Smart strategies for the transition in coal intensive regions

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TRACER
TRANSITION IN COAL INTENSIVE REGIONS

Decision Support Toolkit on post mining landscape management

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TRACER website: www.tracer-h2020.eu

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Definitions *as presented in* (ICMM, 2019), (WB, 2021)

Mining life cycle*: This is the full period of the mining process. Typically includes exploration, development, operations, closure and post-closure.*

Closure*: Processes and actions planned for and implemented when a mine ceases operation or a portion of a mine (or mine facility) is permanently removed from use for mining purposes. It includes rehabilitation or reclamation, remediation, decommissioning, demolition and/or dismantling.*

Post-closure*: General term referring to the period after the completion of all works needed to implement the closure of the mine site. Sometimes used to refer only to a period of monitoring and maintenance leading up to relinquishment, but may include a period in which ongoing activity (such as the operation of a water treatment plant) is needed.*

Post-mining land use*: Refers to the use of mined lands once active mining is complete. This may include land use during the period when the site is undergoing closure activities, particularly when closure activities stretch over many years or decades (such as during water treatment).*

Reclamation*: Actions performed during or after an exploration project or mining operation to shape, stabilize, revegetate or otherwise treat the land in order to return it to a safe, stable condition consistent with the establishment of a productive post-mining use of the land and the safe abandonment of a facility in a manner which ensures the public safety, as well as the encouragement of techniques which minimize the adverse visual effects.*

Rehabilitation*: Return of land to a stable, productive, and self-sustaining condition after considering beneficial uses of the site and land. Reinstatement of degrees of ecosystems and function where restoration is not the objective.*

Relinquishment*: The end of site ownership by the mining company and of their responsibility for the site, with transition of ownership and residual liability to the jurisdictional authority or a third party. Implies that the mining company has completed all obligations outlined in the closure plan to the satisfaction of the authorities (and possibly other stakeholders).*

Remediation*: The action of remedying something, i.e. reversing or stopping environmental damage. Often used in context of contaminated soils or water. Remediation may include activities carried out to clean up or mitigate contaminated land or water.*

Repurposing*: Beneficial reuse of a closed mining operation, whether through value-added reuse of the land (i.e. energy generation or residential), reuse of infrastructure at another site or derivative business opportunities to create positive economic activity. This may facilitate transfer of the site to a third party for relinquishment or provide an offset for ongoing post-closure operating and maintenance costs.*

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

Executive summary

The EU-funded TRACER project (www.tracer-h2020.eu) aimed to support, throughout its 3-year duration, nine coal-intensive and former coal-intensive regions[1], which are at different stages of their energy transition, to shape or fine-tune their Research and Innovation (R&I) Strategies and exchange previous experiences in order to facilitate transition towards sustainable energy systems.

The TRACER project, coordinated by WIP Renewable Energies – Germany, facilitated the mobilisation of a wide range of stakeholders in all nine European regions, to discuss and agree on a shared vision and priorities for coal transition. Several TRACER reports were delivered until now covering thorough analyses of the current situations, in terms of energy, environment and social aspects, and 2030-2050 transition projections in all 9 coal intensive regions, together with best practices assessment globally. The R&I Strategies were based on the European Union's "Smart Specialisation Strategy" (S3) approach and the Entrepreneurial Discovery Process (EDP) focused on each of the 9 coal-intensive regions, while for the energy technologies were considered the R&I priorities of the EU's SET Plan.

This current document is mainly based on the prior deliverables in TRACER project (TRACER-D2.5, 2019) and (TRACER-D3.3, 2020), previous work performed by CRIT - the Secretariat of the Initiative for coal regions in transition (EC-CRIT, 2020), World Bank Document "MINE CLOSURE: A Toolbox for Governments" (WB, 2021) and the 2nd edition of the Good Practice Guide of the International Council on Mining & Metals (ICMM) on Integrated mine closure (ICMM, 2019).

It is part of a set of two Decision Making Toolkits (DSTs) that will serve as guidance for stakeholders in coal regions in transition for a better-informed decision-making process, on how to plan, set targets, choose optimal solution during implementation in compliance with legal and regulatory framework, and be prepared to secure finance for the transition to a sustainable energy system:

A. ***Decision support toolkit on substituting coal-fired generation with clean energy*** that will serve as a guideline for stakeholders in coal intensive regions on how to substitute energy production from coal with clean energy (demand of the energy production through alternative/clean energy resources, investment costs, estimated work places from the alternative energy resources/technologies, etc.), to get a feeling what it really means to substitute coal in an existing energy system;

B. ***Decision support toolkit on post mining landscape management*** (ecosystem services) which will help policy makers, local authorities and planners to take informed decisions, to set targets, access financial resources and attract investors. This guidance will lead to choosing optimal solutions in compliance with the environmental legislation in force.

This current document (B) will highlight a logical sequence of a set of actions, for an effective and environmental oriented remediation, reclamation and repurposing of former mining perimeters, whether it is about underground mines or open casts, including all assets and resources (land, buildings/constructions, other infrastructure, oversized mining equipment and machinery, mine waters, syngas, etc.).

The online versions of both documents are interactive pdf formats easy to navigate and to access references.

[1] Lusatia Region (Brandenburg DE40 and Dresden DED2 - Germany), West Macedonia (EL53 - Greece), Wales (UKL1 and UKL2 - UK), Southeast Region (BG34 - Bulgaria), Jiu Valley, West Region (RO42 - Romania), Kolubara region (RS11 and RS21 - Serbia), Donetsk region (Ukraine), Upper Silesia (PL22 - Poland), North West Bohemia (CZ04 - Czech Republic)

Most often decision-support tools are applied with the help of purpose-designed software packages and drawing on specialised databases. TRACER DSTs are guides aiming to present in a non-technical language all relevant aspects related to TRACER target regions transitioning from coal.

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What does this DST stand for?

The aim of this toolkit is to provide guidance on how to plan, to set targets, access financial resources and monitor-evaluate in order to implement optimal solutions for the remediation, reclamation and repurposing of former coal mining perimeters.

Why is needed?

This toolkit will highlight a logical sequence of a set of actions for an effective and environmental oriented post mining landscape management. Taking better-informed decisions are less resources (i.e. time, human and money) consuming.

Where is useful?

Coal intensive regions, already in transition or about to initiate the transition process towards a sustainable energy system, must make the most of this guidance related to former mining perimeters, including existing mines (active, under conservation or under closure and post-closure) and legacy sites, including coal tailing dumps, whether it is about underground mines or open casts/pits, including all assets and resources (land, buildings/constructions, other infrastructure, oversized mining equipment and machinery, mine waters, syngas, etc.).

