POTENTIALS

RFCS AM PROJECT

Synergistic potentials of end-of-life coal mines and coal-fired power plants, along with closely related neighbouring industries: update and re-adoption of territorial just transition plans

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Deliverable 2.1

Unsorted list of relevant variables of the system

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Executive summary

The general objective of the POTENTIALS Accompanying Measure is to identify and assess the challenges, opportunities and impacts related to the synergistic potentials of end-of-life mine sites and coal-fired power plants (and related infrastructure), along with closely related neighbouring industries. It will take advantage of their joint potential to stimulate new economic activities, developing jobs and economic value especially in relation to Coal Regions in Transition, and supporting the update and re-adoption of territorial just transition plans.

During this work, the most important key variables were determined to address the synergistic potentials of end-of life coal mine sites and coal-fired power plants. These were defined against closely related neighbouring industries, the implementation of business models relying on renewable energy, circular economy and scaling energy storage.

The outcome of this work is an unsorted list of relevant variables that are important to understand the potential opportunities that end of life coal related infrastructure presents. The list was determined between partners that populated a database based on experts' judgement. An initial population of 117 variables was collected and subsequently was reduced to 69 ones, screened on importance and duration of the project. The 69 variables were further analysed and defined by WP2 partners to form a representative statistical sample to be analysed by the software MICMAC. The software analysis in subsequent steps will provide insights on to the interrelations of these variables. It is expected that an understanding of optimum potential uses of existing infrastructure will emerge.

1 Introduction

The main objectives of this deliverable are:

- To identify all the potential variables that will address and describe the system of end-of-life coal mine sites and coal-fired power plants
- To analyse and reduce the number of variables according to their importance and relevance to the project.

Variables were defined based on the knowledge and results gained from CoalTech2051 and RECPP, as well as on the opinion of experts from the European Network of Clean Coal Technologist established by CoalTech2051, including stakeholders identified by RECPP.

Work progressed on collating 117 key variables into a list proposed by all partners. The list was reduced at 69 variables based on priority criteria and the time duration of the project. The actual number was predetermined due to analytical capabilities of the MICMAC software.

The variables characterize both technical and evaluation criteria related with renewable energy technologies, scale energy storage, assets, resources and circular economy contributions. The final list is the outcome of an online brainstorming session organised by CERTH and concluded by subsequent email communication.

The result of the present work is an unsorted list of variables, accompanied with a short definition to facilitate the upcoming WP2 Tasks and their deployment at Micmac software. A more detailed description was provided by all partners, explaining the importance of each specific variable. This allows for a better perception of the variables interrelations for their further analysis.

Verification of the descriptions were performed by GIG and UNIOVI to assure an appropriate interpretation of the selected variables.

2 List of unsorted variables

Below, a list of 69 unsorted variables is presented along with a short and a long definition. To provide a fit-for purpose definition for each variable, a methodological approach was performed that included a combination of literature review from publications and reports as well as information based on the partners' expertise participating in the Potentials Project. For the literature review engines used were Google Scholar, ResearchGate and Science Direct research. Additional sources for reports were derived from organisations, namely International Energy Agency (IEA), International Atomic Energy Agency (IAEA) and Organisation for Economic Co-operation and Development (OECD). Variables/keywords relevant to the scope of the research, were inserted in the search engines and the organisation sites, in combinations as well as individually, to find relevant reports and publications. From the total amount of publications found, only those that included at least one of the variables in their title, abstract, or list of keywords and were published in journals and books of related scientific interest were selected. As an example, such journals and books are "The Extractive Industries and Society", "Groundwater for Sustainable Development", "Atmospheric Environment", "Resources Policy", "Economics and management" and "Handbook of hydrocarbon and lipid Microbiology". For additional information on variables description and definition, partners provided their knowledge based on their scientific field; risk assessment, underground mining, mining extraction, postmining, power plant operation, power plant technologies, power distribution, power plant dismantling, power plant repurposing, environmental issues and energy geological storage.

The short definition serves to facilitate the upcoming development of Task 2.2 "Specifying the relations between the variables". A group of experts will be selected to provide judgement on specific relations between variables; short definitions will support this process providing a better understanding of each variable under the analysis.

The long definition provides a detailed description about the importance of each specific variable to the system under exploration. System in this context is understood as end-of-life mine sites and coal-fired power plants and related infrastructure, along with closely related neighbouring industries.

1. Depth of mine

Short definition

The variable determines the maximum depth of the mine - the depth at which the deepest exploitation level is located or where the deepest workings/goafs are located and that can be adapted to produce green energy.

Long definition

In Europe, the depth of hard coal mines ranges from 500 to over 1200 m. Increasing the depth of exploitation means that the depth of the mine workings/longwalls may be deeper than the depth of the shafts. The variable is important in terms of the use of geothermal energy, underground pumped hydropower storage (UPHS), etc.

2. Ground movement

Short definition

The variable determines the possible tectonic movement of rock mass influencing underground workings/reservoirs/shafts and infrastructure on the surface (after the end-of-life of the coal mine with or without flooding of the mine).

Long definition

Many years of exploitation of hard coal seams disturb the stability of the rock mass. The end of exploitation causes that the voids in the rock mass, drainage of rock layers, or the impact of faults, can still cause rock mass movements and affect the surface (UPHS upper reservoir, plants) or underground infrastructures (UPHS lower reservoir, penstock, shafts, etc.).

3. Geological singularities of the mine

Short definition

The variable refers to the existence of singular geological structures in the mine: impermeable strata, absence of faults, etc. (with no geological disturbance)

Long definition

The existence of specific geological conditions may encourage the coal mine to be used as a reservoir for different solid, liquid or gas materials storage. It is important that workings intended for this purpose are surrounded by impermeable rocks and that there are no faults or other discontinuities in their vicinity - which will significantly reduce undesirable migration / mixing of liquids and gases.

4. Methane surface emissions (AMM)

Short definition

The variable determines the concentration, flow and an estimation of future emissions of Abandoned Mine Methane (AMM).

Long definition

Abandoned Mine Methane (AMM) is the one extracted when active ventilation has ceased in a flooded or non-flooded mine. As methane emissions finish approximately 15 years after the closure of the mine, to estimate future emissions it will be necessary to know how many years ago the mine was closed. There is a mathematical model that allows to estimate future emissions based on actual concentration and flow, as well as the number of years since ventilation has ceased. AMM can be used for energy production.

5. Methane resources (CBM)

Short definition

The variable refers to the reserve of natural gas stored in coal seams, called Coal Bed Methane (CBM).

Long definition

Reserve of natural gas stored in coal seams, called Coal Bed Methane (CBM), which productivity will depend primarily upon permeability within micro-fractures; several approaches may be used to stimulate CBM reservoirs when extracted through vertical wells: hydraulic fracturing, CO_2 fracturing, nitrogen fracturing and cavitation. CBM, that has concentrations much higher than AMM, can be used also for energy production.

6. Coal spontaneous ignition

Short definition

The variable determines the ability of coal in coal seams to develop endogenous fires that may affect both underground and surface by means of pollution of the atmosphere and change of mine water chemistry.

Long definition

Endogenous fires may occur in closed mines. In the case of oxygen access to the goafs (especially those with remaining coal), the coal may self-ignite, which will have consequences both in terms of air pollution and changes in the chemistry of mine water. It should be emphasized that the control and activation of an endogenous fire in an active mine is a difficult task, and in case of a closed mine it may be practically impossible. Therefore, in the case of the implementation of geothermal energy / UPHS infrastructure in underground workings, special attention should be paid to the tightness of workings and goafs.

