Mine Closure 2024 – AB Fourie, M Tibbett & G Boggs (eds)

doi:10.36487/ACG_repo/2415_09

Integrating the Sustainable Development Goals into post-mining land use selection

Gareth B Simpson [a,*], Kim Ferguson [b], Neeltje Slingerland [b], Raina Hattingh [c]

[a] *WSP, Australia*

[b] *WSP, Canada*

[c] *Whitehaven Coal, Australia*

Abstract

Active mines regularly commit to post-mining land uses (PMLUs) several decades before their planned closure. Considering the mounting global challenges of water, energy, food, livelihood securities, and climate change, many of these PMLUs may now – in 2024 – be sub-optimal. Whether new land uses are being defined or existing land uses are being refined, options for PMLUs should be selected using various planning lenses. In this paper, three of these lenses are considered to demonstrate how post-mining landscapes could contribute to addressing complex global challenges through effective mine closure transitions. These lenses are:

1. *safe, stable, and non-polluting*
2. *suitable, practicable, and aligned with land capability and local/regional needs*
3. *integration of the Sustainable Development Goals (SDGs) and the water-energy-food (WEF) nexus.*

This approach is presented as a proposed conceptual framework, demonstrating how the SDGs could be utilised as a lens for selecting PMLUs – and which of these PMLUs are aligned with addressing water, energy, food and/or livelihood security and climate change mitigation. Selected case studies are highlighted, whereafter, policy recommendations are made.

Keywords: *mine closure, post-mining land use, Sustainable Development Goals, framework, policy*

1 Introduction

Mining has unlocked countless contradictions. It has yielded the fuel and materials that enabled the Industrial Revolution. Yet the processes and the use of many of the products emanating from mining – principally carbon-based fuels – have contributed towards another revolution: Global warming and the associated climate crisis. Mining is both an enabler of energy supply and energy-hungry itself (Ti Tree BioEnergy n.d.).

However, mining remains essential to our everyday life; it has been said that 'if you can't grow it, you have to mine it' (World Economic Forum 2022). Our reliance on mined materials is endless, from gravel for roads to phosphates for fertilisers, copper for telecommunication, and iron for infrastructural development. Like other modern mobile devices, iPhones have at least 30 different chemical elements, from common to rare earth metals (Frank 2023). This reliance is predicted to increase as we generate more lithium batteries, electric cars, solar panels, and wind turbines. Furthermore, mining operations often serve as the economic backbone of communities, particularly in remote or developing regions. Mining activities generate stable incomes and create business opportunities – including primary, secondary, and tertiary industries – thus enhancing local, regional, and national prosperity (Ali 2024). Since mining is a temporary land use, dedicated

* Corresponding author. Email address: gareth.simpson@wsp.com

efforts are required to manage and mitigate the potential environmental impacts and socio-economic vacuum that can follow in its wake.

The call for a 'Just Transition' has been widely heralded (Sanya & Konisky 2020; Strambo et al. 2019). The Just Transition framework was developed to secure the livelihoods and rights of workers and their communities in the transition to a low-carbon economy, including those communities impacted by the closing of thermal coal mines. It includes the dual commitment to human wellbeing (concerning income, education and health) and sustainability (vis-à-vis e.g. decarbonisation, resource efficiency, and ecosystem restoration) (Swilling et al. 2015). The Just Transition aligns with the 17 sustainable development goals (SDGs) the United Nations General Assembly adopted in 2015 (United Nations 2024). These goals provide an ambitious, aspirational roadmap to eradicate poverty, reduce inequality, and protect the planet against climate change by 2030 (Fong & Roy 2023).

We argue that when mines close, their post-mining land uses (PMLUs) should, where possible, be aligned with relevant SDGs. In so doing, mine closure and asset transition could contribute to, inter alia, water, energy, food, ecosystem, and livelihood security. To achieve this, we recommend that mine closure policy include the SDGs as a complementary lens for selecting PMLUs in tandem with the safe, stable, non-polluting paradigm and the knowledge base associated with the mine. We recommend this for both mine sites with authorised baseline PMLUs and greenfield developments proposing PMLUs.

