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

This project has received funding from the Research Fund for Coal and Steel under grant agreement No 101034042

Deliverable 3.1

Exploratory scenarios

European Commission

Research Fund for Coal & Steel

Authors

Pedro Riesgo Fernández, UNIOVI (Spain)

Alicja Krzemień, GIG (Poland)

Agustín Menéndez Díaz, UNIOVI (Spain)

Francisco Javier Iglesias Rodríguez, UNIOVI (Spain)

Ana Suárez Sánchez, UNIOVI (Spain)

Gregorio Fidalgo Valverde, UNIOVI (Spain)

Aleksander Frejowski, GIG (Poland)

Adam Duda, GIG (Poland)

Stanisław Tokarski, GIG (Poland)

Christos Karkalis, CERTH (Greece)

Pavlos Tyrologou, CERTH (Greece)

Kai van de Loo, THGA (Germany)

Julia Tiganj, THGA (Germany)

Sabine Polenz, VGB (Germany)

Adolf Aumüller, VGB (Germany)

Deliverable 3.1	
Due date of Deliverable	31.03.2022
Start - End Date of Project	01.07.2021 – 30.06.2023
Duration	2 years
Deliverable Lead Partner	UNIOVI
Dissemination level	Public
Work Package	Work Package No 3
Digital File Name	D3.1 Exploratory scenarios
Keywords	Scenarios planning, scenarios assessment, multi-stakeholder environment

Table of contents

List of Figures

List of Tables

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 Task 3.1, the construction of exploratory scenarios developing business models that rely on renewable energy, contribute to the circular economy or scale energy storage was accomplished.

To achieve this goal, Morphological analysis was used as the methodology to explore possible recombinations of the elements that make up the studied system. This method is used primarily for the construction of scenarios developing business models that rely on renewable energy, contribute to the circular economy or scale energy storage, but is equally well suited for both technological forecasting and creating potentially new products or services through the recombination of technologies. The MORPHOL tool, that was developed by the Institut d'Innovation Informatique pour l'Entreprise 3IE, was used for this purpose.

The result of this work will be the "scenarios space", characterized by all the feasible combinations of components of the system, or key variables (strong influence & strong dependence of variables) that were determine within Work Package No 3.

1 Introduction

The main objectives of this deliverable are:

- To explore possible recombinations of the elements that make up the studied system by means of a morphological analysis.
- To undergo the construction of exploratory scenarios developing business models that rely on renewable energy, contribute to the circular economy or scale energy storage.

Task 3.1 that will be led by UNIOVI with the cooperation of all the partners will use morphological analysis as the methodology to explore possible recombinations of the elements that make up the studied system. This method is used primarily for the construction of scenarios developing business models but is equally well suited for both technological forecasting and creating potentially new products or services through the recombination of technologies.

The MORPHOL tool, developed by the Institut d'Innovation Informatique pour l'Entreprise 3IE, will be used for this purpose.

The system will be broken down into subsystems or components, in our case as a result of the structural analysis developed in Work Package 2, that gave the key variables of the system.

It is a delicate operation as the components or variables must be as independent as possible and taken together must comprise the entire system under study. A certain balance is required as too many components will render the analysis impossible and too few components will result in a poor analysis.

A given scenario (business model) is characterized by a specific configuration of components. There will be as many possible scenarios as there are possible combinations of components.

The possible combinations therefore represent the entire field of possibilities called the "scenarios space".

2 Morphological analysis

Villacorta et al. (2012) stated that one of the technologies more used to undergo prospective analysis is the scenario method. On the first place, structural analysis has to be developed in order to determine the most important variables of a system. This was made within Work Package 2 using the MICMAC software.

On the second place, and after the decomposition of the system into sub-systems (variables), a set of configurations has to be associated to each component or variable. The different combinations will allow to identify specific scenarios after the application of preference and exclusion criteria (Balouli & Chine, 2019). This is known as morphological analysis.

Morphological analysis has been used for a long time in technology forecasting and not much in economic or sectoral foresight. However, it is well suited to scenario building. A global system can be broken down into demographic, economic, technical, social or organisational issues or variables, with for each of these key variables or issues for the future a certain number of hypotheses or possible answers for the future. Since the early 1990s, it has been used quite systematically in prospective studies.

Morphological analysis aims to systematically explore the possible futures, starting from the study of all the combinations resulting from the breakdown of a system. Once the system is decomposed into subsystems, each subsystem is broken down into a number of development hypothesis for a given working horizon. In the scenario building method, a scenario is characterised by the selection of a particular hypothesis in each of the subsystems that make up the overall system. There will be as many possible scenarios as there are combinations of hypotheses. The set of these combinations represents the field of possibilities, also called "morphological space". A probability of occurrence can be associated with each hypothesis of a given subsystem. Certain combinations of scenarios, even certain families of combinations, are impossible: to meet the quality requirements of the scenarios, the second stage of the morphological analysis takes care of reducing the initial space to a useful subspace by introducing exclusion constraints and selection criteria (economic, technical, etc.), on the basis of which the relevant combinations can be examined (Godet & Durance, 2011).

A path, i.e., a combination associating a hypothesis (trend, alternative, break) of response for each variable in question, is nothing more than a scenario. The morphological space defines very precisely the range of possible futures.

The MORPHOL tool, developed by the Institut d'Innovation Informatique pour l'Entreprise 3IE, will be used for this purpose (http://www.laprospective.fr/methodes-de-prospective/les-methodes-de-prospective-strategique.html). The cascade stages of the MORPHOL tool are presented in Figure 2-1.

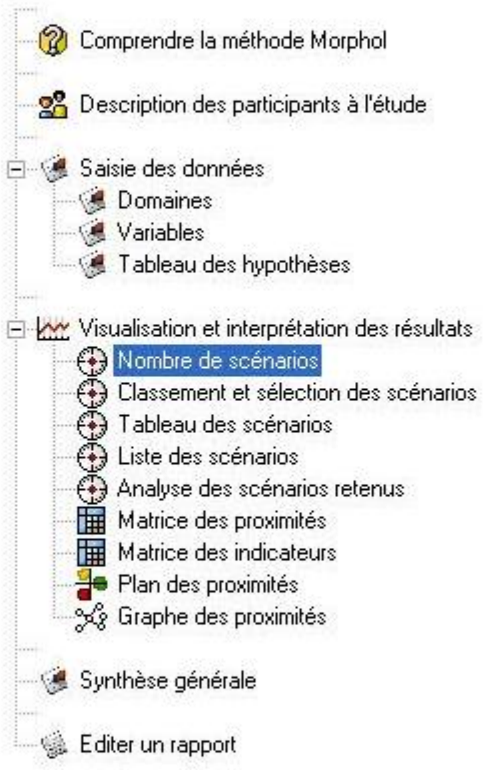

Figure 2-1. MORPHOL tool cascade stages.

3 Relevant variables for scenario development

Within Task 2.3 Identifying the key variables, and using the MICMAC software, the interrelationships between variables were analysed and interpreted.

The main problem when performing structural analyses was the wide variety and range of variables. The number and diversity of variables on the one hand accounted for the high content value of the matrix, and on the other hand posed a challenge for the appropriate selection of parameters for the analyses.

Therefore, it was decided, in addition to the system-wide analysis, “Potentials” variables, to conduct analyses for three groups of variables: "Power plant", "Surface mining" and "Underground mining" separately. The results obtained from these analyses allowed the identification of key variables in the above areas, which would not have been possible with a holistic analysis.

Thus, analyses were conducted for 4 alternative groups of variables:

1. MICMAC analysis for **"Power plant"** variables.
2. MICMAC analysis for **"Mining surface"** variables related to the surface part of the mine.
3. MICMAC analysis for **"Mining underground"** variables associated with the underground part of the mine.
4. MICMAC analysis for all variables - both "Mining" variables and "Power plant" variables, called **“Potentials”**.

The structural analysis performed for all variables clearly indicated that the key variables for the whole system are only those from the "Power plant" group. This was mainly due to the fact that the variables in the "Mining" group referred to both the underground and surface parts of the mine, which meant that most of them did not show any influence/dependence on the others. In contrast, there was a greater number of influences/dependencies between the variables in the “Power plant” group, which consequently caused the variables in this group to 'dominate' the results of the analyses.

Starting from this structural analysis it is necessary to undergo a selection of the variables that will be used for scenario development with morphological analysis.

Table 3-1 presents the key variables (strong influence and strong dependence of variables), determinant variables (strong influence and low dependence of variables) and result variables (low influence and strong dependence of variables) from the system.

Table 3-1. Relevant variables for scenarios development

VARIABLES	POWER PLANT	MINING SURFACE	MINING UNDERGROUND	POTENTIALS
KEY VARIABLES (strong influence & strong dependence of variables)	47: Available space for new technologies/projects	18: Area of the waste heap	8: Volume of pumped water	47: Available space for new technologies/projects
	51: Land use restrictions (power plants)	19: Height of the waste heap	17: Flooding status of the mine	51: Land use restrictions (power plants)
	52bis: Character of local area/proximity to industry	**21bis: Geometry of waste heaps**		**52bis: Character of local area/proximity to industry**
	54bis: Access / proximity to transport infrastructure	24: Fire hazard at the waste heap		**54bis: Access / proximity to transport infrastructure**
	66: Electro-intensive industries	27: Status of reclamation of the waste heap		66: Electro-intensive industries
	68: Constant energy consumption industries	30: Land use restrictions (mine)		
DETERMINANT VARIABLES (strong influence & low dependence of variables)	36: Number of units decommissioned	22: Material type deposited on the waste heap	1: Depth of mine	1: Depth of mine
	37: Water reservoir capacity		3: Geological singularities of the mine	36: Number of units decommissioned
	56: Access / proximity to water reservoir		11: Depth of the shafts	37: Water reservoir capacity
				56: Access / proximity to water reservoir
RESULT VARIABLES (low influence & strong dependence of variables)	49: Availability to concession for power generation	25: Gas hazard at the waste heap	4: Methane surface emissions (AMM)	4: Methane surface emissions (AMM)
	50: Cost of decommissioning and remediation		9: Pumped water chemistry/quality	**21bis: Geometry of waste heaps**
	61: Obligations arising from concessions, contracts and other regulations in case of a power plant decommissioned		10: Hazardous substances in the pumped mine water	23:Geotechnical stability of waste heaps
	65: Relevant resources for land lease & rental		13: Shaft technical condition	24: Fire hazard at the waste heap
	67: Industries likely to use H_2		14: Function/status of shaft (liquidated, pumping station, ventilation working)	27: Status of reclamation of the waste heap
	69:Companies manufacturers of goods and/or suppliers of services		15: Water inflow	30: Land use restrictions (mine)
			16: Pumped water temperature	49: Availability of concession for power generation
				50: Cost of decommissioning and remediation
				61: Obligations arising from concessions, contracts and other regulations in case of a power plant decommissioned
				65: Relevant resource for land lease & rental
				67: Industries likely to use H_2
				68: Constant energy consumption industries
				69:Companies manufacturers of goods and/or suppliers of services

The most important variables are the key variables, as they are characterized by both the highest degree of dependence and the highest influence on others. They are by nature, unstable and correspond to the challenges of the system. Therefore, these variables will be used in the analysis, but it will be necessary to select them from the three groups of variables: "Power plant", "Mining surface" and "Mining underground", as if we only consider “Potentials” variables, the focus will be located on the “Power plant” group, with o reference to the mines in the system.

The second important variables are the determinant variables that are characterized by high impact and a limited dependence or relationship. Depending on their evolution, they can become brakes or drivers of the system. These variables will be considered in some cases for the morpholgical analysis.

Finally, result variables have a low influence on the others but high dependence. They are often descriptive indicators of the system's evolution.

It will be interesting not to select many variables from each group of variables, in order that the field of possibilities or "morphological space" will not be huge and impossible to handle.

3.1 Selecting "Power plant" variables

The key variables from "Power plant" are the following ones:

- 47 Available space for new technologies/projects
- 51 Land use restrictions (power plants).
- 52bis Character of the local area / proximity to industry.
- 54bis Access/proximity to transport infrastructure.
- 66 Electro-intensive industries.
- 68 Constant energy consumption industries.

The determinant variables from "Power plant" are the following ones:

- 36 Number of units decommissioned.
- 37 Water reservoir capacity.
- 56 Access/proximity to water reservoir.

The result variables from "Power plant" are:

- 49 Availability of concession for power generation.
- 50 Cost of decommissioning and remediation.
- 61 Obligations arising from concessions, contracts and other regulations in case of a power plant decommissioned.
- 65 Relevant resources for land lease & rental.
- 67 Industries likely to use H_2.
- 69 Companies manufacturers of goods and/or suppliers of services.

On the first hand, as variables 66 Electro-intensive industries, 68 Constant energy consumption industries, 67 Industries likely to use H_2, and 69 Companies manufacturers of goods and/or suppliers of services, can be considered as development hypothesis for a given working horizon of variable 52bis Character of the local area / proximity to industry, they will be considered as such hypothesis, and not as variables.

On the second hand, variables 47 Available space for new technologies/projects, 36 Number of units decommissioned, and 65 Relevant resources for land lease & rental, can be encompassed as development hypothesis for a given working horizon of variable 47 Available space for new technologies/projects.

On the third hand, variables 37 Water reservoir capacity, 56 Access/proximity to water reservoir, and 54bis Access/proximity to transport infrastructure can be encompassed as development hypothesis for a given working horizon of a variable like: Available infrastructures for new technologies/projects.

Finally, variables 49 Availability of concession for power generation, 50 Cost of decommissioning and remediation, and 61 Obligations arising from concessions, contracts and other regulations in case of a power plant decommissioned, can be encompassed as development hypothesis for a given working horizon of a variable that can be called Concessions, contracts and other regulations in case of power plant decommissioning.

Thus, the variables to be considered *a priori* in the morphological analysis from “Power plant” may be:

1. Character of the local area / proximity to industry.
2. Available space for new technologies/projects.
3. Available infrastructures for new technologies/projects.
4. Concessions, contracts and other regulations.
5. Land use restrictions (power plants).

3.2 Selecting “Mining surface” variables

The key variables from “Mining surface” are the following ones:

- 18 Area of the waste heap.
- 19 Height of the waste heap.

- 21bis Geometry of the waste heap.
- 24 Fire hazard at the waste heap.
- 27 Status of reclamation of the waste heap.
- 30 Land use restrictions (mine).

There is only one determinant variable from "Mining surface":

- 22 Material type deposited on the waste heap.

There is also one result variable from "Mining surface":

- 25 Gas hazard at the waste heap.

On the first hand, variables 18 Area of the waste heap, 19 Height of the waste heap, and 21bis Geometry of the waste heap, can be combined in one variable such as Waste heap physical characteristics, with the variables representing development hypothesis for a given working horizon.

On the second hand, variables 24 Fire hazard at the waste heap, 25 Gas hazard at the waste heap, and 27 Status of reclamation of the waste heap. can be combined in the variable such as Waste heap development constraints, with the variables representing development hypothesis for a given working horizon.

Thus, the variables to be considered *a priori* in the morphological analysis from "Mining surface" may be:

1. Waste heaps physical characteristics.
2. Waste heaps development constraints.
3. Land use restrictions (mine).
4. Material type deposited on the waste heaps.

3.3 Selecting "Mining underground" variables

The key variables from "Mining underground" are the following ones:

- 8 Volume of pumped water.
- 17 Flooding status of the mine.

The determinant variables from "Mining underground" are the following ones:

- 1 Depth of mine.

- 3 Geological singularities of the mine.
- 11 Depth of the shafts.