Who is addressing?

Policy makers, local and/or regional - national authorities, mining or energy companies, planners and civil society representatives from coal intensive regions, involved directly or indirectly in the mine closure processes.

When to make use of it?

It is recommended to be studied prior to mine closure and post-closure planning process, for defining an optimal and adaptive post-mining landscape management.

How to make the most of it?

For its effectiveness, it is recommended to make use of this "tool" simultaneously with the legally regulated mine closure and post-closure process implementation, for an efficient and successful post-mining landscape management, which in TRACER project focused on the 3Rs remediation-reclamation-repurposing steps/stages.

2 Challenges

The coal mining industry is essential for industrial and societal development. However, coal exploitation carries significant risks of long-lasting negative impacts on the environment, particularly on water resources and landscapes, as well as on local communities, to which coal use, mainly for energy purposes, is adding the air quality degradation.

According to the European Commission, coal, still one of the main fuels in the European energy mix, ensures in 2020 approx. 230 thousand jobs in the mining and energy production industry for 31 development regions (NUTS2) in 11 EU countries.

In the context of climate change, cost-inefficient mining and/or depleted resources, the transition to cleaner sources of energy and innovative technologies is happening and accelerates as coal is replaced by more sustainable and competitive alternatives.

Coal mine decommissioning takes several years and should be preceded by a one- to three-year planning stage. However, the effects of mine decommissioning are much more long-lasting than the decommissioning itself and can linger for decades. Such a chain reaction of the coal industry collapsing has substantial impacts of a collective nature, such as a decline in the income of local governments, major jobs loss, lack of support for local social and cultural initiatives, the progressive pauperization of local society. Another adverse effect of mine decommissioning may be the disorganization of social relations in the area covered by the mine (Jonek-Kowalska I., 2014).

Impacts summary (F. Pavloudakis, 2009):

Environment	Social and economic
- Alteration of morphology - Changes in hydrological pattern - Loss of wild animal habitat - Degradation of landscape value - Reduction of property value - Loss of topsoil - Loss of agricultural land	- Changes in economic activities - Occupation of land for a long period (usually many decades) - Limited access to public utilities

The decline of the coal era also has a number of specific impacts, either on the environment or the socio-economic aspects, each coal intensive region having its particularities, as was observed during the TRACER project, depending on the site hydro-geological profile and size, the local community level of development in terms of institutional capacity, technology, innovation, economy, labour market (up- and re-skilling needs), education infrastructure, cultural heritage, demography (aging, migration, brain drain, depopulation, shrinking communities), the psycho-social and behavioural characteristics and, not least, the political context.

Box.1 Post-mining challenges

In Poland, closing an unprofitable mine is considered a social and political rather than technical problem. This is due to the loss of jobs for miners. The direct cause of the liquidation of coal mines is usually the exhaustion of the mined deposits. The process can also result from the lack of technological possibilities to continue mining, unprofitable production or political decisions. Less frequently, mines are liquidated for social or environmental reasons (Uberman R, 2010).

For Kolubara coal region in the Republic of Serbia, important challenges are related to socioeconomic issues, as: reorientation and upgrading in a sustainable way of other coal dependent industries (steel industry, mining equipment manufacturing, coal terminals, etc.); the mono-industrial feature of local communities generating massive layoffs, both directly in the mining and energy industry and indirectly in other related industries and services, substantially reducing families income; youth migration in search for carrier development opportunities; worsening of health problems related to heart, respiratory, mental, bones and joints diseases according to the official regional “Occupational Health Reports”.

The major social impact generated by the increase in unemployment in coal regions in transition raised a major **challenge** for local communities, namely the labour market reconfiguration with a substantial need for workers’re- and up-skilling, according to the

analysis performed in TRACER-D2.4 “Best practice report on labour markets, social issues and tourism”, including examples from the TRACER Best Practices Platform.

Challenges and risks vary depending on the type of region (rural or urban), the type of mining (open cast mines or underground) and the predominant assets for which repurposing is sought (land, buildings, other infrastructure, etc.) (Wuppertal Institute, 2022).

Considering the challenges and impacts generated by mine closure and post-closure activities, the following **risks** need to be considered (WB, 2021):

- Economic;
- Environmental;
- Financial;
- Health and safety; and
- Social.

One of the main risks, when planning the rehabilitation of former mining perimeters, including coal tailing dumps and ponds, can be prevented or mitigated by securing:

- Human capacities, new competences & skills, and sustainable employment via social cohesion and civic engagement; investments with high added value; skills matching and long-life-learning programs; respect for, and protection of human and labour rights;
- Site safety in terms of geomechanical stability (slope’s landslides / at open casts and tailing dumps, waste dumps slumping or liquefaction, mine subsidence / at underground mines) and geochemical characteristics (existence of hazardous substances, mine wastes acidification, surface & underground water and air quality, soil fertility);
- Financing, in order to ensure the ability of mining/energy companies to fully covering the mine closure and post-closure costs;
- Ownership conditions of the former mining sites and assets, in order to avoid overspending and delaying deadlines.

When referring to the environmental impact, one of the main risks is the hydrogeological imbalance associated with the cessation of dewatering of the rock mass. It results from an increase in the level of the underground water table, which leads to the occurrence of local flooding, as many times areas drained by long-term drainage of the rock mass during mining operations. In addition, changes in the chemical composition of groundwater in the zone of influence of the mine drainage system can threaten the quality of clean drinking water and surface water bodies and watercourses.

The ecological risks assessment should be carried out with the participation of objective, interdisciplinary external experts whose expertise should reflect the ecological, social, technological and legal aspects of such a comprehensive risk assessment analysis. (Jonek-Kowalska I., 2014).

In view of the significant and diverse costs of coal mine decommissioning, there is a need to develop and apply comprehensive environmental and social risk management systems at mining companies. Responsible management of environmental and social risks requires dialogue and mutual respect for all stakeholders and, at some point, a refocusing of perspective from short-term benefits to long-term value creation, through positive relations with all parties involved. It is necessary to develop detailed procedures to help manage these risks. The identification of risks should be carried out as early as possible in the optimal situation, already at the design stage of the mining exploitation/perimeter (Jonek-Kowalska I., 2014), (Ostręga A., 2005). In the preparation of these risk management procedures, all potentially affected stakeholders (mining companies’ employees, academia - researchers

(environmentalists), representatives of local, regional - national authorities, NGOs) should participate.

