Smart strategies for the transition in coal intensive regions

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TRACER

TRANSITION IN COAL INTENSIVE REGIONS

Report on the environmental impacts and sustainable reclamation solutions in nine coal regions

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TRACER website: www.tracer-h2020.eu

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Abbreviations

AFS	agro-forestry system
AGS	acid generating salts
Al	aluminium
Al_2O_3	aluminium oxide
AMD	acid mine drainage
ANMR	Annual Mining Operating Plan
As	arsenic
a.s.l.	above sea level
B	boron
Ca	calcium
CaO	calcium oxide
Cd	cadmium
CH_4	methane
CHHP	coal handling preparation plant
Cl	chloride
CO_2	carbon dioxide
CP	Country Park
Cr	chromium
CRP	mine closure and reclamation plan
Cu	copper
CZK	Czech koruna (currency)
D	Deliverable (TRACER project)
DM	dry matter
EC	European Commission
ECw	electric conductivity (water)
EEC	European Economic Community
EIA	Environmental Impact Assessment
EPA	Unites States Environmental Protection Agency
EPS	Power Utility of Serbia
ESIA	Environmental and Social Impact Assessment
ESP	electrostatic precipitator
EU	European Union

Fe	iron
FeO	iron oxide
FeS_2	iron disulphide (pyrite or marcasite)
FGD	flue gas desulphurisation
GDR	German Democratic Republic
h	hour
ha	hectare
HAP	hazardous air pollutants
Hg	mercury
HIA	Health Impact Assessment
HPP	hydro power plant
K	potassium
K_2O	potassium oxide
km^2	square kilometre
kWh	kilowatt hour
LCF	lignocellulosic feedstock
LNR	Local Nature Reserve
LPA	Local Planning Authority (Wales)
m	metre
m^2	square metre
Mg	magnesium
Mg	mega gram (1,000 kilograms = 1 ton)
MHPP	micro hydro power plant
µS	microsiemens (electric conductivity)
mil.	million
MIPPS	Ministerial Interim Planning Policy Statement (Wales)
ML	metal leaching
Mn	manganese
MPA	Marine Protected Area (Wales)
MPPW	Minerals Planning Policy Wales
MTAN	Minerals Technical Advice Note (Wales)
MU	management unit (in agriculture)
MW (th/el)	megawatts (thermal output/electric output)
N	nitrogen
NGO	non-governmental organisation

Ni	nickel
NO_2^-	nitrite
NO_3^-	nitrate
NNR	National Nature Reserve
NP	National Park
NUTS	Nomenclature of Territorial Units for Statistics
PAH	polycyclic aromatic hydrocarbonates
Pb	lead
PCB	polycyclic biphenyls
pH	pH-value
pH_{KCl}	pH-value, measured in potassium chloride solution
PPC	Public Power Corporation (Greece)
PV	photovoltaics
RES	renewable energy sources
SAC	Special Area of Conservation
Si	silicon
SiO_2	silicon dioxide
SO_2	sulphur dioxide
SPA	Special Protection Area
SRC	short-rotation coppice
SSSI	Sites of Special Scientific Interest wales
t	1 ton (1 mega gram = 1,000 kilograms)
T&CPA	Town and Country Planning Act (Wales)
TOC	total organic carbon
TPP	thermal power plant
TWh	terawatt hour
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WDA	Welsh Development Agency (Wales)
WMLC	Western Macedonia Lignite Centre
WHO	World Health Organisation
yr	year
Zn	zinc
%	percent

1 Preface

There is a diverse geomorphological impact of mining, both by running operations and closed down mines with their waste rock dumps, contaminated sites, brownfields and underutilised fallow land. **Notably, very land-consuming surface mining affects all ecosystem components. It turns the pre-mining landscape *upside down* and transforms it into a new technogenic environment - the so-called *post-mining landscape* which is often far from a state of equilibrium and therefore quite sensitive to failures** (MUDROCH et al. 2002, MARTÍN DUQUE et al. 2010). In addition, the environmental risks of underground mining in general are widely known and described in many specific and summarising publications (YOUNGER 2004, DIDIER et al. 2008, etc.). In addition to the site-related impact of coal mining, there are numerous indirect effects putting pressure on the surrounding landscape. Further coal-dependent and energy intensive industrial sectors settle down close to the mines, like metallurgy, chemical industry, mechanical engineering, glass processing, etc. Urban sprawl and infrastructure development play their part in transforming the environment (OSTERKAMP & MORTON 1996, RYBICKA 1996, RIVAS et al. 2006). **Among the so-called *off-site impacts*, the disturbance of watersheds and pollutant emissions are most important having ecological consequences far beyond the end of mining operation.**

Although we can see a lot of progress considering environmental concerns nowadays due to stricter EU and national environmental legislation and profound planning procedures including *Environmental Impact Assessment* (EIA), *Environmental Social Impact Assessment* (ESIA) and/or *Health Impact Assessment* (HIA), **coal intensive regions still belong to the most contaminated and degraded areas across Europe**. There are many case studies, reports and scientific publications with respect to air, water and soil pollution and human health. Unfortunately, the data situation very often remains fragmented, not publicly available, outdated or reduced to special aspects not easy to compare with other regions. And it is hard to transfer specific findings on the ecological impacts from one mining area to another due to the different ecological situation and mining specifics. Also, **best practice restoration measures and available technologies have to be adjusted to the regional framework conditions** (PRACH 2003).

This report builds on the previous best practice report Deliverable 2.5 on environmental protection and best practice post-mining land reclamation. Therein the focus lies on the reutilisation and post-mining landscape development by evaluating the international specialist literature on best practice technologies. In this report the TRACER experts and contact partners get a chance to discuss their point of view in a regional context: At first the general environmental impacts in coal mining are described - as more or less relevant in the addressed regions. The second part of the study goes in more detail showing the regional baseline situation concerning environmental problems, mine planning and approval procedures but also practical experience/measures in land reclamation. For this purpose, we used semi-structured individual interviews following the same questionnaire, so that the results are easier to compare. It reflects the opinion and knowledge of the mentioned TRACER consortium partners.

Considering the designated phase-out of coal mining in Europe and the transition towards a low carbon economy land reclamation gains increasing importance. Thus Deliverable 3.3 serves as a good example giving a concise and comparative overview. Thereby, we hope to promote the dialogue between regions facing similar ecological problems - on their way to a sustainable post-mining landscape development. **Decision-makers and technical experts on different levels should learn from each other and create political alliances in the interest of the regional population affected by mining and coal processing for a long time. In fact, creating and restoring an attractive environment worth living is one of the most important (soft) location factors for the future regional development, especially to face the ongoing migration of young enterprising people (*brain drain*) from coal intensive regions** (see Deliverable 3.1 / *Report on the current role of coal mining and related policies in the TRACER target regions*).

2 Landscape impact of lignite coal opencast mining and processing industry - most pressing issues

Affecting TRACER Target Regions: BG34, CZ04, DE40, DED2, EL53, *Kolubara*

2.1 Lignite opencast mining - landscape consumption and remodelling

In Europe coal mining is by far the most widespread and intensive mining type according to its present importance for energy security and industrial development. But the undeniable socio-economic benefits are standing against considerable environmental challenges. **Coal industry leads to a number of unavoidable negative impacts on the terrestrial landscape as a whole** - right from the beginning of extraction to the utilisation and in many ways (CHADWICK et al. 1987, DREBENSTEDT & KUYUMCU 2014). It touches the sustainability of ecosystems and is associated with a degradation of natural resources / environmental goods. Besides air pollution by coal burning, health implications resulting from dusts and aerosols or the negative contribution to the global green house budget, there are the direct ecological costs emerging from landscape destruction (MIRANDA et al. 2003, YOUNGER 2004, VRABLIK et al. 2017).

Especially, surface mining, which is responsible for 70% of the worldwide mining activities, causes an extensive land consumption, topographical alteration and complete remodelling of the ground in a very short time. For the prospected coalfield, there is a complete loss of landscape-forming elements and ecological functions securing public services - including groundwater, well-developed soils, productive agricultural land, forests, special biotopes worth of protection, settlements, the supply infrastructure and cultural heritage (ŠKUTA et al. 2017). In other words: by moving and depositing the existing rock material man is transforming pre-mining areas into a new anthropogenic living space with unique site conditions (SCHMIDT & GLAESSER 1998, HÜTTL & GERWIN 2004, HENDRYCHOVÁ 2008, KRÜMMELBEIN et al. 2013). For example, in the *Lusatian Lignite District* / Eastern Germany at average about 600 hectares of land are stripped for the annual production of 60 million tons raw lignite each year. The ongoing reclamation expenses are arising from both the restoration of abandoned or instable ground and waste materials left behind, but also dealing with specific mining induced processes affecting the post-mining landscape, like acidifying mine drainage (YOUNGER 2004).

Added to this, the mining operation disrupts the surrounding landscape ecosystems - in particular, by temporal ground water lowering, acid-mine drainage and other effluents from the dumps sites and landfills, discharge of polluted water into the receiving waters and deposition of mining-related combustion residues like fly-ash or fine dust. Finally, lignite and hard coal burning is most relevant for the air quality and deposition regime since the early industrial age - on national and European level (MYLONA 1996).

2.2 Hydrogeological impact and ground water table lowering

Large-scale open-pit coal mining affects the landscape in a wide range, from the anthropogenic sphere to the pedo- and hydrosphere. Active lignite opencast mining requires and extensive and sustained draining of the mining area down to the lower aquifers. The large-scale lowering of the ground water table by pumping through top and deep wells starts before the excavation and is destroying ground water bodies going below the coal strata (WAGNER & HÜSENER 2014). Sometimes the ground water table needs to be lowered up to several hundred metres beneath the untouched land surface, depending on the special geological situation of each deposit (KAVVADAS & MARINOS 1994). In general, there is no balance of groundwater extraction and natural recharge during active mining. To illustrate the dimension: for example, **in the *Lusatian Lignite District* still 900 km^2 are affected by dewatering**. In 1989 with the maximum of 16 coal mines in operation the disturbed area covered approx. 2,500 km^2 with a ground water deficit of 13.6 billion m^3 in those days.

Ground water table lowering and destruction of aquifers leads to manifold impacts on surface water ecosystems and groundwater-dependent wetlands of the surrounding landscape. Moreover, growth depressions in agriculture and destabilisation of forest ecosystems are reported for lowlands near groundwater with water sorption poor soils. But groundwater subsidence may also affect the infrastructure, e.g. causing cracking in the walls of houses or road surfaces due to settlement of dewatered geological strata, for example of marsh soils. **In most cases it is hopeless to restore the former ground water level afterwards because of the disturbed aquifers with irreversible changes of the physical-structural conditions and flow paths.** Moreover, the very high evaporation of residual lakes after flooding or natural groundwater increase beyond coal leads to an ongoing lowering of the ground water table in the surrounding landscape.

In certain circumstances, e.g. considering protected and endangered biotopes like the wetlands in the northern part of the *Rhineland Lignite Mining Area* or the UNESCO biosphere reserve *Spreewald* in Lusatia, recharge measures by selective infiltration of pumped groundwater are practiced. On the other hand, the far-reaching disturbance of the aquifer and hydrological flow system can also lead to a local increase of the ground water table as compared to the pre-mining situation. Sometimes it is even necessary to maintain a level low enough for protecting human settlements in the long term. To minimise the damage for the affected catchment areas mine-related mine operation plans must be adjusted beforehand to the regional water resources management plans (GRÜNEWALD 2001).

2.3 Acid mine drainage and metal leaching

As a general rule, coal mining regions suffer from serious hydro-chemical problems, triggered by sulphide mineral oxidation (FeS_2, pyrite, marcasite) of overburden material and acid-induced silicate weathering in contact with rainwater (WISOTZKY & OBERMANN 2001, KLAPPER 2002). **Combined *Acid Mine Drainage* (AMD) and *Metal Leaching* (ML) are one of the most serious off-site environmental challenges posed by coal but also sulphide-containing ores lasting for decades or even centuries** (SINGH 1988, JOHNSON 2003, JOHNSON & HALLBERG 2005, etc.) - a worldwide pollution problem, most persistent and considering both active mining and closed mines (JAMAL et al. 1991, BLOWES et al. 2003). In general, the chemical buffer capacity of carbonate-free cover sediments is quite low, so it cannot neutralise the percolating water. The resulting acidic leachate, seepage or drainage are characterised by exorbitant high sulphate, iron and aluminium concentrations (WISOTZKY & OBERMANN 2001).

Highly mineralised and saline seepage water does not only effect the raising groundwater and the water status of artificial residual lakes, but also rivers draining the mining districts (GELLER et al. 1998, MCCARTHY 2011, LINDBERG et al. 2011, MESCHKE et al. 2015) - a very complex issue depending on many factors, like source terms, hydraulic conditions, distance relationships, chemical reactions during transport and mixing/dilution effects by upstream water bodies (GRAUPNER et al. 2014). Such phenomena are even having a considerable impact on the regional and global carbon and sulphur budgets (RAYMOND & OH 2009). **Without additional active and passive reclamation measures tailored to the acid formation (STOTTMEISTER et al. 1999, JOHNSON & HALLBERG 2005), especially an ongoing liming of acidic mining lakes and a long-term treatment of the affected out-flowing water, it is hardly possible to achieve a good (*near-natural*) water quality in the outflow according to the *EU Water Framework Directive 2000/60/EC* (BENTHAUS & TOTSCHE 2018).**

2.4 Structural instabilities / liquefaction of new ground

Most serious long-term and on-site problems provide the structural instability of course-grained spoils, like sands and gravels in contact with the arising groundwater (NESTLER & STOLL 2001, TRIANTAFYLLIDIS 2015). Besides external impacts, like rainfall, earthquakes or raising groundwater regime, also system-included internal factors not fully understood can trigger a sudden collapse of residual-lake slopes or even whole dumps, i.e. by an increasing pore water pressure or the substrate *break-off* (VOGT et al. 2014). Such material-induced failures occur when the disintegration resistance of the grain skeleton is exceeded. Especially in the *Lusatian* lignite region the problems are evident after the post-mining groundwater rising is almost finished, with actually 206 km^2 affected. It can be assumed that in other geological and hydrogeological comparable situations, e.g. in *North Bohemia*, such impacts will occur in the next decades when mining comes to its end.

Due to the complex geotechnical situation and lack of specific information regarding the dumping technique and the construction features the occurrence of liquefaction events remain largely unpredictable. The modelling or prediction of such geospatial phenomena is rather difficult due to the complexity of relationships, limited process understanding and lack of available data and controlling parameters (NOACK et al. 2014).

2.5 Uncontrolled waste disposal

Lignite and hard coal mining are associated with numerous industrial activities, especially regarding energy intensive industries like metallurgy and the petrochemical branch. In the past, very often abandoned pits nearby the production facilities and workers residential areas were used for lower-cost disposal of chemical residuals like highly mobile hydrocarbons from untreated pyrolysis water, solid waste products (e.g. slag, residual ash) but also domestic waste - regardless of the long-term ecological effects (ECCARIUS 1998, SCHRECK 1998). For example, in the *Bitterfeld/Wolfen* region (*Middle German Lignite District*) the contaminated groundwater covers about 25 km^2 and is endangering the down streaming receiving waters and the river *Mulde* (PETELET-GIRAUD et al. 2007). Much more alarming is the current situation in other coal districts (Serbia, Romania, etc.) and above all the *Donetsk* hard coal mining region - although detailed data are missing. **Over there in the Ukrainian-Russian border region, about 4 billion tons of industrial waste containing toxic components are deposited, in most cases less documented and uncontrolled due to a long industrial history and political conflicts.**

The waste disposal in open pits is problematic due to the lack of a proper landfill sealing and ongoing leaching of harmful substances into the groundwater. The waste disposal in abandoned mine sites bears special environmental risks for the surrounding landscape, especially regarding the uprising groundwater after mine closure and the uncontrolled dispersion and diffusion of harmful effluents (CHRISTOPH & DERMIETZEL 2000). Moreover, pyrite-containing mine substrates cause a strong acidification and salinisation of surface and shallow aquifers, thus stimulating the pollutant mobilisation. But also the immediate public health hazards are obvious, especially when looking at the regional drinking water quality and contamination of residual lakes.

2.6 Chronic effects on the health of the population

Even though the release of dust particles, SO_2 and aerosols by coal (lignite, hard coal) combustion seems unlikely to cause toxicological effects through the food chain, here may be a direct impact on man through inhalation (SABBIONI et al. 1984). A focus lies on solid dust particles smaller than 10 µm (PM10) since their inhalation mainly damages the lung and cardiovascular systems. Especially, children are vulnerable to carcinogens as demonstrated by VAN LEEUWEN et al. (2006) and VRABLIK et al. (2017) exemplary for the *North Bohemian Brown Coal District* in the Czech Republic (*North Bohemia, Most, Chomutov, Teplice, Ústí nad Labem).* Furthermore, SCHNEIDER (2004), GLODEK & PACYNA (2009) and the AMERICAN LUNG ASSOCIATION (2011) point out strong arguments for cleaning up coal-fired power plants following the state of the art. According to a study of EPA in 2004 coal-fired power plants shorten nearly 24.000 lives - alone in the USA. Already PETERS et al. (2000) observed an increased mortality in a highly polluted coal mine region north-west of the Czech Republic as compared to a rural study region in nearby Germany (*Bavaria*), which is consistent to the findings in the United States.

However, EU's 2008 new *Air Quality Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe* followed by *Commission Implementing Decision 2011/850/EU* and *EU Directive 2015/1480/E*C and are setting down nation binding limits and information and reporting standards on target air pollution values for different particle sizes and substances. Already starting with the *Council Directive 80/799/EEC* and *85/203/EEC* on air quality standards for sulphur dioxide and nitrogen dioxide, a bundle of legal frameworks has led to significant improvements in the Member States, including the above mentioned *North Bohemian* region. The largest steps were made for emissions on fine dust, e.g. by installation of electro-mechanical fine particular air filters (electrostatic precipitators / ESP, cyclones) for older plants or the complete wet and dry flue gas desulphurisation, notably by dry sorbent injection, acid gas control and carbon injection.

3 Landscape impact of hard coal deep mining and processing industry - most pressing issues

Affecting TRACER Target Regions: PL22, RO42, UKL1, UKL2, *Donetsk*

3.1 Hard coal deep mining - urbanisation and related industry

On a first, rather superficial sight from the outside, underground mining activities seem to be more selective, less land consuming and stressful for the surrounding environment as compared to opencast mining. Quite easily visible are the typical spoil heaps/waste rock dumps nearby the winding shafts associated landfills, tips and tailing ponds. **Even more than with lignite opencast mining, the environmental impacts recorded are arising from both the mined voids and from the wastes and processing residuals left behind at the surface (YOUNGER 2004, DULIAS 2016).** Unsolved ecological problems are putting substantial pressure on the landscape (PIETRZYKOWSKI & KRZAKLEWSKI 2018, *inter alia*).

But in fact, especially in urban agglomerations with concentrated mining, it affects and modifies the landscape as a whole, especially when including the pollutant emission caused by the coal mining-related industry with power and coking plants, briquette factories and related metal and chemical industry having negative effects on the natural resources (YONG et al. 2015). For example, in Poland there are 413 km^2 land under mining activity. And looking back to the 1990s mining and processing industries produced more than 600 million tons of spoil and over 490 million tonnes of tailings (RYBICKA 1996). It is estimated that for one ton hard coal excavated by deep mining about 0.4 to 0.5 tons of waste rock material are dumped. Although mining exploitation has been significantly reduced in comparison to levels occurring 50 years ago alone in the *Upper Silesian Coal Basin* there are still 19 coal mines in operation, leaving behind about 50 million tonnes waste rock per year (SZCZEPAŃSKA & TWARDOWSKA 1999). PIETRZYKOWSKI & KRZAKLEWSKI (2018) name over 200 residual heaps, covering over 44 km^2 in this region. **Below the line, over 150 years of industrial mining activities have changed all components of the natural environment - the quite typical and so-called *man-made mining landscape* develops, with specific environmental hazards in the long-term (GAWOR 2013, GUS 2018).**

3.2 Continuous and discontinuous land subsidence

Concerning underground and especially hard coal mining the most critical long-term effect relates to land surface deformation and significant subsidence caused by collapsing galleries after exploitation or in case of uncontrolled spontaneous coal seam fires (*auto oxidation*, BAEK et al. 2008, PRAKASH et al. 2010, VIVANCO & MELO 2013, YUAN et al. 2017, ZHENG et al. 2018, etc.). Movements and mining related ground deformations (vertical, horizontal) cause substantial changes of the natural relief leading to destruction of residential areas, commercial and industrial settlements and infrastructure (DULIAS 2015). In general, continuous subsidence is a long-term phenomenon characterised by a slow and flexible depression of the ground surface (PENG 1996). For example, alone in the *Upper Silesian Coal Basin* over 413 km^2 are subjected to land subsidence with complex and difficult to handle challenges for the regional development calling for the improvement of environmental impact assessment methodologies and risk management (KRZEMIEŃ et al. 2016, GUS 2018).

On the opposite of gradual land depression, the dynamic failure of individual mine workings can cause sudden surface collapse and vertical cracks generating acute damage to people and infrastructure. Such events indicate a general instability of mining operations, often caused by excessive overexploitation in deep mines (DIDIER et al. 2008). They are hardly foreseeable in detail and need complex risk assessment studies defining the predisposition, probability of occurrence and magnitude of an event. The related hazard management methods, like the costly backfilling of underground works, or a risk-adapted land use management should be combined with an early-warning monitoring network.

