Canada and South Africa. Aa result, this limitation skews the dataset toward particular regions.

As large as the S&P database is, it is not complete and tends to focus on mines in development or operation. So in addition to researching the S&P cases, we also drew on existing grey and academic literature to locate further examples. These included the iconic *101 Things to do with a Hole in the Ground* (Pearman, 2009). However, very few of examples in this book were industry-led transitioning or re-purposing. Rather, they were led by governments, civil society groups or small businesses. We also referred to the annual International Mine Closure Conference papers and its published proceedings (led by the Australian Centre for Geomechanics, Perth). Though this conference focuses on the environmental or physical aspects of rehabilitation, there are a small proportion of papers by industry and consultants of case studies of closed operations that have transitioned via forms of repurposing. We also examined government initiatives, including the National Coalfields Program which established the Coalfields Regeneration Trust in the UK, and Abandoned mines programs in Australia, including Qld and most recently WA (2016), amongst other sources. amongst the academic literature on post-mining land uses, we were able to find a number of case studies of particular mines (e.g. Berthelot et al., 2019; Chaloping-March 2017), or regions (e.g. Kivinen, 2017), where repurposing has been attempted. There is also a small segment of the literature incorporating socio-economic, and environmental perspectives into mine closure and post-mining land use planning (e.g. Everingham et al., 2018; Limpitlaw and Briel 2014; McCullough et al., 2020).

As this was a scoping project, we were constrained by timing and resourcing in the number of cases we could identify. We aimed for a sampling coverage from the major regions of the world, attempting to find around 20 cases per region. For some regions, we struggled to find any cases, while in others we limited ourselves to 20.

1.2. Organising the data

In developing the repurposing database we realised that repurposing often occurs after or alongside other activities in the closure process. We established four 'transition categories' as the first order of activity. The first three categories refer to post-closure repurposing activity, and the fourth refers to repurposing initiated during the operations phase.

[1] As the Framework indicates: "While the most common PMLU [post-mining land-use] for Western Australian mines is to revert to pre-mining land use, such selection should be based on a thorough examination of all possible options. Alternative post-mining land uses should not be ruled out, as it may achieve a beneficial outcome for the key stakeholders in some circumstances. Where the opportunity presents, mining companies may also consider repurposing the use of the land for other beneficial uses if the legislation allows and relevant stakeholders and regulators agree (Young et al 2019: 16).

The transition categories are:

1. Rehabilitation and remediation
2. Regeneration and reclamation
3. Repurposing

} post closure

Co-purposing } during operation

We acknowledge that, to some extent, our allocation of each operation within these particular categories was subjective, and based on secondary data. Nevertheless, given the available information about each operation, we have attempted to be consistent in the application of these categories to particular operations. In this section, we define each category, and discuss their use in the database. The Australian Government's Mine Rehabilitation guide (DITR 2016b), part of the "Leading Practice Sustainable Development Program for the Mining Industry", was used as a basis for defining our terms as explained below.

1.2.1. Rehabilitation and remediation

This category is used for the technical environmental aspects of closure (i.e. dealing with acid mine drainage, soil contamination) to ensure a stable, non-polluting environment. This environmental clean-up is usually necessary before safe human and flora/fauna activity can be reinstated and as a result may be the most immediate and obligatory activity.

Rehabilitation: The return of disturbed land to a stable, productive and self-sustaining condition, after taking into account beneficial uses of the site and surrounding land. Reinstatement of degrees of ecosystem structure and function where restoration is not the aspiration.

Remediation: often referring to abandoned mine sites, remediation aims to return sites to a physically and chemically stable state. This includes undertaking corrective actions to reduce environmental contamination to acceptable regulation-based standards.

1.2.2. Regeneration and reclamation

This category mostly refers to processes of restoration of ecosystems that have been degraded, without the need for active decontamination of the environment. Such sites include some strip mining and quarries, or other components of a mine site including roads and building sites.

Regeneration: Re-establishment of ecosystem structure and function to an image of its prior near-natural state or replication to a desired reference ecosystem.

Reclamation: Reclamation focusses on returning land and/or infrastructure to a state where economic, environmental or human uses are possible.

1.2.3. Repurposing

Repurposing: Repurposing utilises elements of the existing mining infrastructure (i.e. roads, mine housing, operational buildings) and/or the reconfigured aspects of the landscape (i.e. mine voids and mine features) for a different activity post closure. This activity may purposefully assist in transitioning the local economy. It may also mitigate the loss of the mine by building on and/or establishing new forms of attachment to the site and region (Chaloping-March 2017). One of the first two categories above are usually necessary to achieve before repurposing, but not always.