Several risks regarding post-mining landscape management can be reduced by the correct and timely application of the legislation in force related to mine closure and post-closure, whether it is law enforcement rules or instructions / orders of the governmental entities involved. However, the legislation is sometimes too rigid, not enough R&I oriented, re-use or repurposing opportunities often being lost due to the absence of specific regulations regarding the 3R remediation-reclamation-repurposing of post-mining landscapes and lack of communication and cooperation between the mining or energy companies and the academic & research environment in the coal regions in transition.

Box.2 Risks and barriers in post-mining landscape management

In Upper Silesia, Poland, a factor that significantly reduces the value of sites and objects requiring revitalization are unregulated ownership issues and the accompanying difficulties in finding common ground between different owners' categories (public local administration, individuals, and mining companies). The revitalization of sites that often have great opportunities to give them new functions that take advantage of their features, and at the same time are desired by society, cannot take place due to unregulated ownership issues (Ostręga A., 2005).

In Jiu Valley, Romania, inappropriate post mining land & buildings re-use management, legal disagreements, unclear and bureaucratic regulations and no formally temporary exemption from taxes at ownership transfer, have led to long delays and the loss of financing opportunities, at that time (2012-2017). To this aim, in TRACER project reports was highlighted the need to simplify and update mine-closure procedure to be efficient, less time-consuming in terms of ownership transfer and R&I oriented, opened to safely make-use of the existing potential (i.e. MMC, UCG, heat storage, mine waters heat pilot projects tec.), from early stage of the closure process (TRACER-D3.1, 2019), (TRACER-D3.2, 2020).

More about risk assessment and management are provided in ICMM Tool 8 from Integrated Mine Closure – Good Practice Guide, 2nd Edition (ICMM, 2019).

Despite the major challenges coal regions in transition are facing, an effective, research-based and flexible post-mining landscape management can offer a vast potential for future **opportunities** and for positive impacts on several fields, such as: agriculture, silviculture, bioenergy crops; tourism (industrial, leisure, adventure, cultural, etc.); other sustainable innovative industries (renewable energy, energy storage, high & medium technology manufacturing, ITC, robotics, etc.); circular economy; residential areas regeneration, etc.

According to Wuppertal Institute the mining land should be treated as assets to attract new businesses and create new jobs in the region. Coal-related infrastructure often has assets (like railway lines, strong electricity grids, access to rivers, and so on), which could offer interesting potential for future uses (such as industry, renewables, etc.) (Wuppertal Institute, 2022).

In order to avoid time-costs overlaps and public non-acceptance, the whole process of post-mining landscape management must roll-out a transparent, trustworthy and constant communication, aiming stakeholders' awareness and freewill engagement, from the early stages of mine-closure planning. Within TRACER project, each target coal intensive regions mobilised a wide range of quadruple helix stakeholders (the business environment – industrial/business associations, mining/energy companies, SMEs; research & education institutions; public authorities; and the civil society – trade unions, NGOs, mass-media, the general public representatives) to participate in the process of developing a shared vision and priorities for 'life after coal'. As TRACER project has incorporated a Smart Specialisation (S3) approach into the heart of the project design, the **stakeholders' involvement** was

based on an inclusive – bottom-up approach, centred on the “entrepreneurial discovery” process (EDP).

As already mentioned, for a successful overall just transition from coal, in particular a post-mining landscape management, a high level of continued stakeholder involvement and empowerment is necessary during mine closure & post-closure planning and implementation stages. It is very important to have an open, transparent and collaborative relationship mainly between the mining/energy company and the regional and/or neighbouring local authorities - a partnership prepared to engage with the rest of 4 helix stakeholders, prior to post-mining stage and ownership transfer, from the planning stage of post-mining assets use.

To this aim, it is essential to develop collective or collaborative leadership, so that all quadruple helix stakeholders’ representatives are included in flexible decision-making structures. S3 **governance structure** should be able to prevent policy capture by specific interest groups, powerful lobbies, or major regional stakeholders.

More about stakeholders’ engagement – approach, tools and tactics and governance structures in the Analytical report on the outcomes of the mobilisation process in TRACER target regions (TRACER-D5.2, 2022).

3 Remediation – Reclamation – Repurposing solutions (options)

According to the Science Policy Report on a new vision of sustainable management in mining and post-mining landscapes (Leopoldina, 2019), elaborated by several international research institutions, mining landscapes should be understood as spaces of multifunctionality rather than mono-functionality. To this aim, the post-mining landscape management must be of multipurpose and flexible enough to be adaptive in real time.

The scientific literature does not provide a clear dedicated definition for "post-mining landscape management", referring in particular to "post-mining land use", but within the TRACER project the analysis of the nine targeted coal intensive regions was carried out from the larger perspective of the 3R aspects remediation -reclamation-repurposing.

Two international guidelines – the International Council on Mining & Metals (ICMM, 2019) and the World Bank (WB, 2021) define **basic principles** and objectives of good closure planning practice that can be used as a basis. If the good mine closure practice principles exemplified below are applied starting from earliest stages of mine closure planning, then the post-mining landscape management process will be a time & cost-effective one, accepted by stakeholders involved in the decision-making.

ICMM

- Safety
- Physical stability
- Chemical stability
- Socioeconomic transition
- Ecological stability
- Risk limitation
- Cost effectiveness
- Long-term care mitigation/elimination

WB

- Preparation of a closure plan at the beginning of a project
- Definition of productive, sustainable post-closure land use
- Definition of key technical assessments that must be included in closure plans
- Preparation of a closure cost estimate based on the closure plan
- Placement of a financial assurance based on the closure cost estimate
- Regular updates of the closure plan and cost estimate
- Involvement of diverse stakeholders
- Management of socioeconomic transitioning

- Collection of relevant data
- Preparation of a final closure plan/design near the end of the operational phase of the project

The status quo of the mining situation in the nine TRACER target regions was described in comprehensive reports, including the ecological situation with regard to coal mining and the phase-out of coal. The most specific environmental issues/questions are answered in the reports TRACER-D 2.5 (2019) and TRACER-D 3.3 (2020). According to TRACER-D 2.5 (2019), there are few **key principles** to consider when planning mine closure and implementing post-mining remediation-reclamation-repurposing works.