3.3 Sinkholes - collapse craters

Moreover, near-surface mining of lignite and hard coal leaves the risk of dangerous sinkholes, e. g. instable mine roofs or remaining extraction cavities. In contrast, to the large-scale ground deformation the sudden appearance of surface collapse craters is a local phenomenon often affecting few to several tens of meters in diameter.

Besides a shallow extraction (<50 meters below soil surface), also weak, unconsolidated overburden and geological discontinuities are triggering factors (Piggot & Eynon 1978, Singh & Dhar 1997). Already the local risk of sudden earth drops and mass movements impedes or makes even impossible the regular agricultural or forest land use. A sudden collapse of cavities can destroy buildings and infrastructure thus endangering humans (NICHOL 1998).

3.4 Instable abandoned heaps, tailings and tailings dams

Tailings deposits and dams are one of the most unstable landforms resulting from mining having a high geomorphic activity (MARTIN DUNQUE et al. 2015). Besides ongoing surface erosion of tailings (e.g. NYSSEN & VERMEECH 2010, BEULLENS et al. 2014), in particular, the sudden collapse of heaps may have serious or even catastrophic impacts on environment as well as human health and safety: A sadly famous example for a negligent design of an unconsolidated coal waste heap is the *Aberfan Disaster / South Wales* (1966), where a 34 metres high colliery spoil tip collapsed after three weeks of heavy rain. About 110,000 cubic meters sliding spoil killed 142 people (VAN NIEKERK & VILJOEN 2005). **Taking closer look to the situation in Romania, actually about 17% of the tailings dump slopes in the *Jiu Valley* are mechanically unstable, and over 80% of the land is uneven.**

But also breakdown of tailings and impoundment dams can still happen, e.g. in *Kentucky (2000)*, when 1.16 million cubic metres of coal sludge polluted over 400 kilometres rivers. Another remarkable disaster happened in *Baia Mare* and *Baia Borsa / North West Romania* (2000). Over there the embankment of a gold mining settling pond collapsed quite unexpected. The danger is also evident in some European coal mining regions: recently heavy rainfall caused a crack in the tailings dump near the *Green Lake* (*Lupeni Mine*) Romania leading to the damage of 76 households, half of them flooded with mud and tailings.

However, best available technologies and safeguarding measures according to national legal approval requirements and established control / monitoring systems in European countries should rule out such disasters in the future. Especially older heaps and dumps have a considerable risk potential, in particular, when the structure and geo-mechanical situation is not well documented. The main reasons and triggering factors for instabilities are always similar: (1) engineering errors relating to the water regime, missing water drainage, planning failures in the heap / dam structure, (2) misevaluation of external impacts, notably heavy rainfall events leading to a water saturation, (3) uncontrolled run-off from slopes, non-observance of particle sizes of the deposit materials and (4) operational / management problems, like ignoring provisions regarding the tailing disposal and construction.

3.5 Water balance and contamination

The flooding of underground coal mines causes in general long-term and cumulative problems concerning the regional watersheds, especially by acid-stimulated mineral weathering and leaching of sulphur and chloride containing coal-bearing sediments (DOKA 2009). In general, spoiled groundwater is not suitable for drinking without an expensive purification (GOMO & VERMEULEN 2014, CHEN & GUI 2017, etc.). Besides coal mining causes irreversible changes in the landscape water regime. These include the formation of drain-off free basins or changes in the course of rivers and receiving waters. **Very often the affected area is larger than the extracted coal field in a narrower sense.** Typical water management issues relate to the drainage volume, flow schemes together with the contamination level (MAYES et al. 2008, JANSON et al. 2009).

But also mine spoils and heaps are considerable sources of environmental hazards, for example by in situ burning of coal caused by exothermic pyrite oxidation, mechanical instability of slopes and uncontrolled leaching of dissolved acid (*Acid Generating Salts*/AGS) mobilising contaminants like aluminium, iron and heavy metals like zinc and manganese (SZCZEPANSKA & TWARDOWSKA 1999, YOUNGER 2004). For example, in the *Upper Silesia* there are about 1,720 km^2 affected by acid mine drainage.

Another environmental problem taken seriously arises from the subsidence of hazardous disposal sites, like basins filled with residuals from coal preparation (milling, washery, refining) or a mixture of industrial and municipal waste (KLAPPER 2002, DOKA 2009). Moreover, it may cause? an infiltration of contaminated (phenolic) wastewater from coal processing and associated industry into the regional hard rock aquifers (STOTTMEISTER et al. 1998). Thereby, the dimension of environmental impact is not only depending on the intensity and character of mining and contamination level but also from the local geological tectonics / strata, landscape morphology and relief. **Moreover, operational experience shows that waste water treatment efficiency in some mining regions like *Kolubara* (Serbia) or *Donetsk* is not at the sufficient level and below legal requirements.**

3.6 Air pollution issues

First, the emissions of endogenous and surface mitigating mine gases notably methane and sometimes carbon dioxide are making a substantial contribution to the global greenhouse effect (TAUZIEDE et al. 2002, KRAUSE & POKRYSZKA 2013). In fact, coal burning makes the largest contribution to the human-induced increase of CO_2 in the atmosphere. But also, coal combustion whether by hard coal or lignite remained the major emission source for sulphur dioxide in Europe throughout the 20th century. As calculated by MYLONA (1996) total anthropogenic releases increased by a factor of 10 between the 1880s and 1970s when they peaked at approximately 55 million tonnes of sulphur dioxide, followed by a 30% decline in the 1980s due to first effective emission reduction measures (desulphurisation) in the north-western and parts of central Europe.

Deliberate or accidental coal burning is leading to further environmental stress for a long time after mine closure (STRACHER 2007, SINGH 2013). In this regard, air pollution relates to typical combustion gases (CO_2, CH_4), but also fumes and airborne particles (RÓŻAŃSKI 2013). **Finally, released organic pollutants and heavy metals impair the local and regional air and land quality by entering the hydrological and biogeochemical cycles (YOUNGER 2004).** For example, coal-fired power plants contribute to the regional fall-out of mercury and other recognised as *Hazardous Air Pollutants* (HAP) according to EPA) to soil and water. A good overview about the diverse groups of critical substances emitted provide GOLOMB & FAY (2004). Some of the most relevant are: hydrogen chloride, hydrogen fluoride, polycyclic aromatic hydrocarbons cyanide, dioxins and furans but also heavy metals and metalloids like mercury, antimony, beryllium, cadmium, cobalt, lead, manganese, nickel, some radioactive isotopes (uranium, thorium) and other collateral particulates.

Moreover, so-called *gas leak effects* remain a major problem in abandoned hard coal mines worldwide. Furthermore, uncontrolled methane emissions even from unmined parts of a mine involve the risk of explosions bearing the risk of explosion, suffocation and poisoning over decades as well reported in the technical literature, *inter alia* by JACKSON (2000) and ROBINSON (2000). **But also the emission of polycyclic aromatic hydrocarbons from thermally active mine waste dumps remain an urgent environmental problem (KUNA-GWOŹDZIEWICZ 2013).**

The basic EU air quality standards are now twenty years old. Some of the limit values are less restrictive than the 2005 *WHO Air Quality Guidelines* on thresholds and limits for key pollutants that pose health risks. Nowadays atmospheric impacts of coal burning and processing for industrial purposes underlie a permanent monitoring in all EU Member States. **From that point of view, the political task should be to install the "maximum achievable control technology for air purification" - for all running power plants, even for the transition period to the final coal phase-out.** Following this major field of environmental-political action in the heavily affected coal regions, especially in South-East Europe, it is expected that the current emissions will decrease further in the nearby future.

4 Environmental impact and sustainable reclamation solutions - as seen by the TRACER partners

4.1 Bulgaria Maritsa East / Southeast Bulgaria (BG34)

1. Letterhead		
1	Country	Bulgaria
2	Target region	NUTS-2-region: Maritsa East / Southeast Bulgaria (BG34) *Yugoiztochen*
3	Type of mining	Lignite surface mining
4	Project partner / institution	Black Sea Energy Research Centre (BSERC)
5	Contact person(s)	Lulin Radulov, radulov@bserc.eu, office@bserc.eu

2. Baseline / Landscapes in Transition		
6	Total land taken by mining so far / reclaimed land	Total productive area 240 km^2 Reclaimed land 46 km^2
7	Land use distribution before vs. after mining	There is no data about land use distribution before 1955. Current assumptions on land use: agriculture (68%), underutilized/ barren land (24%), forests (5%), settlements/infrastructure (3%) Long-term plans (till 2060) are to reclaim 93% of the used land, thereof 80% for agriculture and 20% for forestry. The remaining space will be used for two artificial lakes
8	Main environmental challenges	Dust emissions, release of mining waters, development of dump sites for industrial wastes, retrace of river, movement of villages
9	Time-lag between devastation and reclamation / re-vegetation	The first TPP started operation in 1959 - 15 years before the start of the first reclamation in 1974.
10	Stripped land not yet reclaimed, including the mine operating area	154 km^2
11	Waste dumps and heaps, not remodelled / uncovered	3 waste dump sites for industrial wastes and ashes 3 heaps for removed soil
12	Land affected by mining	240 km^2
13	Groundwater lowering	No information available
14	Rising groundwater / land flooding	No information available

2. Baseline / Landscapes in Transition		
15	Mechanical instable heaps, dumps and slopes	No information available
16	Land deformation / geological instable caved area	The geological strata is stable.
17	Deposition / soil contamination / hazardous sites	No information available
18	Instable tailings / stockpile collapse / landslides	No information available
19	Acid-mine drainage / acid mining lakes	No information available
20	Unsolved environmental problems	All environmental problems are addressed in the complex permission for mining works. No further information available.

3. Reclaimed land in subsequent use		
21	Agriculture	37.3 km^2
22	Forestry	8.7 km^2
23	Nature conservation, semi-natural revegetation	Currently all used lands for mining works are supposed for reclamation
24	Water areas / residual lakes	There are plans for construction of two artificial lakes in the future
25	Land for renewable energies (solar power, wind power, energy cropping	The potential for electricity and heat generation from solar radiation is very high - > 1500 kWh/m2/year.
26	Land in principle available for renewables - utilisation potential	In principle, land for RES is available, but its utilisation depends on the specific conditions.
27	Geothermal energy production and hydro power plants	There is no geothermal and hydropower potential in the region.
28	Special reclamation activities, e.g. creation of leisure parks, mining museums, etc.	Currently there are no such plans.

4. Legal Framework for Reclamation - Planning procedures & Objectives		
29	Regional planning regulations, legal environmental obligations relevant for land reclamation	*Spatial Development Act* *Environment Protection Act*
30	Environmental impact assessment (EIA) before mining operation	Yes
31	Mine closure and reclamation plans - CRP	The Ministry of Energy has approved a project for the release of the concession area, liquidation, reclamation, including activities and costs for the removal of facilities, technical and biological reclamation.
32	Planning of mine reclamation activities prior to a mine being permitted or started	No
33	Overall reclamation target	To provide as much as possible technical reclamation for use of land for forestry and agriculture Partially development of artificial lakes
34	Planning procedures / mining operation plans	Part of the contract for concession for mining activities At this stage these plans are general
35	Is the reconstruction of the pre-mining landscape intended?	Yes Since the landscape is flat, most of the reclamation activities are for agriculture or forestry use
36	Public participation in reclamation planning	There is procedure for public participation in hearings for *Environmental Impact Assessment Report* developed at the time of concession for mining works
37	Criteria for the release of land from mining supervision	According to the instructions of the regional inspectorate for environmental protection for each specific case

5. Organisational Principles and Processes		
38	Overall responsibility for reclamation: ongoing mining *versus* closed and abandoned mines	Overall responsibility for reclamation of ongoing mining is fully foreseen in the concession agreement. Each concessioner opens an escrow bank account in order to secure the fulfilment of its obligations related to the final release (liquidation, reclamation) activities of the concession area. In case a concessioner fails to fulfil its obligations for liquidation and reclamation, the State has the right to use the accumulated funds to design and carry out these activities.
39	Public planning and approval procedures in reclamation	According to the procedures for territory arrangement planning
40	Financing of reclamation activities	Based on deductions from mining incomes
41	Post-mining environmental monitoring system	Yes Monitoring of air and waters in dedicated boreholes
42	Land consolidation and reorganisation	Yes Since it is not due for returning to the previous owners

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
43	Most-promising best practice procedures in agriculture and forest reclamation	Technical reclamation under specially developed design adopted by the Ministry of Energy
44	Measures against land deformation and mechanical instabilities	In responsibility of the current mining operator, no further information
45	Applied technologies in waste-water cleaning	Use of purification water stations
46	Measures facing groundwater contamination	No data about groundwater contamination
47	Measures to avoid water and wind erosion, ecological engineering	There are such prescriptions by the local inspectorate for environmental protection.
48	Engineered heap covering systems for waste disposal sites	Engineering systems for covering landfill piles have been implemented under the activity contract.
49	Other cost-effective strategies and approaches for contaminated land	No information available
50	Backfill of rock deposits and residuals into opencast voids	Only after permission by the local inspectorate for environmental protection

7. "Ecological Restoration" / Promising energy cropping systems		
51	Common growing systems and/or plants in agricultural practice	Biological reclamation is performed with suitable shrubs, grass or tree species, etc.
52	Practical experience with energy cropping and special crops on reclaimed land	The information is limited and can be found in the municipal plans/reports of the settlements in the area.
53	Average cropping potential, yields, exemplary for cultivated and promising plants in agriculture	According to the municipal plan of the municipality of Radnevo, the reclaimed lands give higher yield than before coal mining.
54	Indication of profitable and sustainable, reclamation-supporting production chains already working - good examples	Mandatory for the successful reclamation is the participation of mines, but in recent years, due to financial difficulties, this activity is almost abandoned.

4.2 Czech Republic North West Bohemia (CZ04)

1. Letterhead		
1	Country	Czech Republic
2	Target region	NUTS-2-region: North West Bohemia (CZ04)
3	Type of mining	Lignite surface (underground) mining
4	Project partner / institution	Charles University (CU) Czech University of Life Sciences Prague (CULS)
5	Contact person(s)	Jan Frouz, frouz@natur.cuni.cz Markéta Hendrychova, hendrychovam@fzp.czu.cz

2. Baseline / Landscapes in Transition		
6	Total land taken by mining so far / reclaimed land	259.3 km^2 / reclaimed: 166 km^2 (64 %), ¼ of reclaimed land located in *Sokolov District*, ¾ in *Ústí District*
7	Land use distribution before vs. after mining	Pre-mining (estimate based on study focused only on *North Bohemia Brown Coal Basin*): dominating agricultural landscape (80%), forest patches (12%), orchards (3%), water bodies and streams (1.5%), settlements and other land use forms (3.5%) Post-mining: agricultural land (26%), forests (46.5%), mosaic of water, especially lakes (12.5%), roads and other (16%) The *Land Cover Database* registered the biggest changes in mining areas in the *Most Region* during 2006 to 2012 with 8.4% of the territory transformed
8	Main environmental challenges	Acid mine drainage from spoil heaps, rising ground water level in surrounding villages after pits flooding, water sources for flooding of residual lakes deep up to 200 m Ecological territorial limits correction and possibility to mine longer Inner spoil heaps - mechanical stability, erosion control Very slowly (rarely) come spontaneous succession into practice. In *Karlovy Vary* area problems are similar but much less pronounced, this area had also higher precipitation
9	Time-lag between devastation and reclamation / re-vegetation	Average 20 years Heaped parts of spoil dumps lie usually 2 to10 years for structural consolidation
10	Stripped land not yet reclaimed, including the mine operating area	93 km^2, aprox. 1/4 mines, 3/4 rest of non-reclaimed area (new inner spoil heap, mining foreground) 5 operation mines: *Ústí District - Vršany*, *ČSA*, *Bílina* and *DNT* mines, *Karlovy Vary District – Jiří*
11	Waste dumps and heaps, not remodeled / uncovered	Deposits of by-products of brown coal power plants *Prunéřov*, *Tušimice*, *Ledvice* (*Ústí District*) and *Vřesová*, *Tisová* (*Karlovy Vary District*) *Růžodolská* and *Hornojiřetínská* spoil heaps of chemical factory (*Unipetrol RPA*) which creates some own tailing ponds and fly ash deposits Very huge landfill (*Celio*) of former *Most-Ležáky* mine (fully reclaimed) These dumps are potential danger to already reclaimed land, especially lakes

2. Baseline / Landscapes in Transition		
12	Land affected by mining	259.3 km^2
13	Groundwater lowering	More than land directly affected by mining Water is pumped from the bottom of up to 200 m deep open mines; a lot of stream where relocated water flows in concrete channels, river *Bílina* flows in four conduits Hard to present an exact area, there is no reliable data from the time before the mining began It is impossible to say what the *normal* (pre-mining) groundwater level was for individual collectors. The problem is, that monitoring systems are located mainly well in advance of the face front,but the rest of the mine including the dumps is usually not monitored
14	Rising groundwater / land flooding	Local phenomenon around first flooded pits
15	Mechanical instable heaps, dumps and slopes	If there are some geotechnical problems, all is usually remodelled. Small landslides occur on the slopes or at the edges of mines when snow melts quickly in combination with heavy spring rains. Nowadays, it is rather a small problem, mainly due to prevention and efforts not to create too sloping territory. Some landslides are visible in the foothills of the *Ore Mountains* at the edge of the *ČSA* mine (old event), but everything is being gradually redeveloped and reclaimed. The outer spoil heaps are usually already finished with reclamation and only the inner heaps are heaped. The problem occurred in the *Sokolov Region* in 2009, when there was a large landslide of the inner heap of the *Jiří* mine into the space dividing the *Jiří* and *Družba* mines. That is why the mining in the *Družba* mine was stopped and the neighbouring mine *Jiří* will overload the area
16	Land deformation / geological instable caved area	Land deformation is typical on site undermined by deep mines, a lot of deep mines operated here 200 years ago - the last deep lignite mine *Centrum* closed in 2016. Undermined flat areas are usually full of small or larger wetland, former agricultural lands stay without management and overgrow by shrubberies and group of trees. New habitats are very valuable from nature protection point of view, e.g. wetlands in *Dolní Jiřetín* A lot of undermined areas were or will be overmined by open mines or were overheaped by external spoil heaps
17	Deposition / soil contamination / hazardous sites	*Ústí Region* is one of the most hazardous region in the Czech Republic, a large number of old environmental burdens are concentrated around mines, power and chemical plants, see section 2, item 11

2. Baseline / Landscapes in Transition		
18	Instable tailings / stockpile collapse / landslides	See section 2, item 11 Completely reclaimed fly ash deposits and tailings: *Růžodol* chemical tailing pond, *Saxonia* coal treatment tailing pond, *Ledvice* and *Tušimice* fly ash deposits
19	Acid-mine drainage / acid mining lakes	AMD is not such a huge problem as in other lignite mining regions, for example, Eastern Germany. It may occur, but very locally on small patches - so far. The pumped water from mine divisions is treated in mine water treatment plants or re-treated on limestone beds and wetlands. The effluent from the dumps does not usually suffer from high pollution and acidity. Lakes and smaller hydric reclamation ponds have usually good water quality.
20	Unsolved environmental problems	Starting with rest pit flooding It is not clear, what will be future with water balance in lakes, who will pump underground water after coal mining (if any), what will be the effect on underground water level Ownership, management and use of future reclaimed landscape There are no more specific studies and plans on how to exploit the potential of land and how to ensure higher fertility of agricultural areas (reclamations)

3. Reclaimed land in subsequent use		
21	Agriculture	46 km^2, grasslands dominate, usual also arable land, rarely orchards and vineyards (older reclamations)
22	Forestry	75 km^2 Forestry is a major way or restoration, most of afforestation was done by broadleaf trees
23	Nature conservation, semi-natural revegetation	Natural succession for restoring in small proportion of area (several hundred hectares) It is usually declared as biodiversity hotspot in frame of forest reclamation although ecosystem development is rather fast. Two interesting sites (54 ha) were originally left for scientific purposes without reclamation on the *Radovesice* spoil heap. After approx. 20 years of semi-natural succession, the technical reclamation plan was withdrawn and, due to its exceptional nature conservation values, registered as an important landscape element and this area is protected by the law
24	Water areas / residual lakes	40 km^2 - new residual lakes *Milada*, *Most*, *Medard*, older and smaller lakes, e.g. *Michal*, *Barbora*, *Benedikt*, *Matylda* 5 large residual lakes will be in future
25	Land for renewable energies (solar power, wind power, energy cropping	So far, no solar or wind power plants on Czech brown coal spoil heaps Energy cropping only sporadic for research
26	Land in principle available for renewables - utilisation potential	Lakes with higher spoil heaps in surrounding, flat parts of spoil heaps not in recreation areas - 1/5 of the surface considered Winds are not too strong, because all spoil heaps are situated on the bottom of basin between high *Krušné Hory Mts*., it is not too much windy area, but the upper parts of the mountains are suitable for wind parks - the largest in the Czech Republic - *Kryštofovo Hamry* - is located here
27	Geothermal energy production and hydro power plants	Not yet, but a pumped-storage power plant or power plants using waves on lakes are considered at *Lake Most*
28	Special reclamation activities, e.g. creation of leisure parks, mining museums, etc.	Yes Technical mining museum, geological park, parks for short-time recreation, several golf courses, hippodrome, autodrome, airport A test circuit for *BMW* at the *Velká Podrušnohorská* spoil heap is planned, inline and bike trails are very favourite