In our database, we found 85 cases of repurposing following on from another transition type (60.28%), and 48 cases of direct repurposing (34.04%). We note the limitations of the secondary data we accessed and thus some of these cases of direct repurposing may have required forms of mitigation before re-use.

1.2.4. Co-purposing

Co-purposing: Co-purposing consists of developing a beneficial activity on a site where operations or management relating to the primary business is on-going. We included examples of concurrent or progressive reclamation of a closed area of an on-going operation that also demonstrate additional beneficial transitions beyond rehabilitation. The practices we found look beyond closure to engage with possible post-mining land uses and demonstrate a commitment to community benefit. We found eight co-purposing cases (5.67%).

1.2.5. Multiple uses

As we found more examples (from the range of sources discussed earlier), it became obvious that when a mine site is repurposed, there is often more than one land use. To ensure that our database could capture this detail and diversity, we developed a typology of land-use categories and sub-categories ('activities'). In developing our typology we have taken inspiration from two sources in particular. These are the recent "Framework for Developing Mine-Site Completion Criteria in WA" (Young et al., 2019)[2] and an academic article on "Mined Land Suitability Analysis and Post-Mining Land Uses" (Soltanmohammadi et al., 2009). These two sources both provide an overarching framework for assessing the possibilities that each site presents for different kinds of post-mining land uses. These sources are based on established land use frameworks, The FAO's (Food and Agriculture Organization of the United Nations) Framework for Land Evaluation for Soltanmohammadi et al. (2009), and Australian Land Use and Management classification for Young et al. (2019). Specifically, we used the land-use category plus land-use activity structure of Soltanmohammadi et al. to enable us to group post-mining land uses under broad land-use categories (e.g. agriculture, conservation, education and research), and sub-category indicating the specific activity within the broader category (e.g. arable land/cropping, pasture or hay-land, nursery, food production/subsistence, aquaculture are the land-use activities under the land-use category of agriculture). As our search for repurposed sites progressed and we entered new items into our database, we expanded and refined the categories and activities. Our final classification categories are presented in the Appendix.

We realised that it was possible for mine sites to be re-used for more than one purpose, so we allowed for up to three levels of classification in the database. We named these primary, secondary and tertiary land-use categories and activities, although it was not always clear if there was a difference in scale or importance from the data available. In cases where this was not obvious, we reflected the order of mention from our sources. Our judgements about categorisation were somewhat subjective, given that there is some overlap in categories and we were only able to work from available information, which was often very minimal. We separately entered site data into our database, and then reviewed each other's entries to try to improve the reliability of our categorisations. We came to consensus decisions on the few instances of divergence.

Allowing for more than one categorisation led to one of the key findings. This is that mine sites were very often re-used for more than one purpose, indicating that though the previous mining land-use may have been singular, post-mining transitions are not. As can be seen in Table 1, we identified 313 different activities at the 141 repurposing sites in our database, an average of 2.22 uses per case. Perhaps the most important feature to note about the repurposing land-use categories in these three tables is that the post-mining land uses address a singular purpose in only 25.53% of our sample ($N = 36$).

Table 1
Concurrent activities.

One land use only	Two land uses	Three+ land uses
36 cases (25.53%)	38 cases (26.95%)	67 cases (47.52%)

[2] Available from https://www.dmp.wa.gov.au/Documents/Environment/Framework_developing_mine-site_completion_criteria_WA.pdf

2. Results

In this section, we discuss some of the findings from the data-set. We discuss our general observations on the research process and the most common repurposing land uses we found.

2.1. General observations on the research process and findings

Overall, we observed that there were very few examples of repurposing relative to the number of closed mines. We know that there are thousands of closed mines globally – beyond the 1804 captured by the S&P database – yet we were only able to find information approximately 141 operations that had progressed to a form of repurposing (including co-purposing). Our time was limited, yet we found it difficult to even find this many examples. We found very little to no information available about (recently) closed mines generally. Most mining company websites we visited contained little to no information about mines that had closed and thus activities that are being, or have been, undertaken to manage closure. Most information about rehabilitation related to ongoing or concurrent activities. There were a handful of mentions of successful relinquishment.[3]