The result variables from “Mining underground” are:

- 4 Methane surface emissions (AMM).
- 9 Pumped water chemistry/quality.
- 10 Hazardous substances in the pumped mine water.
- 13 Shaft technical condition.
- 14 Function/status of shaft (liquidated, pumping station, ventilation working).
- 15 Water inflow.
- 16 Pumped water temperature.

On the first hand, variables 1 Depth of mine, and 11 Depth of the shafts will be considered as equal, although this is not necessarely true, but at least Depth of the shafts can be considered quite an approximation of Depth of the mine. Moreover, there is usually a direct relation between Depth of the shafts and variable 16 Pumped water temperature. Nevertheless, specific depths will may not condition development hypothesis for a given working horizon, so these three variables will not be considered in the analysis.

On the second hand, variable 8 Volume of pumped water can be considered a good proxy of variable 15 Water inflow. Nevertheless, the volume of pumped water *per sé* will not condition specific development hypothesis for a given working horizon, so both variables will not be considered in the analysis.

On the third hand, variable 9 Pumped water chemistry/quality, can be considered to include variable 10 Hazardous substances in the pumped mine water.

On the fourth hand, it will be very difficult to develop hypothesis for a given working horizon for variable 3 Geological singularities of the mine, so this variable will be dismissed.

Finally, 4 Methane surface emissions (AMM), 13 Shaft technical condition, and 14 Function/status of shaft (liquidated, pumping station, ventilation working), will not be considered as they are not really representative of alternative business models. Moreover, they are result variables, this is, descriptive indicators of the system's evolution, that do not correspond to the challenges of the system. This will simplify the morphological analysis.

Thus, the variables to be considered *a priori* in the morphological analysis from "Mining underground" may be:

1. Flooding status of the mine.
2. Pumped water chemistry/quality.

3.4 Selecting final variables

Taking only in consideration that the variables: Land use restrictions (power plants) and Land use restrictions (mines) cand be joined in one variable called Land use restrictions, the final list of variables that define the system of end-of-life coal mines and coal-fired power plants, along with closely related neighbouring industries, is the following one:

1. Character of the local area / proximity to industry.
2. Available space for new technologies/projects.
3. Available infrastructures for new technologies/projects.
4. Concessions, contracts and other regulations.
5. Land use restrictions.
6. Waste heaps physical characteristics.
7. Waste heaps development constraints.
8. Material type deposited on the waste heaps.
9. Flooding status of the mine.
10. Pumped water chemistry/quality.

3.4.1 Character of the local area / proximity to industry

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

This variable will also refer to the existence of electro-intensive industries in the proximity of the coal mine/coal power plant, likely to use H_2 as an energy input, to reduce greenhouse gas emissions; and to the existence of industries with constant energy consumption such as green data centers or aluminium factories.

Thus, the development hypothesis for a given working horizon for this variable will be the following ones:

a) Non-populated or scarcely populated area.

b) Mainly populated area.

c) Mainly industrial area.

d) Electro-intensive industries (likely to use H_2 as an energy input).

e) Constant energy consumption industries (e.g., data centers or aluminium factories).

3.4.2 Available space for new technologies/projects

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.

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.

As it was previously stated, Available space for new technologies/projects, Number of units decommissioned, and Relevant resources for land lease & rental, can be encompassed as development hypothesis for a given working horizon of variable Available space for new technologies/projects.

Thus, the development hypothesis for a given working horizon for this variable will be the following ones:

a) Relevant available space for new technologies.

b) Limited available space for new technologies.

3.4.3 Available infrastructures for new technologies/projects

The infrastructure that may facilitate the adaptation of the power plant 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, CO_2 capture installation. External infrastructure: water treatment plant, raw water pumping station, landfills, temporary storage areas, power distribution/transmission grid connection, water accessibility, road infrastructure, railway infrastructure.

Thus, the development hypothesis for a given working horizon for this variable will be the following ones:

a) Relevant available infrastructures for new technologies.

b) Limited available infrastructures for new technologies.

3.4.4 Concessions, contracts and other regulations

Variables 49 Availability of concession for power generation, 50 Cost of decommissioning and remediation, and 61 Obligations arising from concessions, contracts and other regulations in case of a power plant decommissioned, can be encompassed as development hypothesis for a given working horizon of a variable that can be called Concessions, contracts and other regulations in case of power plant decommisioning.

Obligations such as to provide thermal energy supply after the decommissioning or arising from concessions, contracts and others, may condition the future repurposing of the power plant. Also, the amount of time (years) during which the power plant will still have the concession for power generation, can be considered.

Thus, the development hypothesis for a given working horizon for this variable will be the following ones:

a) Concession for power generation.

b) Obligations arising from concessions or others.

c) No concessions / obligations.

3.4.5 Land use restrictions

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

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 areas 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.

Thus, the development hypothesis for a given working horizon for this variable will be the following ones:

a) Existence of land use restrictions.

b) No land use restrictions.

3.4.6 Waste heaps physical characteristics

Variables 18 Area of the waste heap, 19 Height of the waste heap, and 21bis Geometry of the waste heap, can be combined in one variable such as Waste heap physical characteristics, with the variables representing development hypothesis for a given working horizon.

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.

Thus, the development hypothesis for a given working horizon for this variable will be the following ones:

a) Flat area, geotechnically stable.

b) Inclined area, geotechnically stable.

c) Landslides and/or wind and water erosion.

3.4.7 Waste heaps development constraints

Variables 24 Fire hazard at the waste heap, 25 Gas hazard at the waste heap, and 27 Status of reclamation of the waste heap. can be combined in the variable such as Waste heap development constraints, with the variables representing development hypothesis for a given working horizon.

Thus, the development hypothesis for a given working horizon for this variable will be the following ones:

a) Gas or fire hazards.

b) Reclaimed or partially reclaimed waste heaps.

c) Natura 2000 area or specific territorial development plan area.

d) No development constraints.

3.4.8 Material type deposited on the waste heaps

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.

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.

Thus, the development hypothesis for a given working horizon for this variable will be the following ones:

a) Separate wastes (feasible recovery of critical raw materials).

b) Inert waste.

3.4.9 Flooding status of the mine

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

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.

Thus, the development hypothesis for a given working horizon for this variable will be the following ones:

a) Non-flooded.

b) Completely flooded.

c) Partially flooded.

3.4.10 Pumped water chemistry/quality

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

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.

On the other hand, 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).

Thus, the development hypothesis for a given working horizon for this variable will be the following ones:

a) Pumped water with hazardous substances.

b) Pumped water with high content of mineral substances.

c) Pumped water with low content of mineral substances.

4 Morphological analysis with MORPHOL

4.1 Domains

In the first place the domain names should be introduced. Although it was possible to use as domains "Power plant", "Mining surface" and "Mining underground", it was decided to consider only one domain, “Potentials”, as the project considers only one system including end-of-life coal mines and coal-fired power plants, along with closely related neighbouring industries (Figure 4-1).

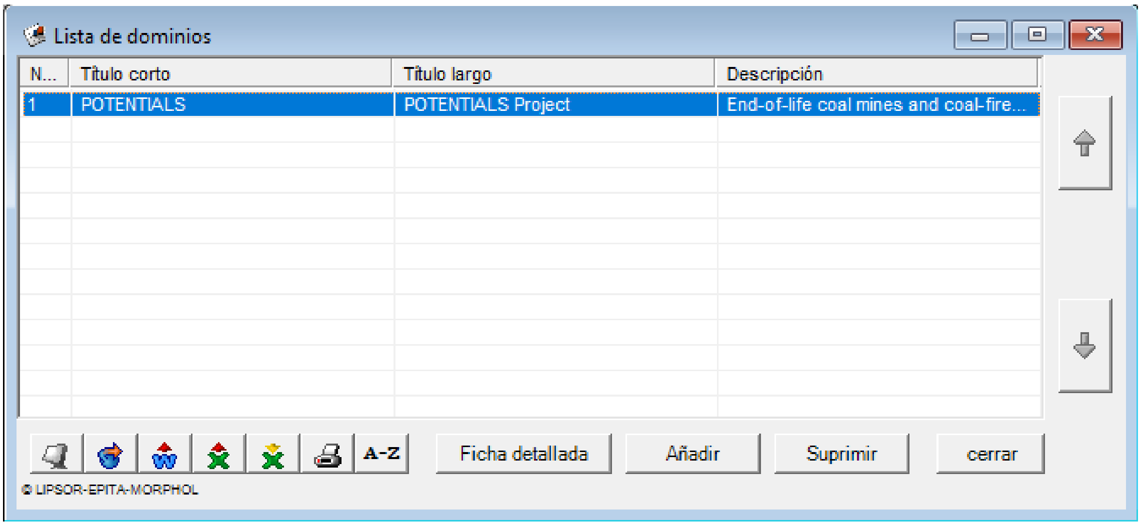

Figure 4-1. List of domains.

4.2 Variables

Figure 4-2 shows the list of the final variables that were previously selected. Each variable is defined by a long name, a short name, description and its domain name.

4.3 Hypothesis

The next step is to introduce the development hypothesis for a given working horizon for each of the variables considered. Figure 4-3 presents the list of hypothesis for each variable that was extended with an “indifferent” option for each variable, in case that none of the rest of hypothesis is specifically needed.

The combination of the different hypothesis for each variable allows computing a total of 100,000 possible scenarios.

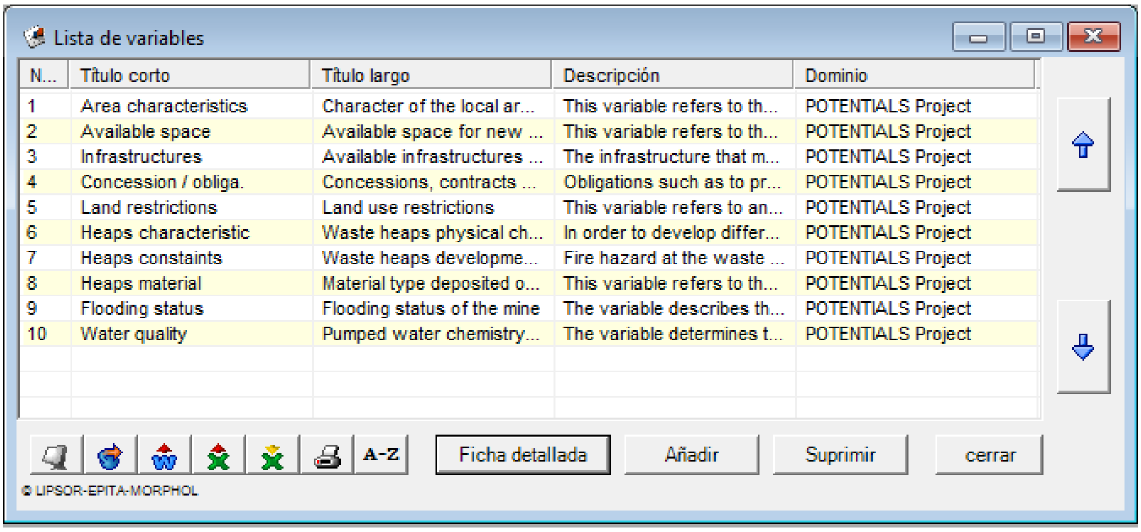

Figure 4-2. List of variables.

Cuadro de escenarios

Dominios	Variables	Hipótesis					
		H1	H2	H3	H4	H5	H6
POTENTIALS	Area characteristics	Non-populated or scarcely populated area 0 %	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %			
	Infrastructures	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %			
	Concession / obliga.	Concessions for pover generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %		
	Land restrictions	Existence of land use restrictions use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %			
	Heaps characteristic	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %		
	Heaps constaints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %	
	Heaps material	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %			
	Flooding status	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %		
	Water quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %		

Figure 4-3. List of hypothesis.

5 Scenario's development

Scenarios represent the next stage of the morphological analysis process and correspond to the development hypothesis for a given working horizon for the variables.

Although it could be possible to select micro-scenarios addressing, for example, only "mining" variables, as POTENTIALS deals with synergistic potentials of end-of-life coal mines and coal-fired power plants, along with closely related neighbouring industries, global scenarios will be addressed in the first place.

Some micro-scenarios that can address partially some objectives are described after the global scenarios. Their application will depend on the specific needs or wills of the coal regions interested in exploring these possibilities, and they can always complement more specific scenarios.

Here follows an example of several exploratory scenarios, showing how they were built. In the Annex, there will be more exploratory scenarios and, in the next point, the scenarios space proposed. Apart from the morphological analysis, some of them were obatined via brainstorming, in order not to leave specific combinations of variables that, due to time constraints, did not appear during the analysis.

5.1 Scenario 1: Virtual power plant

The first scenario to be considered will be a Virtual power plant where the energy produced (renewable) will be sold to the grid or used to power companies with constant energy consumption located in the near area, such as aluminium factories or green data centres.

Energy production will be based on solar photovoltaic and wind power (if possible) that will be deployed mainly on the waste heaps.

To maintain a competitive and constant supply of electricity, energy storage is necessary. Storage can absorb excess electricity generation and re-inject it later, effectively reducing curtailment due to excess generation or demand constraints.

Unconventional pumped hydro storage using dense fluids is the best option for underground mines that are not flooded, as it is necessary first to develop the infrastructure previously to the flooding of the mine.

In order to expand energy production as much as possible, geothermal energy will also be deployed and synergies will be searched concerning the transformation of heating/cooling customers into prosumers or customers who produce excess electricity from solar panels on their roofs. The aim is to maximise the number of business opportunities and thus the impact on employment. Finally, circular economy technologies based on the valorisation of fine coal waste, a by-product of coal processing often stored in landfills, which directly addresses and complements the scenario's specific needs will be pursued. In the first hand, to develop the high-density fluid required for the unconventional hydro energy storage system. In the second hand, to restore waste heap areas before the installation of photovoltaic/wind renewable energy infrastructure using different combinations of fine coal waste together with local by-products and substances considered as "non-recoverable" waste such as sewage sludge, decarbonisation lime from water screening processes. Etc. Finally, to concentrate critical raw materials through mineralurgical processes (Figure 5-1).