4. Legal Framework for Reclamation - Planning procedures & Objectives		
29	Regional planning regulations, legal environmental obligations relevant for land reclamation	*Mining Act* (*No. 44/1988 Coll.*) Most important regulation which mandates the implementation of comprehensive land-use and land-use structures after mining and safe financial reserve for complete sanitation and rehabilitation, followed by other regulations and decrees Regarding environment and reclamation, there is no dedicated reclamation law, but plans must respect a number of special regulations, most notably the *Act No. 334/1992 Coll. on the Conservation of Agricultural Land*, the *Forest Act* (*No. 289/1995 Coll.*), the *Water Act* (*No. 254/2001 Coll.*) and the *Act on Nature and Landscape Protection* (*No. 114/1992 Coll.), Act on Land Use Planning and Building Code* (*183/2006 Coll.)*
30	Environmental impact assessment (EIA) before mining operation	Yes If new area for mining is planned The EIA process proposes a number of measures to minimise the negative impact of mining on the environment and human health. The parties are also determined the conditions under which mining can be permitted (extended)
31	Mine closure and reclamation plans - CRP	Yes Obligatory for each mine CRP is part of preparation, opening an extraction plan which is needed for mining permission. A comprehensive plan for remediation and reclamation addresses the restoration of the landscape throughout the mine and dump areas, which are already disturbed by mining, or where mining activity is planned in the future. The plan respects finished reclamations and the surrounding landscape, local geological, pedological, climate and social and other specific conditions, describes the overall concept of reclamation, future terrain, land-use representation, the method of firing and treatment of the residual pit, schedule, financial costs and calculation of the financial reserve for reclamation The plan shall be binding, but must be updated and re-approved if necessary by the authorities concerned, planning documents processed for the entire life of the mine
32	Planning of mine reclamation activities prior to a mine being permitted or started	The reclamation plan of the mine and its spoil heaps is created before actual mining, but it can be updated or improved in more detailed implementation projects

4. Legal Framework for Reclamation - Planning procedures & Objectives		
33	Overall reclamation target	Mechanical stabilisation of spoil heaps, remove dangerous or contaminated sites, secure old mine workings, create a good base for long-term targets Use the potential of landscape differences, increasing the attractiveness of the area for recreation etc. The longer-term objectives are to create a functioning landscape combining production areas of agriculture and forestry with land prevailing non-production habitats significantly contributing to landscape stabilisation, restoration of the hydric regime and nature conservation. Landscape should be connected with the surrounding landscape and connected with existing road networks
34	Planning procedures / mining operation plans	Mining is approved for a certain period and mining area under predetermined conditions. Preparation of the area before mining, removal of land from agricultural land and forest land, drainage of the mine area, as well as the mining process and method, the design of conservation and compensatory measures plan or future land use proposal are approved by state authorities at state and regional level, owners - mostly lands have already been bought into state ownership - and other interested authorities, environmental NGOs and the EIA process can comment. The *Ministry of the Environment* and regional departments of environmental protection and the *Mining Authority* (in *Most* and *Sokolov*) play an important role in this Mining operation plans predetermine the main objectives and procedures of landscape restoration, connection to the territorial system of ecological stability, land use distribution. In the mine area, classic land use plans are not valid, but the surrounding municipalities take over the reclamation plan into their land use plans if their cadastral area includes spoil heaps and mines

4. Legal Framework for Reclamation - Planning procedures & Objectives		
35	Is the reconstruction of the pre-mining landscape intended?	No Impossible, because as a result of mining, the relief, microclimate and pedological conditions are totally transformed Only the same area of agricultural land must be returned approximately to the agricultural land fund from which the land was temporarily removed prior to mining activities and the mining company has to pay considerable fees for it Creating a completely new landscape fulfilling a wide range of functions Usually it is a mosaic of forests (prevailing), fields and meadows, water areas (mainly lakes and retention reservoirs) and areas of other purpose, especially destined for recreation (near villages and towns, around lakes and so on). The spoil heap areas are also very specific from an ecological and nature conservation point of view, therefore areas spontaneously developing, although very rarely so far, are included Also in many parts effect of mining is combined with other historical changes. Substantial part of mining area was *Sudeten* with very dynamic movement of people for political reasons non related to mining which makes return to original land use virtually not possible
36	Public participation in reclamation planning	Yes The public, both lay and professional, various associations and non-governmental organisations, representatives of the municipalities concerned, etc. may take part in all proceedings (EIA, territorial and building proceeding). At the level of individual reclamation projects (stages), the authorities responsible for spatial planning, the *Mining Authority*, the *Building Authority*, the environmental departments, representatives of the nature and landscape protection agency, etc. decide on the result and incorporation of their requirements
37	Criteria for the release of land from mining supervision	According to the *Mining Act*, the mining company is obliged to carry out proper remediation and reclamation of the area, but the manner and final form is not defined here. The ending of reclamation and release from mining activities for common use is based mainly on the approval of local authorities focused on the protection of land resources (soil quality control) and forest (involved and grown forest stands corresponding to the composition in the approved project). If the parameters are not sufficient (high mortality, different assortment of woody species - e.g. non-native), local authorities will order continuation of cultivation care or remedying of deficiencies Care for forest reclamation usually 9 years, reclamation crop rotation on agricultural land 5 to 8 years

5. Organisational Principles and Processes		
38	Overall responsibility for reclamation: ongoing mining *versus* closed and abandoned mines	Reclamation in responsibility of the mining company - now a state-owned joint-stock company There are four active quarries, where *Severočeské Doly - Bílina* mine and *Nástup Tušimice* mines, *Sokolovská Uhelná* - all mines in the *Sokolov* area operate. Furthermore, the mines *ČSA* and *Vršany* are operated by the *Czech Coal Group*, a non-state company (*Seven.en Energy* and *Vršanská Uhelná*). These companies also deal with reclamation of areas where the damage occurred prior to the privatisation of previously state-owned enterprises and is the responsibility of the state, but it is financed by the state. The management of closed mines *Most-Ležáky* and *Chabařovice* and old mine workings was entrusted to the state enterprise *Palivový Kombinát Ústí*
39	Public planning and approval procedures in reclamation	The designers of the reclamation plan generally to incorporate public interests into their plans if they are known and the mining company - or the mining authority - agrees with them
40	Financing of reclamation activities	Reclamation is financed by mining companies that have caused damage to the landscape. For these purposes, they must make a financial reserve, which was determined on the basis of a comprehensive plan for remediation and reclamation and is based on the estimated costs of reclamation and coal reserves (CZK per ton of coal excavated). The money is paid into a special account maintained by the Mining Office and from this reserve it releases the money annually for planned reclamation. Another source of financing for reclamation is the so-called *15 ecomillions*, which the state has freed to correct the damage it caused by mining prior to privatisation
41	Post-mining environmental monitoring system	Post-reclamation monitoring is provided by the state-owned company *Palivový Kombinát Ústí*, or by a mining companies. Research institutes are also involved. There is now a *Coal Commission* in the Czech Republic - quite similar to Germany, which solves the future of the mining area from various points of view
42	Land consolidation and reorganisation	The distribution of land use in the landscape is based on habitat conditions and needs. For example, recreational parks and facilities are situated close to municipalities, these areas are accessible by roads, flat land is primarily intended for agricultural purposes, forest reclamations are proposed in the slopes to stabilise them, water bodies are designed further from the heap foot. On the other hand, nature protection areas require more peace and are located away from inhabited areas. Building constructions are also permitted on already consolidated substrates

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
43	Most-promising best practice procedures in agriculture and forest reclamation	During agricultural reclamation, a layer of topsoil (min. 0.5 m) or topsoil with other recoverable soils (loess, loess soil) and fertilisers (compost, sludge, manure) is spread on the area In addition, suitable crops alternate for 5-8 years to improve the physical, biological and chemical properties of soils, plowing of green matter, growing of bean plants. Final stands are usually permanent grasslands. Orchards and vineyards are not planned today Forestry outplanting of nursery seedlings is carried out directly into the clay surface of the spoil heap, seedlings are regularly digged, fertilised, the trunk is trimmed, the trees are protected against game bite. The assortment includes both target and amelioration trees, alternating in groups of similar growth rates. It is not allowed to plant non-native species, as it was before. In the *Sokolov* region, spruce or oak is more common, while other species suffer from game bites. In the *Ústí* region there are typical more thermophilic species (maple, ash, oak, hornbeam, lime tree, alder, etc.)
44	Measures against land deformation and mechanical instabilities	To minimise instability, the spoil heaps are shaped appropriately (steep slopes are shattered, provided with stone feet), soils are heaped selectively. Biotechnical measures such as grass hydro-sowing or forest reclamation are used to stabilise slopes
45	Applied technologies in waste-water cleaning	The water in the reservoirs, lakes and the outflow from the ditches from the spoil heaps are not treated, there is no problem with acidification. Only water accumulating in active mines is treated. The department handles water from the upper parts of the mine (less polluted - they can be used, for example, to sprinkle dusty roads). It is more difficult to treat water that has come into contact with the coal seam and accumulates at the bottom of the mine. These waters are treated in chemical treatment plants (iron precipitation, increased pH by liming) or treated in special wetlands

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
46	Measures facing groundwater contamination	The groundwater that is pumped from the old underground mines is biologically purified (aeration, flow in the limestone bed, wetlands). They then flow into the lake or into adjacent streams
47	Measures to avoid water and wind erosion, ecological engineering	The main anti-erosion measures include suitable greening of sloping areas (grassing, forest planting), strengthening of lakes and streams (aggregates, geotextiles, hygrophilous trees), drainage ditches draining water safely from dump bodies with long slopes, etc. etc. Wind erosion is considerable on spoil heaps, unless covered by vegetation, but alleys that were established as a measure against wind erosion often suffer from breakdown
48	Engineered heap covering systems for waste disposal sites	Too acidic soils, soils with a higher proportion of residual coal (above the coal seam) are trying to situate the mining operation in the deeper layers of dumps. If they appear above, they must be covered with a sufficient covering layer of the insulation and fertile layers. However, there are also places where soil with a pH of 2-3 or very sandy are found on the surface of the spoil heaps. classical reclamation is not successful here, but the areas show unique properties in terms of occurrence of rare and protected species. Deposits of by-products of coal-fired power plants or potential municipal waste dumps must also be reclaimed according to the *Waste Act*, they are isolated and covered by a reclamation layer, often greened only by grassing
49	Other cost-effective strategies and approaches for contaminated land	Very low costs are associated with areas left for spontaneous (completely cost free) or low managed development (e.g. 1/10 of the price of forest reclamation). The most important factor is the absence of technical reclamation and the preservation of very rugged relief, sky ponds, parts with continuous erosion, etc. The result does not have to involve forests or forest-steppe communities where spontaneous succession in Czech brown coal districts is usually directed. Valuable are sites with sporadic vegetation. Nevertheless, such areas are only exceptions in the Czech Republic so far as a common part of practice, because modern ways of landscape regeneration have yet to come into law or the reclamation authorities
50	Backfill of rock deposits and residuals into opencast voids	Missing information The shafts of the abandoned underground mines are mainly closed at the point where it enters the residual pit of the mines to be flooded in order to prevent water loss. Entrances to mines are secured against entry of unauthorised persons

7. "Ecological Restoration" / Promising energy cropping systems		
51	Common growing systems and/or plants in agricultural practice	After topsoil application, which is characterized mainly by low biological activity and poor edaphone life, the agricultural areas are sown most often with fabaceous plants (clovers, pike trefoil, melilotus, alfalfa, pea), which enrich the soil with nitrogen, help increase soil porosity, increase organic mass in soil (plowed annually). Broad-row crops are excluded. Along with clover-grass mixtures, cereals are also grown at the beginning, but the areas are passed on as permanent grassland for further use
52	Practical experience with energy cropping and special crops on reclaimed land	The cultivation of energy crops is not very widespread in spoil heaps. There are rather drier meadows with low yields. Some areas are rented for growing cereals, others are used as pastures. However, there were also attempts to grow energy sorrel (*Rumex* sp.), technical hemp (*Cannabis sativa*) or safflower (*Carthamnus tinctorius*) In previous periods, rapidly growing hybrid poplars were planted on forest reclamations, but nowadays the eco-stabilising and soil-protective function of forests (with a varied mixture of native tree species) is favoured
53	Average cropping potential, yields, exemplary for cultivated and promising plants in agriculture	No reliable data But for example for one spoil heap is known bad experience with sheep grazing due to low grass production
54	Indication of profitable and sustainable, reclamation-supporting production chains already working - good examples	The cultivation and use of energy crops, as well as grazing at dump sites, is still in its infancy in the Czech Republic. Energy is currently available to hay and straw from agricultural areas that have to mow in the reclamation cropping process, recreational areas, etc. There are many former (older) agricultural reclamations that have remained unused after the reclamation and release from *mining* life, overgrown with small-reed (*Calamagrostis epigejos*) and shrubberies. In addition, the forest is trimmed in newly established forest reclamations (at least 6 years), but this biomass remains on the area as a mulch around the seedlings

4.3 Germany
Lusatia / Brandenburg (DE40), Dresden (DED2)

1. Letterhead		
1	Country	Germany
2	Target region	NUTS-2-regions: Brandenburg (DE40), Dresden (DED2) *Lusatian Lignite District*
3	Type of mining	Lignite surface mining
4	Project partner / institution	Research Institute for Post-Mining Landscapes (FIB)
5	Contact person(s)	Dirk Knoche, d.knoche@fib-ev.de Anne Rademacher, a.rademacher@fib-ev.de Rainer Schlepphorst, r.schlepphorst@fib-ev.de

2. Baseline / Landscapes in Transition		
6	Total land taken by mining so far / reclaimed land	879 km^2 / 557 km^2, in reclamation and not yet released from mining supervision: 69 km^2 Over 150 years of industrial coal mining in the region
7	Land use distribution before vs. after mining	Before / after mining: agriculture 31% vs. 18%, forestry 59% vs. 55%, water area 1% vs. 14%, infrastructure (others) 9% vs. 13%, nature protection areas are statistically included in the other land use categories
8	Main environmental challenges	Complete destruction and remodelling of the pre-mining landscape in a geological dimension; acid-sulfurous (pyrite / maracasite, (FeS_2)-containing) substrates, acid mine drainage (AMD) and acid salt leaching (ASL) with a strong impact on the surrounding landscape (groundwater, downstream quality) Geo-mechanical instabilities of sandy textured spoils and embankments, sudden *liquefaction* of dumps due to rising and surface-near groundwater
9	Time-lag between devastation and reclamation / re-vegetation	Nowadays in active mining 15 to 20 years Unreclaimed *lunar landscapes* of the early 1990s belong to the past
10	Stripped land not yet reclaimed, including the mine operating area	Working zone 330 km^2, thereof 134 km^2 unvegetated extraction area; at present 4 active surface mines: *Jänschwalde*, *Welzow-Süd*, *Nochten*, *Reichwalde* with approx. 60 Mio. tons lignite excavated per year; for comparison in 1989: 16 mines in operation, with an annual production of 190 Mio. tons raw lignite, in those days about 30 km^2 were taken by mining each year
11	Waste dumps and heaps, not remodeled / uncovered	Power plant ash and FDG gypsum dumps in operation: *Boxberg*, *Jänschwalde*, multi-layer mineral soil coverage systems combined with technical layers and a complex drainage system according to German *Waste Disposal Ordinance (2002)* Waste dumps and contaminated sites of the former lignite processing industry / thermal and chemical decomposition and refining, e.g. phenolic wastes, tar disposals, other processing residuals, already restored or still in decontamination
12	Land affected by mining	*See item 6 and item 13*
13	Groundwater lowering	Approx. 900 km^2, for comparison 1989: 2,500 km^2 with a water deficit of 13.6 billion m^3
14	Rising groundwater / land flooding	Local phenomenon affecting the structural stability of mining ground, problematic in overbuild areas; in general groundwater lowering as compared to the pre-mining situation, even after flooding of pit holes

2. Baseline / Landscapes in Transition		
15	Mechanical instable heaps, dumps and slopes	Hydraulic failure and liquefaction of dumps, under the geomechanical presetting raising post-mining groundwater and heavy precipitation events can trigger sudden liquefaction (*quicksand*), actually 206 km^2 affected with 45 km^2 agricultural land, from that 28 km^2 with temporary use restrictions and 17 km^2 are *off-limits* blocked for biomass production in the long term
16	Land deformation / geological instable caved area	Only local, caused by abandoned (historical) lignite deep mining (second half 19th century, early 20th century), no landscape relevance, backfilling of shafts and mines almost completed, no barrier for regional structural development
17	Deposition / soil contamination / hazardous sites	Hundreds of post-industrial hazardous sites, >600 contaminated and suspected areas in the mining region, concerning waste products of lignite processing (lignite pyrolysis, distillation, gasification, briquetting, etc.), e.g. tar disposal sites *Terpe* and *Zerre* (760,000 tons' waste), industrial park and former power station *Schwarze Pumpe*, numerous briquette factories Also concerning the lignite-relating and energy intensive industry (refineries, aluminium smelting, galvanisation, mechanical engineering, etc.) and other mixed municipal and industrial landfills, since 1990 under public environmental monitoring, safeguarded or in still ongoing remediation
18	Instable tailings / stockpile collapse / landslides	For the *Lusatian Lignite District* irrelevant: the few piled up and levelled heaps, like *Nardt*, *Plessa*, *Buckow*, *Nochten* or *Burghammer*, are uncritical from the geomechanical point of view, no further need for restructuring or stabilisation
19	Acid-mine drainage / acid mining lakes	Far-reaching hydro-chemical problems, triggered by sulphide? mineral oxidation (pyrite, marcasite), pH_{KCl} drop <2.5 and acid-induced silicate weathering of overburden material in contact with rainwater Residual lake flooding and rising groundwater triggers chemical reactions and pollutant migration into the surrounding landscape Mineralised groundwater enriched with chloride, sulphate and iron effects shallow freshwater aquifers
20	Unsolved environmental problems	AMD/ASL, restoration of groundwater quality in the post-mining landscape, reestablishment of a self-regenerating and self-sustaining water balance - a century-long task Without additional reclamation measures tailored to the acid formation, especially an ongoing liming of acidic mining lakes and a long-term treatment of the affected out-flowing water it is hardly possible to achieve a near-natural water quality according to the *EU Water Framework Directive 2000/60/EC* Mechanical instable inner dumps in landscape dimension, from today`s perspective the ongoing stabilisation measures by blasting and vibro-flotation compression will take decades

3. Reclaimed land in subsequent use		
21	Agriculture	100 km^2 (plus 19 km^2 in reclamation of active mining); as a rule, the better yielding *Quaternary* overburden substrates, like calcareous loam, sandy loam or loess, are exclusively reserved for arable land
22	Forestry	311 km^2
23	Nature conservation, semi-natural revegetation	84 km^2
24	Water areas / residual lakes	78 km^2
25	Land for renewable energies (solar power, wind power, energy cropping	Selective and expandable, e.g. existing wind parks: *Cottbus Nord* (22 MW), *Sallgast Süd* (26 MW), *Klettwitz* (93 MW), Klettwitz Süderweiterung (50 MW), *Kostebrau* (10 MW), Euro Speedway Lausitz (8 MW) Solar parks: *Finsterwalde* (1.98 km^2, 40 MWp / 4.3 MW) and *Senftenberg/Schipkau* (15.3 km^2, 246 MWp / 26.5 MW, the largest solar complex in Germany) Approx. 2 km^2 short-rotation coppices for energy cropping on reclaimed land, average biomass ingrowth in the second rotation period approx. 7 Mg DM ha^{-1} yr^{-1}, spread over different post-mining locations, main cultivation focus at *Welzow-Süd*
26	Land in principle available for renewables - utilisation potential	Concerning all agricultural reclamation sites, climate-friendly alternative to conventional agriculture on low-yielding land However, before mobilising land for new bioenergy/ligoncellulosic value chains the techno-economic feasibility and profitability have to be proved, otherwise it is impossible to convince the landowners
27	Geothermal energy production and hydro power plants	No - nevertheless, the geological situation for using geothermal energy for heating (near-surface <400 metres depth) are rather good, the prevailing loose rock sediments have a high thermal conductivity and heat storage capacity In fact, there is a considerable unused potential for using deep geothermal energy (>400 metres depth), but no regional experience considering electricity production
28	Special reclamation activities, e.g. creation of leisure parks, mining museums, etc.	*Lusatian Lake Land*, *International Building Exhibition Fürst-Pückler-Land* (2000-2010) with 30 reference conversion projects New *Lusatian Lake Land*, the largest artificial landscape in Europe with manifold leisure and water world activities around the *lake town Senftenberg*, with floating houses, sports centres (diving, sailing, speedboats), etc. *Energy Heritage Route of Lusatian Industrial Culture*, *Exhibition / Vistors Mine F60 / Lichterfeld* (former opencast mine *Klettwitz-Nord*), *Geological Park Nochten* (iceage boulders), event power plant *Plessa*, briquette factories *Domsdorf* and *Knappenrode*