1.1 Global sustainability challenges and opportunities

In their seminal work, Meadows et al. (1972) warned almost half a century ago,

> *'If the present growth trends in world population, industrialisation, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years.'*

Some three decades later they stated that:

> *'the human economy is exceeding important limits now and that this overshoot will intensify greatly over the coming decades'* (Meadows et al. 2004).

In 2011, before the release of the SDGs (when the Millenium Goals were the aspirational sustainability target), the water-energy-food (WEF) nexus was proposed as a framework for addressing the synergies and trade-offs of resource security (Simpson & Jewitt 2019). This focus was due to the growth in demand for food, water, and energy by 2030, which were 35, 40, and 50%, respectively (National Intelligence Council 2012). Predictions like these were driven by an increasing global population, urbanisation, and an additional three billion middle-class people by 2030 (WWF & SAB 2014). There was also the dire need to enhance the livelihoods of the 'bottom billion' largely undernourished population without access to electricity, clean water, and safe sanitation.

When the SDGs were released, the target horizon was 2030. By 2023, only 15 % of SDGs were on track due to challenges such as the COVID-19 pandemic, the deteriorating climate crisis, and the war in Ukraine (Fong & Roy 2023). The 2023 Sustainable Development Report stated categorically, 'at the midpoint of the 2030 Agenda, all of the SDGs are seriously off track' (Sachs et al. 2024). The world is facing a conundrum: how to achieve energy security amid a climate crisis in a manner that underpins distributive, recognitional, and procedural justice (Swilling et al. 2015). Simultaneously, land degradation and sustainable land management have been termed 'wicked problems' (Barkemeyer et al. 2015). Van Vuuren et al. (2019) state that if no new policies related to water, energy, food, biodiversity, and climate change are adopted, food production and energy generation could increase by 60 % between 2015 and 2050.

1.2 Mine closure challenges and opportunities

Few mining companies globally have achieved the milestone of a closure certificate (Pikal 2024). In a review of the closure of 800 mines (Laurence 2006), it was found that:

- 25% of the mines closed due to resource exhaustion or depletion
- 24% due to high costs, price drops, or declining grades
- 8% due to open pit resource depletion, but with underground reserves remaining or underground reserves depleted (with plans to open cut the remainder)
- 7% due to receivership or voluntary administration.

A separate study found that approximately 75% of the 1,000 worldwide mine closures between 1981 and 2009 were sudden and premature (Syahrir et al. 2021). EY's 2024 report on the top-ten business risks for mining and metals ranked environmental, social and governance (ESG) as the highest risk, licence to operate at three, and climate change at four (Mitchell 2023).

While mining houses (and consultants!) produce countless rose-coloured, glossy reports on sustainability, many question whether sustainable mining is an oxymoron. Mining occurs in urban, rural, and remote areas, as well as first-world and developing nations. Marginalised communities abound in former mining regions, particularly in the least developed countries (Spiegel & Brown 2017). Mine closure, including rehabilitation and repurposing, has not generally yielded a positive narrative. The thousands of ownerless, abandoned, and unrehabilitated mines globally also speak to a loss of livelihoods and economic activity—there are some 80,000 abandoned mines in Australia alone (Yellishetty & Bach 2023).

There is enormous potential for beneficial use of mining land post-closure to promote sustainable initiatives. In a recent study using the visual interpretation of Sentinel-2 images for 2019, researchers identified that globally over 100,000 km^2 of land is used for mining (Maus et al. 2022). Not only do these sites yield much-coveted land for alternative/substitutive industries, but they typically have many other assets, e.g. access roads, parking, rail loops, high-voltage power supply and distribution, water supplies, infrastructure, engineered platforms/terraces, and a skilled workforce who can be reskilled, up-skilled, side-skilled, or redeployed. It has been argued that 'closure' is the incorrect term to apply to mining assets approaching the end of their economic life. Instead, the process should be viewed as succession planning – a transition of land from one purpose or custodian to the next (Leonida 2021).