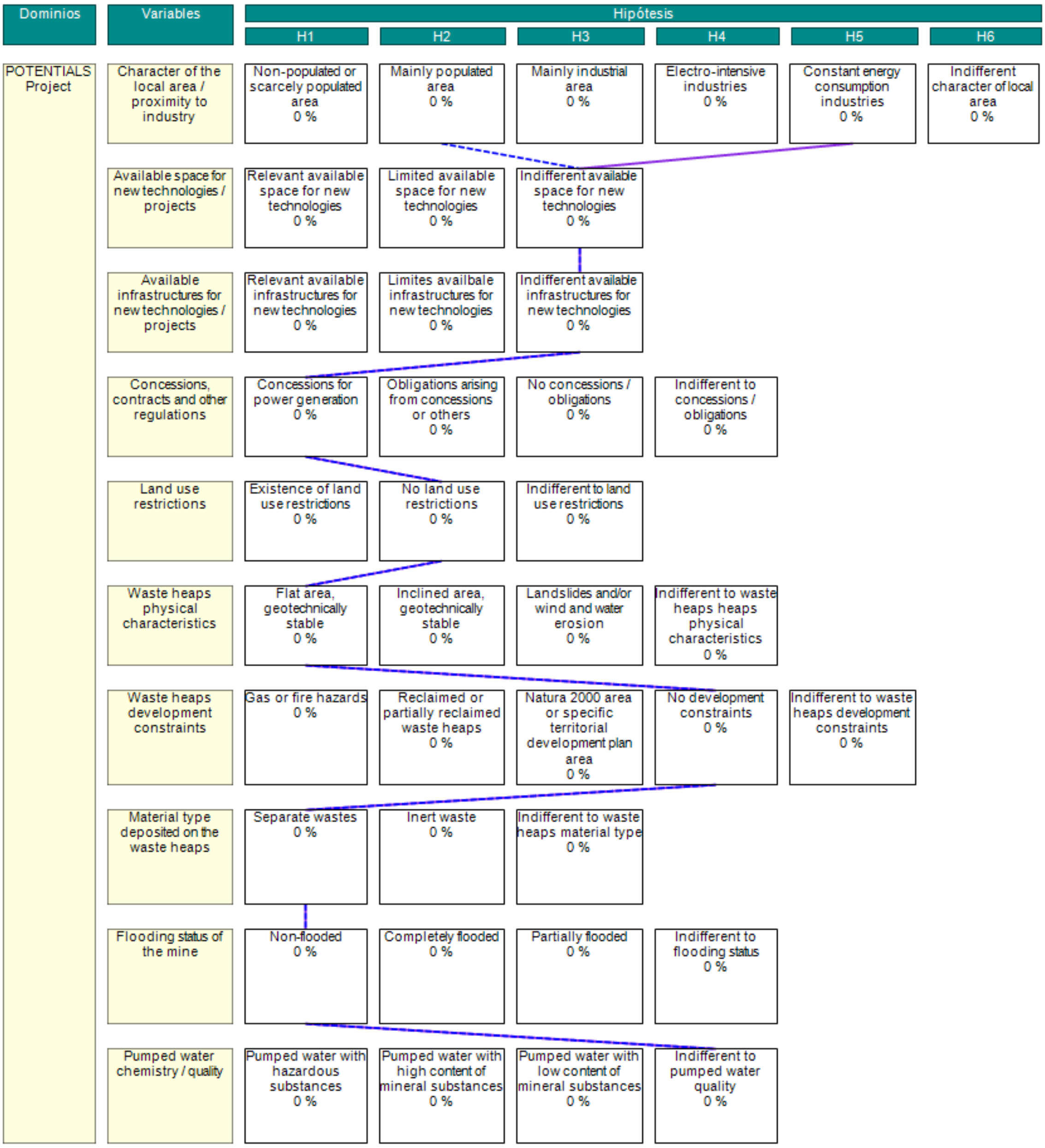

Figure 5-1. Virtual power plant scenarios

Figure 5-2 shows the list of the two main scenarios for a Virtual power plant. Of course, this scenario is still valid when the character of the area is purely industrial, etc.

Lista de escenarios

S1	S2
P / Equi : 0	P / Equi : 0
Constant energy consumption industries	Mainly populated area
Indifferent available space for new technologies	Indifferent available space for new technologies
Indifferent available infrastructures for new technologies	Indifferent available infrastructures for new technologies
Concessions for power generation	Concessions for power generation
No land use restrictions	No land use restrictions
Flat area, geotechnically stable	Flat area, geotechnically stable
No development constraints	No development constraints
Separate wastes	Separate wastes
Non-flooded	Non-flooded
Indifferent to pumped water quality	Indifferent to pumped water quality

Figure 5-2. List of scenarios for a Virtual power plant

As it is easy to understand, this scenario may be still valid without, for example, circular economy technologies. Nevertheless, and as it was stated before, only global scenarios will be addressed.

5.2 Scenario 2: Green hydrogen plant

The second scenario to be considered will be a Green hydrogen plant where renewable hydrogen will be produced by electrolysis of mine water and electricity from renewable sources. It is a clear alternative to selling renewable energy to the grid or to power industries with constant energy consumption. The energy produced will be used to power electro-intensive industries located close to the area.

The urge to reduce greenhouse gas emissions, the increasing costs for CO_2 emission certificates, and the increasing ambition in climate mitigation put pressure on conventional production processes in energy-intensive industries such as steel, cement, chemicals, and others. Green hydrogen becomes a vital decarbonisation option in processes where electrification and other solutions such as material and energy efficiency improvements are not available.

Green hydrogen can also play a complementary role to renewable electricity: (1) as an energy storage system (even seasonal) thanks to its large volume and extended lifetime in a similar way to how strategic reserves of natural gas or oil is used, making it possible supplying renewable hydrogen reserves to support the electricity grid; or (2) by opening up the option of hydrogen mobility, one of the keys to help decarbonise transport, especially long-distance maritime transport, rail and heavy goods transport by road.

Nevertheless, and in the first place, currently there is no economic feasibility to use green hydrogen as an energy storage system, as all the rest of energy storage systems are more economic. In the second place, as hydrogen mobility is not yet enough developed in any kind of transport, this is not a realistic current alternative.

Finally, the alternative to blending hydrogen into the existing natural gas grid would undermine gas quality standards, posing a risk to the operations of many industrial users that rely on a high and constant gas quality for their processes. Moreover, European gas networks can only integrate very low amounts of hydrogen into the existing infrastructure due to a phenomenon known as "hydrogen embrittlement" that causes damages to the infrastructure. Thus, blending hydrogen into existing gas networks is likely not an efficient development for renewable energy. As in the case of a Virtual power plant, energy production will be based on solar photovoltaic and wind power (if possible) that will be deployed mainly on the waste heaps. Unconventional pumped hydro storage using dense fluids will be used for underground mines that are not flooded. The same circular economy technologies, as in the Virtual power plant will be considered.

Figure 5-3 presents the two Green hydrogen plant scenarios more interesting for end-of-life coal mines and coal-fired power plants, along with closely related neighbouring industries. The existence of concessions and obligations may not influence this scenario.

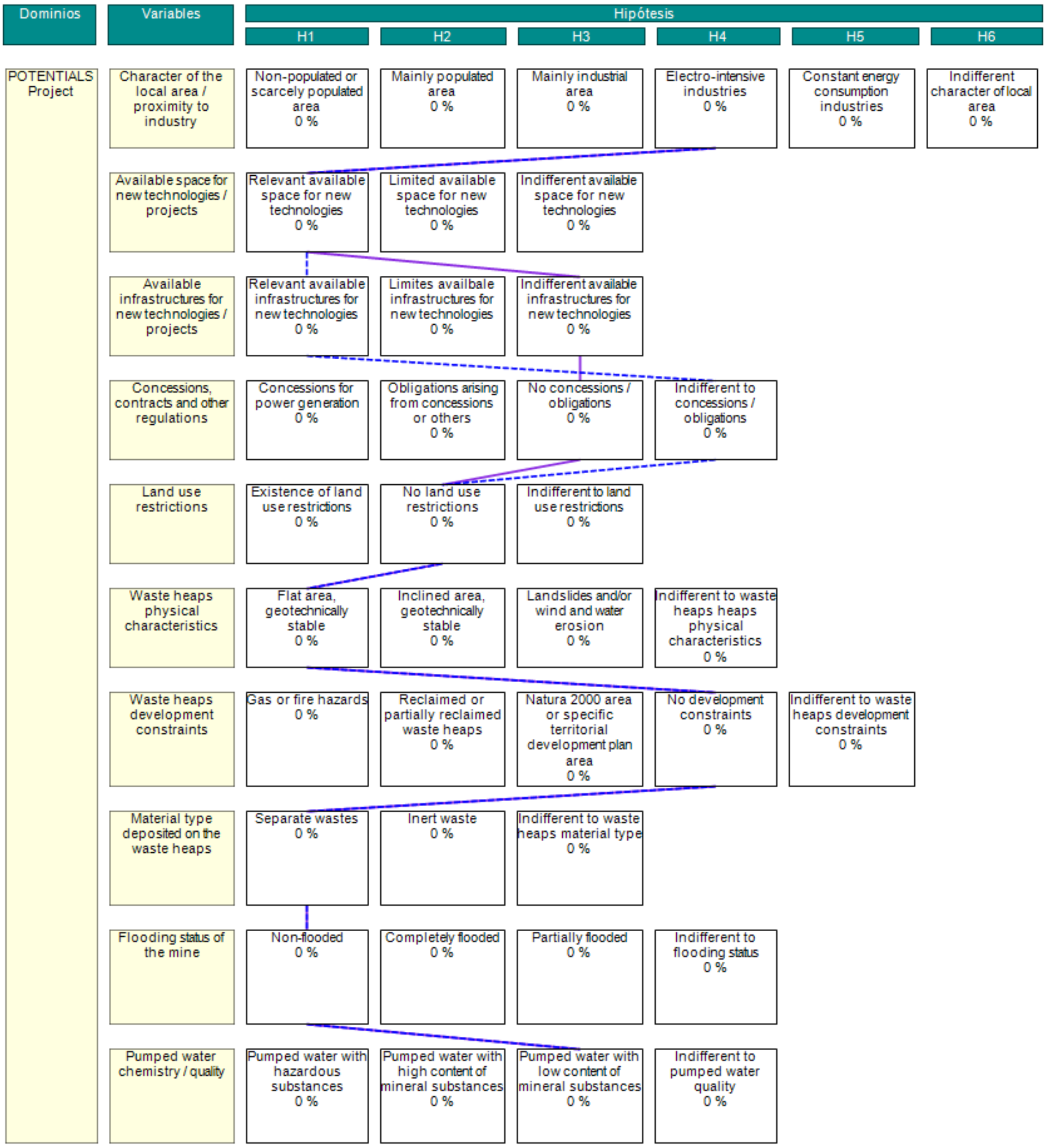

Figure 5-3. Green hydrogen plant scenarios

Figure 5-4 shows the list of the two main scenarios for a Green hydrogen plant.

Lista de escenarios

S1	S2
P / Equi : 0	P / Equi : 0
Electro-intensive industries	Electro-intensive industries
Relevant available space for new technologies	Relevant available space for new technologies
Indifferent available infrastructures for new technologies	Relevant available infrastructures for new technologies
No concessions / obligations	Indifferent to concessions / obligations
No land use restrictions	No land use restrictions
Flat area, geotechnically stable	Flat area, geotechnically stable
No development constraints	No development constraints
Separate wastes	Separate wastes
Non-flooded	Non-flooded
Pumped water with low content of mineral substances	Pumped water with low content of mineral substances

Figure 5-4. List of scenarios for a Green hydrogen plant

Finally, Figure 5-5 shows the proximity chart between the two main scenarios that were analysed yet: Virtual power plant (2) and Green hydrogen plant (2). As it can be noticed, the two scenarios of Green hydrogen plants are more closed between them than in the case of Virtual power plants, indicating that the Virtual power plant may be a more flexible scenario than Green hydrogen plants.

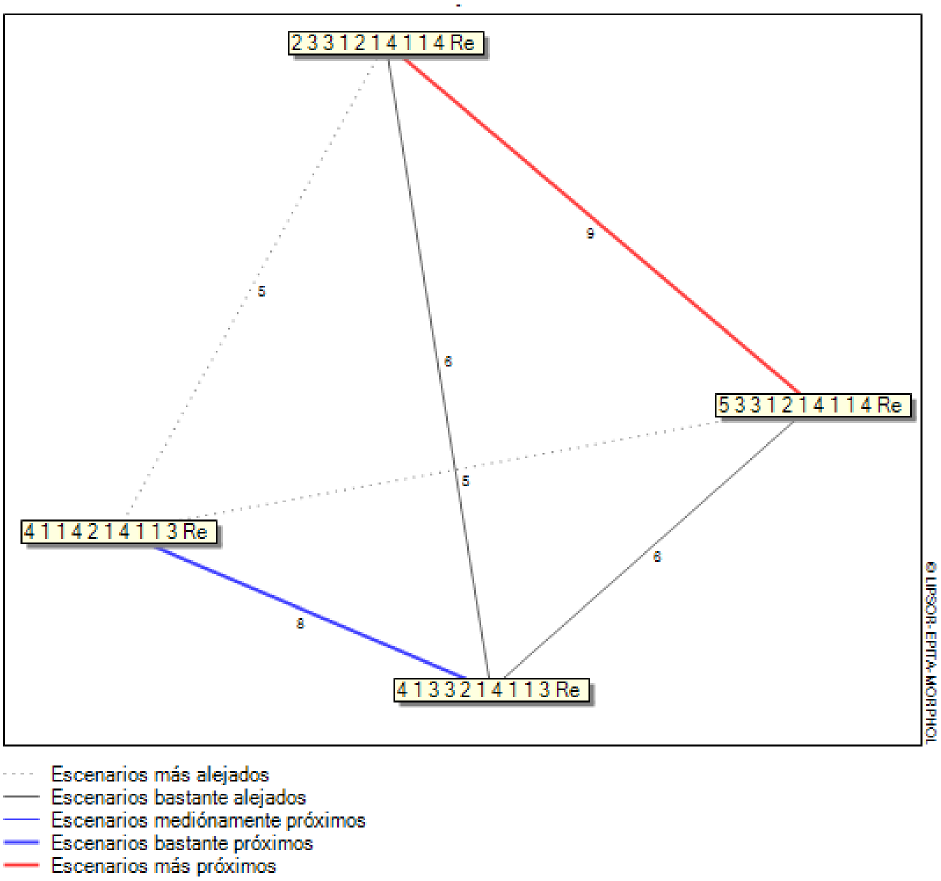

Figure 5-5. Proximity chart between Virtual power plant scenarios (red) and Green hydrogen plant scenarios (blue)

5.3 Scenario 3: Molten salt plant

When no pumped hydro storage is possible, one of the technologies with some pilot plants already implemented around the world are Molten salt plants, using energy storage in the form of tanks with heated molten salt. They allow to smooth the fluctuation of renewable energies such as solar and wind. Nevertheless, and in order to achieve better efficiencies, they preferable should be coupled with concentrated solar power (CSP) plants where a heat transfer fluid (HTF) such as oil absorbs the energy.

In CSP plants, excess heat that is not used for electricity generation is diverted to the molten salt, which is then stored in an insulated tank. After sunset, this thermal energy can be used to produce steam and generate electricity when the sun is no longer providing energy to the CSP plant (Johnson et al., 2019).

According to Bielecki et al. (2019) Molten salt reservoirs have high storage efficiency (above 90%), but the efficiency of the energy transformation from heat to electricity is much lower at about 50%, which is a significant disadvantage

Besides of increasing efficiency and thanks to increased controllability, Molten salt plants may now be used not only to cover baseload but also as more agile dispatchable generators (Bielecki et al., 2019).

Figure 5-6 presents the Molten salt plant scenario. This scenario considers separate wastes in the waste heaps, in order to develop circular mining technologies. On the other hand, pumped water quality was considered with high content of mineral substances, in order to be also possible to apply circular economy technologies to extract mineral substances from water while cleaning it for other purposes.