First of all, any concrete guidelines for ecological remediation & restoration should be an integrated part of the mine resource management through the life of a mine, always regional specific, situative and considering the available scientific information on both substrate quality and usability, best as possible. However, and besides key milestones that have to be achieved in mine closure, there still remains a degree of uncertainty when looking at the long-term ecosystem development on new ground − even more as nowadays the climatic conditions in Europe are changing rapidly thus overlapping endogenous, soil and ecosystem forming processes. In addition, the economic framework conditions and production targets in agriculture and forestry continue to develop, one example are the innovative biomass processing chains. It makes sense to apply the risk-spreading precautionary principle when conclusive information on long-term ecosystem development is missing in detail.

For reclamation performance and quality control there must be detailed conceptual descriptions and assessments of all reclamation activities including target criteria that have to be achieved in definite time, like soil target values in agriculture or biomass growth and biodiversity indicators for afforestation. It must be ensured that the reclamation objectives have been met once operations cease. Otherwise, additional maintenance measures are necessary. However, the land management itself should be adaptive to react reasonably if the cropping situation changes, e.g. by integrating natural succession processes in restoration or site adapted native species and cultivation methods developed for the revitalisation and valorisation of fallow land.

A mosaic of different land use categories is promising the highest economic and ecological added value, including also stakeholder acceptance across the full process of post-mining landscape management. Basically, post-mining land use can be divided into three main fields of action, with their special requirements for reclamation, aftercare and maintenance:

Agricultural reclamation

- Agricultural reclamation of suitable arable mine spoils may contribute significantly to assure the continued existence of agricultural enterprises affected by mining activities, especially in times of an increasing shortage of fertile agricultural land worldwide;
- As compensation for the minus of production area, an agronomic upgrade should de intended − in particular, through the provision of high-yielding substrates and a proper topsoil preparation;
- The application of organic materials (composts, solid and liquid manure, digestates, etc.) with a balanced ratio between carbon and plant available macronutrients is stimulating soil development. But equally important is a soil fertilising and structuring crop rotation with nitrogen-fixing legumes in a key position;
- Scientific preliminary studies and a monitoring of the soil and yield development are necessary for the elaboration and adaption of all restoration procedures and land management activities, under the special site conditions on dumps and tips;
- Guideline (target) values for soil properties and a monitoring of the yield development provide an evaluation or control of the reclamation progress and success. The key

criteria for the topsoil evaluation are: pH-value, humus and carbon content, plant available macronutrients, water storage capacity and bulk density;

- On humus and nutrient poor raw soils, the first yields do not reflect the real cropping potential. Improving soil fertility is a long-term, biological driven process taking 60 to 80 years until the site-adapted and sustainable yield production potential is achieved.

Forest reclamation

- In the temperate climate zone afforestation and natural reforestation of stripped land are the most obvious and promising solution for revegetation. Forests are the climax vegetation form providing basic ecosystem functions and services in the long term;
- In principle, the biological self-organisation of forests can follow technical reclamation and natural succession, depending on the landscape planning objectives, i.e. the requirements of the society and subsequent users of the reclaimed land. Leaving behind or creating a suitable rooting medium is an essential precondition for ecosystem development − especially, if forest management orientates primarily at economic targets;
- The overall challenge is to establish diverse, low-risk, forward-looking and sustainable forest ecosystems for multifunctional use options. Scheduled afforestation by planting or seeding and natural succession should complement each other, with different nuances and emphases in detail;
- Implementing natural succession can expedite the artificial establishment of forest habitats. Even though successional tree species cannot replace commercially valuable crop trees in an economic sense, they are most important for wildlife and early soil revitalisation;
- The of artificial forest ecosystems with productive functions but close to nature is promoting a self-supporting development. On the other hand, natural forest succession can be accelerated by introducing late and final successional, heavy-seeded species such as oak trees or beech;
- It is well known that deciduous trees support humus quality, soil life, soil forming processes, ecosystem nutrient turnover and mineral nutrition − all aspects considered having positive effects on timber growth a reclamation progress;
- As for all long-living and complex ecosystems it makes sense to assess the reclamation quality by a combined growth evaluation and biodiversity check. In contrast to agriculture, soil target values which have to be achieved in a short management period are questionable, since after initial revegetation there is no more regular soil cultivation;
- Forest ecosystem and soil development are long-term processes, although mature forests on reclaimed land show quite similar functional features as forest stands of the surrounding area regarding biomass growth, mineral nutrition, water turnover, nutrient cycling.

Nature conservation

- Technical agriculture and forest reclamation implies a landscape design and soil preparation adequate to the management demands of the land users. By this the structural diversity and small-scale patchwork of the ground surface resulting from spoil heaping gets levelled out to some extent;
- Moreover, strictly reclaimed land is developing much faster from the starting point. Notably basic soil amelioration and regular fertilisation speeds up ecosystem development in the early stage;

- A dilemma from the ecological point of view: Intensification of mining operation and standardised good reclamation practice are in general leading to a more productive but also uniform, artificially smoothed post-mining landscape;
- Especially, when looking at a higher landscape scale, better-yielding cropping systems correspond with a loss of biodiversity as compared to human-undisturbed sites. In contrast, many comprehensive studies reveal, that both natural self-development and guided succession lead to better ecological values as compared to one-way technical reclaimed areas;
- As a counterpoint to production targets the different plans in the active mining and mine closure should always take into account the management requirements to ensure biodiversity values and ecological variety in the developing post-mining landscapes. In particular, habitats with extreme substrate and specific microclimatic conditions are a good refuge for endangered species;
- Various management strategies are available and exercised to support the formation and conservation of scarce habitats in post-mining landscapes suitable for the re-colonisation of indigenous and threatened species;
- Therefore, the establishment and conservation of sparsely vegetated, nutrient poor and dry bare substrates, dunes and wetlands play a key role. Another option relates to agro-environmental measures for conserving the open landscape and early successional stages, e.g. by extensive grazing and cutting regimes;
- Summing up, nature conservation measures should contribute to improve biodiversity upon the pre-mining conditions, even if there is no concrete legal obligation. However, even in designed nature reserves landscaping cannot stand against overruling and legally-binding reclamation targets, notably considering long-term erosion control and safeguarding of ground stability.

It is known that **post-mining landscape repurposing options** depend on the site-specific characteristics, ranging from agriculture to civil and industrial infrastructure in open casts or underground mines, including coal tailing dumps and ponds, and ash & slag dumps.