7. Coal processing plant capacity

Short definition

Capacity of the coal preparation and processing plant in the vicinity of the mine that is directly related with it, without relying on other mines

Long definition

Capacity of the coal preparation and processing plant that includes a series of processes: breaking, crushing, screening, wet or dry cleaning and thermal drying. It can separate coal from impurities, remove mineral impurities from raw coal and split it into different product specifications. There are usually wet and dry treatment areas.

8. Volume of pumped water

Short definition

The variable determines the amount of water [m^3/h] that can be pumped from the mine to its surface using existing shafts per unit time for production of geothermal energy or UPSH.

Long definition

The volume of pumped water in UPSH depends on the dimensions of the reservoirs: upper (on the surface) and lower (in workings or in workings/goaf). It also depends on the depth of the shaft (more specifically the vertical distance between the upper and lower reservoirs) and shaft diameter. Depending on the amount of energy that we want to obtain (produce and store), the appropriate size of the installation is selected, and therefore the amount of pumped water. In the case of geothermal energy, the volume of pumped water depends on the number and size of adjacent objects/buildings to which thermal energy will be supplied.

9. Pumped water chemistry/quality

Short definition

The variable determines the quality and chemistry (content of mineral substances [mg/dm^3] & pH) of pumped mining water.

Long definition

The chemistry of water is variable and depends on the depth and the type of overburden. Generally, it can be assumed that content of mineral substances in mining water increases with depth and in regions where the overburden is impermeable and there is no freshwater inflow from the surface. In mining water, apart from large amounts of sulfates and chlorides, also barium and metal compounds can be found, mainly iron and manganese, the presence of which may necessitate water treatment, for the proper functioning of the geothermal/UHPS installation. On the other hand, the UPSH/geothermal can induces hydrochemical changes in groundwater. Induced hydrochemical changes may have an impact on the environment and/or the efficiency (e.g., corrosions and incrustations affect facilities) of UPHS/geothermal plants. Assessing the influence of hydrogeological parameters (chemistry of pumped mine water) helps to locate UPSH plants. For heat pump use, the heavy load of dissolved matter that coal mine waters commonly contain can cause problems by precipitating during heating and cooling, so effective (and expensive) water softener and descaling treatment may be necessary.

10. Hazardous substances in the pumped mine water

Short definition

Pumped mine water may contain hazardous substances that are toxic for the environment, such as heavy metals, radioactive elements (226Ra and 228Ra) or PCBs (polychlorinated biphenyls) used in electrical equipment (as dielectric fluids).

Long definition

Mine dewatering is the removal of water from the mine, including active (in open-pit mines, for lowering the water table) and reactive (in both open-pit and underground mines). By that, the ingress and leakage of water in the mining areas are reduced, allowing safer, more efficient, and uninterrupted working conditions. Mine water may originate from rainwater precipitation, melting snow, and subsequent floodwater that mainly affect open-pit mining, or subterranean waterways, and long-term rise of the water table from precipitation that mainly affect underground mines. Mine waters may contain heavy metals (i.e., As, Cd, Cr, Pb). Polychlorinated biphenyls (PCBs) from electrical equipment used in underground mines may also contaminate the mine water. PCBs include a group of 209 structurally related artificial chemicals that are toxic. Even though they are hazardous for the environment, they are still used in electrical equipment, mainly as dielectric fluids. When such equipment is abandoned in the mine, PCBs may be released into the ground water, with difficulty or no possibility for retrieval [1, 2, 3]. In water different pollutants are present which may cause damages to the environment, among them radium isotopes. In several coal mines the radium removal from mine water was necessary to mitigate negative results of radium release with mine effluents.

11. Depth of the shafts

Short definition

The variable determines the depth of the shaft [m] understood as distance between surface level and shaft bottom.

Long definition

At some cases the shaft depth will determine the possibility of its usage for given technology. The deeper the shaft, the bigger space can be allocated for installation. The deepest shafts reach more than 1200 m.

12. Shaft diameter

Short definition

The variable determines the shaft diameter [m].

Long definition

At some cases the shaft diameter will determine the possibility of its usage for given technology. The wider shaft is the more space can be allocated for installation. Majority of coal shafts are between 3.0-8.0 m wide.

13. Shaft technical condition

Short definition

The variable describes the shaft technical condition that can be: good (with no repairs required), average (minor repair required - small cracks of the lining, loss in lining structure), bad (mayor repair required - the technical condition is hazardous for shaft stability and general safety).

Long definition

The shaft technical condition can be: good (with no repairs required), average (minor repair required - small cracks of the lining, loss in lining structure, bad (mayor repair required - the technical condition is hazardous for shaft stability and general safety). Periodic inspections of shaft technical condition are required by Polish regulations. As the shaft stability has potential impact on general safety the bad state of shaft can exclude its further usage.

14. Function/status of shaft (liquidated, pumping station, ventilation working)

Short definition

The variable describes the shaft status and function. Some shafts are used as pumping stations and cannot be liquidated or repurposed, also reopening of liquidated shafts is questionable.

Long definition

Some shafts are used as pumping stations and cannot be liquidated or repurposed, also reopening of liquidated shafts is questionable. The current function of shaft also can determine the infrastructure installed in shaft as well as auxiliary installations (shaft winch, methane engine etc.).

15. Water inflow

Short definition

The variable determines the amount of natural water inflow [m^3/h] to the mine during the exploitation and possible inflow after the end of exploitation.

Long definition

The water inflow to the mine is a value variable with time, and it depends not only on the hydrogeological conditions, but also on the exploitation depth and the size of the extraction. The mines located in the eastern part of the USCB in the Vistula region are characterized by the largest inflow to the mine, with the highest average inflow value from a few to more than 60 m^3/min. The inflow to the mine after its closure should stabilize after some time. The size of the inflow to the closed mine is important for the protection of the neighboring - active mines. This variable is important from the point of view of geothermal energy production and UPHS.

16. Pumped water temperature

Short definition

The variable determines the temperature [ºC] mining water pumped from the underground workings to the surface.

Long definition

Underground mining water is at the temperature of the rocks in which it is located. Mining water pumped to the surface typically has a much lower temperature, ranging from 13 to 23 °C. The temperature of the pumped water is closely related to the distance over which thermal energy is supplied. The higher this temperature, the more thermal energy can be supplied over longer distances (up to 500 m and even 1000 m). This variable is important from the point of view of geothermal energy production.

17. Flooding status of the mine

Short definition

The variable describes the flooding status of a liquidated mine, related to the depth to which it was flooded and the flooded area.

Long definition

Flooded level of underground mine has to be controlled. This should include: removal of potential water hazards; filling the surfaces that might collapse during or after the flooding process; installing water diversion systems; installing, at both the surface and underground, a system to monitor hydrogeological and geotechnical aspects; and making a projection of hydrological and hydrogeochemical development of mining water.

18. Area of the waste heap

Short definition

This variable refers to the area [m^2] of heaps of extractive waste from excavation or coal processing wastes that are generated at extraction/processing sites.

Long definition

Extracting coal generates vast amounts of residues during excavation, including overburden, interburden or waste-rock. Coal processing also generates large amount of wastes. These large amounts of extractive waste from excavation and coal processing wastes are managed on heaps. This variable refers to the area in m^2 occupied by these waste heaps and that can be used for different purposes.