Comparatively, abandoned and historical mines seem to have greater research, historical, and interest group documentation. Government websites occasionally had information about closed and abandoned mines, but rarely included detailed information. The little information available about repurposing from company websites reflects a focus on rehabilitation over repurposing, but also that barriers to repurposing exist (either imaginative or practical). Where we did find examples of repurposing, we nonetheless found it difficult to access detailed information about the social, regulatory, financial etc. processes that enabled repurposing. Nevertheless, we understand that there are industry initiatives, such as the North American Mine Closure Working Group (NAMCWC) established in 2014 to "share learnings and best practices in closure, reclamation or remediation of our mines, smelters and refineries…and [to] promote thought leadership/innovation in closure and repurposing/co-purposing of mining properties".[4]

Historically there has been an ad-hoc approach to mine closure and repurposing. Indeed, mine closure regulations are a relatively recent requirement in many jurisdictions, including Australia (Kabir et al., 2015; Campbell et al., 2017) and Canada (Hiyate 2018), and as indicated by the vast numbers of abandoned mines both in Australia (Unger 2017), and Canada for instance (Cowan et al., 2010).

There are a variety of innovative and successful examples of repurposing post-closure, but these appear to be relatively isolated. With the exception of government initiatives in Germany, the UK, the Czech Republic and China (on a regional scale), we found that repurposing of mine sites is uncommon. Thus, many of the examples of environmental and, consequently economic, rehabilitation are in mining regions and many of these address historic or legacy issues when mines closed prior to regulations. Nevertheless, there are important lessons to be learnt from these regional scale approaches that also deal with cumulative impacts and economic transitions.

Though we inserted an Indigenous peoples' category in the repurposing database, this category was rarely able to be populated. There are a handful of operations, predominantly from Canada and Australia, where we found data indicating that closure processes actively engaged Indigenous interests. These include the Wesfarmers Collieburn coal mines in Western Australia. This company engaged with the local Ngalang Boodja Aboriginal Council to establish an enterprise using the mine-pit lakes (ABC Rural News 2014). Meaningful engagement with Indigenous Peoples around repurposing is clearly a gap in available data, and likely also in the majority of practice. Given the importance of long-term connections to land for Indigenous Peoples and associated livelihoods, they should be centred in any engagement about mine transitions.

2.2. Repurposing land uses

In this section, we explore some of the most common repurposed land uses. We also discuss the land uses that make significant contributions to sustainable development. As broad categories, the most common repurposed land uses in our database are shown in Table 2.

The most common category of repurposing was 'community and culture'. This category includes: cultural/historical precincts, reclamation art, museums or exhibitions of mining/industrial history, and community event spaces. This form of repurposing emerged 76 times in our sample. An important element of this form of repurposing is reconfiguring mining infrastructure as cultural heritage. However, this was not usually led by industry, and tends to relate to abandoned mines and/or historical sites. Though we found exceptions to this.

The next most predominant repurposing practice we found was 'conservation and eco-system services' at 63 occurrences. This category encompasses wildlife habitat, native woodlands, carbon offset and sequestration, and wetlands. Sites that were rehabilitated back to their prior state, only as woodlands or native habitat for instance, were not included.

'Non-intensive recreation' is the third most predominant category of land use with 51 occurrences. This category encompasses park and open green space, public/botanical gardens, paths for walking, hiking, running, cycling and horse-riding and eco-tourism. Of note, is that the categories of 'conservation and eco-system services' and 'non-intensive recreation', together make-up more than one third of the total in terms of primary re-purposing categories and often co-occur.

While a lot of mining occurs in remote/regional areas, of the 141 repurposing cases, we found that 94 (66.67%) of them were less than 50 km from a community or township. Within this range, 33 (23.40%) of the repurposing cases are within 10 km or less of a township with 50,000 or fewer residents and 65 cases (46.10%) are within 20 km of a township. So in other words, most of the cases of repurposing are near people and townships.

2.3. Regional comparisons of repurposing

A brief discussion of regional comparisons highlights the global diversity of approaches to repurposing. We provide an overview of the key patterns and themes to emerge from the cases that we located from the

Table 2
Repurposed land use by category.

Land-use categories	Number of cases
Community & culture	76
Conservation & eco-system services	63
Non-intensive recreation	51
Education & Research	32
Construction	20
Intensive recreation	19
Lake or pool	16
Agriculture	14
Light industrial	12
Alternative health	6
Forestry	4
Grand Total	313

[3] These include Glencore's new Wallsend coal mine in NSW, two operations in WA: BHPs Beenup titanium mine and the Rio Tinto subsidiary Norgold Bottle Creek gold mine, multiple cases in the Czech Republic (coal and lignite), the Petangis mine in Indonesia and the Momino mine in Bulgaria.