Repurposing options are summarized and schematically structured in the table below.

agriculture and forestry	agriculture	- nitrogen-fixing plant species can be used to condition soil different crops; - medicinal herbs; - pasture grasses; - viticulture (wine growing);
	silviculture	- agroforestry; - forests;
ecology	nature conservation	- restoring ecosystems and preserving biodiversity;
circular economy	industrial waste re-use	- ash & slag re-use
Industrial and civil infrastructure	clean energy	- renewable energy – solar & wind; mix of small medicinal plants with ground PV; - mine waters – closed and flooded underground mines have good potential as low-enthalpy geothermal resources; - energy storage – pumped hydropower; - bioenergy – energy crops;
	water bodies	- pit lakes for fish-farming; - pit lakes as reservoirs for livestock watering, crop irrigation;
	wastes management	- solid (and hazardous) waste storage, transport, disposal; - hazardous - low-level radiological waste storage;

	urban regeneration	- former industrial buildings renovation and repurposing; architectural aesthetics; - regional planning and residential growth;
	tourism	- industrial; - leisure; - adventure; - cultural, etc.
	Other industries	industrial parks including SMEs active in - high & medium technology manufacturing; - ICT; - robotics, etc.
R&I in all above fields of action (agriculture, civil & industrial infrastructure, circular economy, ecology, etc.) and others		- carbon sequestration; - MMC (Mine Methane Capture); - thermal energy storage tanks, etc.

Implementing these projects need close cooperation between key stakeholders - mining companies, regulators, land-use planners, investors, the regional/local government and citizens, aiming to identify the most sustainable solutions and to maximize social-economic development.

More information on implemented solutions for post-mining landscape repurposing in: ▪ TRACER Best Practice Platform; ▪ Wuppertal Institute for Climate, Environment, Energy: A Just Transition Toolbox for coal regions; ▪ ICMM Integrated mine closure: good practice guide – Tool 4; .▪ World Bank MINE CLOSURE: A Toolbox for Governments.

According TRACER-D 3.3 (2020), a brief summary of the main findings on *Coal mine reclamation planning, Implementation rules and best practice* and *Agricultural and forest reclamation* is given below.

Coal mine reclamation planning

There is a good agreement within the TRACER consortium that a suitable and effective post-mining land use is crucial for the acceptance of mining in the societal discourse. **Post-mining conditions should provide ecosystem services and produce lands capable of supporting the future needs.** Good environmental conditions and life perspectives are counteracting partially the ongoing economic-driven depopulation of European mining regions in transition. Nevertheless, **in many regions there is missing an overall publicly discussed guiding principle (*landscape vision*) for the long-term development of post-mining landscapes − beyond the implementation of technical and biological land reclamation.**

Coal mining follows complex and multilevel planning and approval procedures. Due to the legislative harmonisation within the EU, there are similar environmental standards and legal approval procedures in running coal mining − for example, regarding the implementation of EIA (Environmental Impact Assessment) or ESIA (Environmental and Social Impact Assessment) − but also embedding land reclamation into the planning and approval process.

Thus, in active coal mining, the companies are obliged to conduct pre-mining analyses of the site, prepare a mining plan, and designate a land use that could be achieved during and after mining operation. In addition, they are responsible to carry out all measures which are necessary to restore soil, water and vegetation cover. Therefore, they have to build up adequate financial reserves under government control and access − in the case of insolvency or an improper reclamation not compliant with the minimum legal requirements as laid down in the approved operating and restoration plans. In fact, the expenses for land reclamation are only a small part of the total costs (and profits) of mining operation.

In the case of closed, abandoned or former state-owned and not privatised older mines the competent national authorities or state-run mining companies take over safeguarding and reclamation. **In some TRACER regions this task is obviously underfinanced due to the overall economic situation − that`s a crucial factor why there are still considerable land reclamation deficits.**

Implementation rules and best practice

Practical coal mine reclamation includes a number of technological tasks e.g. movement and deposit of overburden material, surface layer modelling and relief shaping, but also the determination and construction of the final land use system. Therefore, it must have detailed conceptual descriptions and assessments of all reclamation activities including target criteria that have to be achieved in definite time.

Land reclamation follows the approved mining operation and closure plans. In no case landscaping can stand against overruling and legally-binding restoration targets, notably considering long-term erosion control and safeguarding of ground stability. Therefore, reclamation implementation rules and technical guidelines (rulebooks) are provided on national level to ensure land consolidation and preparation for a proper follow-up land use as designated in the mine closure and reclamation plans. **However, in some TRACER regions the procedure and responsibilities of the license holder do not comply. In such cases neither local authorities nor citizen representatives have a proactive attitude − a general lack of civic engagement.**

Land reclamation methods in the TRACER target regions are tailored to particular locations, geological conditions and site/soil properties but also an outcome of mining history and applied technologies. It is common sense in CRP that a reconstruction of the pre-mining (original) landscape is almost impossible due to the very specific relief and site conditions after mining. In addition, landscapes are dynamic systems and permanently changing. It is hard to define a generally accepted reference/baseline situation.

There are some sounding examples for sustainable reclamation strategies and post-mining landscaping. However, **in most cases there are no ecological criteria to define and evaluate the restoration success as intended in mine closure planning. In addition, long-term investigations on ecosystem development are lacking.**

Agricultural and forest reclamation

By far, the less demanding forest reclamation is dominating the land use distribution in post-mining landscapes. It is the natural climax vegetation, and thereby, natural ecological processes are stimulated and used to achieve rehabilitation cost-efficient. However, the experience and knowledge in practical reclamation and also the available financial resources for a proper soil preparation vary widely.

Nowadays the desired time lag between mining impact and scheduled reclamation is between 10 and 20 years, whereas in the past barren land remained untouched for decades with all negative effects on the surrounding landscape, e.g. surface erosion, AMD, metal leaching. But due to historic land overexploitation, technological reclamation deficits, ecological limitations or insufficient regulations on impact control and restoration in the past but also available funds there is a different progress in land reclamation today.

In each of the TRACER regions there is practical knowledge in agricultural and forest reclamation with some recommendations on promising plants and/or cropping systems, although at a different level - with or without scientific support. However, **the practical experience with energy cropping, special crops or other renewables on reclaimed land is very low, with only view promising examples, especially regarding SRC with poplar and black locust, although the processing chains are underdeveloped. In some**

regions post-mining landscapes are already activated for wind energy and solar power.