2 Post-mining land use selection

Changes in natural resource patterns and functions influence how and what land can be used for. Conversely, the implementation of specific land uses affects the patterns and functions of the remaining natural or rehabilitated resources. As mining converts and modifies natural resources, the maintenance of these altered landscapes significantly impacts the land's capability to continue to provide its pre-mining goods and services (Hattingh 2018). Hence, alternative, practical, and functional uses must be defined for the post-mining landscape as early as possible in the mine life cycle.

While there is no single process for selecting PMLUs, several principles are used in identifying and evaluating land use options (International Council on Mining and Metals [ICMM] 2019). These include:

- legislative frameworks driving localised statutory requirements, including current approval conditions, post-mining ESG conditions, the land surrender process, and transferring/relinquishing land ownership to third parties
- developing an organised, comprehensive knowledge base to inform PMLU selection and then support the PMLU(s) achievement
- the consideration of post-mining land capability and suitability

- early consideration and incorporation of the PMLU into the mine planning process will enable the progressive implementation of the required post-mining land capabilities
- stakeholder engagement that includes, inter alia, Indigenous peoples, government, community organisations, and private land owners
- the consideration of substitutive economies for repurposing the mining site or portions thereof. This can include the release of a public expression of interest to invite third parties to present plans to repurpose portions or the whole of the site
- learning lessons from other mine closure and asset transition success stories—and failures.

2.1 Background

When mining projects are in the approval phase, the submission of a closure plan is often part of the permitting process. This closure plan typically outlines the draft closure vision, objectives, and completion criteria. A proposed, or 'baseline', PMLU is also presented. Once approved, the closure plan becomes a legal contract. Changes to agreed PMLUs are not a straightforward regulatory exercise in many jurisdictions. In a recent case in New South Wales, Australia, the Black Rock Motor Resort — to be developed on the former Rhondda Colliery — took a developer seven years to obtain approval for their proposed alternative PMLU (Cheong & Johnson 2024).

Crucial goals in mine closure include safe, stable, and non-polluting mine sites, the PMLU being suitable, practicable, and aligned with land capability and local/regional needs. Society also increasingly expects mining land to be transferred to new productive uses, which typically requires at least a decade-long planning horizon. The closure and repurposing of mines must, therefore, be incorporated into the mine planning as early as possible—ideally before initiating active mining operations.

2.2 Literature review

Several frameworks have been developed to assist in the complex process of selecting appropriate PMLUs, some of which are identified in Table 1. CRC TiME notes that the roadmap to mine repurposing in many developed economies is time-consuming and potentially influenced by many hurdles (Beer et al. 2022). In their roadmap, for a mine to be repurposed, the site must pass through several gateways; all of which may undermine the viability of the proposed re-use. One challenge with their proposed gateway decision tree is that the requirement to rehabilitate a site seems to preclude repurposing. Rehabilitation and repurposing are, however, not mutually exclusive. It is also important to note that there could be various potential repurposing options at a mine site, given that a specific site may have diverse assets and land uses, e.g. a final void, waste dumps, infrastructure, and rehabilitated opencast areas.