[4] Unpublished - NAMCWG Repurposing/Co-purposing Guidance – Consolidated Draft, 11 March 2019.

jurisdictions.

Latin America	According to the S&P data base there are 153 "closed", "inactive" and "rehabilitation" mines in this region. Of the 15 mines from this region we followed up from the S&P database, the Pearman (2009) text and on-line searches we could only find three cases that have been industry-led repurposing.
USA	The S&P database has 590 properties listed in the "closed" and "inactive" categories in the USA, while six of these are listed as in "rehabilitation", and several are in "care and maintenance". Of the 20 possible cases we investigated 14 were industry led, while of these we included three cases of concurrent reclamation.
Canada	For this jurisdiction the S&P database has 112 properties listed as closed, with the vast majority listed as "inactive", only four are listed as "rehabilitation". These four were followed up, with one of them being a case of repurposing. We found 12 cases of repurposing and co-purposing in this jurisdiction, half of which were by industry. All of the cases we found were from long life mines, from over 100 years old to the 1970s.
Australia and New Zealand	As the jurisdictions with the most readily accessible information to us, we anticipated finding a greater number of examples for this jurisdiction, than for others. This was not the case. We located a total of 17 sites, two of these being in New Zealand.
Europe	There are large numbers of closed mines in Europe. Several countries – particularly former coal producing countries - have undertaken regional or national programs of rehabilitation and repurposing, particularly in relation to preserving industrial heritage.
China	Although the S&P database contains 198 "closed" properties in China, we found it difficult to access information about repurposing beyond one national initiative and one commercial case. Most of the cases included in the database came from the National Mine Park program which transformed former mines into tourism destinations.
Japan	Only eight properties are listed in the S&P database. There are a variety of uses for the repurposed sites, including: conservation, with eco-tourism and educational facilities; amusement parks and sports venues; and high tech scientific research laboratories, primarily for physics research.
Indonesia	In the case of Indonesia, where we were able to identify eight cases, there is a clear process for companies to follow in order to achieve lease relinquishment, generally including transfer back to the local government. Food production appears to be a priority.
The rest of Asia, the Pacific, Africa, Russia and the Middle East	For the rest of the world, we were not as successful at identifying repurposing cases. We found three cases in South Africa, three in Thailand and one in Taiwan. We attribute this result to a combination of limiting factors including: language, public documentation, research time, and familiarity with the regions. Further, mining in many of these regions has only recently opened up to major international or publicly listed mining companies, or are in jurisdictions with limited regulatory capacity.

3. Discussion

3.1. Influencing factors

Based on the cases we found, we were able develop a set of factors that influence whether repurposing occurs, both external and internal to the company. We also make some initial observations about industry approaches to repurposing. Because our main interest in the scoping study was to influence future industry-led and/or funded repurposing, the factors that enable or inhibit repurposing are relevant to the analysis and the observations we made are drawn from our data (though also see ICMM 2019).

External factors

The first of the external factors is the *location* of the operation, which importantly includes the proximity of the mine to communities and towns (Keith 2017). If it was a long life mine it is likely to have changed over the life of operation as both the mine and the town footprint and thus its population, expands. Likewise, over generations attachment of residents to towns (though 'closed') may hold residents who champion repurposing and economic transitions. The location of the site to existing infrastructure, such as roads, railways, energy networks and thus readily being able to plug into connectivity was also found to be important. Likewise, the ecological value of the mine location, in regional context, and its potential to add to eco-system services, habitat and associated community values (Liesch, 2016). Finally, the type of land zoning and the tenure may either hinder, or assist, in re-developing and re-imagining the site.

In broad terms, the second external factor is the potential *economic viability* of the transition to a re-purposed site. These economic factors will include local supply and demand issues, if the aim is a commercial venture (Avango and Rosqvist 2020). While a constellation of inter-related repurposing projects that synergise with each other are more likely to be economically effective. There are also examples of extractive industry companies diversifying into alternative energy resource projects, or commercial & residential real estate. The Pilbara Regional Investment Blueprint is an emerging example of a regional framework for a more structured and co-ordinated approach to mine closure and repurposing (Murphy et al., 2019).