19. Height of the waste heap

Short definition

The variable determines the waste heap height [m] as a distance between the heap base and the top.

Long definition

Waste heap height is designed by mine operator at the stage of the waste material storage. This variable has multiple implication for hazards occurrence, landscape transformation, heap access and other. This variable could be important from the point of view of wind power turbines installation. It can also define other revitalization possibilities like skiing slopes, etc.

20. Angle of slopes of the waste heap

Short definition

The variable describes angle of the slopes [º] of the waste heap.

Long definition

Usually the angle of the slope is designed by mine operator to provide required slope safety factor, optimizing the waste volume sored at a given facility. During the heap formation the angle of the slope can be adjusted to future usage. It can variate from 15˚ up to the 45˚ upon local conditions.

21. Geometry of the waste heap

Short definition

The variable describes the geometrical shape of the heap (cone, truncated cone, trapezoid, irregular, etc.)

Long definition

The waste heaps generally have a conical or irregular shape with a profile in relation to the local topography. It can impact the area available for new activities as well as the technologies to be used for foundation, condition the access, etc.

22. Material type deposited on the waste heap

Short definition

This variable refers to the specific characteristics of the materials that are deposited in the waste heaps, as well as if they are separated in extractive waste and coal processing waste or mixed together.

Long definition

Depending on the mining companies, extracting wastes and coal processing wastes are deposited together or separately. In case that they are deposited separately, it may be possible to extract valuable substances from coal processing wastes. For example, data appears to show that cleaning enriches some rare earths, etc.

23. Geotechnical stability of waste heaps

Short definition

This variable refers to the geotechnical stability of the waste heaps, with special focus on landslides and stability protection against wind and water erosion.

Long definition

In order to develop different rehabilitation actions for the waste heaps, it is important to consider previously their geotechnical stability. Extractive waste heaps are usually reshaped to the angle of natural repose, depending on the extractive waste characteristics, resulting in a geomorphic shape that, either in itself or after placing a cover, provides long-term stability and adequate stability protection against wind and water erosion.

24. Fire hazard at the waste heap

Short definition

This variable refers to a potential fire hazard in waste heaps, usually related with the presence of coal in the waste heaps.

Long definition

Where there is a potential fire risk in the waste heaps, many of the restoration options that are commonly developed are not feasible.

25. Gas hazard at the waste heap

Short definition

This variable refers to a potential gas hazard in the waste heaps, usually related with the presence of coal in the waste heaps.

Long definition

Where there is a potential gas hazard in the waste heaps, specific measures need to be developed to capture and destroy this gas, as its energy exploitation is often unfeasible.

26. Acidity potential of the waste heap material

Short definition

Mining activities produce wastes which can be categorized in waste rock, tailings and mine water. Waste heaps are dynamic systems, usually composed of sulphide minerals and when exposed to atmospheric conditions, they may generate acid drainage and cause pH variations.

Long definition

Waste heaps comprise from waste material derived during the excavation of the coal mine, usually including the overburden layer of soil and rock between the coal seams and the surface. Its content varies in chemical and physical properties. Waste heaps have a relatively thin aerobic surface region to a depth of around 1 m, with a microaerobic/anaerobic core. Rainwater can percolate through the outer aerobic zone leading to the creation of acid mine drainage (AMD). Spoil heaps are prone to erosion and have low water holding capacity, which accelerates the leaching of chemical compounds from these sites. Since the source of acidity can remain active, regardless the closure of a mine, it is essential for environmental and safety reasons that the waste heaps are properly sealed and the mounds are surface treated [4].

27. Status of reclamation of the waste heap

Short definition

The variable describes the status of reclamation (active waste disposal heap, non reclamated, partially reclamated, fully revitalisated) as well as the ownership of the waste heap.

Long definition

The main revitalisation and valorisation of the dumps-waste heaps are: civil engineering, agriculture; sport and hobbies activities; renewable energy installation: wind turbines, solar panels; sites for biodiversity conservation. The new ways of usage can be limited due to current function of the waste. On the other hand, partially reclamated heap can be easier to adopt for new activities.

28. Neighborhood density

Short definition

This variable refers to the number of people that live in the proximity of the mine.

Long definition

Number of people that live in the proximity of the mine may be crucial for some business opportunities. For example, it will condition the deployment possibilities of geothermal energy. When geothermal energy is based on district heating and cooling networks that allow multiple energy sources to be connected to multiple energy consumption points through a set of pipelines. The development of district networks for the surrounding areas allows for integrating renewable sources such as geothermal and photovoltaic into these centralised systems. District networks will help increase photovoltaic deployment by producing synergies concerning transforming heating/cooling customers into prosumers or customers who produce excess electricity from solar panels on their roofs, maximising the number of business opportunities.

29. Existence of historic or singular buildings

Short definition

This variable refers to the existence of heritage buildings, singular buildings, or industrial infrastructure, that must be conserved or that it is interesting to conserve by the coal mine.

Long definition

The existence of heritage buildings, singular buildings or industrial infrastructure may condition the future planning of the mine area, although it may contribute positively to specific developments such as museums, leisure facilities, new business uses, etc. The reuse of abandoned buildings may bring bright ideas to once faded facades, and keen entrepreneurs inside these complexes may help to lift the mood of places with plenty more to be optimistic about. Thus, reterritorialization can produce a post-industrial and delocalized landscape where heritage is transformed into industries or business.

30. Land use restrictions

Short definition

This variable refers to any kind of land use restrictions, mainly related with territorial development plans approved by the authorities, that may condition specific industrial, commercial, business centers or residential deployments.

Long definition

The development of industrial parks around closed coal mines, commercial areas, business centers or residential areas, are conditioned by territorial development plans. The optimization of the mine area should be based on socio-economic and environmental criteria helping to achieve sustainable development with the intention of increasing economic gains and improving environmental quality, but it is limited by present territorial development plans that, in some cases, are susceptible to be changed by the authorities.

31. Connection capacity of mine to the grid

Short definition

This variable refers to the connection capacity [MW] and voltage [kV] to the grid that are usually connected to medium voltage lines between 1 and 60 kV through substations.

Long definition

Mines are usually connected to the grid via overhead lines. They are typically connected to medium voltage lines through substations. The capacity depends on the demand/needs of the mine. The lines enter directly into the substations equipped with metering equipment, transformers, and other protective equipment. In this way, they can be easily adapted to inject electricity into the grid. Moreover, these connections facilitate the installation of electrolysers for producing green hydrogen.

32. Power plant connection capacity to the grid

Short definition

This variable refers to the connection capacity of the power plant [MW] and voltage [kV] to the grid. A substation is a vital part of electricity generation, transmission, and distribution. It transforms voltage from high to low or vice versa, or execute other roles. It can be used for the new green power plant to reduce costs.

Long definition

The typical parameter which describes the power plant. The capacity means the amount of electricity which could be produced at the power plant, and defined by the voltage of the substations to which it is connected (typically 400kV, 220kV). A power substation is a vital part of the electricity generation, transmission, and distribution. It transforms voltage from high to low or vice versa, or execute other roles. Electric power may flow through substations of various voltage levels until it is distributed to the customers. A power substation consists of medium voltage substations, low voltage substations, fault clearance, substation enclosures and the substation cabling. The existence of a ready-to-use power substation remains a major asset for the repurposed power plant, regardless of the type of the new exploited fuel. It will save time, cost, and energy that would be needed to build a new substation, but also it allows employees, already occupied in the existent facilities, to maintain their jobs. Maintenance of the previous power plant stuff not only promotes the local public acceptance, but also reduces the working hours that an unskilled stuff would consume to be trained. Thus, the new green energy power plant will be able to respond to expectations for a greener energy demand and to the demands of the local society [5], [6].