Table 1 Selection of frameworks for post-mining land use decision-making and the factors included

Framework author	Factors included in post-mining land use decision-making
Murphy et al. (2019)	A draft framework to facilitate the repurposing of mine sites in Western Australia has focused on existing mines and mimics the land tenure pathway for irrigated agriculture (LTPIA) process
Soltanmohammadi et al. (2010)	Fifty economic, social, technical, and mine site factors
Arratia-Solar et al. (2022)	Integration of stakeholders' involvement, geographic information system (GIS), multi-criteria decision-making and fuzzy logic
(ICMM 2019)	The collection of information The listing of constraining and facilitating characteristics Developing potential options to consider. Data collection from a diverse array of categories

When considering ecological restoration and the recovery of mine sites, the highest level of ecological recovery possible should be sought (Young et al. 2020). In Queensland, Australia, selecting and justifying appropriate and viable PMLUs is a vital statutory obligation within the regulated progressive rehabilitation and closure plans (PRCP) (Côte et al. 2023). The Office of the Queensland Mine Rehabilitation Commissioner lists potential PMLUs for residual material-filled voids: native ecosystem, grazing, cropping, renewable energy (solar, wind farms, pumped hydro-energy storage, hydrogen), phytomining, protected horticulture, intensive livestock, regenerative cropping, manufacturing, and tourism (Côte et al. 2023). They also list PMLU options for water-filled voids: aquaculture, 'smart' water supply systems, including irrigation, mine-water trading, aquatic ecosystems, and the production of algae, seaweed, biomass, or microalgae. Notwithstanding significant research, many of these potential uses have not been proven as viable options.

The Australian Land Use and Management Classification provides a nationally consistent method to collect and present land use information for various users across Australia (Australian Bureau of Agricultural and Resource Economics and Science 2016). It includes six primary land use classes:

1. conservation and natural environments
2. production from relatively natural environments
3. production from dryland agriculture and plantation
4. production from irrigated agriculture and plantations
5. intensive uses
6. water.

Pershke & Elliott (2019) propose an approach to PMLU selection based on a strategic land use planning process: context analysis, opportunity analysis, opportunity evaluation, strategic plan development, and implementation. They note that the approach can bridge the gap between traditional mine closure planning and regional socio-economic development planning.

Simpson (2019) presented a framework where a nexus within the SDGs serves as a lens for selecting PMLUs. In that framework, a land-water-energy-food-jobs nexus was used to guide the reconsideration of the baseline PMLU. The first step was to review the obligations to confirm, inter alia, the baseline PMLU, which included the knowledge base and land capability, applicable legislation and authorisations, and regional and local strategic development plans and priorities. This review generated the development of a list of potential alternative PMLUs aligned with SDGs 13, 9, and 12. Following a review of the closure vision, principles, and SMART closure objectives and relinquishment criteria, these PMLU options were subject to a sustainability assessment (social, environmental, economic, and technical), whereafter, a risk/opportunity process was undertaken. After the identification of latent risks, the preferred closure alternative was selected based on a set of evaluation criteria.

2.3 Integrating PMLUs and the SDGs

Some may view 'sustainable mining' as an oxymoron. However, an innovative approach to mine closure – including responsible rehabilitation and land or asset repurposing – could help ensure humanity meets its present needs without compromising the ability of future generations to meet their needs. The influence of mining can be sustainable if site-specific, substitutive economies are developed during the mine's operational and closure phases, particularly if they are aligned with the SDGs. To achieve this, extensive stakeholder participation, the mitigation of environmental liabilities, and the identification of third parties are some of the fundamental considerations.

Integrating the SDGs into PMLU selection is aligned with the ICMM's performance expectations, which seek to define best-practice ESG requirements for the mining and metals industry (ICMM 2019). These expectations include integrating sustainable development into corporate strategy and decision-making processes, biodiversity conservation, social performance, and water stewardship.

Table 2 presents examples of how different PMLUs could be aligned to one or more SDGs, although not exhaustively. When using the WEF nexus as an additional lens for identifying PMLUs, SDGs 2, 6, and 7 generally serve as the primary aspirational goals. In Table 3, several case studies are linked to the particular SDGs, demonstrating how they can be integrated into mining operations, processes, and rehabilitated mine sites. The case studies are categorised according to relevant SDGs, although several PMLUs straddle multiple SDGs.