Internal factors

The first of three internal factors to the industry/companies we identified are their *stakeholder & community engagement* practices. These include whether the company has a 'beyond the gate' approach to local/regional stakeholder engagement. By this term we mean whether the company has policies and procedures to ensure that they look beyond the purely operational and technical factors that occur within the mining lease to the social impacts of the operation. An inclusive approach to community engagement through life of mine, including during concurrent or progressive reclamation, will more likely lead to positive post-mining land-use transitions. Likewise, we found innovative approaches include establishing foundations and trusts for local communities to develop their own local ventures and development initiatives.

Though we have not analysed the policies and standards of every company that has successfully engaged in repurposing or co-purposing, we note that where such guidance and leadership exists, the internal structures in place may assist in establishing a business case for repurposing. Such standards, as noted amongst the major companies that are engaging in repurposing (also at legacy sites), include Closure Standards that specifically address beneficial post-mining land uses and consideration of subsequent economic activities, conservation or community use (e.g. Rosa et al., 2018).

Another internal factor and trend we noted in successful repurposing was the continuity of the company and the operation. Many of the examples we found of industry led repurposing were of mining companies with long life mines and established attachments with the local region. These included small locally based operations and family businesses (notably quarries) with local commitment and community attachment

invested in beneficial land-use transitions.

3.2. Industry approaches

While our research is exploratory, we are able to make some initial observations about existing approaches to repurposing from industry. These include, that there are very few examples of industry-led and/or funded repurposing relative to the number of mines in post-production. They are limited to 12 countries in our dataset (and that we could locate information about in the time available). They include the US, Australia, Indonesia, Canada, South Africa, Thailand, Brazil, New Zealand, China, Honduras, Japan and France, totalling 47 cases (33.33%).

Themes to have emerged from industry approaches to repurposing include:

- Economic diversification beyond a singular industry (and commodity) has become an interest of industry, communities and governments. Transitioning away from the production of carbon energy resources to renewable and sustainable alternatives is linked in many cases to energy transitions, as a global issue.
- Association between long life mines and industry investment in post-mining land use and economic transitions. There appears to be a link between a mining company 'putting down roots' as part of its investment in a long life mine and also taking an interest in and responsibility for post-mining land use and economic transitions on closure. Of the 47 cases where we could find firm evidence of industry led repurposing, approximately 23 cases were from long life mines (48.94%). Though this may not appear as a strong correlation, there was, interestingly, more on-line information available about these sites.
- Approaches that recognise the cumulative impacts of mine regions/mine clusters. The majority of regional scale repurposing is led by the state and there is now a considerable repository of research on the drivers behind these initiatives and the mechanisms behind the best practice examples. It seems that without state intervention in terms of policy development and financial support, establishing socio-economic transitions in post-mining regions is very challenging.
- Out-reach for input and innovation. There is an example of a company reaching out to communities and educational groups for input into potential repurposing options. Freeport-McMoRan's Henderson Mine has collaborated with the Colorado School of Mines to hold a student challenge to: 'Develop a concept for sustainable repurposing of the Henderson Mine surface facilities and land holdings that provides a socioeconomic benefit to the surrounding communities, is economically sustainable, socially acceptable and provides a positive and lasting legacy in the state of Colorado.'
- Community partnerships and concurrent rehabilitation. Some companies have established community partnerships to develop shared goals in education and conservation in reclamation projects. Community partnership panels are one avenue for integrating post-mining land use with rehabilitation outcomes. Creating land uses that coincide with community sustainability objectives and the potential uses for reclaimed land.

3.3. Lessons from non-industry-led repurposing

More than half of the cases we found were not industry led and/or industry funded. Nonetheless, these cases provide useful and relevant lessons for the industry on the key ingredients for successful post-mining land-use regeneration and economic rehabilitation. Our findings are congruent with Pearman's (2009) key ingredientsand include: leadership, vision and commitment; local solutions to fit local circumstances (hence the essential need to consult locally); creative partnerships for funding, development and implementation (coalitions of NGOs and community groups); collaboration with diverse interests and expertise; and community involvement and consultation at all stages, developing shared responsibility and ownership.

3.4. Regional approaches to environmental and socio-economic transitions

The repurposing database includes examples of regional environmental and, consequently economic, rehabilitation. Regional approaches can address historic or legacy issues, particularly for regions where mines closed prior to closure regulations. There are many regional examples, including: the coal districts of the Ruhr valley, Germany (Regionalverband Ruhr 2020); the China Clay pits of Cornwall, UK (Eden Project 2020); the Limburg region, the Netherlands (ICLEI 2020); and Appalachian coal country (Comp 2013), US.