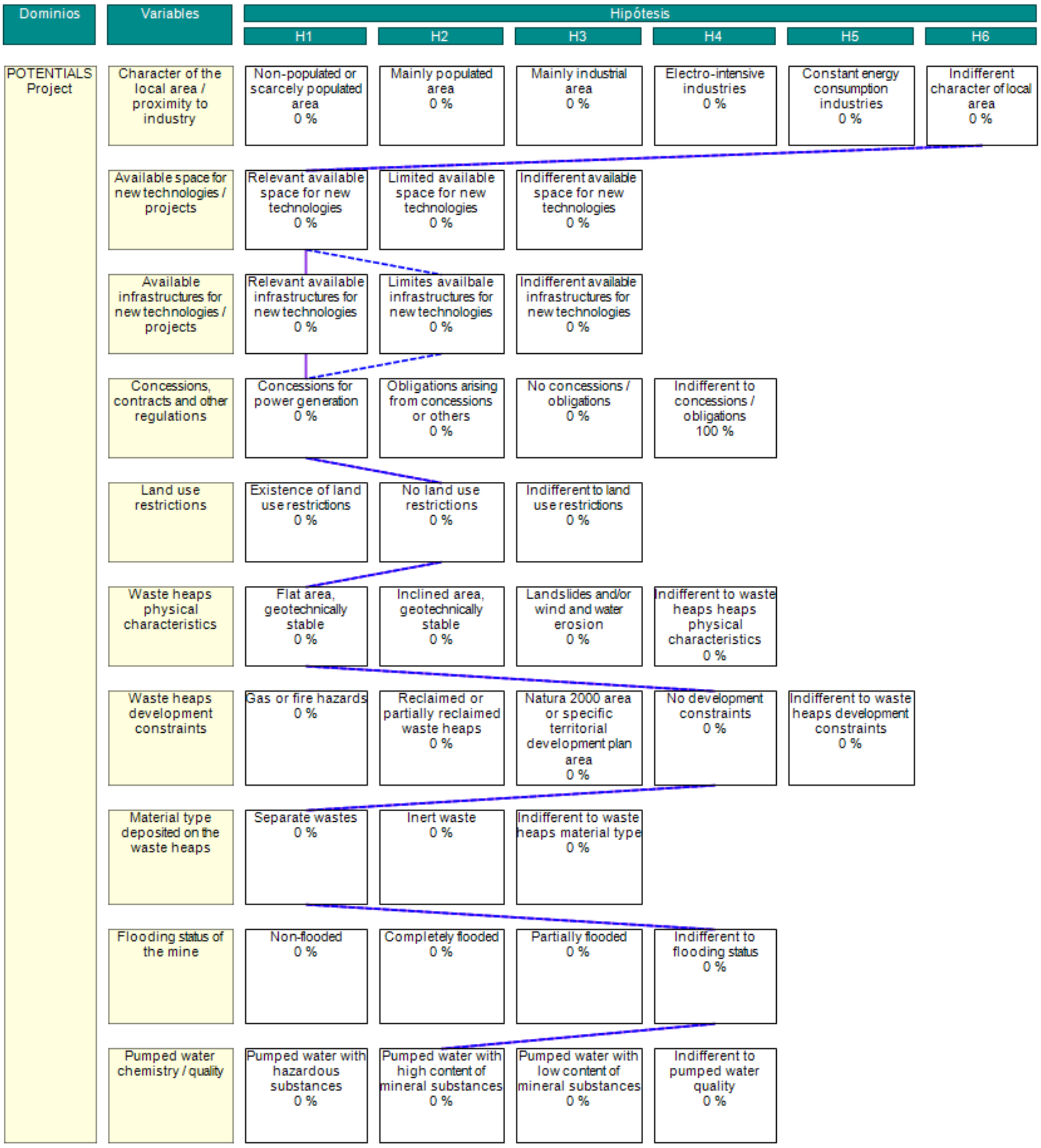

Figure 5-6. Molten salt plant scenario

5.4 Scenario 4: Eco-industrial park

Eco-industrial parks are an integrated alternative for sustainable energy generation technologies and circular economy contributions at these sites. The main objective of industrial parks is to reduce waste and pollution by promoting short distance transport, optimizing material, resource and energy flows within the industrial parks.

Sustainable energy generation technologies comprise solar and wind energy production together with energy storage, as well as geothermal energy in order to provide cooling/heating to the companies/industries that will take part of the Eco-industrial park.

As well as in the case of Virtual power plants, synergies will be searched concerning the transformation of heating/cooling customers from the Eco-industrial park into prosumers or customers who produce excess electricity from solar panels on their roofs.

Circular economy requires the development of a social network between industrial producers acting as sources of material, energy and resources and the others acting as users, usually called “industrial symbiosis”. The optimization is based on socio-economic and environmental criteria helping to achieve sustainable development around coal industry in general and with the intention of increasing economic gains and improving environmental quality (Martín Gómez et al., 2018; Wei et al., 2017; Zhao et al., 2018). The circular economy approaches have been mainly tested in the US, China and Australia.

Figure 5-7 presents the Eco-industrial park scenarios with and without considering circular mining technology addressing waste heaps materials and mine water.

Moreover, as in this case energy storage needs are lower than in the case of Virtual power plants and Green hydrogen plants, even batteries may cover the specific needs despite their prices.

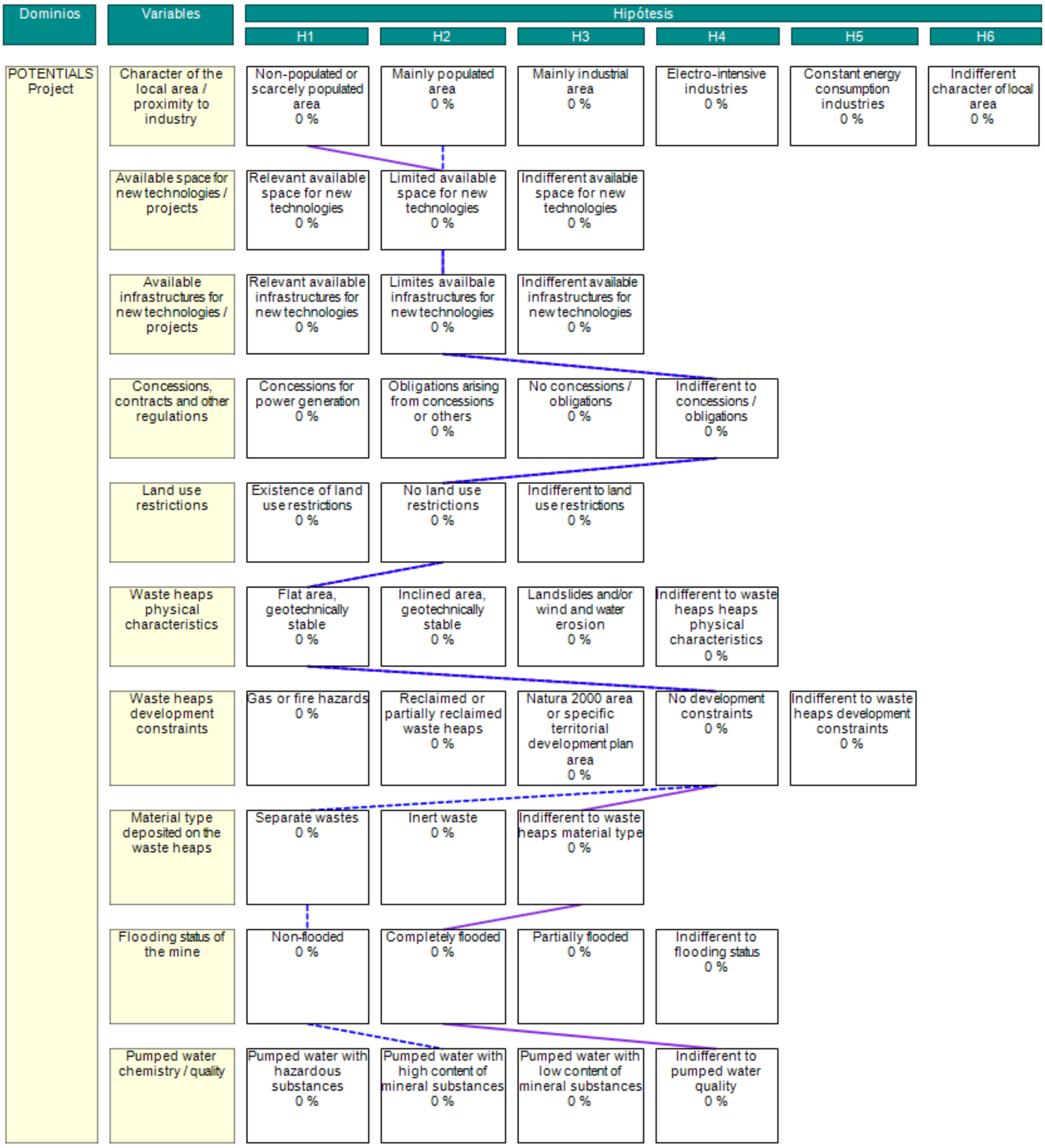

Figure 5-7. Eco-industrial park scenarios

6 Micro-scenarios development

6.1 Micro-scenario 1: Circular mining technologies (waste heaps)

Figure 6-1 presents the scenario for the circular mining technology based on waste heap materials recovery. The fact that wastes are landfilled separately according to their characteristics is very important.

Cuadro de escenarios

Dominios	Variables	Hipótesis					
		H1	H2	H3	H4	H5	H6
POTENTIALS	Area characteristics	Non-populated or scarcely populated area 0 %	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %			
	Infrastructures	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %			
	Concession / obliga.	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 100 %		
	Land restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %			
	Heaps characteristic	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %		
	Heaps constaints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %	
	Heaps material	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %			
	Flooding status	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %		
	Water quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %		

Figure 6-1. Circular mining technologies scenario for waste heap material recovery

On the other hand, it should be possible to install a material recovery plant, something that has to be permitted according to the territory development plant.

6.2 Micro-scenario 2: Circular mining technologies (mine water)

Figure 6-1 shows the circular mining technologies scenario for pumped water material recovery. Again, as in the case of waste heaps material recovery it should be necessary to install a mine water treatment plant; that is why no land use restriction are foreseen.

Cuadro de escenarios

Dominios	Variables	Hipótesis H1	H2	H3	H4	H5
POTENTIALS	Area characteristics	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Infrastructures	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concession / obliga.	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Heaps characteristic	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Heaps constaints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Heaps material	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Water quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

© LIPSOR-EPITA-MORPHOL

Figure 6-2. Circular mining technologies scenario for pumped water material recovery

Undoubtedly, if there is a water treatment plant available at the power plant, it could be probably used for the purposes of this micro-scenario.

7 Scenario's space

Here follows the list of scenarios and micro-scenarios obtained from the morphological analysis. However, some of them were obatined via brainstorming, in order not to leave specific combinations of variables that, due to time constraints, did not appear during the analysis.

7.1 Scenarios

1. Virtual power plant.
2. Green hydrogen plant.
3. Molten salt plant.
4. Eco-industrial park.
5. Cultural heritage and extreme sports using green energy.
6. Floating PV panels at flooded open-pit coal mines.
7. Agrophotovoltaics (APV) at former open-pit coal mine areas.
8. Pumped hydroelectric storage (PHS) at former open-pit coal mines.
9. Fisheries in flooded open-pit coal mines.
10. Ancillary services provided by batteries.
11. Combined Cycle Gas Turbines (CCGT) plant.
12. Electrolysers powered by PV and/or Wind turbines, CCGT, Use of energy for recycling of minerals from pumped mine water.
13. Mine gas utilization for gas-powered CHP power units.
14. Open cycle gas turbine, block heat and power plant, gas engine.
15. Small modular reactors (SMRs), Open cycle gas turbines, CCGT.
16. Usage of methane from degasification units on closed coal mines.
17. Park for industries with energetic and distribution needs.

18. Cultural/recreation areas (museums, aquapark, beaches, tunnel of terror, cemetery, etc.).
19. Laboratory park (wind tunnel, zero gravity, fire simulations, explosions, etc.).
20. Recycling plant for photovoltaics and wind energy generators.
21. Training areas for technicians (rescue training center, etc.).
22. Tursim and industry fairs.
23. Batteries storage plant.
24. Pellet factory.
25. Biomass production.
26. Engineering School.
27. Biofuel plant.
28. E-fuel plant.
29. fly and mealybug farms.
30. Animal farms.
31. CO_2 capture via plants and algae.
32. Underground turbines using natural ventilation.
33. Apple plantation (protected designations of origin, protected geographical indications).

7.2 Micro-scenarios

1. Circular mining technologies based on waste heap materials recovery.
2. Circular mining technologies scenario for pumped water material recovery.
3. Green energy relax and extreme mine & plant (trail tracks, etc.).
4. Forest restoration at former open-pit coal mines.
5. Plantations inside the mine.

6. Bacteria development inside the mine.
7. Inert wastes storage.
8. Server rooms in the floors closer to the surface or in a coal power plant (cryptocurrencies such as bitcoin, etc.).
9. Seeds bank.
10. Hydro screws in rivers.
11. Wine cellars.
12. Cheese cellars (protected designations of origin, protected geographical indications).
13. Anaerobic fermentation processes.
14. Parking.
15. Auditoriums.
16. Speleology.

8 Conclusions and lessons learnt

The number and diversity of the variables from the MICMAC analysis pose a challenge for the appropriate selection of parameters for the morphological analysis.

Therefore, it was decided, instead of analysing the whole system ("Potential" variables), to carry out analyses for three groups of variables: "Power plant", "Surface mining" and "Underground mining" separately. The results obtained from these analyses made it possible to identify the key variables in the above areas, which would not have been possible with a holistic analysis.

The process of identifying the final variables was rather complicated, as sometimes several variables could be combined into one, and some of them represented development hypotheses for a certain working horizon of the variable. In other cases, variables were directly related to other variables and were therefore eliminated from the analysis. Also, several variables did not condition the development hypothesis for a given working horizon, so these variables were not taken into account in the analysis. In some cases it was possible to combine several variables into one variable.

After this process, the final number of variables selected from the three groups for the morphological analysis was only ten. However, the combination of the different hypotheses for each variable allows a total of 100,000 possible scenarios to be calculated. Thus, the scenario space was large enough to allow for an extremely deep analysis of the system.

Although the morphological analysis was able to produce a fairly large number of scenarios, it was necessary to develop a brainstorming session in order not to leave specific combinations of variables that, due to time constraints, did not appear during the analysis.

Finally, in some cases it was difficult to decide whether it was a normal scenario or a micro-scenario. However, once any scenario has been selected, it is important to review any additional possibilities that are not incompatible with the main scenario.

9 Glossary

AMM – Abandoned mine methane

CRM – Critical raw materials

CSP – Concentrated solar power

HTF – Heat transfer fluid

HUNOSA – Hulleras del Norte S.A.

MICMAC – Software tool for structural analysis developed by the Institut d'Innovation Informatique pour l'Entreprise 3IE

MORPHOL – Software tool for morphological analysis developed by the Institut d'Innovation Informatique pour l'Entreprise 3IE

UNIOVI – University of Oviedo

References

Agrawal, N.M. (2019). Modelling Deming's quality principles to improve performance using interpretive structural modelling and MICMAC analysis. International Journal of Quality & Reliability Management 36(7), 1159-1180. https://doi.org/10.1108/IJQRM-07-2018-0204

Balouli, H.E. & Chine, L. (2019). Morphological analysis of agricultural entrepreneurship in Algeria using Morphol method. Roa Iktissadia Review, vol. 09(01), 113-120.

Bielecki, A., Ernst, S., Skrodzka, W., & Wojnick, I. (2019). Concentrated Solar Power Plants with Molten Salt Storage: Economic Aspects and Perspectives in the European Union. International Journal of Photoenergy, vol. 2019, Article ID 8796814, 10 pages. https://doi.org/10.1155/2019/8796814

Dhir, S., & Dhir, S. (2020). Modelling of strategic thinking enablers: a modified total interpretive structural modelling (TISM) and MICMAC approach. International Journal of System Assurance Engineering and Management 11(1), 175-188. https://doi.org/10.1007/s13198-019-00937-z

Duperrin, J. & Godet, M. (1975). SMIC 74—A method for constructing and ranking scenarios. Futures 7, 302–312.