Table 2 Potential post-mining land uses and the sustainable development goals they could address (Simpson et al. 2023)

Sector	Potential post-mining land use	Sustainable Development Goals																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Water	Water treatment		■	■			■								■			■
	Lake		■				■								■	■		■
	Irrigation	■	■	■		■	■		■	■	■	■	■			■		■
Energy	Solar photovoltaic (PV)	■		■	■	■		■	■	■	■	■	■	■				■
	Concentrated solar	■		■	■	■		■	■	■	■	■	■	■				■
	Wind energy	■		■	■	■		■	■	■	■	■	■	■				■
	Bioenergy	■		■	■	■		■	■	■	■	■	■	■		■		■
	Hydropower	■		■	■	■		■	■	■	■	■	■	■				■
	Pumped storage	■		■	■	■		■	■	■	■	■	■	■				■
	Energy vault	■		■	■	■		■	■	■	■	■	■	■				■
	Geothermal	■		■	■	■		■	■	■	■	■	■	■				■
	Compressed air storage	■		■	■	■		■	■	■	■	■	■	■				■
	Wave shaft	■		■	■	■		■	■	■	■	■	■	■				■
	Hydroelectric	■		■	■	■		■	■	■	■	■	■	■				■
	Bioreactor landfill	■		■	■	■		■	■	■	■	■	■	■				■
Agriculture	Livestock	■	■	■	■	■			■		■	■	■			■		■
	Cultivated land, non-irrigated	■	■	■	■	■			■		■	■	■			■		■
	Cultivated land, irrigated with raw water	■	■	■	■	■			■		■	■	■			■		■
	Cultivated land, irrigated with mine water	■	■	■	■	■			■		■	■	■			■		■
	Hydroponics	■	■	■	■	■			■		■	■	■			■		■
	Aquaculture	■	■	■	■	■			■		■	■	■		■	■		■
	Apiculture	■	■	■	■	■			■		■	■	■			■		■
	Game farming	■	■	■	■	■			■		■	■	■			■		■

Sector	Potential post-mining land use	Sustainable Development Goals																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Fresh produce market	■	■	■	■	■			■		■	■	■			■		■
	Essential oils (e.g. lavender)	■	■	■	■	■			■		■	■	■			■		■
Environment	Eco park			■	■	■	■		■	■	■	■		■	■	■		■
Environment	Carbon sequestration	■		■		■					■	■	■	■		■		■
Environment	Biochar	■		■		■					■	■	■	■		■		■
Environment	Planting trees (e.g. spekbome)	■		■		■					■	■	■	■		■		■
Environment	Forestry	■		■		■					■	■	■	■		■		■
Environment	Ecosystem goods and services	■		■		■	■				■	■	■			■		■
Repurpose infrastructure	Offices	■			■	■			■	■	■	■	■			■		■
Repurpose infrastructure	Workshops	■				■			■	■	■	■	■					■
Repurpose infrastructure	Training and education centre	■			■	■			■	■	■	■	■					■
Repurpose infrastructure	Residential housing projects	■		■		■				■	■	■	■					■
Repurpose infrastructure	Community health centre	■		■		■			■	■	■	■						■
Repurpose infrastructure	Agro-processing	■	■		■				■	■	■		■					■
Repurpose infrastructure	Manufacturing centre (e.g. turbines)	■			■	■		■	■	■	■	■	■	■				■
Repurpose infrastructure	Biodiesel	■				■		■	■	■	■	■	■	■				■
Repurpose infrastructure	Waste site with biogas recycling centre			■		■			■	■	■	■	■	■				■

Table 3 Selected post-mining land use case studies per sustainable development goal