One example of an innovative practice that is regional in scale is the concept of "community greenways", which appears to have emerged in British Columbia, Canada. This approach recognizes the "interconnected corridors linking human development and natural systems" (Backhouse 2012). A key component of the concept is the "integration of mine sites and working landscapes that acknowledge the importance of resource extraction activities and incorporate these requirements within a comprehensive plan for sustained environmental and recreational networks".

This concept was applied to the repurposing of at least five abandoned coal mines. Engaging this approach can assist with long term site management, as Backhouse states:

> *Perhaps counter intuitively the development of a post use plan that incorporates recreational access and environmental protections can assist over the medium and longer term by encouraging casual surveillance by recreational users. Recreational amenities developed as part of a greenway plan are frequently undertaken with the support and contribution of recreational user groups and environmental organisations. The contribution is significant for the obvious initial benefit of lowering implementation costs…building…public support for the greenway experience which in turn leads to a high level of reporting of incidental damage or vandalism (2012: 766).*

3.5. Abandoned mines and mining regions: lessons from state-led repurposing

Though we actively sought examples of repurposing by industry post mine closure, approximately 15 of the examples in our database relate to abandoned mines (10.64%) and we have included them in the study as they offer lessons for industry, government and civil society. Some developed states have established abandoned mines programs, e.g. the UK's Homes and Community Agency National Coalfield Programme (2010) where there is a regional approach to transformation and economic rehabilitation.

In Australia, several states have abandoned mines policies, including Western Australia (WA) and Queensland (Qld). Two northern Canadian abandoned mines programs, the CLEANS (Clean-up of Abandoned Northern Sites in Northern Saskatchewan) and a research program, led by Arn Keeling and John Sandlos, (funded by the Canadian Social Science and Humanities Research Council) both marry environmental science with community volunteerism, and also environmental science with Indigenous Ecological Knowledge (see Sandlos and Keeling 2016).

3.6. Remediation and restoration: Coupling the science with the social

Some leading edge cases of repurposing by the state and public/private coalitions couple the science with the social, such that effective post-mining transitions and repurposing also take into account the politics and social dimensions of landscape repair. Recent Canadian research (Sandlos and Keeling 2016; Beckett and Keeling 2019), in particular, has focused attention on the ways in which remediation has

been the sole remit of the technocratic sciences to the exclusion of the communities of people who will be taking over custodianship of the landscape. Reimagining and reclaiming these processes enables ecological restoration to be understood in terms of how communities can create or recover economic, cultural and social value through the processes of healing environmental damage (Jones and MacLean, 2013). Examples of this approach include the state led remediation followed by public/private partnerships of the abandoned Britannia Mine and associated infrastructure of in British Columbia, Canada (see also O'Hara et al., 2010). Restoration has the potential to foster a new sense of place, as we found in all of the 15 examples of legacy and abandoned mines that we identified, and that have been remediated and repurposed near townships.

4. Practices that may adversely impact on sustainable transitions and repurposing

The following reflections have surfaced during the research for this project, as practices that may either hinder or assist in repurposing options.

4.1. Progressive (or concurrent) rehabilitation

Concurrent or progressive rehabilitation has become a standard practice during the life of mine in many developed states.[5] Though there are benefits to the environment in rehabilitation over the life of mine, as well as benefits for the company in spreading out the cost of the rehabilitation, in this context of post-mining transitions, the implications of this practice need to be considered. Questions to consider include, whether this on-going activity precludes community and stakeholder engagement in post-mine planning, or is the progressive rehabilitation part of the closure plan agreed to with the community and other stakeholders? Another issue might be if progressive rehabilitation potentially impacts on, or limits, creative final land use options.

On the other hand, concurrent reclamation *can* contribute to post-mining land-use planning. In our database we have included four examples of concurrent rehabilitation (three from the US and one from Australia) that also demonstrate engagement with possible post-mining land uses, and subsequently they could be regarded as examples of co-purposing See Freeport McMoRan, 2014). These good practice examples illustrate how inactive areas of long-life mines can be rehabilitated at the same time as consideration is given to land-use transitions. The three examples from the US offer multiple transition pathways through community partnerships and outreach.

4.2. Industry factors: on-selling, minerals sector volatility

Our findings suggest that the practice of major company's on-selling no longer productive mines to smaller companies that do not have either the financial resources or the social performance capabilities to effectively take on reclamation and repurposing may be one of the reasons for the lack of industry funded examples. For instance, in relation to the industry-led repurposing cases we found evidence of in Australia, they were all by major companies. If junior companies are repurposing, then they are rarely publicising it online and we acknowledge that this may be a limitation.