4. Legal Framework for Reclamation - Planning procedures & Objectives		
29	Regional planning regulations, legal environmental obligations relevant for land reclamation	*Federal Mining Act* (BBergG 1980) with its implementation rules like RegBkPlG (2002) has replaced a confusing mass of former state mining regulations by a single unified, albeit not definitive, public regulatory regime Other regulations of the general legislation that stand opposed should be applied only to the extent that any deleterious impact on exploration and extraction can be kept to a minimum Mining regulations are overriding to speed up and simplify the complex planning process insofar prevailing public interests do not stand against However, concerning reclamation in detail the demands of the general legal provisions are relevant, i.e. soil protection (BBodschG, BBodschV), water legislation (WHG), nature conservation (BNatSchG), forest (BWaldG), waste regulations (KrWG) and other environmental regulations (USchadG), They "will be applicable insofar the BBergG and derived ordinances do not regulate impacts in detail" - which is actually in most cases Moreover, mine reclamation planning should also be consistent with the overall regional spatial plan
30	Environmental impact assessment (EIA) before mining operation	Yes EIA scoping obligatory, essential part of the mining approval procedures, pre-mining analysis of the site, fully integrated into the mining operation
31	Mine closure and reclamation plans - CRP	Yes CRP obligatory, component of the complex mining approval procedures and operation planning, mining plan designates the land uses that should be achieved after mining
32	Planning of mine reclamation activities prior to a mine being permitted or started	Yes Already starting with the finding and exploration of the deposit

4. Legal Framework for Reclamation - Planning procedures & Objectives		
33	Overall reclamation target	Fulfillment of all legal obligations which apply for the mining companies Establishment of useful and stable ecosystems connecting technical and biological methods Hazard prevention, warranty of the public safety and *regular* and sustainable after use of the reclaimed land according to mine planning
34	Planning procedures / mining operation plans	The general *lignite plan* as part of regional spatial planning defines the framework and describes the key environmental goals and protection measures - it has a legislative character decided by the federal state parliaments Approved mining operating plans are the essential precondition for the whole operational management and thus also reclamation, in particular, the assignment of surface design, land use types, aspects of substrate quality, minimum requirements of restoration, soil target values Subordinated operating plans of the mining company concretize the general targets and measures; the need to be confirmed by the responsible mining authorities - in Brandenburg (DE40), for example, the *State Office for Mining, Geology and Raw Materials*
35	Is the reconstruction of the pre-mining landscape intended?	No reconstruction of the original landscape; much more there is developing a new / unique post-mining landscape (technical ground) with its very specific landscape elements, soil-forming substrates and habitats, ecological potentials and cropping properties
36	Public participation in reclamation planning	Multilevel and interdisciplinary planning process with participation of different parties of public interest in the region (elected, nominated and volunteers, like labour unions, public, authorities, county commissioners, regional planning consortiums, etc.) Participation and consultation process The final implementation / single area-related planning is done by the responsible mining company
37	Criteria for the release of land from mining supervision	The *Federal Mining Act* (BBergG 1980) requests the proper rehabilitation (so-called *Wiedernutzbarmachung* (reutilisation) of the stripped land, otherwise there is no release from mining supervision

5. Organisational Principles and Processes		
38	Overall responsibility for reclamation: ongoing mining *versus* closed and abandoned mines	Active mining according to the *German Mining Law* (1980): the mining company *Lausitz Energie Bergbau AG* (LEAG), private stock corporation Restoration mining / abandoned mining / land recycling: *Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH* (LMBV), state-owned / *Federal Ministry of Finance* (BMF) Addressing former German Democratic Republic (GDR) & older mining activities and decommissioned lignite processing and refining facilities not privatised in 1990, as unfulfilled public obligations
39	Public planning and approval procedures in reclamation	Even though the mining regulations are overriding, they have to integrate the diverse public interest parties (so-called *agents of concern*)
40	Financing of reclamation activities	Active mining: the mining company LEAG (creation of capital reserves for reclamation is obligatory) Restoration mining / abandoned mining / land recycling: common task of the *Federal Republic of German*y and the *Federal States Brandenburg* and *Saxony* (NUTS-2-regions DE40 and DED2*)*, administration and project management by LMBV, project control by the so-called *Steuerungs- und Budgetausschuss der Braunkohlesanierung* (StuBA), a joint board of the *Federal Republic* and touched *Federal States*
41	Post-mining environmental monitoring system	Yes For example, complex post-mining hydrological monitoring including flow and level measurements, water sampling and analytics; management and after care system to fulfill the regulatory requirements
42	Land consolidation and reorganisation	Yes Within the redesign of the landscape, definition of priority areas for different land use forms, with an optimal area design and adequate substrate quality, management units are designed according to the operational needs of the land users For example, in agriculture, there are agronomical-technical targets considered like a minimum field size of 20 to 50 hectares, a moderate surface inclination or an easily cultivable rectangular field shape

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
43	Most-promising best practice procedures in agriculture and forest reclamation	Agriculture reclamation: all procedures relate on a stepwise and sustainable development of soil fertility: aggregation to so-called *management units* (MU) with target values considering the yield-relevant soil properties - special humus-forming crop rotations - special mineral fertilisation Forest reclamation: afforestation in a legal sense with site-adapted *target tree species*, in good agreement with the climax vegetation of the region / no soil-preparing previous use or pioneer wood needed, but special fertiliser regime to promote early ecosystem development until a self-sustaining nutrient cycling is established (10-20 years)
44	Measures against land deformation and mechanical instabilities	Preventive measures: large scale regulation of the groundwater table by permanent pumping, selective dumping of mine substrates regarding geotechnical aspects, forward-looking installation of mechanical barriers in dumps Reclamation measures: dynamic surface compaction by controlled high-energy tamping, vibro-flotation densification, innovative blasting compression
45	Applied technologies in waste-water cleaning	*In-lake* measures, like periodic liming of residual lakes exposed to acidification (*liming ships*), stimulating biological driven alkalization; *ex-situ* purification of discharged waste waters before draining into the downstream, precipitation iron hydroxide and sulphates
46	Measures facing groundwater contamination	*In-situ* sulphate reduction in the aquifer by stimulating microbiological processes (e.g. infiltration of with easily degradable organic substances, like glycerine); funnel and gates systems for treatment of polluted groundwater water
47	Measures to avoid water and wind erosion, ecological engineering	Temporal greening after levelling, basic amelioration (liming) as needed, cultivation with site-adapted plant species, low-input and soil conserving management and cropping systems, promoting perennial soil-covering and restoring crops, like lucerne or clover
48	Engineered heap covering systems for waste disposal sites	Yes In the case of landfills (power plant ash, FDG gypsum), construction of multi-layer coverage systems according to the national *Waste Disposal Ordinance* (2009)
49	Other cost-effective strategies and approaches for contaminated land	Implementation of natural succession into forest reclamation practice by designation of special forest development, unguided re-vegetation with a long-term forest development goal
50	Backfill of rock deposits and residuals into opencast voids	Local, limited to abandoned mining and the safe-guarding of drainage tunnels

7. "Ecological Restoration" / Promising energy cropping systems		
51	Common growing systems and/or plants in agricultural practice	Typical initial crop rotation on poorly structured raw soils involves the cultivation of quite stress-tolerant, soil-building and fast growing perennial plants, with lucerne and other legumes in a key position At the beginning of biological reclamation, the proportion of perennial lucerne or lucerne-grass-mixture cultivation is almost 40 to 50% within the crop rotation whereas the proportion of grain 25 to 35 % With ongoing initial soil development, the proportion of grain growing can be increased to 40 to 45% High-performing and stress tolerant energy and "industrial platform" crops, like *Sorghum* or Sudan grass, can be embedded to a moderate extent into the standard crop rotation without impairing the development of soil fertility
52	Practical experience with energy cropping and special crops on reclaimed land	Yes Diverse expertise regarding conventional energy crops in agriculture (maize, *Sorghum*, sunflowers, etc.) but also perennial and low-input, lignocellulosic feedstock (LCF), short-rotation coppices (SRC, growing poplar, black locust and willow clones), agro-forestry systems (AFS) in the experimental stage Despite all ecological benefits there are up to now only 2 km^2 reclaimed land cultivated with fast-growing woody biomass which is only 2% of the agricultural reclaimed area
53	Average cropping potential, yields, exemplary for cultivated and promising plants in agriculture	Some data based on yield monitoring / on-farm cultivation practice on reclaimed land depending on the soil properties, reclamation age, weather conditions and sorts growing: lucerne: 2-17 Mg DM ha^{-1} yr^{-1}, grass farming: 3-5 Mg DM ha^{-1} yr^{-1}, silage maize: 6-14 Mg DM ha^{-1} yr^{-1}, *Sorghum / Sudan grass*: 8-17 Mg DM ha^{-1} yr^{-1}, winter rye /winter barley / winter wheat (corn+straw): 6-11 Mg DM ha^{-1} yr^{-1}, *Miscanthus* 13-20 Mg DM ha^{-1} yr^{-1}, SRC poplar: 0.3-9 Mg DM ha^{-1} yr^{-1}, black locust 1-11 Mg DM ha^{-1} yr^{-1}, willow: <0.1-5 Mg DM ha^{-1} yr^{-1}
54	Indication of profitable and sustainable, reclamation-supporting production chains already working - good examples	Reclaimed land is suitable for the production of diverse renewable raw materials which opens the pathway for different regional processing concepts, e.g. whole crop bio refineries (straw-, grass-silage-, lignocellulosic-, sugar/starch-based), biogas-production or energy wood for burning Unfortunately, there are still missing techno-economic feasibility studies on this topic to establish a forward-looking green economy, moreover, the available agricultural land is already used in other processing chains

4.4 Greece
West Macedonia (EL53)

1. Letterhead		
1	Country	Greece
2	Target region	NUTS-2-region: Western Macedonia (EL53)
3	Type of mining	Lignite surface mining
4	Project partner / institution	Centre for Renewable Energy Sources and Saving (CRES)
5	Contact person(s)	Charalampos Malamatenios, malam@cres.gr Georgia Veziryianni, gvezir@cres.gr

2. Baseline / Landscapes in Transition		
6	Total land taken by mining so far / reclaimed land	170 km^2 taken by mining / 40 km^2 reclaimed Thereof 20 km^2 reforested, 15 km^2 agricultural land and 5 km^2 parks, lakes, etc. According to *Public Power Corporation* (PPC) restored areas to 27.3% (2015)
7	Land use distribution before vs. after mining	No data on land use distribution before mining Exploitation of the lignite deposits in the region already started in the 1930s, and was intensified in the 1960s. It is estimated that (large) parts of the area (lowlands) were arable land, others - forests. During mining some villages were removed
8	Main environmental challenges	Random mixture of aggregates in nearby deposit areas leading to the permanent damage and loss of cultivable land PPC's common practice at least until the early 2000s
9	Time-lag between devastation and reclamation / re-vegetation	Minimum time-lag between devastation and reclamation / re-vegetation 3 years Based on the EIA of the mines in the *Kozani Regional Unit*, the restoration works are expected to be completed by 2053. More specifically, the mining works are scheduled to be finished in the *South Field*, *Main Field* and *Kardia Field* by 2039, 2044 and 2050, respectively.
10	Stripped land not yet reclaimed, including the mine operating area	130 km^2 Finally, once the restoration programme has been implemented in all points (2053), there will be 50.15 km^2 of cultivable areas, 53.74 km^2 afforested and11.67 km^2 residual lakes

2. Baseline / Landscapes in Transition		
11	Waste dumps and heaps, not remodeled / uncovered	No information on reclamation shortcoming The waste dump areas are levelled as soon as they reach their final limits. Fertile topsoil is added wherever necessary
12	Land affected by mining	See item 6
13	Groundwater lowering	In a recent study that investigated the *Amyntaio Basin*, where a productive semi-confined aquifer is developed at the quaternary deposits. The piezometric curves which have been extracted before the beginning of the mine activity in 1992, were compared with the recent ones, aiming to study their diachronic changes. From the subtraction of the two aforementioned piezometric surfaces, a significant ground water drawdown that reaches 70 m near the mine was observed. This drawdown proves that the aquifer has been overexploited by both the mine of PPC - to protect the slopes and to prevent the water outflow in the mine - and the wells for irrigation purposes Also, for the protection of the *South Field* open mine of *Ptolemais Basin*, from the intrusion of groundwater, the aquifer, which lies above the lignite layer and consists of Neogene and Quaternary sediments, is being drained by wells and surface pumping stations Extensive groundwater quantities are also being pumped from the same aquifer for domestic, agricultural and industrial use along the *South Field Basin*. Over-pumping has created a negative water balance resulting in a continued decrease in groundwater level
14	Rising groundwater / land flooding	Not observed
15	Mechanical instable heaps, dumps and slopes	A major landslide occurred in *Amynteon* mine on June 10, 2017. The total rock volume that was moved is estimated 80 Mm^3 and the affected area is ca. 3.5 km^2. Earth moving works for re-shaping the topography and recovering part of the lignite deposit are in progress Instability problems also exist at the west side slopes of *Mavropigi* mine. The affected area is of limited extent and the impacts concern short-term mine planning and operation and not land reclamation During the last 20 years, landslides occurred in the internal dump and north side slope of *Amynteon* mine, the external dump and the west side slope of *South Field* mine. These areas do not exhibit now instability problems and the impacts have already been mitigated

2. Baseline / Landscapes in Transition		
16	Land deformation / geological instable caved area	Land deformation of the waste heaps final surfaces is expected and can be predicted. Therefore, there is no risk relevant to the land uses that are developed in reclaimed mine land Underground mining stopped 60-70 years ago. The affected areas are of limited extent and the probability of land deformation is negligible No Karstic formations
17	Deposition / soil contamination / hazardous sites	Contaminated sites due to waste disposal activities that were taking place in the past without applying measures of pollution containment This includes the disposal of municipal waste produced from towns and villages located in the greater area of the mines Although mines are currently operating based on environmental permits and an ISO14001 certification, there is still a probability to occur soil contamination due to accidental leakages at waste storage sites or in workshops where hazardous waste are produced, e.g. used lubricants, batteries
18	Instable tailings / stockpile collapse / landslides	No lignite beneficiation plant, tailings or dams that would possibly collapse No danger of landslide Lignite stockpiles in mines and thermal power plants are of limited height
19	Acid-mine drainage / acid mining lakes	No serious concern about AMD, in general, natural water bodies are not affected by mining activities (excavations, transportation, dewatering, waste and fly ash dumping) PH values of water / wastewater vary from neutral to slightly alkaline due to the geochemical characteristics of the rocks surrounding the lignite seams
20	Unsolved environmental problems	Potential environmental threats have been detected and appropriate measures are applied for their elimination However, temporarily problems may occur when the local / regional / national market of waste does not operate properly, such as in the case of used belt conveyors and tires of dumper trucks

3. Reclaimed land in subsequent use		
21	Agriculture	50.15 km² of cultivable areas created until 2053 - final implementation of the restoration programme
22	Forestry	53.74 km^2 of forests finally created
23	Nature conservation, semi-natural revegetation	No specific reference to this kind of reclamation However, former mining areas are following a semi-natural revegetation - apart, from those that are allocated for agriculture or forestry
24	Water areas / residual lakes	11.67 km^2 of lakes created until 2053 covering excavations of mines
25	Land for renewable energies (solar power, wind power, energy cropping	*PPC Renewables*, commenced to develop a power plant project with an intention to construct Greece's largest biomass combined heat and power (CHP) plant providing 25 MW_{el} and 45 MW_{th}. The plant is planned to be installed at an area of approximately 5.8 ha, near the PPC's existing TPP of *Amynteon* and will be using the existing facilities in order to be connected to the electrical and district heating grids *PPC Renewables* plans to develop a photovoltaic park on reclaimed waste heaps surfaces of *Ptolemai*s lignite mines, in four plots covering 500 ha
26	Land in principle available for renewables - utilisation potential	Remaining 50 km² for renewables / RES utilisation
27	Geothermal energy production and hydro power plants	No plans Only use of ground source heat for greenhouses feasible
28	Special reclamation activities, e.g. creation of leisure parks, mining museums, etc.	Yes No further details available In the end special use will occupy 0.8% of the restored area

4. *Legal Framework for Reclamation - Planning procedures & Objectives*		
29	Regional planning regulations, legal environmental obligations relevant for land reclamation	In Greece, all mining and quarrying activities work according to the regulations determined in a *Ministerial Decision* amended in 2011. Moreover, mines and quarries have to meet quality standards and to apply preventive and mitigation measures that are described in numerous national laws and European directives Nevertheless, the main legal tool that regulates all environmental management decisions of a mining company is the environmental permit. The first permit referring to the mining activities at the *Western Macedonia* lignite-mining complex was signed in 2001, after a long period of negotiations with all the involved local and national authorities Since then, additional permits have been signed for all mining operations, as well as for numerous auxiliary activities, such as the ash disposal site of *Meliti Thermal Power Plant* (2002) and the asbestos cement disposal site (2004)
30	Environmental impact assessment (EIA) before mining operation	Yes In order to get the abovementioned environmental permits, it is obligatory to submit an EIA study. Indeed, the general planning of land reclamation is based on the land uses map, as part of the EIA study approved by the *Ministry of Environment, Energy & Climate Change*
31	Mine closure and reclamation plans - CRP	Yes See item 29 and 30
32	Planning of mine reclamation activities prior to a mine being permitted or started	Yes In order to get the environmental permit the mining company has to submit an EIA. In there a detailed land reclamation programme is dealing with reforestation, waste heaps topography, landslides prevention, topsoil management, etc.

4. Legal Framework for Reclamation - Planning procedures & Objectives		
33	Overall reclamation target	CRP foresees land restoration of 81% of the total operation area by 2050, with woodland (45%), agricultural land (46%) and lakes (9%) Remaining areas of special use (0.8%), facilities (0.3%) and other infrastructure (3.4%)
34	Planning procedures / mining operation plans	In the environmental permits for mining operations the following are included: ▪ development and implementation of a land reclamation programme, according to specific reclamation guidelines, ▪ management of various waste streams ▪ and the monitoring of environmental quality Environmental permits refer also to the costs of implementing the terms and conditions for the permitting period and until mine closure & rehabilitation. This cost includes all the activities required for environmental management during mining operations and land reclamation according to the approved plans
35	Is the reconstruction of the pre-mining landscape intended?	No - specific reclamation plans, but not focusing necessarily on the reconstruction of the pre-mining landscape
36	Public participation in reclamation planning	Yes The general planning of land reclamation is based on the map of land uses, which is part of the EIA study that has been approved by the *Ministry of Environment*. These maps are developed taking into consideration both the advices of consultants experienced in land planning of rural areas and the public opinion, as it expressed through the local authorities
37	Criteria for the release of land from mining supervision	No criteria mentioned As soon as the land is reclaimed, it will pass to the local authorities. For the time being, the cultivated land is rented to local farmers at 100 € per ha and year

5. Organisational Principles and Processes		
38	Overall responsibility for reclamation: ongoing mining *versus* closed and abandoned mines	Overall responsibility on the mining companies In the case of *Western Macedonia* the *Lignite Centre* (WMLC) of PPC mining company pays a revenue bond for compensating the adverse impacts of mining on the environment. The reserve fund corresponds to 0.5% of the company's turnover. It is distributed to the regional *Prefectures*, where lignite mining activities are carried out, accordingly to the lignite quantities produced The local authorities have taken full responsibility for using this bond for financing various development projects
39	Public planning and approval procedures in reclamation	General planning of land reclamation based on the land uses map, which is part of the EIA Taking into consideration both the advices of consultants experienced in land planning of rural areas and the public opinion, as it expressed through the local authorities
40	Financing of reclamation activities	Yes Environmental permits refer also to the costs of implementing the terms and conditions for the permitting period and until mine closure / rehabilitation. This cost includes all the activities required for environmental management during mining operations and land reclamation according to the approved plans, and it is up to the mining company, i.e. the one for which the environmental permit has been issued
41	Post-mining environmental monitoring system	No Although monitoring of environmental quality is a pre-requisite for obtaining the *Environmental Permit* It is unclear whether monitoring procedures established during active coal mining are necessary to continue after land rehabilitation.
42	Land consolidation and reorganisation	Yes Planning of land reclamation based on mapping of land use distribution as part of the EIA Significant reorganisation of the land uses foreseen as compared to the surrounding landscape

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
43	Most-promising best practice procedures in agriculture and forest reclamation	The usual reclamation procedures that are applied by WMLC are (a) the development of farming lands in horizontal areas on the top of the waste heaps and (b) the reforestation of the sloped surfaces of the heaps' margins For the selection of the land use that fits better to every plot of mine land, the following criteria are taken into consideration: ▪ the morphology of the final surface, ▪ the position of the area in relation to already reclaimed areas and neighbouring communities, ▪ the type of soil material stacked on waste heap surface, ▪ the altitude of the area, ▪ the exposure to sunlight and winds Tree species usually planted: acacias, rushes, pine trees, poplars, cypresses and ornamental trees First research activities for developing innovative agricultural activities in the reclaimed mine land, such as energy crops, orchards and greenhouses heated with low cost by the steam of the nearby thermal power plants
44	Measures against land deformation and mechanical instabilities	The reclamation works that are usually taking place in mine areas are organised in 4 separated groups of activities: (a) profiling of final surfaces, (b) spreading of topsoil, (c) planting, and (d) development of roads and irrigation networks Continuous mining operation systems stack the wasted material in series of piles that form a completely bumpy surface, whereupon the driving of any vehicles apart from bulldozers is impossible. Profiling is also necessary in foothills of dumping sites, where the steep slopes must be smoothened and benches have to be established to prevent soil erosion 3 m wide benches are constructed in 5 m distance downwards the slope in order to simplify the work of the planting team, reduce surface run-off and, consequently, increase infiltration, increase slope stability and improve efficiency of trees growth due to better irrigation
45	Applied technologies in waste-water cleaning	See item 19 - no significant water pollution and waste-water cleaning technologies applied