33. Electricity production efficiency of power plant

Short definition

The efficiency [%] of energy conversion from primary heat potential to actual power plant output.

Long definition

Energy efficiency typically describes the ability of conversions of primary energy to electricity. Coal fired power plant typical energy efficiency is 36-45%.

34. Power plant concession expiry date

Short definition

This variable refers to the power plant concession expiry date (before 2030/after 2030).

Long definition

The concession expiry date will give an idea of the period of time that the power plant still has in order to find alternatives to its shutdown.

35. Expected technical lifetime

Short definition

This variable refers to the technical lifetime of the power plant, giving a clear indication of the expected lifetime of all the auxiliary equipment that are part of it.

Long definition

The main internal infrastructure of the power plant is composed by the following installations: Water Demineralization, Water Decarbonization, Hydrogen Cooling, Start-Up Fuel Installation, Turbine Oil Installation, Desulphurization, NOx Reduction, Dust Reduction, Ash Removal, Steam Production and Coal Transportation Infrastructure. The expected technical lifetime will give indication about the possibilities of extending their use for alternative purposes.

36. Number of units decommissioned

Short definition

This variable refers to the number of units, their type and the power generated by each unit, that are being decommissioned in order to be able to know the dimensions and capacity of the power plant.

Long definition

The power generated by a power station is measured in multiples of the watt, typically megawatts or gigawatts. Power stations vary greatly in capacity depending on the type and units of power plant and on historical, geographical and economic factors.

37. Access / proximity to reservoirs and water courses. Water reservoir capacity

Short definition

This variable refers to the proximity of the power plant to reservoirs or water courses, as well as the reservoir capacity and/or the flow rate in the water course [m^3/h].

Long definition

Reservoirs and water courses can be usually found in the proximity of power plants due to the refrigeration needs. Water availability could be critical for alternative uses such as H_2 production from water, hydro pumped storage, etc.

38. Repowering: possibility of adapting the boiler for biomass

Short definition

This variable refers to the existence of infrastructure, external and internal, that may facilitate the adaptation of the power plant to biomass.

Long definition

The infrastructure that may facilitate the adaptation of the power plant to biomass can be internal and external. Internal infrastructure: water demineralization, water decarbonation, hydrogen cooling, turbine oil installation, desulphurization, NOx reduction, dust reduction, ash removal, steam production, coal transportation infrastructure. External infrastructure: water treatment plant, raw water pumping station, landfills, temporary storage areas, power distribution/transmission grid connection, water accessibility, road infrastructure, railway infrastructure.

39. Feasibility of reusing air cleaning installation for repowering

Short definition
This variable refers to the feasibility of reusing the air cleaning installation for repurposing the power plant. This includes: desulphurization, NOx reduction, dust reduction and ash removal.

Long definition

The need to meet standards in power plant emissions implies the use of air cleaning facilities such as desulphurization, NOx reduction, dust reduction and ash removal. In order to consider repowering alternatives, the possibility of reusing the air cleaning installation will reduce the investment CAPEX.

40. CO_2 capture installation

Short definition

This variable refers to the existence of CO_2 capture installation.

Long definition

As the price of CO_2 allowances is increasing dramatically, the existence of CO_2 capture installation might be beneficial for alternative developments of the future reuse of power plants.

41. District heating connection

Short definition

This variable refers to the existence of a system for distributing heat generated as steam by the power plant.

Long definition

Some power plants have steam production facilities that are used for distributing heat through insulated pipes for residential, commercial and industrial heating requirements, such as space heating or water heating. This can be of interest in order to develop district networks that allows to integrate renewable sources such as geothermal and photovoltaics. Also synergies can be achieved concerning transforming heating customers in prosumers, or customers who produce excess electricity from solar panels on their roofs.

42. Cooling water installation type

Short definition

This variable refers to the specific type of the cooling water installation, as well as the cooling water requirements of the power plant [m3/h].

Long definition

Water is used to cool the exhaust steam in the condenser and after, it is sent to the wet cooling tower or the outlet of open cooling system. The major characteristic is their high flow. In medium to large size coal-fired power plants, the cooling water installation is vertical column type. In small coal power plants, it could be horizontal axially split type. The cooling water requirements [m3/h] can be of interest in case of repowering the plant, for example for biomass, or for other alternatives.

43. Water treatment plant

Short definition

This variable refers to the control and treatment technologies of wastewater discharges in the power plant and their capacity in [m3/h].

Long definition

Sources of contaminants in aqueous discharges in power plants are diverse: acid and alkali regenerants from the water treatment plant; chlorination and concentration factor from the cooling water; and oil, metal oxides, dissolved additives, dissolved metals, acidity, etc., from boiler and turbine drains, air heater washing, coal stocks drain, and so on. . According to the contaminants, different treatments should be developed, and they can be of interest for alternative developments or power plant repowering. Wastewater treatment plant can be used for next activities after repurposing.

44. Fly ash characterisation

Short definition

This variable refers to the specific characteristics of the fly ash composition, which is the residue from the combustion of coal. Its chemical characterization is very important, as it can be toxic when leaching due to the amount of trace elements it contains.

Long definition

Fly ash is the residue that results from the combustion of coal; thus, its physicochemical characteristics depend on the type of coal and ignition conditions. It mainly consists of Si, Al, and Fe along with substantial amount of Ca, Na, K, Mg and Ti. It also contains amounts of trace metals, such as As, Cr, Mo, Mn, Zn, Cu, Co, Pb, Ni, Cd, Se, U and Th. When these elements are released to the environment, they can cause soil and water pollution. Especially some of them, such as As, can be hazardous to the ecosystem even in small concentrations. For the power plants that do not exploit fly ash and dispose it in landfills, chemical characterization is essential. Also, other features need to be taken into account, such as the particle size of fly ash, as the release of toxic elements and the pollution risk is reported to typically increase with decreasing particle size. Fly ash heaps need to be treated carefully to avoid the release of the hazardous elements in the environment and environmental pollution. Some vital factors concerning the disposal are the location, the climate and terrain, the transportation method, regulation requirements, and the potential for future use [7], [8], [9]. Fly ash can be used for the production of construction materials (i.e. cement, concrete).

45. Power plant landfill area. Hazardous/non-hazardous.

Short definition

Landfills are areas where waste from coal power plants is disposed; an easy and cost-efficient waste management option, yet with high environmental risks.

Long definition

Based on the Directive (EU) 2018/850 amending the Landfill Directive, landfills are categorized in hazardous, non-hazardous and inert. Waste material from coal power plants is usually disposed in landfill areas around the surrounding facilities. Burning coal in a coal-fired power plant produces a variety of solid residues known as coal combustion products (CCPs), coal combustion residues (CCRs) or coal combustion wastes (CCWs). The type of CCW produced in a power plant is determined by the type of coal that is burnt and the design of the boiler. The characteristics of each type of coal ash depends on the type of coal and its source and quality, as well as on the coal mining and preparation method, combustion process, and the emission control technology used. The environmental and human health impacts from the disposal of CCW are related to its characteristics. CCW is likely to contain certain hazardous constituents that pose a risk to human health and the environment if not properly managed, and adequate controls are not in place. The main hazards relate to soil contamination, water contamination, dust dispersion and toxins entering the food chain [10].