Conversely, we found several examples from major companies (Newmont and Rio Tinto) who, in the process of asset acquisition, have acquired legacy sites which they are developing plans to repurpose or have repurposed (respectively Woodcutters in the Northern Territory and Auzat in France (Rio Tinto, 2019)). So in these cases on-selling to major companies can be a positive outcome for post-mining land-use transitions. So that there are suggestions that it may be more beneficial for closure if a major company picks it up who has social performance standards that incorporate sustainability standards (which might include Closure and Reclamation standard and a Community Investment and Development standard).

In contrast, there are several examples of nationalisation of the mining industry. These have occurred in regions where mining has wound down due to government policy, exhaustion of reserves or economic issues. State control of multiple mining properties has underpinned regional-level programs such as the Emscher IBA in Germany (Open-IBA n.d.) and the National Coalfields Programme in the UK (Homes and Community Agency National Coalfield Programme 2010).

4.3. Economic rehabilitation

In the context of post-mining land use and repurposing, the concept of 'economic rehabilitation' is a useful and evocative one. However, we note that it has two possible definitions. Perhaps the most dominant definition in the applied mining context associates 'economic rehabilitation' with re-mining previously uneconomic tailings, often due to the advent of new technologies or changes in commodity price.[6] As a form of transition to a smaller scale local mining economy, economic rehabilitation associated with re-mining may use existing employees or skills. It may be pursued by the original company in on-selling the assets to a smaller company, as this also reduces liabilities for the on-selling company. Though there may be obvious short term benefits for both the on-selling company, the employee base and the local area, in the context of considering post-mining land-use transitions there are also risks with this form of transition.

One risk is that this form of economic rehabilitation is short term or finite (as the previous mining was). This asset on-selling also potentially increases the post-mining risks for the local community and the region as the, usually, smaller company will likely have less CSR investment in the region. And, as local community benefit agreements and mine closure plans were negotiated and implemented with the original company, there may be less corporate commitment to, and investment in, ensuring these commitments are fulfilled. The re-mining will also likely have a significantly shorter lifespan than the previous mine.

While we recognise that re-mining is a form of transition, we have not included examples of this activity in the scoping review. Instead, we focus on non-mining forms of economic rehabilitation. Some examples entail economic diversification of, not only the local community or region, but also of the mining company as they innovate and pursue new forms of investment away from non-renewable extractives and into developing alternative energy sources, notably the case with thermal coal.

[5] For instance, the Australian Government *Mine Closure: Leading Practice Sustainable Development Program for the Mining Industry* (DITR 2016a: 21) states: 'Undertaking progressive rehabilitation before closure can help to reduce liability while providing increased certainty that a sustainable rehabilitation prescription exists. The business case for progressive rehabilitation is multi-faceted, with tangible and intangible aspects. Tangible benefits include decreased financial assurance, compliance with regulatory requirements and more accurate costing for sustainable rehabilitation in closure provisioning. Intangible benefits include those related to timelines and project approvals, when sustainable rehabilitation can be demonstrated and an ongoing social licence to operate demonstrates to external stakeholders that mining can be a valued, responsible and transient land use'.

[6] For instance, the Queensland-based company, Raging Bull, established Century Bull (taking over the Century mine – now known as New Century) to reprocess tailings from remnant mineralisation (zinc-bearing tailings), using existing infrastructure while progressively rehabilitating sites to generate ongoing economic contribution. Available at https://www.i-q.net.au/main/century-bull-reveals-strategy-to-revive-zinc-operation

5. Conclusion

As we noted at the outset of this paper, mining is a temporary activity, though its impacts on the surrounding lands, ecosystems and communities may be irreversible. With this being the case, we acknowledge the increasing focus on repurposing and post-mining land use by industry, governments and civil society as a positive progression, with the potential to contribute to sustainable development beyond current levels. While recent practice has focussed on returning mine sites to their previous or original condition, this is often unrealistic and repurposing focusses on the continuing beneficial use of the land – ideally for local and regional users. The examples in our database, though only an initial exercise, show a wide range of activities with various benefits. Additionally, our database showed a range of potential processes and institutional actors involved in the process of repurposing, and raises a number of questions for future research and debate.