The cropping potential of mine sites depends from a proper land preparation and is often underestimated. Therefore, the exploitation of biomass resources from reclaimed is low and insufficient − effective post-mining management plans and recommendations on land use considering the very special site conditions are missing. In other regions the reclamation and cropping experiences is poor. The major focus lies on revegetation/greening and early plant growth. However, **from the ecological point of view restoring biological systems is a long-range process taking several decades. It remains unclear whether the applied reclamation solutions are sustainable in the long term.**

Unfortunately, **in most cases the later land users are not involved into practical reclamation. Basic failures in land reclamation − like the dumping of unfertile spoil materials, an insufficient amelioration or not site-adapted choice of tree species − are difficult to rectify afterwards.** The course of reclamation is determined already with substrate dumping and land preparation and the choice of site-adapted land use forms. Even more, **it is important to make use of the regional cropping experience to ensure a sustainable land management.**

Despite all the difficulties, the recultivated areas and also the old industrial sites offer enormous economic potential.

Box.3 Success stories in post-mining landscape repurposing

In all TRACER regions, there are initiatives for the further valorisation of these areas. A selection of particularly successful post-mining landscapes repurposing with regard to tourism concepts (Ecotourism, Industrial tourism, Petrila Planet, Recreation and sports areas), alternative energy generation concepts (Photovoltaics and Wind Power, Power-to-X, Solar park Senftenberg, Decentralised electricity production), energy storage (Heat storage, BigBattery Lausitz) and new economic settlements (Conversion to industrial parks in the German Lusatian Lignite District and a chemistry park, and in the Czech North Bohemian coal region) can be found on the TRACER Best Practice Platform and publications, including also a spontaneous succession in North Bohemian post-mining landscape.

In Wales, UK a region that is in a different coal phase-out stage, gathering experience since the 1970s with repurposing of coal mining/industrial land, there are many success stories in former underground mining sites, including Blaenavon UNESCO Site and Big Pit Mining Museum, Rhondda Heritage Park, Cefn Coed Colliery Museum, Cwm Cynon Business Park, Gatewen Colliery, Wrexham (redeveloped to housing and public open space), Maesteg Comprehensive School, Oakdale Business Park, Bargoed Woodland Park and Ebbw Vale Garden Festival Park. Surface mining sites have also been reclaimed for landfill/recycling, schools, leisure centres, golf courses, horse racing tracks, sports pitches, water treatment/sewage works, electricity facilities, campsites and visitor centres.

The Welsh Government, when referring to alternative thermal energy generation concepts in former mining regions, is making considerable progress with research and demonstration/pilot projects regarding heat supply, using water from disused mines. New funding was announced in July 2022 for producing a map showing the potential for mine water heat across Wales' coalfield areas. Feasibility studies will be carried out on those which look promising and which deliver social benefits to the local community. Warm water from Wales' only thermal spring is currently providing heating to a primary school and park pavilion in Taff's Well, using technology similar to that which could be used for mine water.

Effective post-mining landscape management will involve resources from many disciplines across key stakeholders engaged (mining/energy company, local public authorities, business environment (SMEs), research & education, civil society) and will affect directly the financial

performance of the mining/energy company and the third party (usually the local budget of the public authority), after ownership transfer.

A well-documented and collectively governed **decision making process** will generate an optimal cost-effective post-mining land use planning and implementation. The decision-making process, during the whole post-mining land use planning, implementation and monitoring, needs to be based on sound multidisciplinary knowledge incorporating natural, physical and social sciences, medicine, politics and ethics (F. Pavloudakis, 2009).

Several **tools** can be utilised in formulating an appropriate decision when choosing post-mining landscape use solutions according to site-specific characteristics, such as:

- Quantitative and qualitative data gathering assessing site quality and state of play of the neighbouring communities (literature review – guidelines, toolkits, policies, researches, legal framework; large existing database, checklists; SWOT and PESTLE analysis; on site visual screening and measurements/laboratory analysis – water and soils analysis, laser and remote sensing with satellite, drone or aircraft; multi-stakeholders dialogue - EDP, surveys, interviews, public consultations and debates, etc.);
- Standard or predictive modelling tools to predict site physical and chemical stability;
- Establishing KPI (Key Performance Indicators) and ranking of criteria;
- Cost estimations (i.e. Standardized Reclamation Cost Estimator), CBA (Cost-Benefit Analysis) and sensitivity analysis;
- IDM – Initial Decision Matrix and MCDA – Multi-Criteria Decision Analysis, including ranking of criteria;
- Formal risk assessment;
- GIS – Geographical Information System and spatial data analysis;

and more advanced and combined methods for a more realistic, less subjective and time-consuming approach, as:

- MC-SDSS – Multi-Criteria Spatial Decision Support Systems, a field of research which aims at the combination of MCDA with GIS techniques (Amaro S., 2020);
- GIS-MCD-SDSS – a geographical information system and multi-criteria decision-making methods, based on binary integer linear programming models (LP), integrated into a SDSS (Spatial Decision Support System) to select the appropriate post-mining land use solution taking into account social, technical, economic, environmental and safety criteria (F. Pavloudakis, 2009);
- Integrated Information Modelling System based upon a high-resolution spatiotemporal database, utilizing state-of-the-art multi-scale and multi-sensor monitoring technologies, combined with desktop applications and Augmented Reality (AR) for visualization purposes (Benndorf, J.; Restrepo, D.A.; Merkel, N.; John, A., 2022).

It is recommended that the sophistication of the evaluation process, used to support the decision-making process, should be commensurate with the cost and complexity of the measures under consideration.

In order for these support tools, as part of the decision-making process, to be effective, it is vital to ensure transparency by translating the results of these complex analyses into an accessible language for key stakeholders, constantly engaged, regardless their level of education.

Additional guidance for decision-making support tools in: ICMM Integrated mine closure: Good practice guide (ICMM, 2019), A Just Transition Toolbox for coal regions (Wuppertal

Institute, 2022) and TRIM4Post-Mining is a H2020/RFCS-funded project (TRIM4Post-Mining, 2021).

4 Financing sources and how to attract investors

The decline of the coal era generated a domino effect in the economies of European regions affected by massive unemployment, energy poverty and economic decline following the closure of mines and related power plants.

The process of post-mining remediation-reclamation-repurposing is expensive and includes costs directly related to mine decommissioning and long-term costs related to the effects of mining operations, such as the cost of pumping out pit water and of reclamation of post-mining areas. Also included in the scope of mine closure are the costs of remediating mining damage associated with the refurbishment of residential buildings, public buildings, water and sewage networks, street surfaces, etc. (Jonek-Kowalska I., 2014). Securing the financing of the closure and post-closure phases is very important; hence the need for "hard" management tools for risk financing and appropriate legal solutions, such as mandatory decommissioning funds, insurance or agreements with local governments or state authorities. Given the significant financial impact of mine operations, these solutions should be compulsory (Ostręga A., 2005).