46. Coal ash waste landfill area availability [ha]

Short definition

This variable refers to the area [m2] of coal ash waste landfill area that are generated at the power plant.

Long definition

Burning coal generates vast amounts of residues ashes. These large amounts of ash wastes are managed in landfills. This variable refers to the area [m2] occupied by these landfills and that can be used for different purposes after reclamation, i.e. for new investments.

47. Available space for new technologies/projects

Short definition

This variable refers to the accessible space for new technologies installation (apart from waste disposal areas). The space consists of all the area [ha] provided from the surroundings of coal mines and power plants.

Long definition

The available area of an end-of-life coal mine and power plant that can be used for the deployment of alternative technologies is considered a major asset (apart from waste disposal areas). A lot of renewable technologies require space for the construction of their facilities. E.g., compressed air technologies have high demands on the space needed for their implementation. Costs of renting or purchasing new areas will remain minimal due to the available free space.

48. Obligations of thermal energy supply after the decommissioning

Short definition

Thermal energy supply (District Heating) is the pipe distribution of heating and domestic hot water (DHW), to heat the buildings of a city by a central heating system. If there are legal obligations to provide thermal energy [MW] after coal power plant decommission, a plan will be needed to ensure that the city's thermal needs are covered without extra cost for the residents or environmental negative impacts.

Long definition

District heating systems provide several financial, environmental and consequently health advantages to the near cities. After the decommission of a coal power plant, a structured plan will be needed to secure that all the above remain in place. Alternative district heating plans will have to be low on greenhouse emissions as well as affordable to the local households. In addition, it will have to cover other sectors depending on the operation of thermal supply, such as greenhouse agricultures. Over the last decades many cities depend on the aforementioned systems without alternative solutions offered by grids of natural gas. Thus, investments for a new pipeline network will be needed in case the existing infrastructure of transporting hot water will be retired.

49. Availability of concession for power generation

Short definition

This variable refers to the amount of time [years] during which the power plant will still have the concession for power generation.

Long definition

The amount of time [years] that the power plant will still have the concession for power generation allow to switch easy from coal to new fuel. Nowadays it is very difficult to get a permission for new plants, so it is going to give an idea of the haste with which it must decide about the future repurposing.

50. Cost of decommissioning and remediation.

Short definition

Decommissioning and remediation costs include all the expenses that may arise from utility separation, asbestos and hazardous material abatement, structural demolition, salvage and scrap recovery and land restoration of the site to a safe, environmentally sound condition. Where the installation has caused significant contamination of soil or groundwater by relevant hazardous substances compared to the prior land state, the operator must take the necessary measures to address this contamination and return the site to the previous state.

Long definition

After a mine closure or the decommission of a coal power plan, the site will progress through decommissioning and remediation. Time and costs associated with permits, approvals (of permits, plans, funding) and public involvement will increase. Environmental permits typically specify actions to take before, during and after closure. Plant owners must coordinate with public utility and environmental regulators to ensure compliance with permit requirements during the decommissioning and remediation. After decommissioning, any unused coal and hazardous materials associated with both the generation process and the buildings/structures (e.g., process chemicals, asbestos in the building or in equipment, polychlorinated biphenyls [PCBs], lead) are removed. Electrical generating equipment is cleaned and may be removed for use at other locations or sold as scrap. Some demolition of buildings/structures may be performed to facilitate cleaning or equipment removal. Power plants with onsite coal ash ponds or solid waste landfills must follow the federal and state permit requirements for closure of these facilities. Remediation involves the investigation and cleanup of hazardous materials to meet federal or state requirements. The site owner is responsible for ensuring that the cleanup meets all regulatory requirements and works closely with stakeholders, environmental consultants and state environmental agencies to develop and execute the remediation plan. The cost and extent of the cleanup will depend on the anticipated reuse of the site and the type and location of hazardous materials stored or disposed on the property. For example, if industrial use is planned, the cleanup requirements may be less stringent than what is required for residential use, because the likelihood of direct or prolong human exposure to contaminants will be lower. Many power plants are adjacent to bodies of water that may contain contaminants due to power plant operations, which must also be addressed as part of the cleanup. The cost of remediation can vary greatly—from hundreds of thousands of euros to several million euros or more. Decommission and remediation costs may be considered a deterrent for investment opportunities of reusing the existing sites. Among the environmental commitments during the decommission of a coal power plant, there is an obligation against a produced Baseline Report that refers to the original land condition. Where the activity involves the use, production or release of relevant hazardous substances and having regard to the possibility of soil and groundwater contamination at the site of the installation, the operator shall prepare and submit to the competent authority a baseline report before starting operation of an installation or before the update of an existing permit. The baseline report will contain the information necessary to determine the current state of soil and groundwater contamination to provide a quantified comparison with the previous land condition. To restore a brownfield land may involve significant cost of remediation activities.

51. Land use restrictions.

<u>Short definition</u>

This variable refers to the existing legal restrictions of using the land after mine closure and decommission of power plant. Legal framework determines the criteria of land utilisation and its future use.

<u>Long definition</u>

Several issues appear during the implementation of renewable energies. Solar and wind are likely to occupy and affect significantly more land than other electricity sources. Fossil fuels and nuclear generation are vastly more power-dense than renewables; natural gas, for example, is roughly 80 times more power dense than solar power and 200 times as dense as wind. Solar and wind facilities are associated with significant environmental quality impacts. Despite their environmental appeal, renewable development—particularly wind power—does impact environmental quality in a variety of ways, including landscape fragmentation, bird and bat deaths, temperature changes, visibility and noise, and other environmental damage. Before investing to a new renewable project that uses the existing land, all land use restrictions should be taken into account.

52. Character of the local area

Short definition

The variable refers to the characteristics of the surrounding areas: urban, suburban, villages, agricultural, industrial, post-industrial, etc.

Long definition

The character of local areas determines the kind and quantities of infrastructure facilities and connectivity, the local economic development, the ecological value and potentials of the area, etc. The characteristic of the surrounding areas will be crucial for some business opportunities.

53. Neighborhood and proximity to the nearest urban/industry

Short definition

The road infrastructure refers to all types of roads in a given area [11] and includes structures such as tunnels and bridges that reduce the travel time and provide a safer transportation system. The access to road infrastructure is highly important for the transport of employees, goods and services at all operation stages of a power plant.

Long definition

These criteria are the relevant external factors for the strength of socio-economic ties between local residents and the coal mine/power plant site as well as for the regional political framework. Local support and acceptance, existing political and legal land-use concepts and regional plans are key factors when deciding on the future use of coal mines and coal power plants.

54. Access/proximity to road infrastructure

Short definition

The road infrastructure refers to all types of roads in a given area [11] and includes structures such as tunnels and bridges that reduce the travel time and provide a safer transportation system. The access to road infrastructure is highly important for the transport of employees, goods and services at all operation stages.