SDGs		Opportunities/case studies
1	No poverty	Khwezela Colliery agro-industrial hub (Global Compact Network South Africa 2019) and Mogalakwena Incubator sustainable farming (Raats 2018) in South Africa
2	Zero hunger	Hunter Valley crops, NSW (Adams 2020); Aquaculture in South Africa (ARCM 2018; Massie et al. 2018; Rinscheid & Wustenhagen 2019). Collie, Western Australia; and West Virginia, US
3	Good health and wellbeing	Opportunities for contribution to local health facilities and supports. Many mining sites support clinics and hospitals in the jurisdictions that operate
4	Quality education	Eden Project education and training, UK (Pearman 2009)
5	Gender equality	Food processing plant employing women, South Africa (Pearman 2009)
6	Clean water and sanitation	eMalahleni water treatment plant, South Africa (Merta n.d.)
7	Affordable and clean energy	Wind farms in Germany and Scotland, geothermal plant in Holland, photovoltaic plant in Germany, 5.4 MW plant in UK (Pearman 2009); solar farm, China (Pouran 2018); RWE energy company acceleration of wind power, Germany (Hill 2023); Ti Tree Bioenergy (n.d.), Queensland; Kidston pumped hydro Queensland (WSP 2022); Stratford renewable energy, NSW (Yancoal 2024); Muswellbrook pumped hydro, NSW (Idemitsu 2022)
8	Decent work and economic growth	Opportunities for Australian industry (Banfield et al. 2023); Bluewater Shopping Centre, UK (Pearman 2009); Lake Macquarie race track, NSW (Cheong & Johnson 2024); Midland Coal dirt bike park and camping ground, US (Pearman 2009); Teck's Sullivan tourist park and solar farm, Canada (ICMM 2019); Slănic recreation site, Romania (Leão 2024); Deep Sleep Hotel, UK (Giddings 2023); Cheese storeroom, Italy (La Valpelline 2024); Wine cellars, Moldova (Butler 2011); Swimming centre, Canada (St Mary's Quarry n.d.); Ratho rock climbing, Scotland (Wikipedia 2024); Craigpark surf park, Scotland (BBC 2022); Blue Rock diver training, South Africa (Blanchette & Lund 2016); Zollverein swimming pool and ice rink, Germany (UNESCO 2024)
9	Industry, innovation and infrastructure	Arnhem Space Centre, NT (Garrick 2023); Gove Peninsula green ammonia hub, NT (Territory Q 2023); Football stadium, Portugal (Pearman 2009); Banyan hotel, China (van Es 2022); Shanghai Intercontinental hotel, China (Austin 2019); Boulby Laboratory, UK (UKRI 2024); Stawell Underground Physics Laboratory, Victoria, (Muller & Lebedev 2022); Sanford Underground Research Facility, US (White 2015); Physical data storage, US (New York Times 2017)
10	Reduced inequalities	The global exit of coal, followed by mine closures, could disrupt the lives of 33.5 million people (Svobodova 2023) and require long-term planning and extensive stakeholder engagement (Atteridge & Strambo 2021)
11	Sustainable cities and communities	Woodlawn Bioreactor, NSW (Pearman 2009; Veolia 2024)
12	Responsible consumption and production	Opportunities to sustainably support the estimated population of 9.8 billion by 2050. The equivalent of almost three planets will be required to provide the natural resources needed to sustain current lifestyles (United Nations 2024)

SDGs		Opportunities/case studies
13	Climate action	Spekboom Project – carbon sequestration, erosion protection, soil health, South Africa (Seriti n.d.)
14	Life below water	Puy de l'Age Leisure Centre and fishing lake, France (ICMM 2019); Paso de Piedra aquaculture, Argentina (Mallo et al. 2010); Cluff Lake hunting, fishing, drinking water, berry gathering, Canada (Orano 2024; World Nuclear News 2024)
15	Life on land	Richards Bay ecology restoration, South Africa (Ott 2017; Pearman 2009); Peanut Mine public space and sediment entrapment, US (Mborah et al. 2015); Felicíssimo reforestation, Brazil (Sánchez et al. 2014); Svea Nord restoration of a national park, Norway (World Economic Forum n.d.); Bamburi grasslands, wetlands and rainforest, Kenya (Pearman 2009); Butchart botanical gardens, Canada (Pearman, 2009); PT Newmont Minahasa Raya botanical gardens, Indonesia (ICMM 2019); Capel possum finishing centre, WA (CRC TiME 2024)
16	Peace, justice and strong institutions	Arctic cultural heritage features and geodiversity restoration, Norway (Erikstad et al. 2023); Improved sustainability of local economies through mine closures in China (Zhao et al. 2020); Tangshan biodiversity, China (Biennal Internacional De Paisatge Barcelona 2023); Northumberlandia community art park, UK (The Land Trust 2024); Zipaquirá cathedral, Columbia (Adrienne 2023)
17	Partnerships for the goals	Sector partnerships in Hunter Valley, NSW, including job creation (Murphy & Bernasconi 2022); collaborative planning (Crofts & Phelan 2023); and opportunities following BHP closure (Atteridge & Strambo 2021)