Godet, M. (2001). Manuel de propective stratégique. Dunod: Paris.

Godet, M., & Durance, P. (2011). Strategic Foresight for Corporate and Regional Development. UNESCO – Dunod: Paris.

Johnson, S., et al. (2019). Selecting Favorable Energy Storage Technologies for Nuclear Power. In: Storage and Hybridization of Nuclear Energy. 119-175. Academic Press. https://doi.org/10.1016/B978-0-12-813975-2.00005-3

Martín Gómez, A. M., Aguayo González, F., & Marcos Bárcena, M. (2018). Smart eco-industrial parks: A circular economy implementation based on industrial metabolism. Resources, Conservation and Recycling, 135(September 2017), 58–69. https://doi.org/10.1016/j.resconrec.2017.08.007

Villacorta, P.J.; Masegosa, A.D.; Castellanos, D. & Lamata, M.T. (2012). A Linguistic Approach to Structural Analysis in Prospective Studies. In International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems; Springer: Berlin/Heidelberg, Germany, 150–159.

Wei, Z., Xu, D., Wang, Z., & Song, G. (2017). Coal Mine Based Circular Economy Park: A Case Study. Geo-Resources Environment and Engineering, 2(September). https://doi.org/10.15273/gree.2017.02.00

Zhao, H., Guo, S., & Zhao, H. (2018). Comprehensive benefit evaluation of eco-industrial parks by employing the best-worst method based on circular economy and sustainability. Environment, Development and Sustainability, 20(3), 1229–1253. https://doi.org/10.1007/s10668-017-9936-6

Annex

PARTNER: CERTH

PROPOSED SCENARIO NAME (Scenario-1): Floating PV panels at flooded open-pit coal mines

REMARKS: Floating PV panels at flooded open-pit coal mines can be implemented in the Amynteo mine of Western Macedonia (Greece). The lake water will be used for the required cooling of the floating PV panels. Possible synergies include forest restoration of the broader area, whereas extracting critical metals from mining wastes will contribute to a circular economy.

Description:

The ongoing research on solar panels has led to the development of floating photovoltaics (PV), installed on water surfaces. A floating PV system comprises conventional and concentrated PV arrays, while the lake water provides the required cooling that preserves the operation temperature at suitable levels (Trapani & Redon Santafe, 2015; Wieland, 2020). Based on this technology, a possible scenario includes the installation of floating PV on open-pit lakes (Song & Choi, 2016). Therefore, former open pit coal mines are suitable sites for implementing this scenario since they provide large lakes and an already established connection to the grid (Wieland, 2020).

The grid and the nearby power industries will be provided with the produced electricity generated by the PV panels. Providing energy from renewable sources to the grid significantly contributes to decarbonising the power sector. Combining energy production from floating PV panels with energy storage would enhance the stability of the power supply. The storing system would collect surplus energy at times of significant energy generation and provide it to the system when needed. For additional electricity production, synergies with customers from the surrounding area who own small-scale solar panels could be arranged. Installing a floating PV system may appear more expensive. Still, the annual reduction of GHG emissions is significantly higher than other restoration methods, while the income from the electricity generation creates a further advantage (Song & Choi, 2016).

Forest restoration at the broader mine area can accompany the installation of floating PV, further contributing to reducing GHG emissions. The exploitation of remaining mining wastes to recover critical metals will contribute to the circular economy, providing many opportunities for the sustainable development of local communities.

Figure 1 presents the Floating PV panels in the scenario of flooded open-pit coal mines. A mainly industrial area is selected in the relevant variable since the generated electricity from the floating PV will be delivered to surrounding industries and the grid. Considering that the whole site of a flooded open-pit coal mine will be used to implement this scenario, the relevant available space for new technologies and a partially flooded mine are required. Available infrastructures for new technologies/projects will be deployed to connect to the grid. The scenario also considers the concessions, contracts, regulations and obligations that will arise with the local community, including concessions for power generation from the floating PV and other obligations. This scenario applies land use restrictions in the reclaimed forest areas and industrial wastes. These are associated mostly with forest restoration synergies and the exploitation of waste heaps. The proposed area for the implementation of this scenario is mainly inclined and geotechnically stable. Waste heaps could be partially or fully retrieved. In contrast, their physical characteristics should be considered to prevent defects such as landslides, which can be caused by variations in hydrostatic pressure or water erosion. Particular wastes will favour the exploitation of waste heaps, whereas the quality of pumped water is indifferent to the implementation of this scenario.

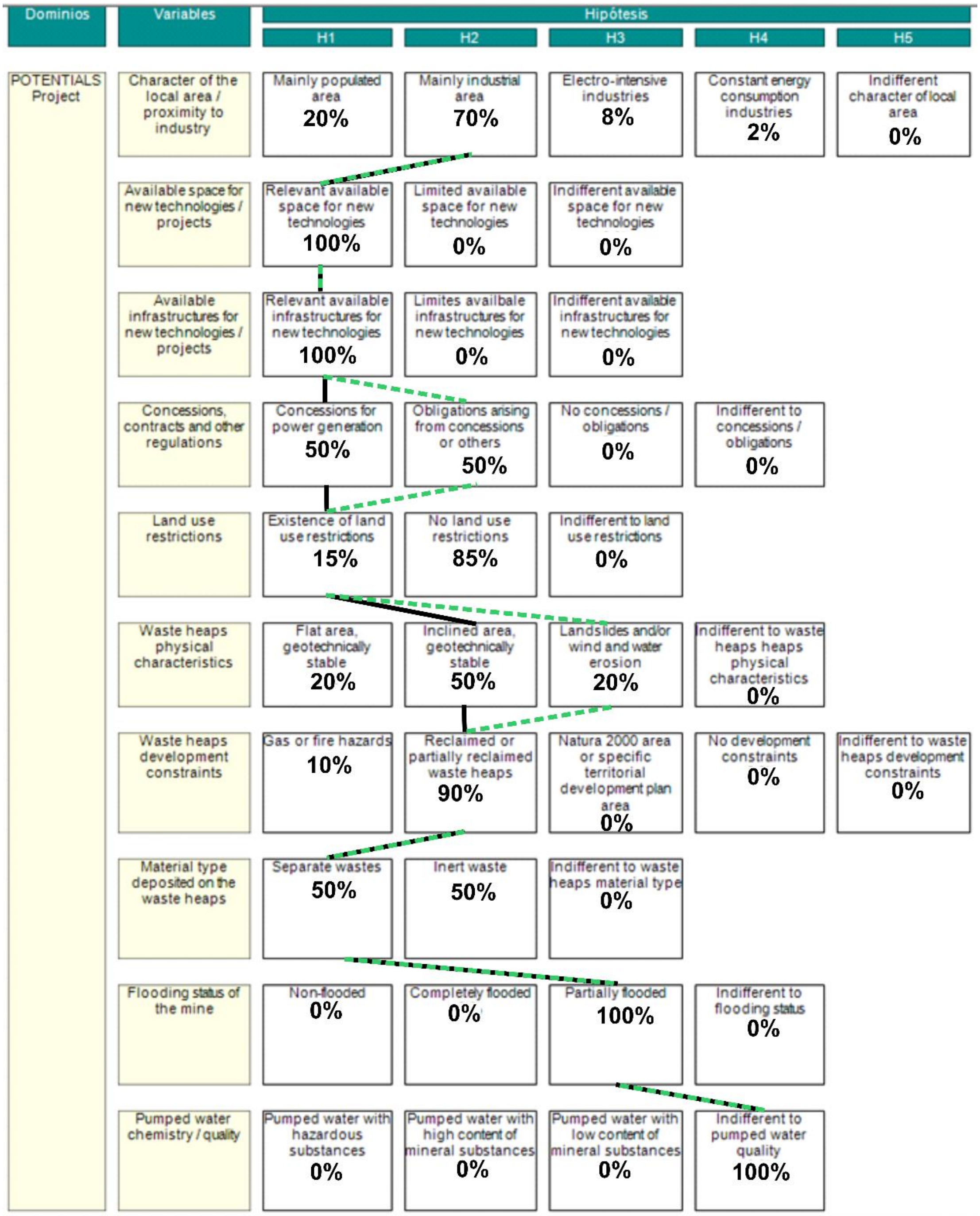

Figure 1. Floating PV panels at flooded open-pit coal mines.

References:

Song, J., & Choi, Y. (2016). Analysis of the potential for use of floating photovoltaic systems on mine pit lakes: case study at the Ssangyong open-pit limestone mine in Korea. Energies, 9(2), 102.

Trapani, K.; Redon Santafe, M. (2015). A review of floating photovoltaic installations: 2007–2013. Prog. Photovolt. 23, 524–532.

Katsikogiannis, O. A., Ziar, H., & Isabella, O. (2022). Integration of bifacial photovoltaics in agrivoltaic systems: A synergistic design approach. Applied Energy, 309, 118475.

Wieland, S. (2020, February 5). Fraunhofer ISE Analyzes Potential of Solar Power Plants Located on Pit Lakes in Former Lignite Mines. Fraunhofer Institute for Solar Energy Systems ISE. https://www.ise.fraunhofer.de/en/press-media/press-releases/2020/fraunhofer-ise-analyzes-potential-for-solar-power-plants-located-on-pit-lakes-in-former-lignite-mines.html3

PARTNER: CERTH

PROPOSED SCENARIO NAME (Scenario-2): Agrophotovoltaics (APV) at former open-pit coal mine areas

REMARKS: The proposed scenario concerns the implementation of agrophotovoltaics (APV) at former open-pit coal mines in the region of Western Macedonia (Greece). Synergies with local customers who own small-scale solar panels will be arranged. Forest restoration at the areas of the open-pit mine will be considered for further reduction of GHG emissions.

Description:

The increasing demand for clean energy and solar panels led to a growing interest in ground-mounted photovoltaics (PV-GM). A drawback arising from PV-GM use is associated with the low PV module efficiency, which subsequently leads to increasing land coverage to produce electricity. The extended land use may lead to economic and social conflicts, such as the consequential forfeit of cropland. The deployment of agrophotovoltaic (APV) systems provides an innovative solution since the exploitation of the land area is located below the PV panels for cultivation, allowing simultaneous crop production and the generation of electricity (Schindele et al., 2020; Katsikogiannis et al., 2022).

Agrovoltaics are raised at a certain height above the surface, ranging from 2 to 4 m, while the crops are cultivated underneath them. Because both solar panels and crops need sunlight for productivity, the optimal density of panels array, the panel type and the crop type must be carefully selected. The topology and the climate of the region are two important parameters that must be considered, whereas the selection of the appropriate crops must be based on plants that can adapt to a certain light (Katsikogiannis et al., 2022; Cho et al., 2020; Weselek et al., 2019). The height and spacing of the APV panels can be modified depending on the crop type and its requirement for light, humidity, temperature and space. The appropriate shading and the zones of optimal plant growth must be identified, whereas the APV system must be modelled before the installation (Katsikogiannis et al., 2022; Toledo and Scognamiglio, 2021). Bifacial PV panels display better performance for APV systems. They are usually adapted to have a wider cell spacing and diffuse cover to increase the photosynthesis rate under shade. Increased height, row spacing and panel transparency result in a logarithmic increase of irradiance homogeneity of the ground and the back-side of bifacial panels (Katsikogiannis et al., 2022).

The proper installation of APVs provides additional functions, such as protection against harmful weather conditions and shading at dry climates or periods of increased sunlight (e.g., summer). These advantages and the synergistic production of food and renewable energy render the APV systems an effective solution for the growing global agricultural/food demand and the energy transition (Katsikogiannis et al., 2022; Toledo and Scognamiglio, 2021). The installation of an APV system will provide jobs to the local society. Still, it will also contribute to the economy of the agricultural sector at the local and national scale. In addition, the grid and power of the nearby populated areas and/or industries will be supplied with electricity generated by the APV panels, contributing to the decarbonisation of the urban and/or industrial power sector.

Energy crops could also be developed. These can be used for the production of bio-ethanol fuel, which is subsequently transformed into biodiesel (Acquadro et al., 2020). The Cynara *cardunculus* is a native Mediterranean specie that belongs to the Asteraceae family. It exhibits better performance at climatic conditions of the southern areas of Mediterranean basin and can provide high amounts of biomass, seed and energy (Irena et al., 2020).

Combining energy production from APV panels with energy storage would enhance the stability of the power supply. The excess of energy generated in low-demand or long-lasting sunny periods can be stored to provide it to the system in energy deficit periods, such as the high-demand winter season. For additional electricity production, synergies with customers from the surrounding area, who own small-scale solar panels could be arranged. Forest restoration at the zones, where the APVs cannot be placed will further reduce the GHG emissions.

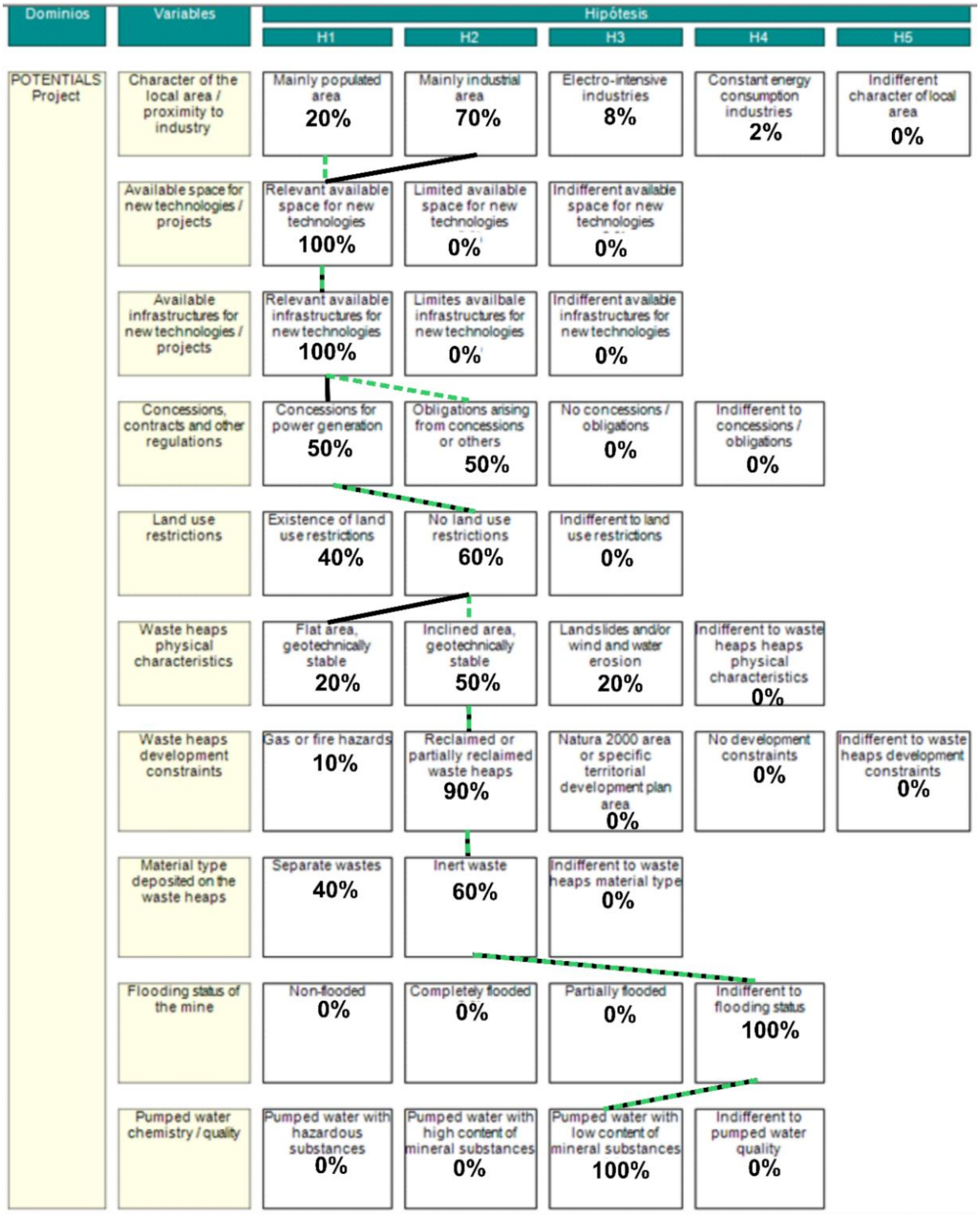

Figure 2. Agrophotovoltaics (APV) at former open-pit coal mine areas.