Long definition

When repurposing an end-of-life mine or coal-fired power plant, the access and the determination of the proximity of the road infrastructure is an important asset. If the transportation system comprises of bridges and tunnels, the width, the radius of the bends (e.g stiff roads), and the clearance under bridges and in tunnels must be adequate for heavy vehicles which will deliver the appropriate equipment in the early stages of the repurposing [12]. The road infrastructure is an essential parameter at all stages of the project, to transport goods towards the power plant during repurposing or equipment maintenance or for the employees commute. Its maintenance and reliability is equally vital [13], during the entire lifetime of the power plant. Easy and fast access to the road system is essential for the power grid recovery after natural hazard impact [13]. Road infrastructures can boost the economy of the surrounding settlements or can create new ones. Such an infrastructure is capable of creating new job opportunities. A well-structured and reliable transportation infrastructure could forge new or enhance already existing trading transactions and promote further the financial, social and environmental advantages of the repurposing project, among communities.

55. Access/proximity to railway infrastructure

Short definition

A railway infrastructure includes all the structures, buildings, land, and equipment to support rail lines. The access to rail infrastructure is highly important for the transport of employees, goods and services at all operation stages.

Long definition

A railway infrastructure provides transportation solutions from and towards the mine and power plant. In mines, railways have been used for many years to move coal and other raw or processed materials around mines, at short distances or to longer ones. When the mine will stop operating, it can be used for coal transportation for non-energy uses. For the green energy plant, the railway will be useful for transportation of raw materials or processed products, fuels and equipment. Under this framework, the railway provides a financially efficient, fast, and easy way to transfer large quantities of biomass as a greener fuel for the new power plant [14]. Also, it may be used as a transportation mean for mine or plant workers, as it is safer than other road means of transport (such as buses), with a relatively low accident rate. Another advantage of the railways as a means of transportation is the avoidance of traffic, rendering it among the fastest and reliable ways for transport [15,16].

56. Access/proximity to water reservoir

Short definition

Water reservoirs are natural or artificial storage areas where water is collected and stored. Natural water reservoirs include rivers, lakes, aquifers and the sea. The availability of water reservoir is important for the power sector as it depends on it for cooling and other services during operation of the plant.

Long definition

Power plants require large volumes of water in order to produce electricity by steam turbines [17]. The coming out steam is cooled, condensed back into water and then recycled through the system [18]. The amount of the required cooling water is determined by power plant thermal efficiency. The latter is independent of the fuel. Coal, gas and uranium have slight differences in thermal efficiency. In particular, nuclear power plants use water for cooling in two ways: firstly, to convey heat from the reactor core to the steam turbines and secondly, to remove and dump surplus heat from this steam circuit [19]. Water reservoirs close to the power plant infrastructures are crucial for the operation of the plant and can limit the potential construction locations when they do not exhibit the favorable quantity and quality of water [12]. It is highly essential to determine the sustainability of the reservoir recharges since the resource recovery may overcome the water accumulation. It would be beneficial to utilize the existing wells and boreholes of the previous mine or power plant. Diminishing the distance from the water reservoir reduces the total cost and minimizes the construction time needed to prepare facilities which exploit water reservoir. It is important when performing the repurposing project to disturb as little as possible the tranquility of the locals and the surrounding environment.

57. Access/proximity to the river (for transport)

Short definition

The proximity to a river provides a financially efficient means of transportation from and towards the mine and power plant. It may be used for transportation of fuel, equipment, for product export, at a lower cost than transportation via road.

Long definition

The proximity to a river provides a financial efficient solution for transportation of fuel, equipment, raw materials or processed products from and towards the mine and power plant. It offers a lower cost comparing to transportation via road, especially for a large load volume. Also, it is a safe and reliable mode of transport, with nearly zero accident rate, due to the absence of traffic congestion and the absence of extreme weather conditions that can encountered in open sea. Another major advantage of river transport is the reduction of the carbon footprint compared to road transportation. For the same amount of goods transported, river transportation consumes three to four times less energy and emits up to five times less CO_2 and other PAHs (polycyclic aromatic hydrocarbons) than a truck or a railway. Therefore, the proximity of the mine/and power plant to a river is considered a major advantage [20], [21], [22].

58. Access/proximity to gas pipeline network connections

Short definition

Gas pipeline network is a complex system that transports gas from an industrial area to a market area for consumption. A gas transmission network can consist of thousands of kilometers of pipelines with several entry points in different countries. It is considered an essential asset for a power plant using natural gas or producing hydrogen.

Long definition

Natural gas can be used in steam turbines and gas turbines to generate electricity, making potential sites close to a gas pipeline network quite favorable. The gas network consists of low-pressure grid-distribution network and high-pressure grid-transport network depending on the diameter of the pipes [23]. Pipeline transmission of natural gas is considered to be a cost efficient way to deliver natural gas in high quantities. The existing pipeline network can be exploited also for other gases such as hydrogen. In early stage trials in small UK networks, it was found that a percentage of 20% can be integrated into the existing pipelines without any change of pipe materials [24].

59. Proximity to industries

Short definition

This variable refers to the existence of industries in the proximity of the power plant and the coal mine, their amount and the number or workers.

Long definition

The proximity of industries may for example condition the deployment possibilities of geothermal energy or the production and selling of renewable energies. When geothermal energy is based on district heating and cooling networks that allow multiple energy sources to be connected to multiple energy consumption points through a set of pipelines. The development of district networks for the surrounding residential areas allows for integrating renewable sources such as geothermal and photovoltaic into these centralised systems. District networks will help increase photovoltaic deployment by producing synergies concerning transforming heating/cooling customers into prosumers or customers who produce excess electricity from solar panels on their roofs, maximising the number of business opportunities.

60. Water treatment plant

Short definition

This variable refers to the treatment technologies used to prepare the raw water from a river or lake which is used for cooling processes or to prepare demineralised water for power boilers, and its capacity in [m3/h].

Long definition

Coal-fired power plants need a reliable supply of raw water from a river or lake which is used for cooling processes or to prepare demineralised water for power boilers, of a specified quality, that must be available over the lifetime of the plant. The quality and the turbidity of a plant's incoming water can vary significantly, depending on storms or other man-made interactions. A number of pre-treatment activities must be performed, such as removing sludge & sedimentation; dissolving suspended organic material; adjusting pH levels; and disinfecting water by killing disease-causing micro-organisms. According to the quality of the water, different treatments should be developed, and they can be of interest for alternative developments or repowering.

61. Obligations arising from concessions, contracts and other regulations in case of a power plant decommissioned

Short definition

This variable indicates any obligations arising from concessions, contracts and others that may condition the future repurposing of the power plant.

Long definition

Sometimes power plants are not completely free to select alternative futures for repurposing. This is why it is very important to know and take into consideration any obligation that the power plant may have, allowing to consider the consequences of not complying with them.

62. Power Plant employment (number of employees)

Short definition

This variable refers to the number of employees still working at the power plant

Long definition

The existence of employees working in the power plant will make it possible to address the skill gaps of these workers to establish the workforce's training and re-skilling needs to facilitate the development of the envisaged business alternatives.

63. Special screening mechanisms for employees (early retirement, paid long-term leaves, voluntary leave programs)

Short definition

Screening mechanisms for employees (early retirement, paid long-term leaves, voluntary leave programs) refer to the management options of companies to reduce their number of employees without firing someone.

Long definition

The closing of a mine and the repurposing of a power plant forces power companies to fire employees and enhance its workforce with new ones, who have different skills and education. The literature on workforce restructuring indicates that where workforce restructuring and downsizing is managed well the result can improve productivity, cost effectiveness and enhanced employment stability for the remaining employees. Where such reforms are managed badly, it was shown that problems with morale, productivity, and general workforce capacity may deteriorate, seriously impairing the ability of company to operate effectively and efficiently and may threaten the sustainability of restructuring over time. Poorly managed downsizing can create (or reinforce) a professional culture that is risk averse and innovation-fearing [25].