2.4 Conceptual framework

A conceptual framework for the selection of PMLUs that incorporates the SDGs as a complementary lens is presented in Figure 1. The overarching requirement is that a post-mining site must be safe (for humans and fauna), stable (erosionally and geotechnically), and non-polluting (geochemically). In this framework, the knowledge base criteria typically included in a PMLU selection process (e.g. commitments, regulations and approvals, opportunities, risk/threats, land capability, etc.) serve as the primary lens for identifying the baseline PMLU and alternative PMLUs. The secondary lens for selecting PMLUs in this framework is the SDGs. Once potential options have been chosen utilising both lenses, the baseline PMLU and selected alternative PMLUs should be subject to a multi-criteria analysis. The preferred PMLU or PMLUs – for multiple PMLUs could be selected for a mining site – should be assessed by undertaking a technical feasibility study, regulatory assessment, and a business plan. This phase could also include developing the designs and undertaking a pilot study. After this assessment, it could be found that the preferred PMLU is not feasible, which would require the process to be restarted. If the preferred PMLU or PMLUs are feasible, investment and regulatory approvals would be necessary before these alternatives are executed.

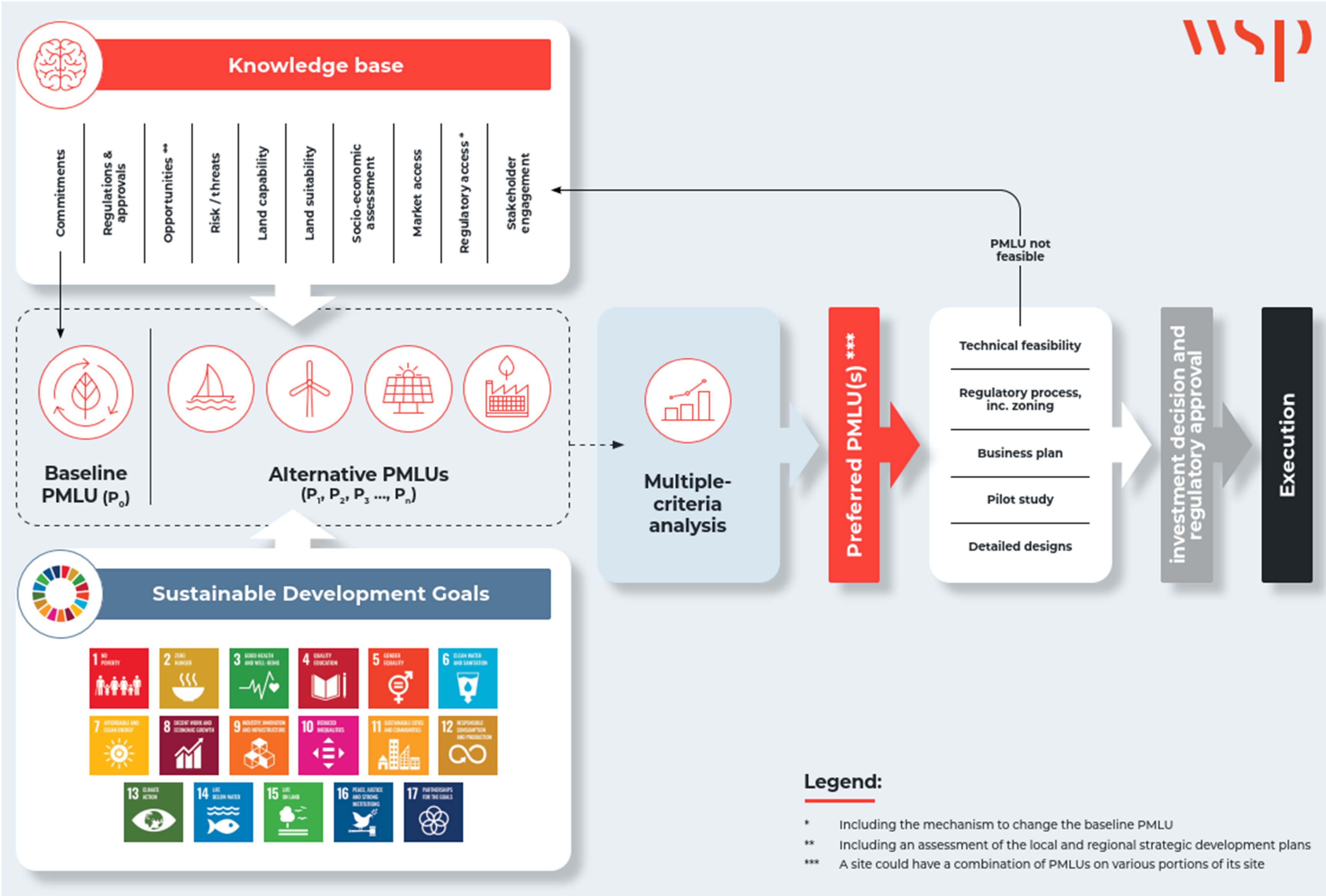

Figure 1 A proposed framework for selecting post-mining land uses with the sustainable development goals as a lens. The baseline and alternative post-mining land uses in the example are indicative

3 Recommendations

We recommend that the identification, development and/or implementation of PMLUs in mine closure policy be informed by the SDGs in addition to the knowledge base associated with a mine. This includes a practical and meaningful incorporation of all relevant SDGs in:

- alternative PMLU selection where there is an existing authorised baseline PMLU