Figure 2 depicts the agrophotovoltaics (APV) scenario at a former open-pit coal mine. The required area should be mainly populated or industrial since the generated electricity from the APVs will be delivered to the local grid and surrounding industries. A large area proximal to the open-pit coal mine will be needed to implement the APV system. Thus, relevant space for new technologies will be needed for solar power generation, whereas the existing infrastructure will be used to connect to the grid. Concessions for power generation and other obligations will be also applied to this scenario. The applied land use restrictions concern reclaimed cultivated areas. The area is inclined and geotechnically stable. Safety issues including landslides that can be caused by hydrostatic pressure or water erosion will be prevented. Waste heaps could be partially or fully retrieved. Given that the APV system will be installed proximal to waste heaps, their material type must be inert to avoid the of toxic substances. The pumped water quality is characterised by low content of mineral substances, since the concentration of heavy metals and metalloids in mining water and natural water in the Greek lignite mines is significantly low (Dimitrakopoulos et al., 2016).

References:

Schindele, S., Trommsdorff, M., Schlaak, A., Obergfell, T., Bopp, G., Reise, C., Braun, C., Weselek, A., Bauerle, A., Högy, P., Goetzberger, A. & Weber, E. (2020). Implementation of agrophotovoltaics: Techno-economic analysis of the price-performance ratio and its policy implications. Applied Energy, 265, 114737.

Katsikogiannis, O. A., Ziar, H., & Isabella, O. (2022). Integration of bifacial photovoltaics in agrivoltaic systems: A synergistic design approach. Applied Energy, 309, 118475.

Cho, J., Park, S. M., Park, A R., Lee, O. C., Nam, G., & Ra, I.-H. (2020). Application of Photovoltaic Systems for Agriculture: A Study on the Relationship between Power Generation and Farming for the Improvement of Photovoltaic Applications in Agriculture. Energies, 13, 4815.

Weselek, A., Ehmann, A., Zikeli, S., Lewandowski, I., Schindele, S., & Högy, P. (2019). Agrophotovoltaic systems: applications, challenges, and opportunities. A review. Agronomy for Sustainable Development, 39, 35.

Toledo, C. & Scognamiglio, A. (2021). Agrivoltaic Systems Design and Assessment: A Critical Review, and a Descriptive Model towards a Sustainable Landscape Vision (Three-Dimensional Agrivoltaic Patterns). Sustainability, 13, 6871.

Dimitrakopoulos, D., Vasileiou, E., Stathopoulos, N., & Dimitrakopoulou, S. (2016). Estimation of the qualitative characteristics of post mining lakes in different lignite fields in Greece. Mining Meets Water–Conflicts and Solutions, IMWA.

Acquadro, A., Portis, E., Scaglione, D., Mauro, R. P., Campion, B., Falavigna, A., Zaccardelli, R., Ronga, D., Perrone, D., Mauromicale, G., & Lanteri, S. (2012, April). CYNERGIA project: exploitability of Cynara cardunculus L. as energy crop. In VIII International Symposium on Artichoke, Cardoon and their Wild Relatives 983 (pp. 109-115).

Ierna, A., Sortino, O., & Mauromicale, G. (2020). Biomass, seed and energy yield of Cynara cardunculus L. as affected by environment and season. Agronomy, 10(10), 1548.

PARTNER: CERTH

PROPOSED SCENARIO NAME (Scenario-3): Pumped hydroelectric storage (PHS) at former open-pit coal mines

REMARKS: Implementing pumped hydroelectric storage (PHS) at former open-pit coal mines in the Amynteo mine of Western Macedonia, Greece, is proposed. The synergies that will be developed include a wind farm and a solar power plant in the broader mining area. In addition, synergies with local customers who own small-scale solar panels will be arranged. Using waste water in soil additives coupled with the extraction of critical metals from mining wastes will contribute to a circular economy.

Description:

Pumped hydroelectric storage (PHS) is a technology that can store excess energy at periods of high energy supply and regenerate it when needed. It can be supplemented by wind farms, solar power plants or other renewable energy systems. The implementation of this scenario requires two partially flooded pits, since the PHS system arrangement includes two water reservoirs at different elevations and their water level should fluctuate. In the region of Amynteo (Western Macedonia; Greece), the partially flooded mine is surrounded by several open pits located in variable altitudes, providing the appropriate features for implementing PHS. The existing connection to the grid will also decrease capital expenditures. Surplus energy is used to forward water from the lower reservoir to the upper one (recharge). In contrast, during high energy demands, the system generates power by the water flow from the upper reservoir to the lower (discharge) assisted by a turbine. The produced electricity will be provided to the grid and power industries located in the surrounding area. For the connection to the grid, the existing transmission network of the former coal power plant will be used.

A wind farm and photovoltaic panels will be installed in the mining area, providing synergies for the PHS, since the produced energy will be dispatched to the grid and the nearby power industries. The generated surplus energy will supply the PHS system for the recharging process. Synergies with local customers who own small-scale solar panels will give additional electricity production. The remaining amount of waste-water or mining waste from the former coal mine can recover critical metals, such as REE. The waste-water can also be used as a soil additive on arable land of the surrounding region (Mehta et al., 2020).

Figure 3 presents the scenario of PHS at the relevant available space of the former open-pit mines in the region of Amynteo (Western Macedonia, Greece). The required area is mainly industrial, whereas the generated electricity will be delivered to the grid and the surrounding power industries. In the Amynteo mine, there is currently one flooded mine. For the needs of this scenario the flooding of another open pit mine, which is located at a different altitude, will be implemented. Relevant available infrastructures for new technologies/projects are selected since the existing infrastructure for the connection to the grid will be used. Concessions and potential obligations associated with the power generation and the region's sustainable development will arise from the local community and the stakeholders. Land use restrictions on installing the wind farm and PVs will be considered. An inclined, geotechnically stable area is required since the scenario design is formed on different elevation levels and the prevention of stability issues such as landslides need to be considered. The available mine waste will be utilised to extract critical metals, whereas the pumped water quality (Dimitrakopoulos et al., 2016) can be recycled for the production of soil additives.

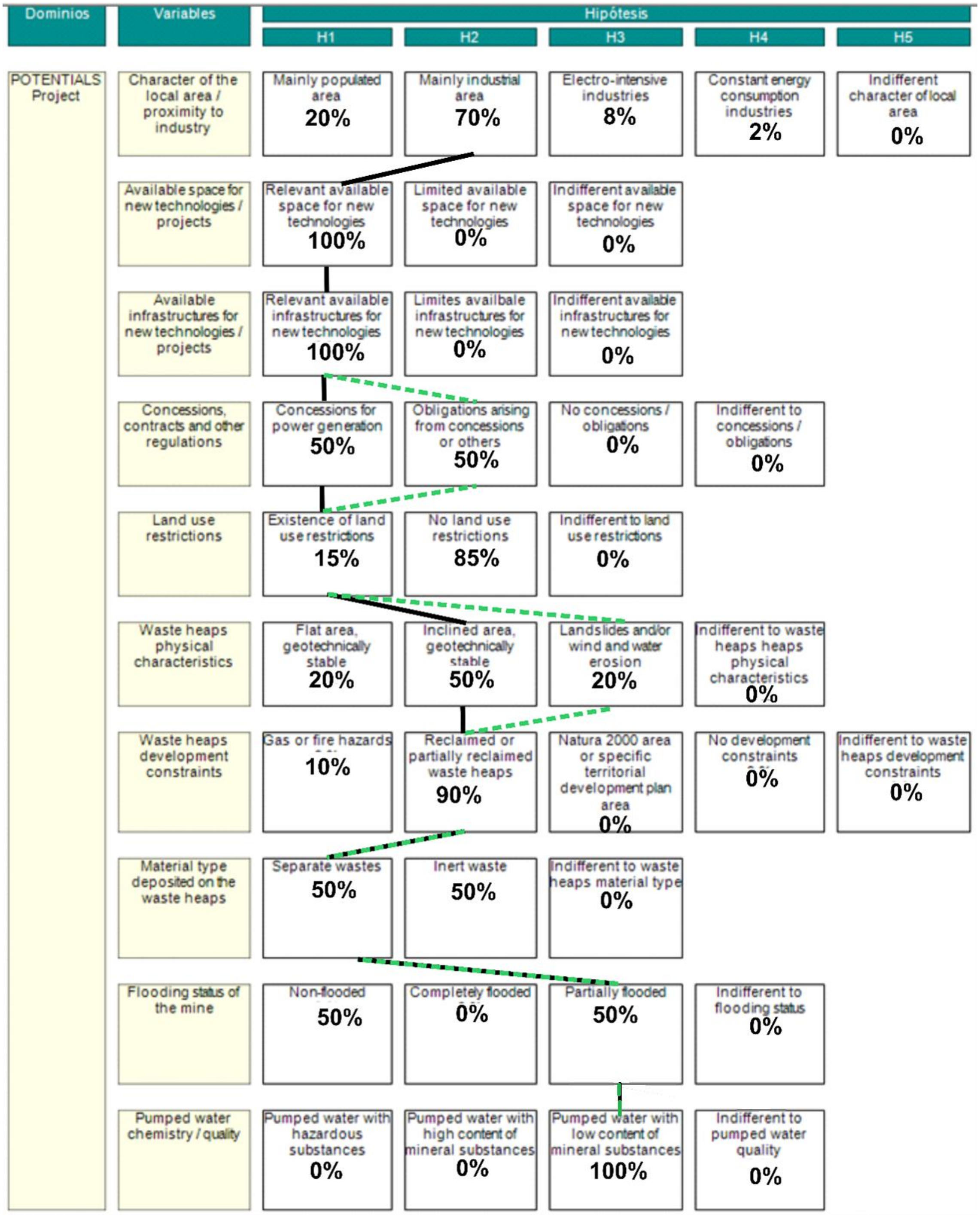

Figure 3. Pumped hydroelectric storage (PHS) at former open pit coal mines.

References:

Mehta, N., Dino, G. A., Passarella, I., Ajmone-Marsan, F., Rossetti, P., & De Luca, D. A. (2020). Assessment of the possible reuse of extractive waste coming from abandoned mine sites: Case study in Gorno, Italy. Sustainability, 12(6), 2471.

Dimitrakopoulos, D., Vasileiou, E., Stathopoulos, N., & Dimitrakopoulou, S. (2016). Estimation of the qualitative characteristics of post mining lakes in different lignite fields in Greece. Mining Meets Water–Conflicts and Solutions, IMWA.

PARTNER: CERTH

PROPOSED MICRO-SCENARIO NAME (Micro-scenario-1): Forest restoration at former open-pit coal mines

REMARKS: Reforestation of the former open-pit coal mines will give several advantages that include the decrease of GHG emissions, as well as the protection against natural hazards (such as landslides and flooding events).

Description:

The implementation of this micro-scenario could be deployed in Western Macedonia, Greece. Several studies have been performed regarding the reforestation process of old mining areas. The development of self-sustaining ecosystems through forest restoration provides a variety of tree species, which are planted to attract animals, increasing the local biodiversity (i.e. birds, small mammals and predators; Haigh et al., 2020). Decontamination of the former mining area and the subsequent reduction of contaminants such as Cd, Cu, Zn, Pb and Mn contribute to the sustainable development of the region (Haigh et al., 2019). The climate conditions of Western Macedonia favour the result of a forest since there is plenty of rainfall and sunlight throughout the year.

The micro-scenario will be implemented mainly in the industrial zone of Western Macedonia (Figure 4). An extended flat and geotechnically stable area is required to develop the forest, whereas there is no need for any technological development and relevant infrastructure. Possible concessions arising from this micro-scenario include the reduction of significant amounts of GHG emissions, as well as the protection against landslides, fires and flooding events. The possibility of gas leakage incidents or fire outbreaks due to the existing waste heaps should be addressed before the implementation of this scenario. Regional territorial development plans will be subjected to the current land use restrictions for forest reclamation. Mining waste should be inert to prevent imminent pollution of the planted trees. The nature of the local pumped water is characterised by low mineral contents (Dimitrakopoulos et al., 2016), favouring the development of flora.

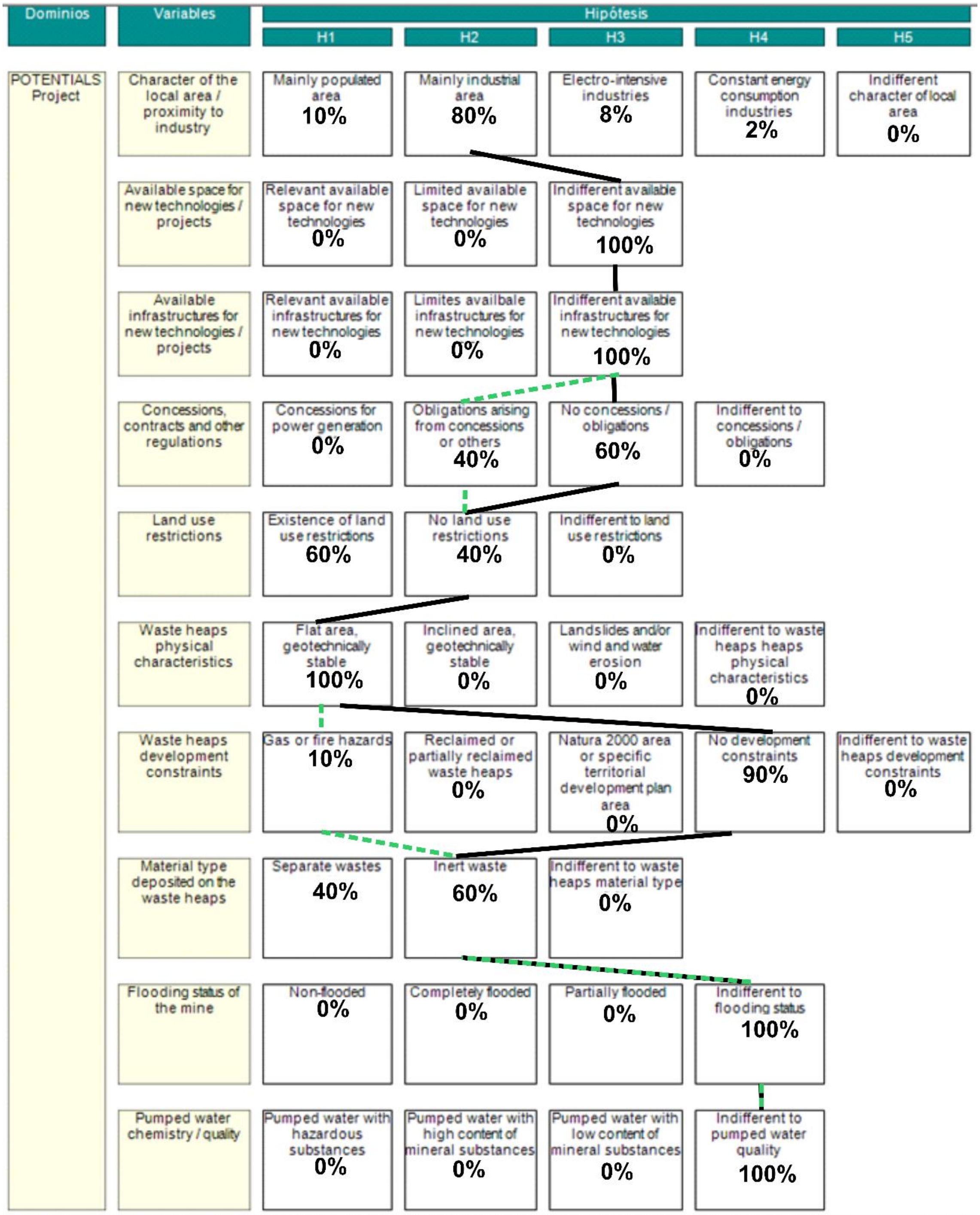

Figure 4. Forest restoration at a former open-pit coal mine.