6. *Hazard Prevention & Best Practice Reclamation Methods and Technologies*		
46	Measures facing groundwater contamination	See item 19 No significant problem of water pollution, no special measures facing groundwater contamination needed
47	Measures to avoid water and wind erosion, ecological engineering	Yes See item 44
48	Engineered heap covering systems for waste disposal sites	Yes See item 44
49	Other cost-effective strategies and approaches for contaminated land	No special problem of land contamination
50	Backfill of rock deposits and residuals into opencast voids	Yes Mainly waste rocks and ash produced from the nearby thermal power plants

7. "Ecological Restoration" / Promising energy cropping systems		
51	Common growing systems and/or plants in agricultural practice	Wheat cultivation Other arable crops recommended: vineyards, edible legumes and aromatic herbs, and marginally cereals Cultivation of energy crops, rye and oats suggested only after soil improvement and where it is economically feasible Cultivation of industrial and forestry crops promising, but no production and value added chains established yet
52	Practical experience with energy cropping and special crops on reclaimed land	No
53	Average cropping potential, yields, exemplary for cultivated and promising plants in agriculture	Crop yields in agriculture (wheat, corn): 1.0 Mg ha^{-1} yr^{-1} to 4.0 Mg ha^{-1} yr^{-1} (average 2.2 Mg ha^{-1} yr^{-1}) Yield potential comparable to surrounding farmland
54	Indication of profitable and sustainable, reclamation-supporting production chains already working - good examples	150 ha of reclaimed waste heaps surfaces will be offered in the future to young farmers for aromatic herbs cultivation

4.5 Poland
Upper Silesia / Silesian Voivodeship (PL22)

1. Letterhead		
1	Country	Poland
2	Target region	NUTS-2-region: Slaskie (PL22) *Upper Silesia*
3	Type of mining	Hard coal deep mining
4	Project partner / institution	University of Agriculture in Krakow (UAK)
5	Contact person(s)	Marcin Pietrzykowski, m.pietrzykowski@ur.edu.pl

2. Baseline / Landscapes in Transition		
6	Total land taken by mining so far / reclaimed land	413 km^2 land under mining activity, 6.61 km^2 reclaimed during the year 2016
7	Land use distribution before vs. after mining	Hard coal mining in *Upper Silesia* has a centuries-old tradition and the coal extraction on an industrial scale begun already in the mid-18th century. Therefore, it is difficult to assess the use of the land before the commencement of exploitation Arable land 52.0%, forestry 32.8%, urban and industrial areas 12.8%, water areas 1.5% (voivodship area 2018) 383 ha of agricultural and forestry land excluded from mining supervision between 2003 and 2017 192 ha for agriculture and 211 ha for forestry reclaimed during 2010 to 2017
8	Main environmental challenges	Main problems relating to geomorphological and hydrological changes - heap construction, subsidence, floodplains The reclamation of hard coal heaps made of rocks and post-production waste encounters the following environmental problems: waste is characterised by poor retention properties (high proportion of stone fraction), differentiated pH value in horizontal and vertical systems, low sorption capacity, presence of pyrite (FeS_2) and the possibility of thermal activity (self-ignition) and formation of contaminated leachate
9	Time-lag between devastation and reclamation / re-vegetation	Nowadays in active mining 10 to 15 years
10	Stripped land not yet reclaimed, including the mine operating area	Land under hard coal mining activities (as at 31 December 2016) occupied 55 km^2 Currently 19 hard coal mines operating

2. Baseline / Landscapes in Transition		
11	Waste dumps and heaps, not remodelled / uncovered	No data available
12	Land affected by mining	See item 6 and 13
13	Groundwater lowering	Long-term mining exploitation and the associated rock mass drainage caused fundamental changes in the hydrogeological conditions of the *SCI* within the range of the areas in which the deposits are found. This applies especially to the rock mass drainage, changes in the hydrodynamic field system and degradation of water quality The greatest changes in the groundwater environment of productive carboniferous material and its overburden were introduced by deep-sea mining of hard coal deposits. Coal mines are mined at depths of 270 - 1,160 m, pumping 489 m^3 min^{-1} of water with mineralisation ranging from 0.5 to 372 g dm^{-3}. Under the influence of mining drainage, there is about 1,720 km^2 of the area of the basin
14	Rising groundwater / land flooding	Total area of anthropogenic tanks, including those resulting from mining activities: about185 km^2
15	Mechanical instable heaps, dumps and slopes	Currently being built heaps from waste from hard coal mining following the guidelines given in the Polish standard (PN-G-07800 *Opencast mining - Reclamation - General Design Guidelines)* are mechanically stable
16	Land deformation / geological instable caved area	413 km^2 of land covered by mining activities in 2016, threat deformation of land in underground hard coal mining sites
17	Deposition / soil contamination / hazardous sites	More than 200 heaps The construction and storage of coal mining waste on dumping grounds may result in the dustiness of the surrounding areas The petrographic composition of coal waste disposal sites is dominated by claystones, mudstones, sandstones, followed by coal shales the percentage of carbon The carbon content of waste poses a threat to the environment, as self-ignition and fires in landfills can occur. During this process, carbon is thermally decomposed (pyrolysis) and emitted: sulphur dioxide, nitrogen dioxide, aliphatic and aromatic hydrocarbons, hydrogen sulphide, carbon disulphide

2. Baseline / Landscapes in Transition		
18	Instable tailings / stockpile collapse / landslides	Currently, heaps under construction (according to PN-G-07800 *Opencast Mining - Reclamation - General Design Guidelines*) are stable
19	Acid-mine drainage / acid mining lakes	Infiltrating waters within the dumping grounds bring about leaching of easily soluble salts, mainly chlorides. Apart from these compounds, other minerals are additionally leached - mainly gypsum and carbonates. Ventilation and oxidation concern mainly pyrite and occur on exposed surfaces of heaps Pyrite oxidation connected with strong acidification of carboniferous waste (pH 2.5-3.0) and the risk of metals activation
20	Unsolved environmental problems	Land subsidence and the formation of pools in the depressions of the terrain Outflow of contaminated waters, restoration of groundwater quality

3. Reclaimed land in subsequent use		
21	Agriculture	Mining in *Upper Silesia* has a centuries-old history. For these reasons, it is difficult to indicate the total amount of post-mining areas intended for agriculture 986 ha (for the years 2003-2018)
22	Forestry	626 ha (for the years 2003-2018)
23	Nature conservation, semi-natural revegetation	No data available
24	Water areas / residual lakes	No data available
25	Land for renewable energies (solar power, wind power, energy cropping	No data available
26	Land in principle available for renewables - utilisation potential	Heaps rather without potential for energy cropping, yield limiting factor is the very poor water retention However, in principle suitable for photovoltaics
27	Geothermal energy production and hydro power plants	No Despite the possibility to obtain geothermal energy from water pumped out of hard coal mines
28	Special reclamation activities, e.g. creation of leisure parks, mining museums, etc.	Yes, e.g. the historic *Guido Coal Mine* and *Luiza Adit* in *Zabrze* are unique on a global scale In the mine, you can see, among others, the geological stratified structure of rocks with tectonic symptoms, learn about the work of miners at the turn of the 19th and 20th centuries in the area of *Silesia*, take an underground boat ride in the historic excavation *Silesian Museum* established on the site of the former coal mine *Katowice* In the regional museum you can admire exhibitions of artistic and documentary photography, painting and Polish poster, etc.

4. Legal Framework for Reclamation - Planning procedures & Objectives		
29	Regional planning regulations, legal environmental obligations relevant for land reclamation	All legal obligations in the field of environmental protection important or reclamation included in national acts: ▪ *Act on the Protection of Agricultural and Forestry Land* (Dz.U. z 2017 poz. 1161) ▪ *Environmental Law* of 27 April 2001 (Dz.U. 2017 poz. 519) ▪ *Nature Conservation Act* of 16 April 2004 (Dz.U. 2004 nr 92 poz. 880) ▪ *Environmental Damage Prevention Act* of 13 April 2007. (Dz.U. z 2007 r. Nr 75 poz. 493) ▪ *Geological and Mining Law* of 9 June 2011. (Dz. U. z 2011 r., Nr 163, poz. 981) While planning the reclamation one should also take into account the conditions contained in the local spatial development plan, as indicated in the Act of 27 March 2003 on spatial planning and development (Dz. U. z 2017 poz. 1073)
30	Environmental impact assessment (EIA) before mining operation	Yes The procedure of EIA is regulated at the level of the EU and the national level by relevant legal acts
31	Mine closure and reclamation plans - CRP	Yes Mandatory under applicable national legislation
32	Planning of mine reclamation activities prior to a mine being permitted or started	Yes Starting with the discovery and exploration of the deposit - in the preparatory phase of reclamation

4. Legal Framework for Reclamation - Planning procedures & Objectives		
33	Overall reclamation target	Reclamation is understood as granting or restoring degraded or devastated land to usable or natural values by creating appropriate land relief, improvement of physical and chemical properties of the land, regulation of water conditions, soil restoration, strengthening of slopes and reconstruction or construction of necessary roads (*Act on the Protection of Agricultural and Forestry Land*, Dz.U. z 2017 poz. 1161)
34	Planning procedures / mining operation plans	Legal acts are in force, including the *Geological and Mining Law Act* and a number of executive regulations issued on its basis. The document adopted by the *Council of Ministers* - Strategy for the operation of the hard coal mining industry in Poland, sets out the directions of activities constituting guidelines for shaping the conditions for the operation of the hard coal mining sector and individual mining companies and enterprises A properly prepared plan of a mining company should: minimise risks from the conducted works, both for the works carried out in underground excavations and for the general safety on the surface, as well as the adverse impact of mining on the surface, and mining on the natural environment through properly planned and performed reclamation
35	Is the reconstruction of the pre-mining landscape intended?	No In land reclamation developed is a new/unique post-mining landscape (technical ground) with its very specific landscape elements, soil-forming substrates and habitats, ecological potentials and cropping properties
36	Public participation in reclamation planning	Yes The choice of the appropriate way for reclamation (destination and development) of mining sites is the result of agreements between all interested parties: the mining company responsible for reclamation, the local government which hosts the sites where the reclamation sites are located and other local organisations and associations
37	Criteria for the release of land from mining supervision	According to the Act on the *Protection of Agricultural and Forestry Lands*, Dz.U. z 2017 poz. 1161), the supervision over reclamation works is exercised by the Minister of the Environment, and the authority deciding on the recognition of reclamation as completed is the Starost The *Higher Mining Authority* (WUG) supervises and controls the construction and decommissioning of mining plants, including the reclamation of the land after mining activities

5. Organisational Principles and Processes		
38	Overall responsibility for reclamation: ongoing mining *versus* closed and abandoned mines	According to the *Act on Protection of Agricultural and Forestry Land*, Dz.U. z 2017 poz. 1161), a legal or natural person whose activity causes the loss or limitation of the value in use of land is obliged to the reclamation of such land. The reclamation should be completed within 5 years from the end of industrial activity interfering with the environment. The obligation to rehabilitate devastated or degraded land may be transferred with the ownership right to the new owner of the land or, in the absence of the owner, to the *Municipal Office* or the *Starost Office*. The supervision over the reclamation works is exercised by the *Minister of the Environment*, and the authority deciding to recognize the reclamation as completed is the *Starost*
39	Public planning and approval procedures in reclamation	Although reclamation activities are defined by national acts, e.g. the choice of the right way of reclamation should be the result of agreement between all interested parties: the mining company responsible for reclamation, the local government which hosts the areas where the reclamation facilities are located and other local organisations and associations
40	Financing of reclamation activities	According to the *Act on Protection of Agricultural and Forestry* Land, Dz.U. z 2017 poz. 1161), a legal or natural person whose activity causes the loss or limitation of the value in use of land is obliged to the reclamation of such land. The reclamation should be completed within 5 years from the end of industrial activity interfering with the environment. The obligation to rehabilitate devastated or degraded land may be transferred with the ownership right to the new owner of the land or, in the absence of the owner, to the *Municipal Office* or the *Starost Office*. The supervision over the reclamation works is exercised by the *Minister of the Environment*, and the authority deciding to recognise the reclamation as completed is the *Starost*
41	Post-mining environmental monitoring system	Yes For example, the complex system of hydrological monitoring after exploitation, management of areas reclaimed for forestry is taken over by the *State Forests*
42	Land consolidation and reorganisation	Yes Within the framework of landscape redesign, priority areas for various forms of land use, with optimal area design and adequate soil quality, management units are designed following the municipality's *Spatial Development Plan* Land intended for reclamation in the agricultural direction must be characterised by adequately fertile soil formations and have a proper surface shape (e.g. the slope of slopes of built heaps for agricultural reclamation must not exceed 1:10) (PN-G-07800 *Opencast mining - Reclamation - General Design Guidelines*). Also for forest reclamation threshold values are given, which in the case of slopes are 1:3.3

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
43	Most-promising best practice procedures in agriculture and forest reclamation	Forest reclamation: biodynamic method is the best way to achieve the best results where, in addition to the main species, phytomeliorative (e.g. alder) and biocenosis species are introduced to support the target species until a self-sustaining nutrient cycle in the restored forest ecosystem is established (10-15 years), in order to achieve better results, the so-called soil method is used (covering the top layer of the heaps with a layer of soil tens of centimetres thick or potentially fertile soil formations)
44	Measures against land deformation and mechanical instabilities	Prevention of geomorphological changes (deformation of the terrain) consists primarily in filling post-mining voids with appropriate materials (e.g. sand) or regulation of the groundwater table through permanent pumping out of excess water Rehabilitation measures to prevent instability of heaps: dynamic surface compaction through controlled compaction, and rapid turfing and afforestation of heaps
45	Applied technologies in waste-water cleaning	Measures in low pH tanks, such as periodical liming of lakes exposed to acidification to stimulate biologically driven alkalisation; *ex-situ* treatment of discharged wastewater to treatment plants

6. *Hazard Prevention & Best Practice Reclamation Methods and Technologies*		
46	Measures facing groundwater contamination	Methods of preventing surface water pollution within the dumping grounds include building drainage infrastructure and collecting and discharging water to sewage treatment plants An example is the *Olza* collector, which collects water from dumping grounds and drains underground mine waters in the *Rybnik* subregion
47	Measures to avoid water and wind erosion, ecological engineering	In the initial period, the use of sprinkler systems that limit the movement of dust (pollution), and ultimately the introduction of woody and herbaceous vegetation on post-mining objects, carrying out reclamation
48	Engineered heap covering systems for waste disposal sites	Yes On some heaps the so-called soil methods are used, where the stored waste is covered with a layer of several dozen centimetres of fertile soil or potentially fertile formations Such solutions are most often used in objects where there are potential sources of toxicity (e.g. high pyrite content)
49	Other cost-effective strategies and approaches for contaminated land	Implementation of natural succession into forest reclamation practice by designation of special forest development, unguided re-vegetation with a long-term forest development goal
50	Backfill of rock deposits and residuals into opencast voids	Yes Filling the cavities (sidewalks) of depleted hard coal by with sand, underground waste or ash

7. "Ecological Restoration" / Promising energy cropping systems		
51	Common growing systems and/or plants in agricultural practice	On hard coal mining heaps, the most frequent direction of reclamation is forest and woodland direction
52	Practical experience with energy cropping and special crops on reclaimed land	No, generally, there are no suitable conditions for establishing crops, especially energy crops, on the landfills of hard coal mining waste. Insufficient amount of water retention by waste causes that the conditions of growth of seedlings of energetic plants preclude an appropriate weight increase (comparable with agricultural areas) - ensuring the economic viability of the plantation
53	Average cropping potential, yields, exemplary for cultivated and promising plants in agriculture	On post-mining objects, the forest and wooded direction implemented is usually protective Upgrowing timber stands are characterised by a differentiated growth rate (0.5-12 Mg DM ha^{-1} yr^{-1}) depending on soil conditions, climate, species composition or density
54	Indication of profitable and sustainable, reclamation-supporting production chains already working - good examples	Currently, most of the waste heaps from hard coal mining are reclaimed in the forest or woodland direction On older waste dumps, where the stored waste can be used as a building material, rock mining is carried out for construction purposes. For example, in 2010, approximately 400 thousand Mg of coal waste was used up and transported for recovery on the constructed A1 motorway from the *Przezchlebie* waste dump (using the convenient location of the waste dump in relation to the constructed A1 motorway - the distance of approx. 3 km) The dumping grounds are also used for reuse to obtain hard coal. Technologies for recovering coal from waste piles are known; in the past, the *Central Mining Waste Deposit* in *Smolnica* (*Sośnicowice* commune), *Bukowo* (*Lubomia* commune), *Czerwionka* (*Czerwionka-Leszczyny* commune), *Panewniki* (on the border between *Mikołów* and *Katowice*), *Knurów* and *Pszów* were operated

4.6 Romania
West Region / Jiu Valley / West (RO42)

1. Letterhead		
1	Country	Romania
2	Target region	NUTS-2-region: West Region (RO42) *Jiu Valley*
3	Type of mining	Hard coal deep mining
4	Project partner / institution	Valea Jiului Social Institute Association (AISVJ), ISPE Design and Consulting (ISPE)
5	Contact person(s)	Emilia Dunca, emydunca@gmail.com Sabina Irimie, sabina.irimie@gmail.com Marian Dobrin, marian.dobrin@ispe.ro Gloria Popescu, gloria.popescu@ispe.ro

2. Baseline / Landscapes in Transition		
6	Total land taken by mining so far / reclaimed land	90 km^2/ 38 km^2 But still under *SNIMVJ - SOCIETATEA NAȚIONALĂ DE ÎNCHIDERI MINE VALEA JIULUI S.A.* supervision - former mines' land and buildings free of juridical charges need to be recorded in the *Land Registry Book* and handed over by *SNIMVJ* to the local public authorities
7	Land use distribution before vs. after mining	Before / after mining: agriculture 25% vs.11%, forestry 60% vs. 52%, water area 0.65% vs. 1%; infrastructure (others) 1.5% vs. 28%, nature protection areas are statistically included in the other land use categories
8	Main environmental challenges	Tailings dumps blocking rivers' valleys, with mining lakes appearance upstream and downstream; CH_4 gas leakage, from the ventilation of active and closed mines, directly into the atmosphere In summer the flying ash particles, from the ash and slag dumps of *CEH - Paroșeni CHPP* running on hard coal, are wind-blown over the city of *Vulcan* Landscape degradation of the *Jiu Valley* due to both tailings and ash & slag dumps. But these can be exploited for SiO_2 and clay contents, and also other useful components
9	Time-lag between devastation and reclamation / re-vegetation	Of 10 to less than 15 years expected The activity did not stop, currently being active mines with two tailings dumps handed over to the *Territorial Administrative Units* to which they belong (the neighbouring communities)
10	Stripped land not yet reclaimed, including the mine operating area	52 km^2 4 underground operating mines: *Lonea*, *Livezeni*, *Vulcan* and *Lupen*i, with a production of about 742 thousand tons per year of hard coal), land not yet reclaimed about 0.016 km^2 In 1989 there were 15 underground mining exploitations, with a hard coal production of 11 million tons per year; 11 closed mines being currently under *SNIMVJ* supervision

2. Baseline / Landscapes in Transition		
11	Waste dumps and heaps, not remodeled / uncovered	Tailings dumps (mining wastes dumps) are summing up an estimated total area of 244.39 ha, of which 195.51 ha (80%) are covered with spontaneous vegetation, disposed directly on the ground Most of the dumps being improvised without observing the environmental protection standards, without drainage system implemented, thus, leading to air, water, soil and esthetic pollution Ash and slag from *CEH* - *Paroșeni CHPP* are hydraulically evacuated to the first tailing pond at *Căprișoara Valley* (48 ha), located at approx. 2 km from *Vulcan* city; the second tailing pond for emergency (10 ha) is at approx. 400 m from *Paroșeni CHPP* Ash and slag from *CEH* - *Deva TPP* were hydraulically evacuated to the *Mures* pond (59 ha), closed on December 31, 2006 Currently, *Bejan* dump (150 ha) is used, together with the rivers' right bank new dump *Mures (*46 ha) in dense slurry technology
12	Land affected by mining	In addition to the 2.44 km^2 covered by tailing dumps, the land was also affected by the subsidence phenomenon (0.51 km^2) that led to: destruction of a large number of households and the cultural centre in *Dâlja Mare* Displacement of the collar and the tower of the auxiliary well no.1 from *Livezeni Mine*; partial destruction of the aeration well support no. 2 *East Petrila* and its removal; impact on the safety area of the metal pillars from the tailing funicular in *Arsului Valley* (*Lonea Mine*) and abandonment of the funicular commissioning; impact on the safety area of the mining colony "80 houses" in *Lupeni*. Thus a large number of colony houses had to be demolished
13	Groundwater lowering	No data
14	Rising groundwater / land flooding	No data *CEH* performs monthly mine water analysis for active mines, and *SNIMVJ* conducts monthly mine water analysis for closed mines
15	Mechanical instable heaps, dumps and slopes	16.66% of the tailings dump slopes in the *Jiu Valley* are mechanically unstable, and over 80% of the land is uneven (in 2002) Heavy rainfall caused a crack in the tailings dump near the *Green Lake* (*Lupeni Mine*) leading to the damage of 76 households, of which 35 houses were flooded with mud and tailings