- proposed baseline PMLUs for all greenfield mining activities
- government, business and civil society regulations and policies governing mine closure.

4 Conclusion

Globally, mine closure has not generally yielded a positive narrative. The thousands of ownerless, abandoned, and unrehabilitated mines worldwide have resulted in the loss of livelihoods and, too often, unacceptable environmental and social impacts.

The primary responsibility of mining companies is to make their sites safe, stable, and non-polluting; however, there is the potential for substitutive economies to be developed on their sites. These commercial opportunities could be led and implemented by third parties. While these developments on former mine sites could yield socio-economic benefits, they also have the potential to reduce the mining company's liabilities post-closure since the new proponent could carry responsibilities for the site's maintenance, e.g. access, erosion and weed control. PMLUs could also be aligned with the SDGs, thereby contributing to national and international efforts to achieve these aspirational goals. To this end, a framework has been proposed for incorporating the SDGs as a lens in PMLU assessments, complementary to the knowledge base. Tables 2 and 3 indicate how PMLUs can be aligned with corresponding SDGs, with selected case studies presented per SDG.

With the global focus on energy transition, the large-scale rollout of renewable energy projects on repurposed mines could yield an ironic conclusion to this industry's narrative — particularly for coal mines, but directly or indirectly, this is also true of many other mineral and metal operations. The transmission lines that entered the mine site to enable fossil-fuel-based energy generation could be repurposed to convey renewable energy in the opposite direction, generating a 180-degree energy transition; but this needs to be scaled if it is to be significant. It will require a concerted global effort.

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