References:

Haigh, M., Woodruffe, P., D'Aucourt, M., Alun, E., Wilding, G., Fitzpatrick, S., Filcheva, E., and Noustorova, M. (2020). Successful Ecological Regeneration of Opencast Coal Mine Spoils through Forestation: From Cradle to Grove. Minerals 10, no. 5: 461. https://doi.org/10.3390/min10050461.

Haigh, M.; Desai, M.; Cullis, M.; D'Aucourt, M.; Sansom, B.; Wilding, G.; Alun, E.; Garate, S.; Hatton, L.; Kilmartin, M.; et al. Composted municipal green waste enhances tree success in opencast coal-land reclamation in Wales. Air Soil Water Res. 2019, 12, 1–10.

Dimitrakopoulos, D., Vasileiou, E., Stathopoulos, N., & Dimitrakopoulou, S. (2016). Estimation of the qualitative characteristics of post mining lakes in different lignite fields in Greece. Mining Meets Water–Conflicts and Solutions, IMWA.

PARTNER: CERTH

PROPOSED MICRO-SCENARIO NAME (Micro-scenario-2): REE recovery from coal mining waste heaps

REMARKS: REE recovery from coal mining waste heaps can be combined with other scenarios contributing to the circular economy. It provides alternative REE resources without the need for a mining licence, also minimising the existing or coal wastes.

Description:

The occurrence of considerable REE concentrations in the mining coal wastes has been confirmed by recent studies (e.g. Pyrgaki et al., 2021). Especially the high REE to ΣREE contents in the local fly ash and coal ash are promising secondary resources for REE extraction. The removal of toxic pollutants and moderation of coal wastes, as well as the sutilisation of possible wastes are additional advantages of REE-recovery (Pyrgaki et al., 2021).

Since recycling is an energy-consuming process, the local area's character is important to have an available energy supply. The recycle unit needs to be proximal to an industrial area to be connected to an energy network. However, the CO_2 emissions must be aligned with significant regulations. The unit must be connected to a green energy supply network (e.g. solar or wind energy) to minimise carbon footprint.

The region of Western Macedonia, Greece, is proposed to implement this micro-scenario. In this area, there are several waste heaps for former open-pit coal mines that could be used for REE recovery.

The implementation of REE extraction (Figure 5) will be developed mainly in the industrial zone of Western Macedonia. The existing available space of the former mine will be used to install the required infrastructure (recycling unit). The utilisation of available infrastructures for new technologies will reduce the operational costs. For example, a coal-processing unit could be converted to a recycling one. Arising obligations include the preservation of the area and the prevention of polluting incidents due to the waste streams that are generated during the recycling process. The land use restrictions that apply to this scenario concern industrial wastes and landfill areas. An inclined, geotechnically stable area is required since the scenario is based on waste heaps and stability issues need to be prevented. Waste heaps will be partially or fully retrieved to facilitate the REE recovery. The flooding status of the mine and pumped water quality are indifferent since waste heaps are disposed outside from the mine pit and no applications of the mining water are developed in this micro-scenario.

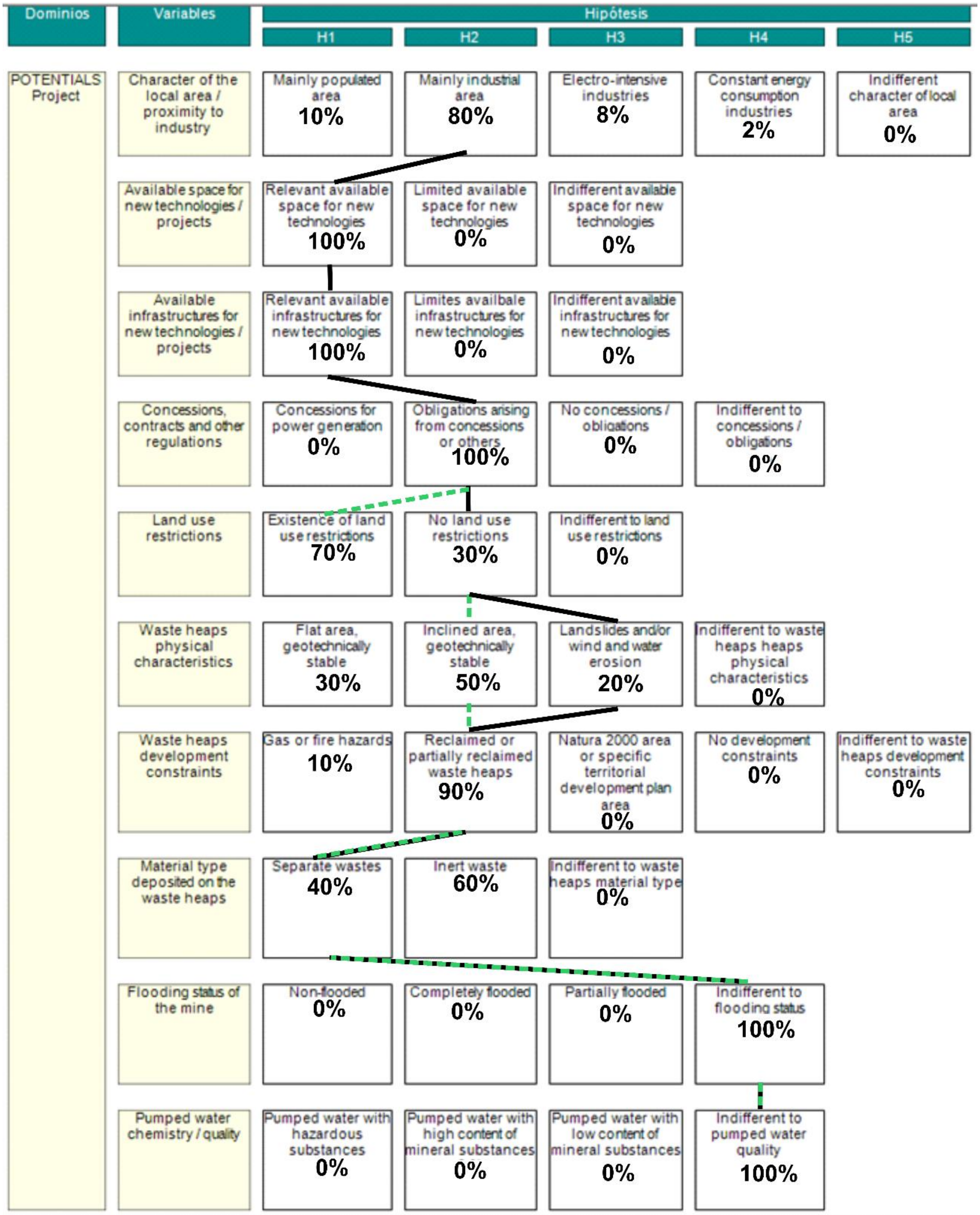

Figure 5. REE recovery from coal mining waste heaps.

References:

Pyrgaki, K., Gemeni, V., Karkalis, C., Koukouzas, N., Koutsovitis P. & Petrounias, P. (2021). Geochemical Occurrence of Rare Earth Elements in Mining Waste and Mine Water: A Review. Minerals, 11, 860. https://doi.org/10.3390/min11080860.

PARTNER: CERTH

PROPOSED SCENARIO NAME: Fisheries in flooded open-pit coal mines

REMARKS: The development of fisheries in flooded open-pit coal mines is an unconventional scenario of incremental innovation that integrates already developed methods that have not been implemented together at a former coal mine. Energy will be generated via biogas produced by fishery residues with the anaerobic digestion method. Developing an ecotoxicity laboratory will provide constant monitoring of the water quality. The laboratory will also promote significant scientific research concerning the effects of possible hazardous substances on fish. The production of fish by-products from fish wastes, such as fish glue, oil for paints and resins, will contribute to circular economy.

Description:

The term aquaculture describes the production (breeding, rearing, and harvesting) of aquatic organisms in various aquatic environments. It is implemented via the controlled manipulation of their growth, reproduction, and mortality rate to obtain the optimal quantity and quality for harvesting products of commercial value. Aquaculture can be applied in open aquatic systems, such as sea environments, lakes, reservoirs or streams, using a mesh or a cage. These systems are called cage systems (Otchere et al., 2004).

An aquaculture system can be installed in flooded open-pit mines as an alternative for reclamation and restoration after coal mining. In addition, if the water quality of a pit lake in an open-pit coal mine is appropriate, fisheries may be used for commercial fish farming or other by-products, enhancing the diversification of the economy in local areas (Otchere et al., 2004; McCullough et al., 2020).

Fisheries in pit lakes also provide an alternative solution for energy production via biogas generation from fish wastes. In particular, the fish viscera, skin, bones, and other residues are usually disposed directly into the sea or landfills during fishing operations or fish processing. These residues correspond approximately to 45% of the total fish production, which causes significant economic losses (Rai et al., 2010; Cadavid-Rodríguez et al., 2019). Most importantly, fish waste disposal has a significant environmental impact due to GHG production and bad odours from the degradation of organic matter (AUNAP, 2013; Cadavid-Rodríguez et al., 2019). The process of energy production from fish-biomass exploits the fish wastes with high organic content for anaerobic digestion. Anaerobic digestion is a promising method for environmentally safe management of fish wastes through their conversion to biogas (Tomczak-Wandzel et al., 2013; Greggio et al., 2018; Choe et al., 2019; Cadavid-Rodríguez et al., 2019). The process takes place in anaerobic conditions (absence of oxygen), where the fish-biomass is degraded and stabilised via microbes to produce methane (biogas), which is characterised as a renewable source of energy (Cadavid-Rodríguez et al., 2019).The produced biogas can be used directly for heating. Alternatively, it could be purified and used to produce electricity. The electricity may be supplied directly to the local grid or stored to provide the local energy demands in cases of energy deficit, for example, in the high-demand winter season.

A major environmental issue that must be considered before the exploitation of a pit lake for aquaculture, involves the water quality that is mainly affected by acid rock drainage (ARD). ARD will increase the contents of toxic metals in the lake water, the fish and can potenitaly affect the human health via the food chain. Hence, protocols must be established based on the water quality (Otchere et al., 2004). Habitat and nutrients are important for sustainable and productive fish cultivation (McCullough et al., 2009; Lund & McCullough, 2011, McCullough et al., 2020). Low nutrient content reduces fish productivity, while very high nutrient content with increased COPC, which might biomagnify, can increase the risk of higher-order consumers, such as birds, mammals, and reptiles (Palace et al., 2004; Wayland et al., 2006; Hakonson et al., 2009; Miller et al, 2009; Miller et al., 2013; Kumar et al., 2016; McCullough et al., 2020). Other parameters that affect the bioavailability of the metals and need to be monitored are the pH, Eh (redox potential) and DOC (dissolved organic carbon). Based on the above-mentioned criteria, laboratory studies are mandatory for bioassays and ecotoxicity tests on different pit material types and water conditions for continuous monitoring of the aquaculture system (Otchere et al., 2004). For this purpose, a potential synergy to the proposed scenario is manufacturing an ecotoxicity laboratory proximal to the pit lake aquaculture. One of the main functions of the laboratory will be the examination of the fish quality for the production of food and fish fertilisers. Additionally, the ecotoxicity laboratory incorporates scientific value to this scenario, promoting research development by examining the effects of toxic metals and other hazardous substances from coal mine pit lakes on fish.

The production of secondary by-products using fishery wastes, such as fish glue and oil will contribute to a circular economy. Fish glue is a commonly produced material developed from fish wastes. It is considered a value-added product and is constructed from the collagen of the scales, skin and bones of the fish. The production process involves cooking these fish parts and subsequent evaporation (Akter et al., 2016). Other products that may be generated include fish oil that is used as an additive substance in paints, resins (Pike & Jackson, 2010; EasyFish, 2021) and gelatine that is used in film constructions [i.e. photographic, X-ray films and electroluminescent (ACEL) devices, EasyFish, 2021; Zhang et al., 2020].

The proposed scenario could be implemented in the flooded mine of the Amynteo region in Western Macedonia (Figure 6). The selected area is mainly industrial with an existing electricity grid that could be used in this scenario. Considering that the whole area of the flooded open-pit mine will be used, relevant available space for new technologies and a partially flooded mine are required. Appropriate available infrastructures for new technologies/projects are selected since the existing infrastructure for the connection to the grid will be used. Concessions and obligations are associated with the supply of the produced energy, as well as the creation of new jobs in the fish by-products industry. Land use restrictions will be applied during the installation of the ecotoxicity laboratory. The area is geotechnically stable and the waste heaps do not imminently affect the implementation of the scenario. However, their physical characteristics should be examined to prevent landslides and erosion that may affect the stability of the area. Waste heaps could be partially or fully retrieved, whereas inert wastes would reduce the pollution of aquaculture due to the absence of toxic elements. Pumped water quality is also significant for the mitigation of the pollution risk. This also applies to pumped water that will be closely monitored to ensure low content of mineral substances and absence of hazardous substances for the safe development of the fishery. In the case of Amynteo mine, pumped water quality with low range of mineral substances is selected since the concentration of hazardous substances in lignite mining water in Greece is significantly low (Dimitrakopoulos et al., 2016).