Securing financing is imperative in order to lower risks for mining/energy companies and regions/local authorities and cover full costs of the environmental and social rehabilitations measures, including long-term post-closure monitoring and maintenance. To this aim, different approaches are recommended (EC-CRIT, 2020), (Wuppertal Institute, 2022), as:

- pooling funds, like an insurance policy fund, for providing a financial guarantee that environmental rehabilitation measures will be implemented;
- covering long-term costs through financial assurance/closure bond that, even when the mining/energy company is closed, existing post-mining contracts/claims will be honoured;
- outsourcing closure planning and implementation, at an early stage of mine operation to create financial liabilities.

It has to be underlined that just the ‘planning & preparation’ part of the post-mining repurposing costs are included in the closure cost estimate, like costs to prepare the site or infrastructure for redevelopment or an alternative land use. Mining/energy company responsibility should be to leave the site in a condition that it could be redeveloped by other parties (usually regional or local authorities/public administration) for the selected post-mining land use (WB, 2021).

The distribution of legal responsibilities and those regarding the coverage of the costs generated by the works and activities performed during closure-post-closure and post-mining stages are schematically presented in the table below.

Actions |Stages		**Scope of work**	**Legal responsibility and costs coverage**
planning management implementation monitoring	mine closure & post-closure	rehabilitation restoration remediation reclamation	mining/energy company government
planning preparation	post-mining	repurposing	

transfer of ownership / relinquishment			
management implementation monitoring	post-mining	repurposing developing	third party / regional-local administration government

Box.4 Post-mining costs coverage

In all TRACER target regions, except for Wales in the UK that is in a different coal phase-out stage, the mining/energy companies are state-owned, as sole or majority shareholder, each governments being involved in financing mines closure and post-closure, including the planning, management and monitoring of the post-mining landscapes, in the remediation and reclamation stages, until the transfer of assets ownership (lands, buildings, and infrastructure) to third parties – mainly regional or local authorities. For the next stage of post-mining repurposing, the legal responsibilities of mining/energy companies in covering also the costs for planning and landscape preparation are not usually included. It depends on how the ownership transfer was carried out, the quality of the decision-making process, securing financial resources and the efficiency of the management act are becoming extremely important related to "after coal life" solutions implementation, customised for each region in an optimal and sustainable (in terms of environment, economy and social fairness) way.

For example in the Czech Republic according to the Mining Act nº.44/1988, mining companies must draw up a Remediation and Reclamation Plan before mining, and subsequently create financial reserves in order to finance these activities; the Ministry of the Environment controls and issues, together with the affected cities and municipalities, an opinion regarding the implementation of the Remediation and Reclamation Plan; finally, the District Mining Office approves the creation and use of the relevant financial resources. However, projects related to post-mining social revitalisation and assets (lands, buildings, infrastructure) repurposing are no more covered by the above mentioned financial reserves.

Different types of financial support are offered by International Financing Institutions, Foundations, the private sector (Wuppertal Institute, 2022) and the EC:

- Bilateral or multilateral assistance through grant-based technical support (i.e. UNDP, USAID, CIDA, JICA, EEA and Norway grants, EC, etc.) for developing and implementing just transition plans, policies and implementation strategies through knowledge transfers, co-creation of policy pathways, trainings, demonstration projects etc.;
- Lending facilities from development banks (i.e. WB, EBRD, EIB, KfW, etc.) for project, policy and programme financing for public sector; debt and guarantee facilities for private sector investors;
- Climate Mitigation Funds (i.e. GEF) through grants, equity or even debt funding of specific clean energy, energy efficiency, clean transport, ecological restoration projects;
- Research & Innovation programs co-financed by the EC, also with focus on 3Rs projects (remediation, reclamation-repurposing);
- Investments from the private sector (i.e. MNCs – multinational corporations) focused on the development of the former coal communities, on workers up- and re-skilling, etc.;
- Private Foundations & CSR Funds (i.e. CIFF – Children's' International Foundation Fund, IKEA, etc.) with dedicated programs for community outreach, identification of policy pathways, knowledge creation and capacity building, social infrastructure development.

A comprehensive guidance related to European financing opportunities for coal regions in transition (i.e. Just Transition Fund, Modernisation Fund, etc.) is presented in TRACER Decision support toolkit on substituting coal-fired generation with clean energy (TRACER-D6.6-DST.A, 2022).

Revitalization of post-industrial sites may not always be economically justified, so the possibility of using various types of financial instruments guaranteed by law would be a desirable form of **attracting investments** in areas and facilities degraded by industrial activity. Similarly, the use of various types of tax preferences or temporary exemption from taxes at ownership transfer or reductions in lease rates or fundraising issued by local authorities would greatly facilitate the management of post-mining landscapes. This is because municipalities have more opportunities to obtain funding, as well as to join the project in a **public-private partnership**. In a situation where many brownfield sites are owned by a municipality, which has no ideas on how to revitalize / repurpose, a public-private partnership could be a win-win for all parties: the municipality, the investor and the public, as beneficiaries of the future developed sites.

An important form of state aid for economically declining regions is the creation of so-called **free economic zones**. The assistance consists in exempting companies established in such a zone from paying taxes, which is supposed to encourage investors to establish business entities and create jobs. Spending money on social security and early retirement for miners from decommissioned mines may solve the livelihood problems of the departing generation of miners and temporarily soothe their political mood, but it does not create future job prospects for the region's younger generation.

Interestingly to mention that post-mining lands have some specific qualities which should be recognized, due to higher ability of several folds to store carbon than soil in surrounding landscapes. Also these landscapes may harbour rare and endangered species, thus a proper ecosystem restoration will make the area more attractive, which can be one of the clues for attracting potential investors to region.

Box.5 Tips on how to attract foreign capital

During the last TRACER event in Jiu Valley, the representatives of two important investors entities shared few tips on how to attract foreign capital:

AmCham - American Chamber of Commerce in Romania

the human capital

The Jiu Valley needs to identify proper solutions to increase the mobility of the human capital within the region and attract human capital from other regions (including from other countries).

infrastructure development and maintenance

It is crucial to connect the Jiu Valley to TEN-T Core and build a modern transport network within the region to allow the easy movement of people and goods.

tailored incentives

The local authorities should remain flexible and work with potential investors to direct local resources towards the support mechanisms that are essential to each investment.

predictability and transparency

Investors need a dialogue partner at the local level who can support them every step of the way.