64. Temporary storage areas

Short definition

This variable refers to the existence of temporary storage areas and their total surface available [m^2].

Long definition

Temporary storage areas may facilitate the adoption of alternative uses such as fuel switch, storage options, short-term power storage, sector coupling and circular economy fuel production.

65. Relevant resource for land lease & rental

Short definition

This variable refers to the existence of land use & rental resources, and the total surface available [m^2].

Long definition

The availability of enough land lease and rental resources may condition the possibility of undergoing specific industrial, commercial, business centers or residential deployments.

66. Electro-intensive industries

Short definition

The variable refers to the existence of electro-intensive industries in the proximity of the coal mine/coal power plant, with a need for stable constant frequency power supply such as the aluminum industry.

Long definition

Electro-intense industries need a lot of power having a stable frequency and security of power supply all around the clock; the costs of the power supply is also important. An example is the aluminium industry.

67. Industries likely to use H_2

Short definition

The variable refers to the existence of industries in the proximity of the coal mine/power plant likely to use H_2 as an energy input, to reduce greenhouse gas emissions.

Long definition

Industries likely to use H_2 as an energy input such as steel, cement, chemicals, and others, as material and energy efficiency improvements are not available to reduce greenhouse gas emissions. The future steel industry need the guarantee of a stable H2 input provided by pipeline deliveries. That means also enough eco-power generation for that purpose to get green H_2 (maybe after a transition period with blue or grey H_2).

68. Constant energy consumption industries

Short definition

The variable refers to the existence of industries with constant energy consumption such as green data centers or aluminium industry.

Long definition

Constant energy consumption industries need a stable supply of energy. This fact can be exploited by former coal mines/coal power plants in order to provide them with green energy based on renewables combined with adequate storage or other energy sources.

69. Companies manufacturers of goods and/or suppliers of services

Short definition

The variable refers to the existence of companies manufacturers of goods and/or suppliers of services, providing possible opportunities to develop alternative business models together with coal mines/coal power plants.

Long definition

The variable is important as companies manufacturers of goods and/or suppliers of services may allow to find synergies in order to address specific business alternatives for coal mines/coal power plants. For example, enabling a vertical integration (degree to which a firm owns its upstream suppliers and its downstream buyers) of the project into the clean energy value chain when addressing renewables.

3 Conclusions and lessons learnt

Partners identified all the relevant variables for coal mines and power plants that will effectively assist the upcoming analysis with the Micmac software and the specification of the relations between the variables for Task 2.2.

During the process of variables identification and discussion on their importance, partners used their scientific expertise to optimum fulfill the list with the most appropriate variables. Indicative of this process is Annex 1, which exhibits the list of 117 initial variables, which after brainstorming and continuous exchange of ideas, was reduced to a list of 69 variables (Annex 2). The final variables were selected based on their importance, the scope and duration of the project.

Each partner originally came with its own view, understanding, approach and methodology based on structured expert judgment and multi-criteria analysis. Based on improving information discussion among the project partners (internal stakeholders), it became evident the adoption of a framework to facilitate a common understanding upon the different options and opinions. Pre-defining a common methodology/ framework can significantly reduce the time to bring a consensus and free resources for more technical details.

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Annex 1

Initial Populated List of 117 Key Variables

MINES

Geothermal energy

1. Depth of shaft [m]

2. Volume of pumped water [m^3/h]

3. Pumped water temperature [C˚]

4. Pumped water mineralisation [mg/dm^3]

5. Chemicals compounds in the mine water (salts, carbonates etc.) => have an impact on the design of the geothermal system such as open loop or closed loop, fouling of the heat exchanger

6. Hazardous substances in the pumped mine water (PCB etc)

7. Flooding status

8. Water inflow into the mine voids [m^3/h]

9. Shaft technical condition

Underground hydro pumping system

10. Depth of shafts [m]

11. Volume of pumped water [m^3/h]

12. Seismic activity

13. Ground movement

14. Number of shafts

15. Shaft lining type

16. Shaft technical condition (accessibility of the shaft and underground infrastructure for the pumping stations etc)

17. Shaft tower status

AMM utilisation for power generation

18. Methane occurrence

19. Methane concentration (Vol.-%)

20. Methane flow (m^3/h) (Both variables determine the methane utilisation potential for Cogeneration plants and in some cases injection into a gas pipeline or supply to other methane consumers)

PV and windmills on waste dumps

21. Area of the waste heap [m^2]

22. Height of the waste heap [m]

23. Geometry (conical, trapezoid) of the waste heap

24. Angle of slopes of the waste heap [˚]

25. Volume of the waste heap (can be calculated

26. Material type deposited on the waste heap

27. Geotechnical properties of the waste material (compressive strength etc.

28. Waste heap soil characterization (see item 29)

29. Acidity potential of the waste heap material [pH] (with regard to Acid Mine Drainage risk

30. Status of reclamation of the waste heap

31. Coal spontaneous ignition

32. Coal processing plant availability (depends on the situation, there are closed coal mines with demolished coal processing plants and on-going works on the adjacent waste dumps)

Other items

33. Function of shaft (liquidated, pumping station, ventilation working)

34. Shaft diameter [m] (will be used for calculation of the volume flow)

35. Access to the waste heap (only relevant if there will be activities related to the topic of the project)

36. Landslides hazard at the waste heap (is a result of the geotechnical properties and slope angles, if planned and done properly no risk of landslide should exist)

37. Fire hazard at the waste heap (see item 31)

38. Gas hazard at the waste heap (Methane occurrence in waste dumps is rather unlikely

39. Distance to grid connection [km]

40. Neighbourhood density

41. Existence of historic buildings (heritage)

42. Cost of decommissioning and remediation

43. Land use restrictions

44. Geological and hydrological characteristics of the area

45. Specific Ecological Conditions: Any information that will be useful when considering the impacts of PV system alternatives on the natural environment, either directly (e.g., by requiring forest management to maintain access to sunlight, or altering vegetative cover that could serve as habitat, etc.) or indirectly (e.g., changing hydrologic conditions and associated sedimentation).

POWER PLANTS

46. Connection capacity to the grid [MW, kV]

47. Electricity energy efficiency % (efficiency of energy conversion from primary heat potential to actual power plant output)

48. Power plant concession expiry date (before 2030/after 2030)

49. Expected technical lifetime

50. Number of units decommissioned

51. Access / proximity to reservoirs and water courses. Water reservoir capacity [m^3/h]

52. Repowering: possibility of adapting the boiler for biomass [MW]

53. Repowering: possibility of reusing NOx reduction installation for biomass [YES/NO]

54. Repowering: possibility of reusing Dust (PM) reduction installation for biomass [YES/NO]

55. Repowering: possibility of reusing Flue gas desulphurization installation for biomass [YES/NO]

56. Repowering: possibility of reusing Installation of ash removal and deslagging for biomass [YES/NO]

57. Repowering: possibility of reusing Coal transportation infrastructure for biomass [YES/NO]

58. Hydrogen cooling installation

59. Cooling water installation type

60. Water treatment plant

61. Fly ash characterisation

62. Coal ash waste landfill area availability [ha]

63. Landfill area. Hazardous/non-hazardous. [YES/NO]

64. Available space for new technologies / projects [ha]

65. Obligations of thermal energy supply after the decommissioning [MW]

66. Natural gas pipelines

67. Availability of concession for power generation [YES/NO, Years]

68. Cost of decommissioning and remediation.

69. Land use restrictions.

70. Character of the local area (urban, suburban, small villages, agricultural, industrial, post-industrial)

71. Neighbourhood and proximity to the nearest town/village/industry

72. Access / proximity to road infrastructure

73. Access / proximity to railway infrastructure

74. Access / proximity to ports (river, sea, ocean)

75. Access / proximity to electric medium or low voltage substations

76. Access / proximity to Gas pipeline network connections

77. Proximity to industries

78. Obligations arising from concessions, contracts and other regulations in case of a power plant decommissioned

79. Commitments - specific obligations aimed at the removal, control, containment or reduction of relevant hazardous substances from soil or groundwater set in permits or the Baseline Report*