The snapshot of repurposing and co-purposing activities by industry and non-industry groups provided by this article and our database is, to our knowledge, the first global study of repurposed mine sites. Unlike previous theoretical studies of potential post-mining land uses, this study has provided empirical data of repurposing that has actually taken place. Though as a desktop scoping exercise, this research was limited by the extent of the publically available data we could access in the time available, it has still provided us with a starting point for engaging with a range of stakeholders about this emerging area of practice, and insights into some of the dynamics that warrant further investigation. We acknowledge though, that our work contains gaps and inconclusive data.

Our research succeeds in demonstrating that there are a range of potential opportunities for repurposing mine leases and infrastructure. The land-uses and activities we categorised showed post-mining activities which can contribute to mitigating the impact of mining and maximising sustainable development in diverse ways. Environmental and eco-system focussed projects sought to redress (some of) the environmental impact of mining. We found several examples of significant ecological restoration which were parlayed into community assets via transfer to government authorities or community organisations for their perpetual management, and community use as learning spaces or community infrastructure such as recreation areas. Conversion from private to public land and enduring protection of these spaces counters the trend of globally diminishing green space, and can play a role in protecting and conserving native ecosystems.

Economic repurposing projects are of increasing interest to mining companies who see these types of projects as opportunities to reduce their closure liabilities by earning income on otherwise cost generating land. Economic repurposing projects which support local employment are seen as a social risk mitigation measure as well, by smoothing the impacts of mine closure. Repurposing projects are unlikely to completely replace the mining economy, however, and a range of factors will influence the level of community engagement in the new activities (e.g. project design, ownership, transferrable skills, length of project) (Akbar et al., 2021). Further research could investigate the economic, social and environmental impact of repurposing projects, and the factors that enabled or limited the impact.

Contextualising mining as a temporary land use, in effect, reframes the way that we should understand mining legacies, including responsibilities to local communities and to sustainable development. If repurposing is to become mainstreamed, both corporate policies and government regulation come into frame. Questions still remain about whose priorities for land use should be given precedence. For example, should the option for repurposing be open to the private sector, the company or the local communities' decision? What land uses should be preferred – options that contribute to sustainable development, economic benefit or company benefit (e.g. to reduce liability or improve reputation)?) Where do Indigenous custodians stand in this process?

Further, there are currently barriers to repurposing. The major one being that supportive government policy does not exist across the board to allow multiple or non-mining use of mining leases. Institutional infrastructure and ongoing governance also present challenges, for example, dealing with ongoing liabilities for contaminated sites. Our study found several examples of mechanisms for community management (e.g. by local government, collectives, perpetual trusts, and Indigenous organisations) which deserve further investigation for their advantages and disadvantages.

Corporate thinking about life of mine planning will also need to change if the possibilities of repurposing are to be mainstreamed. Currently most companies manage mine closure by developing mine closure plans from the outset of project design, updating them with increasingly detailed concepts and plans as the mine progresses, in consultation with regulators and impacted stakeholders. As some companies have begun to do, potential for repurposing should be considered in these plans so that co-/re-purposing opportunities can be identified, repurposing projects can begin without lag or, at the least, options for repurposing are not ruled out. Like other mine planning decisions that could impact human rights or sustainable development, due diligence processes should be applied to repurposing opportunities, and examined from the perspective of all relevant stakeholder groups.

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Declaration of Competing Interest

None

Appendix

Land-use classification categories and land-use activities

Land-use category	Land-use activities
Agriculture	Arable farmland/cropping Pasture or hay-land Nursery Food production/subsistence

(*continued on next page*)

(*continued*)

Land-use category	Land-use activities
	Aquaculture
Forestry	Lumber production
Lake or pool	Sailing, swimming &/ fishing pond
	Town water supply
	Flood protection
Intensive recreation	Sports field
	Ski field
	Amusement park
	Racetrack
Non-intensive recreation	Park & open green space
	Public/botanical garden
	Paths for walking, hiking, running, cycling &/ horse-riding
	Eco-tourism
Community & culture	Cultural/historical precinct
	Reclamation art
	Museum or exhibition of mining/industrial history
	Community events space
Construction	Commercial real estate (i.e. shopping centre, business park, hotel, data centre, casino)
	Housing estate
	Airport
Light industrial	Factory
	Military/Defence
	Recycling & repurposing of decommissioned materials
	Alternative energy
Education & research	Rehabilitation research and education
	Research facility
	Education facility
	School outreach
Alternative health	Therapy
	Medicinal
Conservation & eco-system services	Wildlife habitat
	Native woodlands
	Carbon offset & sequestration
	Wetlands

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