FIC - Foreign Investments Council in Romania

One of the most important measures in attracting the investors is the **dialogue**.

Measures at national level that are considered fundamental in attracting investment in all areas of the economy, including the energy sector, are:

- coherent, stable and predictable legislative and administrative framework;

- implementation of a high value-added investment policy, with a multiplier effect on all sectors of the economy;
- establishing strategic sectors for investments;
- improving the administrative framework of investments (foreign and domestic in external markets).

Recommendations for regional/local authorities:

- the existence of **consolidated data** (available labour force, halls and buildings that can be used, existing providers for different sectors, infrastructure, but also access to education and healthcare services);
- the availability of these information for potential investors as soon as possible.

FIC underlined that economies can increase, if private and public investments are combined, together with measures aiming to: ▪ stimulate digitalization and innovation; ▪ improve the capacity of institutional and state-owned companies; ▪ protect human capital by facilitating access to jobs, education and health; ▪ transform the energy mix and develop the energy infrastructure.

5 Recommendations

The success of any transition strategy or economic transformation process requires continuous monitoring and tools for evaluation of its implementation effects.

A constant monitoring and evaluation process of the current state of play of the former mining site, starting prior to the mine closure & post-closure stages, is a must, in order to:

- Continuously documenting the planning and management of post-mining landscapes 3Rs (remediation-reclamation-repurposing), by gathering data upon process evolution;
- Not losing changes in management and ownership;
- Avoid costs & timing overlaps and help realistic revisions, thus adapting the overall transition strategy, in real time.

ICMM is defining in the Good Practice Guide on Integrated mine closure (2nd Edition) - Tool 2 the following categories of monitoring (ICMM, 2019):

- socioeconomic;
- water;
- terrain;
- ecological; and
- air quality.

According to TRACER-D 3.3 (2020), a brief summary of the main findings on *Environmental impact and monitoring* is given below.

As shown by the nine TRACER target regions, the environmental impact of coal mining is quite serious and over the long-term. Thereby, ecological problems are site/regional specific; but nevertheless, there are similar challenges, as: the restoration of soil functions on dumped raw soils, the waste water decontamination or securing adequate post-mining land stability.

It is obvious that notably abandoned mines provide unpredictable long-term security and ecological risks, like sinkholes, deactivated wells, soil and water contamination by solid waste and production residues, etc. Due to increasing national standards of environmental protection and safety within the EU member states, active coal mining is nowadays under

more or less strict governmental control − from the technical development of the coal deposit to the final land reclamation and release of mining supervision. However, in some regions there is a considerable lack of enforcement in environmental protection and land reclamation. Less than one fifth of the land taken by mining is restored and cleaned up, and in one case it is only 0.3 percent of the residues.

In every mining region there is an environmental monitoring with regard to the so-called *legal protections* (*objects of protection*), notably for human health, water, soil and air quality. The monitoring intensity, parameters and analytical methods, including also national threshold values applied, are very different and for some regions the effectiveness is unclear, especially regarding derived measures. **It is still missing a Europe-wide standardised and implemented ecological monitoring system after mine closure (mandatory and additional parameters, legally binding reference/intervention values).**

Mining companies have to meet many quality standards and to apply preventive mitigation measures, according to the national laws and European directives. Especially when the socio-economic development of a region is highly dependent on mining activities, environmental aspects are - historically viewed - rather subordinated although the need for action in this field is great. The interrelationships between mining industry and policy/authorities should be questioned.

In these cases, a deficit in information policy and public transparency can be noticed. It raises the suspicion that the **ecological effects of mining are widely underestimated and played down, especially regarding mechanical instable dumps/tailings, uncontrolled disposal of hazardous substances/industrial and municipal wastes** (soil and water contamination). Moreover, a **post-mining water and soil monitoring is missing in most countries**. Of course mining has a considerable impact also on the surrounding landscape, e.g. AMD, groundwater lowering, emissions. However, it is rather unclear whether environmental monitoring during active coal mining is necessary to continue after land rehabilitation.

It should be noticed that mine restoration in a wider sense is more than land preparation for a proper follow-up use or minimising the hazardous effects on nearby ecosystems in line with the regulatory requirements. It also addresses the restoration/conversion of industrial sites and damaged natural resources going beyond the mining operation area and facilities as defined by the operating plans.

The Science Policy Report on a new vision of sustainable management in mining and post-mining landscapes (Leopoldina, 2019), elaborated by several international research institutions, underline that all recommendations envisioning mining activities (i.e. planning, management, monitoring, prevention, revitalisation) involve all stakeholders. Thus, information and power should be shared with all relevant parties from the beginning to the end of mining operations.

These recommendations are designed with the following objectives:

- Encourage local involvement and capacity-building;
- Create opportunities for science to become an integral and open-access part of the overall mining process
- Create an international, law-abiding standard to guarantee due diligence and transparency, while simultaneously sharing generated data with stakeholders;
- Institutionalize effective participation of stakeholders during all phases of mining to mitigate the effects of mining and ensure socio-economic prosperity for all involved parties.

Both key resources ICMM (ICMM, 2019) and WB (WB, 2021) also emphasise the essential role of stakeholders engagement and cooperation along the entire mining process, from initiation to post-closure and repurposing, for the mutual benefit of the mining/energy company and its host communities.

The WB, in Mine Closure Toolbox for Governments (WB, 2021), makes a series of additional recommendations:

- the need to regulate the actions/measures taken during the post-mining landscape use stage, including other assets (buildings and infrastructure); the request to carry out the ESIA for impact assessment, with an emphasis on social aspects that should not be neglected during pre-closure, closure, post -closure and repurposing stages;
- the obligation of stakeholders (4helix) engagement from early stage of mine closure, post-closure and repurposing; with the aim of defining a common vision for post-mining assets use (land, buildings, infrastructure), taking into account legal constraints;
- the need for a transparent, efficient and participatory decision-making process, with the use of complex tools, comprehensive enough in terms of the volumes and categories of data processed, with a user friendly interface;
- the enforcement of a legal framework for the existence and financing of both the re-and up-skilling programs - correlated with the need of the post-mining labour market together with the envisaged investments and the regional/national development plans, as well as the retrenchment packages.

6 References and key resources

Applying tools and good practice guides can help strengthen knowledge and optimise post-mining landscape management, extensive professional guidance being available also here:

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