80. Power Plant employment (number of employees)

81. Special screening mechanisms for employees (early retirement, paid long-term leaves, voluntary leave programs

82. Cost of Storage logistics

83. Cost of Transportation logistics of coal (Includin all logistics processes—such as loading, unloading, and transportation)

84. Cost of Land lease & resource rental

85. Cost of Total operating and maintainance

86. Availability of finance (mines and power plants)

NEIGHBOURING INDUSTRIES

87. Electro-intensive industries + Industries likely to use H_2 as an energy input

88. Companies with constant energy consumption (high, middle and low pressure levels (bar), volume flows (m^3/h), condensate recovery system (m^3/h)

89. Energy consumption of neighbouring industries

90. Average energy consumptions

91. District heating system to local community (supply of warm water from mine, power plant or neighbouring industry)

SYNERGIES

92. Mine supplies water to the power plant

93. Direct grid connections between the mine and the power plant (or contracts)

94. Direct material transport between the mine and the power plant (conveyor belt, railway infrastructure)

95. Access for PV project in mining area

96. Available grid connection for RES

GENERAL FOR RES

97. Public awareness

98. Government support

99. Support from interested groups (stakeholders)

100. The upward trend in the price of fossil energy

101. Education and training on the importance and use of RES

102. Price of electric energy

103. Provision of assistance (financial, legislative) by the municipality for the development and use of RES

104. Developing specific environmental standards for the clean energy industry

105. Availability of RES technology (TRL<9)

106. Availability of energy resources

107. Dependence of renewable energies on geographical and environmental conditions at regional level

108. Competitiveness of renewable energy generation

109. Continued optimization of energy supply and demand

110. Balanced and just accessibility to energy at affordable prices

111. RES Energy storage duration: short or long term

112. RES Storage capacity (quantity of available energy in the storage system after charging.) Wst (Wh)

113. RES Efficiency (%)

114. Energy sector restructuring for CO_2 reduction targets

115. Preparing energy consumption standards and guidelines for energy consumption by different sectors

116. Actions to decrease the technology cost of RES

117. Creating employment in the field of RES

Annex 2

Final list of the selected 69 variables

Number	Key Variables	Definition preparation	
		Prepared by	Verified by
1	Depth of mine	GIG	UNIOVI
2	Ground movement	GIG	UNIOVI
3	Geological singularities of the mine	GIG	UNIOVI
4	Methane surface emissions (AMM)	HUNOSA	GIG
5	Methane resources (CBM)	HUNOSA	GIG
6	Coal spontaneous ignition	GIG	UNIOVI
7	Coal processing plant capacity	GIG	UNIOVI
8	Volume of pumped water	GIG	UNIOVI
9	Pumped water chemistry/quality	GIG	UNIOVI
10	Hazardous substances in the pumped mine water	CERTH	GIG
11	Depth of the shafts	GIG	UNIOVI
12	Shaft diameter	GIG	UNIOVI
13	Shaft technical condition	GIG	UNIOVI
14	Function/status of shaft (liquidated, pumping station, ventilation working)	GIG	UNIOVI
15	Water inflow	GIG	UNIOVI
16	Pumped water temperature	GIG	UNIOVI
17	Flooding status of the mine	GIG	UNIOVI
18	Area of the waste heap	UNOVI	GIG
19	Height of the waste heap	GIG	UNIOVI
20	Angle of slopes of the waste heap	GIG	UNIOVI
21	Geometry of the waste heap	GIG	UNIOVI
22	Material type deposited on the waste heap	UNIOVI	GIG
23	Geotechnical stability of waste heaps	UNIOVI	GIG
24	Fire hazard at the waste heap	UNIOVI	GIG
25	Gas hazard at the waste heap	UNIOVI	GIG
26	Acidity potential of the waste heap material	CERTH	GIG
27	Status of reclamation of the waste heap	GIG	UNIOVI
28	Neighbourhood density	UNIOVI	GIG
29	Existence of historic or singular buildings	UNIOVI	GIG
30	Land use restrictions	UNIOVI	GIG
31	Connection capacity of mine to the grid	UNIOVI	GIG
32	Power plant connection capacity to the grid	CERTH	GIG
33	Electricity production efficiency of power plant	HUNOSA	GIG
34	Power plant concession expiry date	HUNOSA	GIG

35	Expected technical lifetime	HUNOSA	GIG
36	Number of units decommissioned	HUNOSA	GIG
37	Access/proximity to reservoirs and water courses. Water reservoir capacity	HUNOSA	GIG
38	Repowering: possibility of adapting the boiler for biomass	HUNOSA	GIG
39	Feasibility of reusing air cleaning installation for repowering	HUNOSA	GIG
40	CO_2 capture installation	GIG	UNIOVI
41	District heating connection	GIG	UNIOVI
42	Cooling water installation type	GIG	UNIOVI
43	Wasteater treatment plant	GIG	UNIOVI
44	Fly ash characterisation	CERTH	GIG
45	Power plant landfill area. Hazardous/non-hazardous.	CERTH	GIG
46	Coal ash waste landfill area availability	GIG	UNIOVI
47	Available space for new technologies/projects	CERTH	GIG
48	Obligations of thermal energy supply after the decommissioning	CERTH	GIG
49	Availability of concession for power generation	GIG	UNIOVI
50	Cost of decommissioning and remediation.	CERTH	GIG
51	Land use restrictions.	GIG	UNIOVI
52	Character of the local area	THGA	UNIOVI
53	Neighbourhood and proximity to the nearest urban/industry	THGA	GIG
54	Access/proximity to road infrastructure	CERTH	GIG
55	Access/proximity to railway infrastructure	CERTH	UNIOVI
56	Access/proximity to water reservoir	CERTH	UNIOVI
57	Access/proximity to the river (for transport)	CERTH	GIG
58	Access/proximity to gas pipeline network connections	CERTH	UNIOVI
59	Proximity to industries	UNIOVI	GIG
60	Water treatment plant	GIG	UNIOVI
61	Obligations arising from concessions, contracts and other regulations in case of a power plant decomissioned	GIG	UNIOVI

62	Power Plant employment (number of employees)	UNIOVI	GIG
63	Special screening mechanisms for employees (early retirement, paid long-term leaves, voluntary leave programs)	CERTH	UNIOVI
64	Temporary storage areas	HUNOSA	GIG
65	Relevant resource for land lease & rental	UNIOVI	GIG
66	Electro-intensive industries	THGA	UNIOVI
67	Industries likely to use H_2	THGA	UNIOVI
68	Constant energy consumption industries	THGA	UNIOVI
69	Companies manufacturers of goods and/or suppliers of services	THGA	UNIOVI