2. Baseline / Landscapes in Transition		
16	Land deformation / geological instable caved area	Only locally caused by hard coal underground exploitation and lack of backfilling works DN7A road sections affected, together with a large number of households (see item 12)
17	Deposition / soil contamination / hazardous sites	2 ash & slag tailing ponds are hazardous, with the related contaminated area and others potentially contaminated, containing heavy and radioactive metals, from hard coal burning: *Căprișoara Valley* (0.48 km^2) and the one for emergencies (0.10 km^2) 3 ponds with coal sludge from the *Coroiești Preparation Plant* (0.25 km^2), an industrial park created in the former *Petrila Sud* mining site (1 sawmill, 2 furniture factories, car paint, etc.); *Vulcan* briquetting facility and other mixed municipal and industrial landfills (0.83 km^2)
18	Instable tailings / stockpile collapse / landslides	Tailings dumps (mining wastes dumps) with instability phenomena: *Lupeni* and *Hondol* (0.26 km^2) but problem solved Ash & slag tailing ponds in the *Jiu Valley* do not exhibit instability phenomena, nor geo-mechanical critical situation, with no need for land stabilisation works
19	Acid-mine drainage / acid mining lakes	No information
20	Unsolved environmental problems	Lack of CH_4 gas capture from active and closed mines Former mining land not biologically cultivated; ash and slag dumps and ponds not environmentally restored Flying ash particles, from *CEH - Paroșeni* CHPP ash and slag dumps Landscaping and economic re-use (e.g. tourism) of the mining lakes formed between the tailing's dumps or by rivers valleys blockage No integrated environmental permit issued for *CEH - Deva* TPP Land not released of juridical charges and not returned to the owners FGD Plant from *CEH - Paroșeni* CHPP not yet commissioned, even though the works are carried almost to 100% In Romania, 8 years ago, 46% of the total households were heated with firewood and coal stoves, in *Jiu Valley* the percentage may be even higher

3. Reclaimed land in subsequent use		
21	Agriculture	4.22 km^2
22	Forestry	18.11 km^2 Restored to forestry after reclamation of closed mining perimeters
23	Nature conservation, semi-natural revegetation	16.05 km^2 Can be recultivated with energy crops, including tailings dumps, ponds and other forms of anthropogenic degradation
24	Water areas / residual lakes	0.35 km^2 Water quality was determined and strategies for ecological rehabilitation and use for different purposes were developed
25	Land for renewable energies (solar power, wind power, energy cropping	No such examples
26	Land in principle available for renewables - utilisation potential	Approx. 2.44 km^2 of tailings dumps, with a great variety of local climates in terms of sun exposure, slope, altitude (750-850 m a.s.l.), relief shapes and locations, and favourable conditions for wind farms, PV development There is a potential to develop grasslands or meadows, thus natural land fertility being confirmed (grass, shrub and tree species), and no additional investments would be needed for energy cropping No technical solutions analysed for the ash & slag dumps, which would add up to 1.17 km^2 of potential land reuse

3. Reclaimed land in subsequent use		
27	Geothermal energy production and hydro power plants	No geothermal sources in the area, but hydro power plants At *Hunedoara County* level, *Hidroelectrica National Company* has 695 MW installed in HPPs and MHPPs managed by the *Hațeg Subsidiary*, of which in *Jiu Valley* are located *Buta* HPP, at *Câmpul lui Neag* (491 MW) and *Valea de Pești* HPP, in *Uricani* (200 MW) APA *Serv Valea Jiului* - the public utilities company is a prosumer, operating 3 x MHPPs: *Valea de Pești* (0.2 MW), *Polatiștea* (0.2 MW) and *Brazi-Vulcan* (0.034 MW) Recently, 2 MHPPs were blocked by the court, both due to the significant environment impact (Natura 2000 protected sites): one illegally in operation, located on the river *Taia* (private investor) and one on river *Jiu* at *Livezeni - Aninoasa*, 55% of the works performed; both MHPPs were short listed by the EC - infringement case no.4036 / 2015
28	Special reclamation activities, e.g. creation of leisure parks, mining museums, etc.	Yes There are initiatives, but funds for expansion are needed; today, funds are obtained from the *World Bank* for the rehabilitation of *Petroșani Mining Museum*, *Petrila Planet - The Romanian Plumber Museum* in *Petroșani and Momârlan Museum* (the natives of some rural communities in *Jiu Valley*, descendants of the *Dacians*)

4. Legal Framework for Reclamation - Planning procedures & Objectives		
29	Regional planning regulations, legal environmental obligations relevant for land reclamation	*Mining Law no. 85/2003*, with all its subsequent amendments and completions, which governs the performance of all mining activities in Romania, including mines conservation, closure and post-closure with environmental restoration and land reclamation works; its implementation and application rules *GD no. 1208/2003*, and *National Regulatory Authority* (ANRM) orders: ▪ *Order no. 116/1998* approving the technical instructions for underground and open pit mines closure procedure ▪ *Order no. 202/2881/2348/2013*, commonly issued with the *Ministry of Environment and Climate Change* and *Ministry of Economy*, approving the technical instructions for implementing and verifying the implementation of measures set out in the *Environmental Restoration Plan*, the *Extractive Waste Management Plan* and the *Technical Project* for the environmental restoration, as well as the operation of the financial guarantee for land reclamation and environment restoration ▪ *ANRM Order no. 243/2019* approving the technical instructions regarding the framework content for the preparation of the *Report on Mine Closure*, *Greening and / or Post-Closure Monitoring Works* The main legislative framework in the mining field is complemented by other associated acts regarding mainly: *EIA – Law no.292/2018* on the assessment of the effects of certain public and private projects on the environment – transposing the EIA Directive 2014/52/EU; *Mining wastes -GD no. 856/2008* on the management of waste from extractive industries - transposing the Mining Waste Directive 2006/21/EC; *Surface and underground waters - Law no. 107/1996* (Water Law) - transposing the Water Policy Directive 2000/60/EC; *Air quality - Law no. 278/2013* regarding industrial emissions - transposing IE Directive 75/2010/EC (former IPPC); *GD no.1403/2007* on the restoration of the areas in which the soil, subsoil and terrestrial ecosystems were affected; and *GEO no. 57/2007* on protected areas, the conservation of natural habitats, of wild fauna and flora
30	Environmental impact assessment (EIA) before mining operation	Yes According to *Mining Law no. 85/2003 (Art.20)* the issue of the exploitation license is subject to a written application/request including 5 documentations: *Feasibility Study*, *Mining Exploitation Development Plan*, *Environmental Restoration (Reclamation) Plan* and *Technical Project*, *EIA Study* and *Balance Sheets*, *Social Impact Assessment and Mitigation Plan*, the last 2 documents being similar to an ESIA report

4. Legal Framework for Reclamation - Planning procedures & Objectives		
31	Mine closure and reclamation plans - CRP	Yes According to *Mining Law no. 85/2003 (Art.20)* even from the exploitation license issuance, within the feasibility study, an initial *Mine Closure Plan* is requested and separately the *Environmental Restoration (Reclamation) Plan*, see item 30 *Art.39* stipulates that the license holder has the obligation to periodically update the *Mine Closure Plan* and submit it for approval to ANRM Additionally the former *Ministry of Industry and Resources* issued the *Order no. 273/2001 for the approval of the Mines Closure Guidebook*
32	Planning of mine reclamation activities prior to a mine being permitted or started	Yes, see item 30 Additionally the future exploitation license owner has to make proof of financial guarantee deposit for environmental restoration, prior to ANRM license issuing approval (*Mining Law* no. 85/2003, Art.22)
33	Overall reclamation target	Mining exploitation owner fulfilling its obligations, ANRM and the *Ministry of Energy* (ME) observing and supporting the proper procedures application, according to the legislation in force. ANRM, ME, APM, ANAR and GNM observing the application of measures and actions proposed within the *Mine Closure*, the *Environmental Restoration (Reclamation)* and *Extractive Wastes Management Plans*, including *Post-closure Monitoring Program* Sustainable and stable ecosystems restoration and land reclamation for economic or recreation purposes, useful to the communities in the area Proper planning for preventing hazardous events, in terms of environmental, technological and social issues
34	Planning procedures / mining operation plans	The precondition for obtaining the exploitation license is a proper planning (*Mining Law* no. 85/2003 Art.20), the necessary documentation to be approved by the NAMR including also the *Mining Operation Development Plan* Within 180 days from the entry into force of the exploitation license, the license holder obtains all necessary permits, pays taxes and draws up the *Annual Mining Operation Program*, then ANRM approves the documents and authorises the start of the mining exploitation ANRM sets out the technical instructions regarding the performance and approval of the *Annual Mining Operation* through Order no. 47/2008

4. Legal Framework for Reclamation - Planning procedures & Objectives		
35	Is the reconstruction of the pre-mining landscape intended?	No The *Environmental Restoration (Reclamation) Plan* describes, evaluates and schedules the measures for land reclamation in the mining operating perimeter, considering also the options of the local authorities regarding post-closure use of the perimeter, without rebuilding identically the pre-mining landscape (*Mining Law no. 85/2003 Art.3*) *ANRM Order no. 254/2019* approving the technical instructions on the framework content for the *Environmental Restoration (Reclamation) Plan*, the *Environmental Recovery Project* and *Technical Project* only emphasises: how to frame the former mining perimeter in the existing urban and spatial planning plans; different versions of post-closure use and alternative solutions to ensure the reintegration of the perimeter into the local / regional landscape
36	Public participation in reclamation planning	No Other tactics/instruments of public participation than the consultative one (in compliance with the *Romanian EIA Law* no. 292/2018) are not applied (e.g. active engagement in the decision-making / planning process); even if the *Mining Closure Guidebook* clearly stipulates the responsibility of the license holder to involve stakeholders and communities consortium during the reclamation planning process, currently in real life the situation is different
37	Criteria for the release of land from mining supervision	According to *Mining Law* no.85/2003 Art.37, GD no. 1208/2003 *Mining Law application Norms*, *Mines Closing Handbook*, and *ANRM Technical Instruction for Mine Closure* (2013 and 2019) the mine land and buildings are released from mining supervision (free of technological and legal charges), within no more than 3 months term after the cessation of the concession, and after having fulfilled the criteria: ▪ physical and chemical stability and safety of reuse, ▪ without financial debt, ▪ restoration of all environmental factors, ▪ land ownership regime clarified and the former mine perimeter registered in the *Land Registry Book*

5. Organisational Principles and Processes		
38	Overall responsibility for reclamation: ongoing mining *versus* closed and abandoned mines	For the active or conserved mines to be closed (*Mining Law no.85/2003*), the reclamation responsibility rests with the license holder (for *Jiu Valley* - SNIMVJ), and implementation observed by several public authorities as ANRM, ME, APM, ANAR and GNM (see item 33) Even if the *Mining Law and the Mines Closure Guidebook* underline that the Ministry in charge (e.g. for hard coal mines in *Jiu Valley - Ministry of Energy*) has the responsibility to finance the closure procedure, including the entire land reclamation process for the abandoned mines, unfortunately, the state authorities did nothing, for the moment
39	Public planning and approval procedures in reclamation	Despite the fact that it is clearly stipulated by the former *Ministry of Industry and Resources* in *Order no. 273/2001 for the approval of the Mines Closing Handbook*, which are the procedure and responsibilities of the license holder. In reality they do not comply, but neither local authorities or citizens representatives have a proactive attitude, as a general lack of civic engagement
40	Financing of reclamation activities	According to *Mining Law no.85/200* *Art.52* if the license holder is a national mining company, the mine conservation / closure works will be financed from the state budget; if it is a private license holder all the mine closure works, including land reclamation will be performed with its own funds *Art.53* the implementation of the post-closure monitoring program will be done by the license holder, with its own funds; if it is a national mining company, the program will be performed with state budget from the ministry in charge (e.g. for CEH, *Jiu Valley* hard coal mines - *Ministry of Energy*)
41	Post-mining environmental monitoring system	Yes According to the *Mining Law no.85/2003 Art.52* the technical program for mine decommissioning or conservation, will also include the post-closure environmental factors monitoring program; the implementation of the post-closure monitoring program will be done by the license holder (e.g. SNIMVJ is performing and managing a five years post-closure monitoring process)

5. Organisational Principles and Processes		
42	Land consolidation and reorganisation	Yes In compliance with Order no. 273/2001 for the approval of the *Mines Closing Handbook* restoration and land reclamation works are provided to ensure consolidation and security for future re-use solutions (e.g. for tailings ponds - stability works, levelling, backfilling and consolidation; drainage and water collection systems etc. For mine wastes dumps - stabilisation by slopes compaction, using geo-textiles or fast fixing of a thick grass cover; drainage and water collection system Land preparation with reference to scarification or deep ploughing for land remediation; for underground mines - fencing or isolation of areas with subsidence risk, ensuring ventilation and drainage etc.) The license holder has to invite the local community for consultation on the potential re-use of former mining land and buildings

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
43	Most-promising best practice procedures in agriculture and forest reclamation	Agricultural reclamation: The fertility of the tailings dumps is proven by the spontaneous installation of the flora from the adjacent ecosystems; the process is gradually installed during 10-20 years, with fertility development and humus formation. No chemical or organic fertilisation are required, because of the embedded fertility components of the tailings; tailings chemical analysis revealed the most abundant element, as Si^{4+} from quartz and feldspar SiO_2, followed by Al^{3+} from biotite and feldspar of Al_2O_3, Fe^{2+} from the biotite FeO, Ca^{2+} from calcium CaO and K^+ from feldspar K_2O; on the tailing dumps free from technological charges from *Petrila*, *Petrila Sud*, *Lupeni* and *Uricani* mining exploitations, locals established pastures for grazing the animals Forest reclamation: At *Vulcan* mining exploitation in 1995, *Puț 7 Vest* tailing dump was ecologically re-cultivated with wild pine and white sea-buckthorn At *Lupeni* mining exploitation *Ileana II* tailing dump was re-cultivated with black pine mixed with white sea-buckthorn, at *Petrila* mining exploitation branch *V* tailing dump was re-cultivated with acacia; the wild pine and black pine seedlings were raised in vegetation pots and were planted directly without an initial soil preparation; the white sea-buckthorn and acacia were planted directly in cuttings in the mining waste; species adaptation was confirmed by the presence of species in the field Local species, with high ecological amplitude and specific requirements for the landfill type of soil, were planted, in order to create an ecosystem that would maintain the nutrient cycle and stop the degradation phenomena (15-20 years)
44	Measures against land deformation and mechanical instabilities	Permanent pumping and evacuation of mining waters from underground operations, backfilling with sterile material or with 1:10 power plant ash levelling, compacting and retaliating the tailings dump surface, creating drains and collecting channels to retrieve the running waters from the dumps' slope
45	Applied technologies in waste-water cleaning	In 2003 the hard coal preparation plant in *Coroiești* was retrofitted and upgraded, thus substantially reducing the impact on the *West Jiu River* ecosystem *Hunedoara Environmental Protection Agency* requires each mining exploitation to be equipped with its own sewage treatment plant. For the purification of industrial wastewaters before being discharged into the emissary; pH = 7-7.5; periodic water quality determination in the lakes formed between the tailings dumps, indicated a pH = 7.42

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
46	Measures facing groundwater contamination	In the area of ash and slag ponds were performed: a clay waterproofing of the slopes, an efficient drainage system and a reverse wells system
47	Measures to avoid water and wind erosion, ecological engineering	Linear bushes from willow pipes, with forest species planted behind them to consolidate the land and reduce the water flow rate on slopes Grassing the slopes of the ash tailings' ponds to avoid the wind-blown; perennial crops on the slopes for grazing animals, with early soil cover
48	Engineered heap covering systems for waste disposal sites	Yes In case of industrial waste dumps the construction of waterproofing systems provided, according to *Law no. 211/2011 regarding wastes regime (Art.20)* Waste management must be carried out without endangering human health and damaging the environment, in particular: a) without generating risks for air, water, soil, fauna or flora, b) without creating discomfort due to noise or odors, c) without adversely affecting the landscape or areas of special interest
49	Other cost-effective strategies and approaches for contaminated land	Yes Tailing dumps are left bare for the ecological succession to be achieved through a continuous process of immigration of the species from the native ecosystems; knowing the ecological succession is important in the manipulation of an ecosystem, usually degraded, in the sense of growth: ▪ of its biomass, if it is intended to obtain an agricultural product, ▪ of the number of species, when a stable ecosystem is obtained that increases the quality of the environment through its cycles, ▪ and for ecological reconstruction
50	Backfill of rock deposits and residuals into opencast voids	Yes Locally backfilling with rocks and residuals For controlling the underground space a pipe was introduced for the collection of air samples; in the case of wells and other vertical works, the concrete slab which covers them is also provided with a Φ 76 mm pipe to prevent any accumulation of gases in the closed areas In active mines the aeration is permanent, and the unexploited spaces are backfilled with tailings and ash from 1:10

7. "Ecological Restoration" / Promising energy cropping systems		
51	Common growing systems and/or plants in agricultural practice	Pure white sea buckthorn crops were located on the tailings dump at *Vulcan*, which allowed for atmospheric nitrogen to be fixed through the roots of the plant, but it was not continued with another valuable crop from an energy or economic point of view, its ecological reconstruction By placing this species, it was found that in the first 5 years it has a rapid development and a total colonisation of the landfill. The quality of the soil has been improved, the permeability for water and air has improved
52	Practical experience with energy cropping and special crops on reclaimed land	No practical experience
53	Average cropping potential, yields, exemplary for cultivated and promising plants in agriculture	The assessment of the benefits of the rehabilitation are related both to obtaining wood mass in an area with a wood deficiency, as well as to the possibility of CO_2 storage and its recovery on the international market From the surface of 17 ha of the *Vulcan* tailings dump at the age of 20 years, middle-class orchards can be obtained, with a wood volume of approx. 828 thousand EUR; carbon storage will be approx. 870.4 t CO_2 / year, approx. 22 thousand EUR For the assessment of the viability of the rehabilitation, the benefit / cost ratio was calculated and it was found that at 1 lei (0.2 EUR) invested it would bring a benefit of 2.43 lei (0.5 EUR)
54	Indication of profitable and sustainable, reclamation-supporting production chains already working - good examples	The forest lands reclaimed has the capacity to maintain crops of various renewable raw materials, which can lead to the diversification of the regional processing concepts (e.g. biofuels plants, biogas or firewood production). So far, there are no feasibility studies to prove and encourage the ecological and economic use of these reclaimed lands Agricultural lands reclaimed are used to a large extent for pasture; other uses have not been analysed. The geographical area being not one with tradition in the field of grapevines cultivation, but the cultivation of sea-buckthorn shrubs promises the most Ash, slag and tailings were used in the production of various building materials (e.g. bolts) With the residuals from the hard coal washing in *Coroiești Preparation Plant*, an attempt has been made to recover them by forming briquettes, but about 70% is clay

4.7 Serbia
Kolubara (RS11 & RS21)

1. Letterhead		
1	Country	Serbia
2	Target region	NUTS-2-regions: City of Belgrade region (RS11), Sumadija and Western Serbia region (RS21) *Kolubara*
3	Type of mining	Lignite surface mining
4	Project partner / institution	Energoprojekt ENTEL a.d. (ENTEL)
5	Contact person(s)	Jasmina Mandic-Lukic, jmlukic@ep-entel.com

2. Baseline / Landscapes in Transition		
6	Total land taken by mining so far / reclaimed land	Total land taken by mining: 52 km^2, actual land taken by mining: 37.4 km^2, reclaimed land 7.19 km^2 (2018) Land planned for reclamation: - eastern part of *Kolubara* basin up to 2050 approx. 23.5 km^2 - open pit mine *Tamnava West Field* 27.3 km^2 - open pit mine *Radljevo* 21.3 km^2
7	Land use distribution before vs. after mining	Land use distribution after mining (mean value): agriculture 74%, forestry 26% Specifically, for open pit mine *Tamnava West*: before / after mining: agriculture 77% vs. 15.3 %, forestry 10.8 % vs. 78.2 %, infrastructure (others) 11.4 % vs. 4.5 %
8	Main environmental challenges	Environmental challenges from mining activities: ▪ Soil degradation ▪ Change in land use in the surrounding region ▪ Local air pollution caused by mining activities and barren soil disposal ▪ Surface water pollution ▪ Groundwater lowering and pollution ▪ Geo-mechanical instabilities of barren soil disposals inside and outside of surface mine pit ▪ Local noise pollution ▪ Change in surrounding terrain morphology due to formation of disposal sites and depressions after coal excavation ▪ Endogenous fire prevention ▪ Implementation of human health protection measures Environmental challenges from power generation and other coal processing facilities: ▪ Near and far-reaching air pollution ▪ Surface and groundwater pollution from solid waste, as well as coal storage ▪ Local noise pollution
9	Time-lag between devastation and reclamation / re-vegetation	15-20 years Reclamation/revegetation activities are planned for each open pit mine, depending on the scheduled coal excavation period
10	Stripped land not yet reclaimed, including the mine operating area	44.81 km^2 Stripped land not yet reclaimed as total land taken for mining (52.00 km^2) minus reclaimed land (7.19 km^2) Land used for mining facilities: 3.75 km^2

2. Baseline / Landscapes in Transition		
11	Waste dumps and heaps, not remodeled / uncovered	Uncontrolled municipal waste disposals: 0.092 km^2 temporary disposals of industrial wastes in line with *Law on Waste Management* - Off. Gazette No. 36/2009, 88/2010, 14/2016 i 95/2018 Closed open pit mines are in some cases used as outside barren soil disposal sites for newly opened pit mines
12	Land affected by mining	37.41 km^2 In detail, open pit mine *Field D* (22.00 km^2), open pit mine *Field B* (4.20 km^2), open pit mine *Field G* (0.51 km^2), open pit mine *Tamnava West* (10.70 km^2)
13	Groundwater lowering	Mining activities in the previous period caused groundwater level lowering, thus many of existing wells are not functional anymore.
14	Rising groundwater / land flooding	No groundwater rising and land flooding by active mining Both are likely to occur only during and after intensive rain, which result in great increase of surrounding surface waters flow. These events can provoke instabilities of barren soil disposal slopes, both inside and outside of the mine pits
15	Mechanical instable heaps, dumps and slopes	No data available Technical documentation for each open pit mine operation include slope stability calculations (both for exploitation areas and barren soil disposals), in line with *Rule Book on Technical Requirements for Surface Exploitation of Mineral Resources* (Off. Gazette No. 96/2010)
16	Land deformation / geological instable caved area	No data available
17	Deposition / soil contamination / hazardous sites	No data available Coal excavation and processing have local impact on soil contamination Soil quality measurements are carried out in line with Serbian regulation requirements (*Rulebook on soil quality monitoring program, risk assessment indicators and reclamation program methodology* - Off. Gazette No. 88/2010 considering 19 parameters: content of clay, humus, total organic carbon (TOC), readily available phosphorus, N, Cd, Cr, Cu, Ni, Pb, Zn, Hg, As, B, Ca, Mg, Mn, Fe, fluorides (F^-), chlorides(Cl^-), nitrites (NO_2^-), nitrates (NO_3^-), bromides (Br^-), orthophosphates (PO_4^{3-}), sulphates (SO_4^{2-}), fuel oil hydrocarbons (C6-C10) and (C10-C28), mineral oils (C10-C40), PAH and total PCBs

2. Baseline / Landscapes in Transition		
18	Instable tailings / stockpile collapse / landslides	Temporary unstable working slopes that occur during mine exploitation, usually on disposal layers, are technically stabilised immediately during exploitation. Applied coal excavation technology does not generate any slurry waste that should be disposed
19	Acid-mine drainage / acid mining lakes	No acid mining lakes during and after coal excavation Coal mine waste waters are discharged into the nearby rivers after pretreatment in sedimentation ponds (pH value range of discharged waters 7.0-8.0)
20	Unsolved environmental problems	▪ Air pollution by emissions from coal processing facility *Kolubara Prerada* - specific pollutants: phenols, sulphur, nitric organic compounds, formaldehyde ▪ Soil contamination with phenols and metals (As, Ni, Cr) ▪ Surface waters (*Kolubara* River and its tributaries) pollution from coal mines and coal processing facilities ▪ Noise level in the nearby region ▪ Population resettlement ▪ Soil instability due to induced landslides

3. Reclaimed land in subsequent use		
21	Agriculture	3.66 km^2 - part of the reclaimed agriculture land is returned to mine activity during 2005-2015 1,00 km^2 of arable land, 0.07 km^2 of orchard
22	Forestry	8.63 km^2 - part of the reclaimed forest is returned to mine activity during 2005-2015 6.11 km^2
23	Nature conservation, semi-natural revegetation	13.9 km^2
24	Water areas / residual lakes	0.27 km^2 / 1.23 km^2
25	Land for renewable energies (solar power, wind power, energy cropping	No actual plans for renewable energy generation plants, there are potentials, see item 26
26	Land in principle available for renewables - utilisation potential	Solar energy: open pit mine *Veliki Crljeni* (2.2 km^2) and open pit mine *Polje A* (1.68 km^2) Solar energy potential annual mean value in the *Kolubara* coal basin region is 1,400 kWh m^{-2}, while the foreseen energy generation is ca. 3.4 to 4 kWh m^{-2}, i.e. 1.22 x 10^5 TWh yr^{-1} with approx. 2,000 "solar hours" per year Actual utilisation of wood resources on reclaimed land is low and insufficient
27	Geothermal energy production and hydro power plants	Some potential for geothermal energy utilisation in the region Regarding existing information about geothermal waters chemical composition, their utilisation should be mainly for recreation and sports, while mineral and thermo mineral springs should be used in medical purposes More detailed geochemical and hydrogeological investigations needed for a better definition of the potentials of this kind of resources No potentials for hydro power plants
28	Special reclamation activities, e.g. creation of leisure parks, mining museums, etc.	Yes Soil amphitheater made of the tailings from the surface mine *Tamnava East*, which has been built for the needs of social activities

4. Legal Framework for Reclamation - Planning procedures & Objectives		
29	Regional planning regulations, legal environmental obligations relevant for land reclamation	*Law on Mining and Geological Investigations* (Official Gazette RS, No. 101/15) *Law on Planning and Construction* (Official Gazette RS, No. 72/09, 81/09, 64/10, 24/11, 121/2012, 42/2013, 50/2013, 98/2013, 132/2014, 145/2014, 83/2018) *Law on Master Plan of the Republic of Serbia* for the period 2010-2020 (Official Gazette RS, No. 88/2010) *Kolubara Coal Basin Master Plan* (Official Gazette RS, No. 107/2017) *Law on Nature Protection* (Official Gazette RS, No. 36/2009, 88/2010, 91/2010, 14/2016, 95/2018) *Law on Waste Management* (Official Gazette RS, No. 36/2009, 88/2010, 14/16 95/18) *Rulebook on Technical Requirements for Mineral Resources Surface Exploitation* (Official Gazette RS, No. 96/10) *National Strategy on the Sustainable Development of Bational Resources Usage* (Official Gazette RS, No. 33/12) *Strategy on the Mineral Resources Management in Republic of Serbia up to 2030* (2015) *Rulebook on the Methodology for the Development of Rehabilitation and Remediation Projects* (Official Gazette RS, No 74/2015)
30	Environmental impact assessment (EIA) before mining operation	Yes Obligatory before mining operation starts
31	Mine closure and reclamation plans - CRP	Yes Obligatory, component of the approval procedures for mine opening and operation planning
32	Planning of mine reclamation activities prior to a mine being permitted or started	Yes Technical documentation for mine opening and operation In the permitting phase including separate volume related to reclamation planning and design

4. Legal Framework for Reclamation - Planning procedures & Objectives		
33	Overall reclamation target	▪ Fulfillment of the requirements regarding preservation of the nature in the regions of mining activities, defined in the national regulation and planning documents ▪ Ecological balance recovery in the region, including landscape and biological features ▪ Mitigation of harmful impacts of mining on the air, soil and water quality in the vicinity of mining region ▪ Mitigation of adverse impacts on land use - reduction of agricultural land, forests, grassland ▪ Mitigation of adverse impacts on settlements located in the vicinity of mine fields
34	Planning procedures / mining operation plans	The main document, which defines plans for reclamation of land under mine activities, is *Long-term Strategy of Kolubara Coal Basin Development*, carried out and approved by *Power Utility of Serbia* (EPS) and Serbian government in 2015, for the period up to 2050 The following aspects concerning land reclamation are contained in the said document: ▪ planned areas for reclamation of the inside barrel soil disposals in the open pits, ▪ reclamation time schedule, ▪ investment time schedule for technical and biological reclamation, ▪ technical and biological reclamation description
35	Is the reconstruction of the pre-mining landscape intended?	Not obligatory Proposal and final decision of landscape reconstruction is result of detailed evaluation of new environmental conditions created during period of mine pit exploitation Each part of land intended for reconstruction is subject of separate design in aim to define optimal way of technical and biological reclamation
36	Public participation in reclamation planning	Yes Planned land reclamation procedure includes public participation in the process of planning documents approval In addition, EPS adopted plan for cooperation with stakeholders, based on best international practice
37	Criteria for the release of land from mining supervision	Defined in the technical documentation for open pit mine closure

5. Organisational Principles and Processes		
38	Overall responsibility for reclamation: ongoing mining *versus* closed and abandoned mines	Owner of the mine-for both ongoing mining and closed mines The *Ministry of Mining* and *Ministry of Environment* shall approve reclamation activities, defined in technical documentation for open pit mine closure
39	Public planning and approval procedures in reclamation	Reclamation procedures are approved by the authorities in the process of planning and technical documentation preparation and approval, as defined in the *Law on Planning and Construction* - Official Gazette RS, No. 83/2018
40	Financing of reclamation activities	*Power Utility of Serbia Resources*
41	Post-mining environmental monitoring system	Yes Post-mining environmental monitoring program including surface and ground waters, soil and air quality control, in line with regulation requirements
42	Land consolidation and reorganisation	Yes Land consolidation and reorganisation defined in technical documentation for open pit mine closure, as well as in the *Coal Basin Master Plan*

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
43	Most-promising best practice procedures in agriculture and forest reclamation	Procedures in land reclamation include the following steps: ▪ agrotechnical reclamation including construction of access roads and land levelling, ▪ technical reclamation, including preparation of the surfaces to be reclaimed for planting, with a top layer of soil substrate, ▪ technical reclamation providing optimal soil development, as well as regulation of hydrological conditions, in aim to achieve terrain stability necessary for revegetation, ▪ biological reclamation, including all necessary biological and plant protection measures (fertilisation and care) for growing plants (trees and/or grass). Each phase is realised according to previously prepared technical documentation in which all kind of works are defined in detail
44	Measures against land deformation and mechanical instabilities	Afforestation and agricultural planting (notably lucerne or plants with deep roots) in aim to eliminates erosion processes and stabilise landslide-prone slopes
45	Applied technologies in waste-water cleaning	▪ Mine waste waters cleaning: before discharge into the recipient river *Pestan*, waste waters are treated in the sedimentation pond ▪ Waste waters from coal processing facilities *Kolubara Prerada*: Waste waters treatment plant consists of collecting tank, sedimentation pond with filters, quick tank with agitator, *Emser* filter, secondary sedimentation tank, lagoons and clean water collecting tank ▪ Waste waters from mining equipment maintenance and repair facilities, *Kolubara Metal*: Waste waters are treated in oil separators, installed near the facilities in *Kolubara Metal*, then discharged in the storm water network and transferred to *PUTOX* for further treatment. Clean water is discharged into the river *Kolubara*

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
46	Measures facing groundwater contamination	Groundwater contamination not identified so far, preventive measures include fuel oil management
47	Measures to avoid water and wind erosion, ecological engineering	Regarding usual reclamation procedures see item 43 On barren soil disposal sites low vegetation (grasses, etc.) is growing shortly after disposal Planting of protection green zones and trees on the final slopes of the disposal sites to avoid water and wind erosion
48	Engineered heap covering systems for waste disposal sites	No
49	Other cost-effective strategies and approaches for contaminated land	Yes Excavated areas shall be prepared for disposal of solid waste generated in thermal power plants / fly and bottom ash and FGD gypsum
50	Backfill of rock deposits and residuals into opencast voids	Yes Opencast voids are backfilled with barren soil

7. "Ecological Restoration" / Promising energy cropping systems		
51	Common growing systems and/or plants in agricultural practice	The choice of plants to be grown on the reclaimed surfaces depends on several factors, mainly of terrain morphology, hydrological and other climate conditions Most of the surfaces defined for reclamation are barren soil deposits. In these cases, the common practice is to grow trees on the slopes of the deposits, in aim to improve stability and fasten development of the soil substrate Flat parts of deposits are usually planted with oilseed rape in the first step (in the autumn). In the second step, in the following vegetation season, after plowing and application of agrotechnical measures, these surfaces are planted with grass
52	Practical experience with energy cropping and special crops on reclaimed land	Not so far Energy cropping is planned on the area of open pit mine *Field B*
53	Average cropping potential, yields, exemplary for cultivated and promising plants in agriculture	Average yields of agriculture plants: ▪ wheat: 3.5-4.0 t ha^{-1} ▪ corn: 4.0-4.5 t ha^{-1} ▪ sunflower: 1.5-1.8 t ha^{-1} ▪ lucerne: 3.1-3.3 t ha^{-1} ▪ apple: 15-20 t ha^{-1}
54	Indication of profitable and sustainable, reclamation-supporting production chains already working - good examples	All applied remediation and biological reclamation methods have shown that selected plants are suitable for greening of degraded areas It is evident that performed reclamation activities are useful and necessary mitigation measure for environmental protection of the region. However, achieved plant yields did not prove profitable results so far

4.8 Ukraine
Donetzk / Donetzk Basin

1. Letterhead		
1	Country	Ukraine
2	Target region	Donetsk Region
3	Type of mining	Hard coal deep mining
4	Project partner / institution	Coal Energy Technology Institute (CETI)
5	Contact person(s)	Igor Volchyn, volchyn@gmail.com Nataliya Dunayevska, dunayevskani@ukr.net Dmytro Bondzyk, bondzyk.dmytro@gmail.com

2. Baseline / Landscapes in Transition		
6	Total land taken by mining so far / reclaimed land	251.2 km² / 0.7 km²
7	Land use distribution before vs. after mining	No data
8	Main environmental challenges	In total, about 4 billion tons of industrial waste containing toxic components accumulated in the region flooding of mines, flooding of soils, salinization of soils, deformation of the earth's surface, formation of dips and cavities
9	Time-lag between devastation and reclamation / re-vegetation	No experience in mine territories reclamation
10	Stripped land not yet reclaimed, including the mine operating area	250.5 km² (99.7%) There are 33 deep coal mines in the target region, 23 mines are in operation now

2. Baseline / Landscapes in Transition		
11	Waste dumps and heaps, not remodelled / uncovered	Power plant ash dumps in operation: *Kurakhivska TPP*, *Slovianska TPP*, *Vuhlehirska TPP*, *Myronivska TPP*, *Kramatorska CHP*
12	Land affected by mining	See section 6 and section 13
13	Groundwater lowering	No information available
14	Rising groundwater / land flooding	60 km² of urban and rural territories located over mines, about 1,660 km² land flooded
15	Mechanical instable heaps, dumps and slopes	About 600 dumps of rocks of coal mines and coal-processing plants in the region, thereof 130 burning
16	Land deformation / geological instable caved area	3 areas in Donetsk region with instable land, that caused buildings deformation Total surface area of instable land / subsidence: over 220 km^2
17	Deposition / soil contamination / hazardous sites	Many dangerous and contaminated places, connected with mining, more than 60 dumps burning Burning rock dumps are a source of emissions for a range of pollutants, namely carbon monoxide, nitrogen oxides, sulphurous gas, particulate matter (carbon dust) and several heavy metals
18	Instable tailings / stockpile collapse / landslides	Some territories in *Donetsk* and *Stahanov* are instable
19	Acid-mine drainage / acid mining lakes	Up to 300 mil. m^3 per year of mineralised mine waters discharged into receiving waters Groundwater enriched with chloride and sulphate effects shallow freshwater aquifers Formation of typical mineral products of sulphuric weathering such as plaster, iron oxides, etc. The oxidation of pyrite when extracting sulphurous rocks from coal mines and storing them on the surface is accompanied by a sharp ph drop of the surface layer/rooting zone. This in turn leads to the mobilisation of acid-soluble and potentially toxic metals, e.g. Fe, Al, Mn, Zn
20	Unsolved environmental problems	Not reclaimed most of dumps in region Burning rock dumps Acid-mine drainage, highly contaminated with heavy metals Wind-driven dumps erosion and dust formation, which is an inconvenience and a chronic threat to nearby communities

3. Reclaimed land in subsequent use		
21	Agriculture	No data - insufficient practical experience
22	Forestry	No data - insufficient practical experience
23	Nature conservation, semi-natural revegetation	No data - insufficient practical experience
24	Water areas / residual lakes	No data - insufficient practical experience
25	Land for renewable energies (solar power, wind power, energy cropping	Not yet It is planned to use reclaimed dump lands for solar and wind power generation
26	Land in principle available for renewables - utilisation potential	Lands that are located near agricultural land can be used for the production of electro energy and thermal energy from renewable sources, such as biomass
27	Geothermal energy production and hydro power plants	No projects There are some plans for using of deep mines potential for hydro power plants
28	Special reclamation activities, e.g. creation of leisure parks, mining museums, etc.	No activities

4. Legal Framework for Reclamation - Planning procedures & Objectives		
29	Regional planning regulations, legal environmental obligations relevant for land reclamation	Land reclamation is regulated by Article 166 of “The Land Code of Ukraine” and SOU (standard, No 10.1.00174125.011:2007
30	Environmental impact assessment (EIA) before mining operation	Yes EIA is a mandatory procedure in planning any business activity, including mine operations
31	Mine closure and reclamation plans - CRP	Yes Mine closure and reclamation is planned when mine closes as planned. But there are a lot of examples of premature closure of non-profit mines
32	Planning of mine reclamation activities prior to a mine being permitted or started	No There are plans for reclamation of existing mines, they are all old. In that there was no reclamation planning. For now there are no plans for opening new mines

4. Legal Framework for Reclamation - Planning procedures & Objectives		
33	Overall reclamation target	Establishment of useful and stable ecosystems connecting technical and biological methods Hazard prevention, warranty of the public safety and *regular* and sustainable after use of the reclaimed land according to mine planning
34	Planning procedures / mining operation plans	Reclamation of waste heaps must be carried out according to the following normative documents: SOU 10.1.001 174125.011: 2007 *Natural waste heaps of coal mines and processing plants. Rules of mining and technical reclamation* SOU N 10.1-05420037-001: 2007 *Rules for biological reclamation of waste heaps of coal mines of Ukraine*
35	Is the reconstruction of the pre-mining landscape intended?	No Developing a new / unique post-mining landscape
36	Public participation in reclamation planning	No The reclamation of waste heaps should be carried out only in accordance with the current national standards
37	Criteria for the release of land from mining supervision	Waste heaps are removed from the balance of the mines after reclamation is complete. Requirements for reclamation are determined by the standards of Ukraine

5. Organisational Principles and Processes		
38	Overall responsibility for reclamation: ongoing mining *versus* closed and abandoned mines	Mine owners are responsible for the maintenance of the waste heaps and their reclamation The private company DTEK owns most of the mines and some are state-owned
39	Public planning and approval procedures in reclamation	Even though the mining regulations are overriding, they have to integrate public interest parties
40	Financing of reclamation activities	Waste heaps reclamation is funded by mine owners
41	Post-mining environmental monitoring system	Yes Post-mining hydrological and heavy metals content monitoring
42	Land consolidation and reorganisation	Yes Within the redesign of the landscape, definition of priority areas for different land use forms, with an optimal area design and adequate substrate quality Management units are designed according to the operational needs of the land users

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
43	Most-promising best practice procedures in agriculture and forest reclamation	No reliable information
44	Measures against land deformation and mechanical instabilities	To prevent land deformation, the layout of the surface of the troughs, filling the gaps with rock, followed by planning and applying a fertile soil layer
45	Applied technologies in waste-water cleaning	For the purification of mine water, a complex of special facilities could be provided in which the water is gradually purified first from coarse and colloidal dispersed, and then from truly dissolved impurities. During cleaning, water should be also disinfected and sediment is treated

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
46	Measures facing groundwater contamination	Measures will be defined after starting of reclamation planning
47	Measures to avoid water and wind erosion, ecological engineering	The main way to prevent water and wind erosion is the landscaping of heaps with the help of forest stands
48	Engineered heap covering systems for waste disposal sites	No In the Donetsk region engineered heap covering systems for waste disposal sites are not used
49	Other cost-effective strategies and approaches for contaminated land	Implementation of natural succession into forest reclamation, unguided revegetation with a long-term forest development goal
50	Backfill of rock deposits and residuals into opencast voids	No Applied to insignificant extent

7. "Ecological Restoration" / Promising energy cropping systems		
51	Common growing systems and/or plants in agricultural practice	No practical experience
52	Practical experience with energy cropping and special crops on reclaimed land	No practical experience
53	Average cropping potential, yields, exemplary for cultivated and promising plants in agriculture	No data, see item 51 and 52
54	Indication of profitable and sustainable, reclamation-supporting production chains already working - good examples	No experience with already working reclamation-supporting production chains

4.9 United Kingdom West Wales and the Valleys (UKL1), East Wales (UKL2)

1. Letterhead		
1	Country	United Kingdom
2	Target region	NUTS-2-region: West Wales and the Valleys (UKL1), East Wales (UKL2)
3	Type of mining	Hard coal deep & surface mining
4	Project partner / institution	Welsh Government (WG)
5	Contact person(s)	Trygve Rees, trygve.rees@gov.wales Neil Hughes, dnhughes@wardell-armstrong.com

2. Baseline / Landscapes in Transition		
6	Total land taken by mining so far / reclaimed land	Surface mining 130 km^2 - cumulative area of recorded surface opencast coal mining (past and present) based on information provided by the *Coal Authority* (CA) under licence *East Pit* (*Celtic Energy Ltd*), *Nant Helen* (*Celtic Energy Ltd*), Selar (*Celtic Energy Ltd*), *Margam* (*Celtic Energy Ltd*), *Tower Regeneration Site* (*Tower Regeneration Limited*), *Ffos y Fran Land Reclamation Scheme* (*Merthyr Limited*) combined area of unreclaimed land: 11.64 km^2 Underground mining *South Wales Coalfield*: 1,786 km^2 The area of underground coal mining is extensive. For the purpose of this exercise we have used the area that has potential for coal bed methane extraction as estimated by the *British Geological Survey*. *Pembrokeshire Coalfield*: 138 km^2 *North East Wales Coalfield*: 366 km^2 The extent of land takes at the surface for past underground coal mining activities is difficult to quantify. Much of the surface will have been subject to various forms of land reclamation delivering a diverse range of after use. To determine the amount of reclamation it would be necessary to look at each individual mining site and establish the current use. The only remaining active underground mine in Wales is the *Aberpergwm Mine* near *Glynneath* operated by *Energybuild Ltd*. The amount of land required for underground coal mining is 23.18 km^2. The extent of ancillary mining operations on the surface associated with *Aberpergwm Mine* is 1 km^2
7	Land use distribution before vs. after mining	Detailed information is not publicly available
8	Main environmental challenges	Water discharging from an abandoned mine due to groundwater rebound upon mine closure is commonly acidic and may contain high concentrations dissolved minerals and metals This water can cause gross pollution of the receiving watercourse leading to AMD

2. Baseline / Landscapes in Transition		
9	Time-lag between devastation and reclamation / re-vegetation	Surface mining Typically, 10 to 15 years, but can extend over a much longer period of time when taking into account the cumulative effect of extensions to original sites Underground mining 21 years (*Aberpergwm Mine* planning permission)
10	Stripped land not yet reclaimed, including the mine operating area	Surface mining 11.64 km^2 (current operational surface opencast mines)
11	Waste dumps and heaps, not remodeled / uncovered	Surface mining Overburden mounds at current operational surface opencast mines 4.32 km^2, including 0.47 km^2 of surface land associated with *Aberpergwm Mine* set aside for permanent disposal of mine waste Underground mining Hundreds of colliery tips of various sizes scattered across the three coalfields A desk based assessment of the coalfield areas identifies c. 50 colliery tips visible in the study area, mostly in the *South Wales Coalfield*. The combined area of these tips is 3.44 km^2. Many additional tips were found to be vegetated, re-engineered or with preserved status and have not been included in this total: ▪ in-house records of former CA owned tips -approx. 30 ▪ tips on *Natural Resources Wales* owned land - approx. 100 ▪ tips identified from a desk based assessment- approx. 105 Many of these would have been subjected to various degree of reclamation and stability/drainage works. Colliery spoil tips existing within the *Blaenavon World Heritage Site* area have not been included
12	Land affected by mining	Refer to item 6 and 13

2. Baseline / Landscapes in Transition		
13	Groundwater lowering	The coal measures strata are classified by *Natural Resources Wales* as minor aquifer which has no strategic significance as a groundwater resource but can have importance at a local level Surface mining sites The currently active opencast sites, e.g. *East Pit*, *Nant Helen*, *Tower Land Regeneration* and the *Ffos y Fran Land Reclamation Scheme* will be continuously pumping ground water and artificially lowering the water table immediately adjacent to the operating area Underground mining areas Potentially, the amount of groundwater lowering could represent the extent of underground working, estimated at 2,290 km^2. Groundwater would have returned to pre-mining levels at many of the former collieries which closed during the period between 1980 and 1990s. When *Tower Colliery* closed in 2008, measures were introduced on site to record the rate of groundwater rebound. The colliery workings extended over a vast area due to workings of former collieries being interconnected with *Tower*. A scheme was developed to identify the potential location of the 'spill point' where groundwater in the flooded workings would come to surface - the location was measured to be some 5.5 km from the main colliery shaft. The *Aberpergwm Mine* in *Glynneath* will also be pumping groundwater from the workings in order to keep the mine operational. The planning consent contains a planning condition requiring a scheme to be submitted to the MPA for approval for the monitoring of ground water and mine water discharge flows from the *Aberpergwm* mine. The scheme will cover long term monitoring to prevent the pollution of receiving waters from the lagoon treatment system and from the recovery of groundwater levels following the completion of mining
14	Rising groundwater / land flooding	Many of the collieries which closed during the period between 1980 and 1990s will now be experiencing groundwater rebound The legal position in the UK is such that no-one can be held liable for the pollution from the majority of mines. It is only since 1999 that the operator of a mine has had any obligation to deal with the consequences of abandonment

2. Baseline / Landscapes in Transition		
15	Mechanical instable heaps, dumps and slopes	Not applicable The construction of tips is subject to various pieces of legislation such as *The Mines Regulations* 2014 (part 8 tips and tipping) and the 1999 *Quarries Regulations* Surface mining Storage mounds containing overburden, topsoil, subsoil and soil forming materials are carefully designed and to constructed in accordance with strict specifications to ensure geotechnical stability Underground mining The majority of colliery spoil tips that were deemed to be either instable and/or experiencing spontaneous combustion issues and posing a health and safety threat to the public have now been treated and reclaimed by the efforts of the former *Welsh Development Agency* (WDA) during the 1980 – 1990s. More recently, reclamation schemes funded jointly by local unitary authorities and EU initiatives have continued the work of the former WDA
16	Land deformation / geological instable caved area	Virtually all shafts and adits of underground mines operated by the former *National Coal Board* since 1947 to 1995 will have been infilled and treated Following privatisation of the coal industry in 1995, the responsibility for dealing with failures of any mine entries has passed to the CA. Since 1995 the responsibility for the treatment of any mine entries associated with active underground coal operations rests with the respective mine owners
17	Deposition / soil contamination / hazardous sites	Not possible to quantify

2. Baseline / Landscapes in Transition		
18	Instable tailings / stockpile collapse / landslides	Not possible to quantify Following the *Aberfan Disaster* of October 1966 and subsequent inquiry led to the creation of various forms of health and safety legislation to deal with the safe and carefully controlled construction of colliery tips
19	Acid-mine drainage / acid mining lakes	A report published in 2000 ("The development of passive mine water treatment in *Neath* and *Port Talbot*, South Wales" stated that: "Environment Agency surveys have revealed that a total of 85 km of rivers in Wales have been impacted by some 150 discharges from abandoned coal mines at approximately 135 locations" A *Policy Paper* published 08 May 2015 by CA (*List of Mine Water Treatment Sites Operated*) lists 15 schemes in Wales
20	Unsolved environmental problems	Localised occurrences of AMD

3. Reclaimed land in subsequent use		
21	Agriculture	Surface mining 77.42 km^2, excluding 11.64 km^2 existing mine workings
22	Forestry	Surface mining 28.730 km^2
23	Nature conservation, semi-natural revegetation	Surface mining National Park (NP) 4.04 km^2, Country Park (CP) 1.46 km^2, Local Nature Reserve (LNR) 1.06 km^2, Special Area of Conservation (SAC) 0.05 km^2, Sites of Special Scientific Interest (SSSI) 0.26 km^2 Underground mining NP 51.96 km^2, Special Protection Area (SPA) 10.03 km^2, CP 15.79 km^2, SAC 24.33 km^2, SSSI 63.886 km^2, National Nature Reserve (NNR) 2.41 km^2, Local Nature Reserve (LNR) 7.19 km^2
24	Water areas / residual lakes	Surface mining 0.89 km^2
25	Land for renewable energies (solar power, wind power, energy cropping	Surface mining ▪ solar 0.752 km^2 and 52.8 MW (Inc. estimation) ▪ wind 0.140 km^2 and 30 MW ▪ anaerobic digestion 0.057 km^2 Underground mining Further installed capacity 1,340.7 MW
26	Land in principle available for renewables - utilisation potential	25 MW of solar power awaiting construction on surface mining sites (5 MW *Castell Ddu* and 20 MW *Bryn Henllys*)
27	Geothermal energy production and hydro power plants	No

3. Reclaimed land in subsequent use		
28	Special reclamation activities, e.g. creation of leisure parks, mining museums, etc.	Surface mining Total area 2.0 km^2 Including landfill/recycling sites, schools, leisure centres, golf courses, horse racing tracks, sports pitches, water treatment/sewage works, electricity facility, campsite and visitor centres There is a further 0.69 km^2 of housing and 0.83 km^2 of industrial estates Underground mining There are numerous examples of reclaimed/restored mining sites but owing to time and budgetary constraints not all mining sites have been examined, e.g.: *Blaenavon UNESCO Site*, including *Big Pit Mining Museum*, *Rhondda Heritage Park*, *Cefn Coed Colliery Museum*, *Cwm Cynon Business Park*, *Mountain Ash*, *Gatewen Colliery*, *Wrexham* (redeveloped to housing and public open space), *Maesteg Comprehensive School*, *Oakdale Business Park*, *Bargoed Woodland Park*, *Cwmcarn Forest Drive*, *Dare Valley Country Park*, *Ebbw Vale Garden Festival Park*, *Park Bryn Bach*, *Parc Cwm Darren*, *Parc Penallta*, *Parc Slip Nature Reserve*, *St. David's Park*, *Ewloe*, *North Wales* (major housing development)

4. Legal Framework for Reclamation - Planning procedures & Objectives		
29	Regional planning regulations, legal environmental obligations relevant for land reclamation	*Planning Policy Wales* (Edition 10) December 2018 This is the principal planning document in Wales setting out land use polices of the Welsh Government and is supplemented by a range of *Technical Advice Notes* (TANs) *Minerals Planning Policy Wales 2001* Sets out guidance on land use planning policy for mineral extraction and related development in Wales *Minerals Technical Advice Note 2*: Coal (2009) (MTAN2) published by National Assembly for Wales in 2009 detailed advice on the mechanisms for delivering the policy for coal extraction through surface and underground working by mineral planning authorities (MPAs) and the coal mining industry. It should be read in conjunction with *Minerals Planning Policy Wales* (MPPW) which sets out the general policies for all mineral development and the Ministerial Interim *Planning Policy Statement* (MIPPS) on *Health Impact Assessment* (HIA) MTAN2 sets out how impacts should be assessed and what mitigation measures should be adopted and seeks to identify the environmental and social costs of coal operations so that they are properly met by the operator. MTAN2 also contains advice on best practice in reclamation Main statutory control over land use in Wales is outlined in: *Town and Country Planning Act 1990* (as amended), *Planning and Compulsory Purchase Act 2004, Planning Act 2008* All mineral workings are required, under Schedule 5 of the *Town and Country Planning Act* (T&CPA) 1990 to be subject to conditions relating to the restoration and aftercare of mineral sites If restoration and aftercare proposals submitted by an operator to support a planning application are considered to be inadequate, the MPA may refuse permission on those grounds
30	Environmental impact assessment (EIA) before mining operation	Yes In accordance with the *Town and Country Planning (Wales and England) Regulations 1999* EIA scoping obligatory, essential part of the mining approval procedures; pre-mining analysis of the site, fully integrated into the mining operation

4. Legal Framework for Reclamation - Planning procedures & Objectives		
31	Mine closure and reclamation plans - CRP	Yes A mining plan is required to be submitted as part of the planning application or a scheme required by planning condition to be submitted to the MPA for approval describing the programme of works upon closure of the mine and reclamation proposals
32	Planning of mine reclamation activities prior to a mine being permitted or started	Yes Any planning application for coal mine development requires creation of a detailed restoration proposal
33	Overall reclamation target	To produce a landform/landscape in accordance with approved planning conditions and/or legal agreements that incorporates the necessary health and safety parameters with a sustainable after use safeguarding environmental and/or economical benefits for the benefit of future generations
34	Planning procedures / mining operation plans	Mineral operations will need careful planning to quantify materials for use in the future reclamation of the site and to put into place plans for the storage and preservation of these materials Phasing of the workings over the life of the mine will outline when restoration can begin to take place in a progressive manner so that the site begins to be restored at the earliest available opportunity rather than be left until the end of the mineral extraction Planning permissions will contain conditions relating to the restoration and reclamation of the sites Phasing plans provide the MPA with the opportunity to monitor progress and compliance with an approved restoration and aftercare scheme
35	Is the reconstruction of the pre-mining landscape intended?	No The post-mining landscape will be required to incorporate aspects of the surrounding landscape character

4. Legal Framework for Reclamation - Planning procedures & Objectives		
36	Public participation in reclamation planning	The preference for specific types of restoration and aftercare has changed over the years in response to growing environmental awareness, increasingly stringent environmental regulation, and increasing public engagement in the planning process The reclamation concept for each mineral sites is subject to consultation with various stakeholder groups. This is either at the pre-submission stage as the mining plans are being developed, or alternatively as part of the preparation of a restoration and aftercare scheme to satisfy a planning condition
37	Criteria for the release of land from mining supervision	A *Restoration Condition* requires that after operations for the winning and working of minerals have been completed, the site shall be restored by the use of any or all of the following, namely, subsoil, topsoil and soil making materials. Conditions should require this to be completed in a timely way. There should be formal notification, as a restoration certificate, by the MPA that restoration has been completed, to initiate the period of aftercare. Standards for restoration should be set by the MPA in Conditions, so that remedial work can be required if necessary An *Aftercare Condition* should always be included, to require that the land be brought to the required standard and ensure satisfactory long-term reclamation. It should be applied to all land to be restored to agriculture, forestry or amenity, including nature conservation. Operations should promote soil recovery, site drainage and revegetation. This should enable the land to be treated for an appropriate number of years after restoration to improve the structure and stability of the soil, to establish the site drainage, and to promote the initial establishment and subsequent management of vegetation for several years. The length of the aftercare scheme should be determined by the MPA Aftercare period should be 5 years, or other such maximum period as may be prescribed, beginning when compliance with the restoration Condition is notified. The long-term success of restoration and aftercare requires continued close liaison. Site meetings will be required during key stages in the reclamation programme to agree final contours, and upon completion of overburden replacement, subsoil replacement and finally topsoil replacement. Annual aftercare meetings should also be arranged, and reports prepared and supplied to the MPA by the operator, to state the progress of the scheme and the work programme for the subsequent year. The MPA should include in Conditions dates and/or timings for site inspections and the submission of the annual aftercare report and future years' programme. The local community should be kept informed of progress. Formal and standardised record-keeping will assist aftercare reporting

<table>
<tr><th colspan="3">5. Organisational Principles and Processes</th></tr>
<tr><td>38</td><td>Overall responsibility for reclamation: ongoing mining versus closed and abandoned mines</td><td>For active sites the responsibility for reclamation of sites rests with the operator under close supervision by the mineral planning authority
The Coal Authority (CA) is the body which owns the vast majority of coal in Great Britain, as well as former coal mines. CA works to protect the public and the environment through the management of the effects of past coal mining to promote public safety and safeguard the landscape. Its statutory responsibilities include:
licencing coal mines in Great Britain,
dealing with subsidence issues which are not the responsibility of the operators,
management of property and historic liability, such as surface hazards and treatment of mine water discharges, and
providing information to the public on past and present coal mining operations.
The CA has three main outcomes which it is working towards:
manage coal safety legacy issues and communicate related information to citizens and stakeholders "so that the safety of the public is protected from historic coal mining",
manage water pollution caused by mining "so that water is protected and improved to good status" and
use its information and skills and experience “so that stakeholders are aware of mining information to make informed decisions and value is created for the Authority”</td></tr>
<tr><td>39</td><td>Public planning and approval procedures in reclamation</td><td>It is usually practice once planning permission for coal development is granted for the establishment of a Site Liaison Committee whereby the progress of the planned development is discussed at a forum comprising representatives of the MPA, statutory consultees and the local community. Site Liaison Committees provide a forum for discussion and explanation which can be very constructive in providing local communities with a better understanding of the impacts. A Site Liaison Committee should:
be established with agreed, balanced, representation,
be chaired by a member of the Local Planning Authority (LPA),
hold quarterly or more frequent meetings as determined by the committee,
have a core agenda for each meeting and
have agreed minutes in the public domain</td></tr>
</table>

5. Organisational Principles and Processes		
40	Financing of reclamation activities	Where appropriate, restoration and/or aftercare requirements may be set out in legally binding agreements (planning obligations), under Section 106 of the T&CPA 1990 Where an operator fails to comply with restoration conditions or obligations despite enforcement action the LPA may commission appropriate restoration work and reclaim the costs of doing so from the operator/landowner under Schedule 5, Part 1, Paragraph 6 of the T&CPA 1990. As is often the case MPAs may also seek a financial guarantee or restoration bond to ensure that a site can be reclaimed if the conditions are not complied with There have been several Acts of Parliament passed, for example, The *Dyfed Act 1987*, *West Glamorgan Act 1987*, *Mid Glamorgan County Council Act 1987* all of which enabled the former *County Council* planning authorities to request financial bonds for mineral planning applications. These powers were transferred to the *Unitary Authorities* in Wales following *Local Government (Wales) Act 1994*
41	Post-mining environmental monitoring system	Yes For example, underground mines that have recently closed there will be a requirement for post-mining hydrological monitoring. See the *Aberpergwm Mine* example under item 13 For surface development then monitoring and management will persist until completion of the aftercare period. If any additional monitoring work is required then this could be covered by an agreement
42	Land consolidation and reorganisation	No

6. Hazard Prevention & Best Practice Reclamation Methods and Technologies		
43	Most-promising best practice procedures in agriculture and forest reclamation	*Aberystwyth University* was involved in this work: Establishment, growth, and yield potential of the perennial grass *Miscanthus× giganteus on* degraded coal mine soils. Frontiers in plant science 8, 726, which evidences the value of *Miscanthus* both economically and environmentally for such sites, but the work was conducted in Poland. Miscanthus has been planted at two *Hargreaves* sites in *Broken Cross* (*Lanarkshire*) and at *Maltby*. In both locations the *Miscanthus* tolerated more than expected and showed potential but it is not known whether *Hargreaves* continued with the trials. *Aberystwy*th await news of a funding application submitted that will include *Miscanthus* trials on lignite mined sites, but these are also outside Wales. They also have experience of *Miscanthus* on heavy metal sites in Poland, France and locally i*n Wales.* As long as the bioavailability of the metal isn't too high *Miscanthus* seems to have great potential
44	Measures against land deformation and mechanical instabilities	All tips associated with active mines will be constructed in accordance with design specifications/approved code of practice and subject to regular inspection and geotechnical assessments Past tips will also be subject to regular inspections to monitor for any deformation or movements. For example, *Natural Resources Wales* conduct annual inspections of all tips and ground movement monitoring of recorded landslides on their landholding
45	Applied technologies in waste-water cleaning	No information
46	Measures facing groundwater contamination	No information
47	Measures to avoid water and wind erosion, ecological engineering	*Miscanthus* provides excellent stabilization potential. To quote colleagues "The perennial nature and belowground biomass improves soil structure, increases waterholding capacity (up by 100-150 mm), and reduces runoff and erosion. Overwinter ripening increases landscape structural resources for wildlife. Reduced management intensity promotes earthworm diversity and abundance although poor litter palatability may reduce individual biomass. Chemical leaching into field boundaries is lower than comparable agriculture, improving soil and water habitat quality." Taken from McCalmont, Jon P., et al. "Environmental costs and benefits of growing *Miscanthus* for bioenergy in the UK." Gcb Bioenergy 9.3 (2017): 489-507

6. *Hazard Prevention & Best Practice Reclamation Methods and Technologies*		
48	Engineered heap covering systems for waste disposal sites	Not known
49	Other cost-effective strategies and approaches for contaminated land	Not known
50	Backfill of rock deposits and residuals into opencast voids	Yes Standard procedure for opencast sites unless the void has been identified for an alternative end use, i.e. landfill

7. "Ecological Restoration" / Promising energy cropping systems		
51	Common growing systems and/or plants in agricultural practice	Agronomies for different land types will need optimising. *Aberystwyth University* have been developing these for marginal/contaminated lands under the projects *MISCOMAR* and will do so on lignite mined land if funded in *MISCOMAR+*. Reference could be made to the paper highlighted in item 43, and we can provide info for systems on marginal land types that we have cultivated so far
52	Practical experience with energy cropping and special crops on reclaimed land	*Aberystwyth University* have a small *Miscanthus* and reed canary grass (*Phalaris arundinaceae*) trial on highly contaminated heavy metal mine tailings in West Wales. The plants have been given very little to survive on but have survived two growing seasons, although they are not thriving. The university have considerable experience in growing *Miscanthus* on marginal land
53	Average cropping potential, yields, exemplary for cultivated and promising plants in agriculture	No data available for coal reclamation sites
54	Indication of profitable and sustainable, reclamation-supporting production chains already working - good examples	Supply chain development is very important and has been done well by https://www.terravesta.com/home, with whom *Aberystwyth University* work closely. The university also work with a similar company in France, but is still establishing the economics, and different sites will require different inputs and yields and produce different returns

5 Conclusions

Environmental impact and monitoring

- As the nine TRACER target regions show the environmental impact of coal mining is quite serious and over the long-term. Thereby, the ecological problems are site/regional specific; but nevertheless, there are similar challenges across regional and country boundaries, e.g. the restoration of soil functions on dumped raw soils, the waste water cleaning or to ensure an 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. But the monitoring intensity, parameters and analytical methods but also national threshold values applied are very different and for some regions the effectiveness is unclear, especially regarding derived measures. **It is still missing an 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 but also mitigation measures according to the national laws and European directives. **Unfortunately, in some TRACER regions the data on environmental impact provided by the mining companies and/or the state authorities is still insufficient, reduced to just a few parameters and/or not public.** 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.

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 or ESIA - 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 regions the procedure and responsibilities of the license holder do not comply. In such cases neither local authorities nor citizens 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 (3) 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 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.**

6 Literature

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