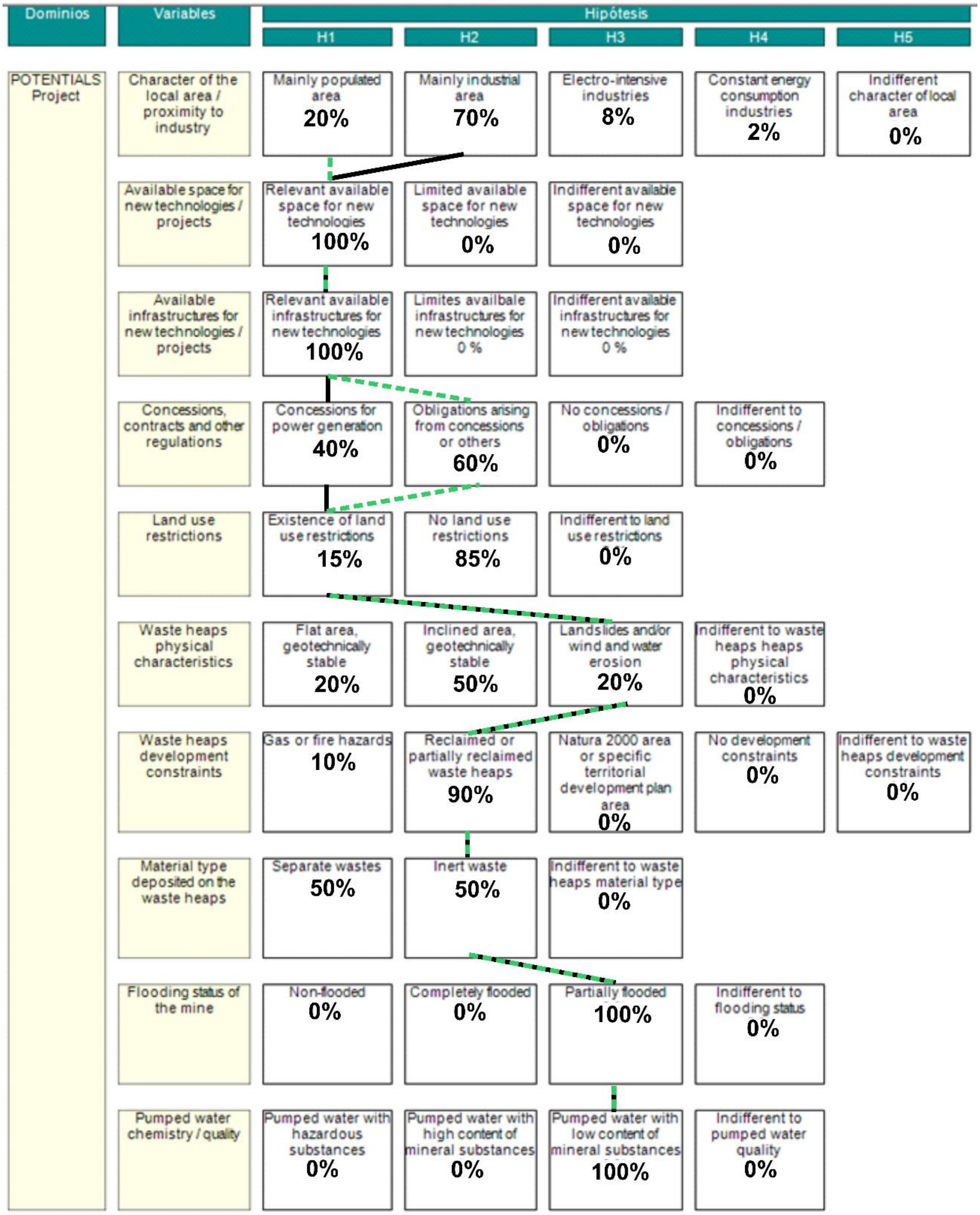

Figure 6. Fisheries in flooded open-pit coal mines.

References:

Cadavid-Rodríguez, L. S., Vargas-Muñoz, M. A., & Plácido, J. (2019). Biomethane from fish waste as a source of renewable energy for artisanal fishing communities. Sustainable Energy Technologies and Assessments, 34, 110-115.

McCullough, C. D., Schultze, M., & Vandenberg, J. (2020). Realising beneficial end uses from abandoned pit lakes. Minerals, 10(2), 133.

Otchere, F. A., Veiga, M. M., Hinton, J. J., Farias, R. A., & Hamaguchi, R. (2004, August). Transforming open mining pits into fish farms: moving towards sustainability. In Natural Resources Forum (Vol. 28, No. 3, pp. 216-223). Oxford, UK: Blackwell Publishing Ltd.

Rai AK, Swapna HC, Bhaskar N, Halami PM, Sachindra NM. (2010). Effect of fermentation ensilaging on recovery of oil from fresh water fish viscera. Enzyme Microb Technol; 46:9–13.

AUNAP. (2013) Plan Estratégico Institucional 2014–2018. Autoridad Nacional de Acuicultura y Pesca (AUNAP): 51.

Tomczak-Wandzel R, Levlin E, Ekengren Ö. (2013). Biogas production from fish wastes in co-digestion with sewage sludge.

Choe U, Mustafa AM, Lin H, Xu J, Sheng K. (2019). Effect of bamboo hydrochar on anaerobic digestion of fish processing waste for biogas production. Bioresour Technol.

Greggio N, Carlini C, Contin A, Soldano M, Marazza D. (2018). Exploitable fish waste and stranded beach debris in the Emilia-Romagna Region (Italy). Waste Manage; 78:566–75.

Lund, M.A.; McCullough, C.D. (2011). "Restoring Pit Lakes: Factoring in the Biology." In Mine Pit Lakes: Closure and Management, edited by C. D. McCullough, 83-90. Perth, Australia: Australian Centre for Geomechanics.

McCullough, C.D.; Steenbergen, J.; te Beest, C.; Lund, M.A. (2009, 19-23 October). "More Than Water Quality: Environmental Limitations to a Fishery in Acid Pit Lakes of Collie, South-West Australia." Paper presented at the Proceedings of the International Mine Water Conference, Pretoria, South Africa.

Hakonson, T.E.; Meyer, V.F.; Dean, A. (2009). "Significance of Biological Productivity of Pit Lakes for Interpreting Ecological Risks." In Mine Pit Lakes: Characteristics, Predictive Modeling, and Sustainability edited by Devin. Castendyk and Ted. Eary, 179-87. Colorado, USA: Society for Mining, Metallurgy, and Exploration (SME).

Kumar, R.N.; McCullough, C.D.; Lund, M.A.; Larranãga, S. (2016). "Assessment of Factors Limiting Algal Growth in Acidic Pit Lakes—a Case Study from Western Australia, Australia." Environmental Science and Pollution Research 23, no. 6: 5915–24.

Miller, L.L.; Rasmussen, J.B.; Palace, V.P.; Sterling, G.; Hontela, A. (2013). "Selenium Bioaccumulation in Stocked Fish as an Indicator of Fishery Potential in Pit Lakes on Reclaimed Coal Mines in Alberta, Canada." Environmental Management 52, no. 1: 72-84.

Miller, L.L.; Rasmussen, J.B.; Palace, V.P.; Hontela, A. (2009). "The Physiological Stress 473 Response and Oxidative Stress Biomarkers in Rainbow Trout and Brook Trout from Selenium-Impacted Streams in a Coal Mining Region." J Appl Toxicol 29, no. 8: 681-88.

Wayland, M.; Kneteman, J.; Crosley, R. (2006). "The American Dipper as a Bioindicator of Selenium Contamination in a Coal Mine-Affected Stream in West-Central Alberta, Canada." Environ Monit Assess 123, no. 1: 285-98.

Palace, V.P.; Baron, C.; Evans, R.E.; Holm, J.; Kollar, S.; Wautier, K.; Werner, J.; Siwik, P.; Sterling, G.; Johnson, C.F. (2004). "An Assessment of the Potential for Selenium to Impair Reproduction in Bull Trout, Salvelinus Confluentus, from an Area of Active Coal Mining." Environ Biol Fishes 70, no. 2: 169-74.

Akter, S., Rahman, M. A., Bhowmik, S., Haidar, M. I., & Alam, A. N. (2016). Assessment of fishery wastes and suitability of its utilisation in the manufacture of fish glue. American Journal of Food and Nutrition, 6, 77-81.

EasyFish (2021). Fish by-products and their industrial uses. Easyfish Service - Sourcing. https://www.easyfish.net/en/blog/fish-by-products-and-their-industrial-uses/.

Pike, I. H., & Jackson, A. (2010). Fish oil: production and use now and in the future. Lipid Technology, 22(3), 59-61.

Zhang, X., Ye, T., Meng, X., Tian, Z., Pang, L., Han, Y., Li, H., Lu, G., Xiu, F., Yu, H. D., Liu, J. & Huang, W. (2020). Sustainable and transparent fish gelatin films for flexible electroluminescent devices. ACS nano, 14(4), 3876-3884.

PARTNER: **GIG Katowice** DATE: **31.03.2022**

PROPOSED SCENARIO NAME: ____

PROPOSED MICRO-SCENARIO NAME: **ENERMINECOIN - MINE**

REMARKS: The use of mining infrastructure for “mining” cryptocurrencies (bitcoin, stabecoin, etc) and secure data collection and storage using green energy.

DESCRIPTION:

The location of a cryptocurrency "digging" unit within closed mines, underground, in addition to access to network infrastructure, may take advantage of the ability to remove heat from the computer units into the workings - ENERMINECION MINE.

Using the underground workings of a closed mine as an installation site for the production of cryptocurrencies such as BTC is an interesting solution. Locating high-powered electronic equipment for cryptocurrency mining in underground conditions allows for proper cooling, practically in a closed circuit. An important condition for the implementation of such a project should be the use of e.g. methane obtained from the goaf to supply the installation with electricity. The ability to ventilate underground workings with a strong current of air will allow excess heat to be removed from operating equipment. These approaches will significantly reduce the cost of 'mining' cryptocurrencies and avoid allegations of negative environmental impacts of the project. In addition, closed mine underground workings can be used to install servers or data banks. This location also makes it possible to ensure the security of data in the event of geopolitical crises or other emergencies that could cause damage to IT structures on the surface.

Dominios	Variables	Hipótesis H1	H2	H3	H4	H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites available infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

PARTNER: **GIG Katowice** DATE: **31.03.2022**

PROPOSED SCENARIO NAME: ____

PROPOSED MICRO-SCENARIO NAME: **ENERMINECOIN – POWER PLANT**

REMARKS: The use of power plant infrastructure for "mining" cryptocurrencies (bitcoin, stabecoin, etc).

Description:

ENERMINECOIN PLANT is a unit located at a coal power plant or surface infrastructure of a coal mine that is dedicated to "digging" cryptocurrencies. ENERMINECOIN can be a name dedicated to a new cryptocurrency, or the unit can be dedicated to "digging" known cryptocurrencies like bitcoin etc.

Coal-fired power plants, in the process of reducing production and decommissioning, typically reduce the hours of operation and the energy supplied to the system during the year. In the process of increasing renewable power generation on the grid from sources whose hours of operation depend on weather conditions and time of day, the power generation profile must be supplemented by controllable coal, gas or energy storage sources. Older coal-fired units were not designed for the regulating character of operation in the power system, and therefore their frequent switching on and off, as well as power reduction, increases the failure rate of these units and may lead to permanent damage. It is therefore technologically advantageous to even out the load curve especially during the period of operation of renewable sources and during the night periods when the energy input from the grid naturally decreases.

Cryptocurrency "digging" units require significant power and electricity to supply computers and other IT infrastructure. The capacity required can reach tens or even hundreds of MW. ENERMINECOIN PLANT is a unit located on land converted to new, lower emission sources, existing coal-fired power plants. In the early stages, they use the energy produced by the coal units, balancing the load curve, and are finally switched to power from new, non-carbon sources. The carbon footprint of the 'mined' cryptocurrency is being monitored and should eventually move towards zero.

The advantages of the solution are mainly the access of a large energy consumer to the grid and production infrastructure, the use of unneeded buildings in energy complexes, and the possibility to use renewable energy, in the transformation process (repurposing) of the power plant. The disadvantages may be the "freezing" of the power plant's energy production from coal and the large carbon footprint of the cryptocurrency.

Dominios	Variables	Hipótesis				
		H1	H2	H3	H4	H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

PARTNER: **Główny Instytut Górnictwa** DATE: **24.02.2022**

PROPOSED SCENARIO NAME: **Cultural heritage and extreme sports based on the infrastructure of coal mines and power stations using green energy.**

PROPOSED MICRO-SCENARIO NAME: **Green Energy Relax and Extreme Mine&Plant.**

REMARKS: **The scenario assumes the production of green energy at the coal mine and coal-fired power plant while adapting them for tourism purposes (especially using mine waste dumps for skiing or underground excavations for extreme sports).**

Dominios	Variables	Hipótesis				
		H1	H2	H3	H4	H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

PARTNER: vgbe____ DATE: 7 February 2022_____

PROPOSED SCENARIO NAME: Ancillary services provided by batteries____________________

PROPOSED MICRO-SCENARIO NAME: ____

REMARKS:____

____

____

____

Dominios	Variables	Hipótesis H1	H2	H3	H4	H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

PARTNER: vgbe____ DATE: 7 February 2022______

PROPOSED SCENARIO NAME: Combined Cycle Gas Turbines (CCGT) plant__________________

PROPOSED MICRO-SCENARIO NAME: ____

REMARKS:____

____

____

____

Dominios	Variables	Hipótesis				
		H1	H2	H3	H4	H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

PARTNER: _VGB PowerTech e.V.________________________ DATE: 18. February 2022____

PROPOSED SCENARIO NAME: Electrolyser powered by PV and/or Wind turbines, CCGT, Use of energy for recycling of minerals from pumped mine water

____

PROPOSED MICRO-SCENARIO NAME: ____

REMARKS:____

Dominios	Variables	Hipótesis				
		H1	H2	H3	H4	H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

PARTNER: vgbe_______________________________________ DATE: 7 February 2022_______

PROPOSED SCENARIO NAME: Mine gas utilisation for gas-powered CHP power units_________

PROPOSED MICRO-SCENARIO NAME: ____

REMARKS:____

____

____

____

Dominios	Variables	Hipótesis H1	Hipótesis H2	Hipótesis H3	Hipótesis H4	Hipótesis H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

PARTNER: _VGB PowerTech e.V.__________________________ DATE: 18. February 2022____

PROPOSED SCENARIO NAME: Open cycle gas turbine, block heat and power plant, gas engine

PROPOSED MICRO-SCENARIO NAME: ____

REMARKS:____

____

____

____

Dominios	Variables	Hipótesis				
		H1	H2	H3	H4	H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

PARTNER: _VGB PowerTech e.V.__________________________ DATE: 18. February 2022____

PROPOSED SCENARIO NAME: _SMRs, Open cycle gas turbines, CCGT_____________________

PROPOSED MICRO-SCENARIO NAME: ____

REMARKS:____

____

____

____

Dominios	Variables	Hipótesis				
		H1	H2	H3	H4	H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

Research Fund for Coal & Steel

POTENTIALS
RFCS AM PROJECT

PARTNER: THGA DATE: 08.02.2022

PROPOSED SCENARIO NAME: Lithium Recovery from Mine Water

PROPOSED MICRO-SCENARIO NAME: —

REMARKS:

Dominios	Variables	Hipótesis H1	H2	H3	H4	H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	~~Non-flooded 0 %~~	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	

Research Fund for Coal & Steel

POTENTIALS

RFCS AM PROJECT

PARTNER: THGA DATE: 08.02.2022

PROPOSED SCENARIO NAME: Usage of Methane from degasification units on closed coal mines

~~PROPOSED MICRO-SCENARIO NAME~~:

REMARKS:

Dominios	Variables	H1	H2	H3	H4	H5
POTENTIALS Project	Character of the local area / proximity to industry	Mainly populated area 0 %	Mainly industrial area 0 %	Electro-intensive industries 0 %	Constant energy consumption industries 0 %	Indifferent character of local area 0 %
	Available space for new technologies / projects	Relevant available space for new technologies 0 %	Limited available space for new technologies 0 %	Indifferent available space for new technologies 0 %		
	Available infrastructures for new technologies / projects	Relevant available infrastructures for new technologies 0 %	Limites availbale infrastructures for new technologies 0 %	Indifferent available infrastructures for new technologies 0 %		
	Concessions, contracts and other regulations	Concessions for power generation 0 %	Obligations arising from concessions or others 0 %	No concessions / obligations 0 %	Indifferent to concessions / obligations 0 %	
	Land use restrictions	Existence of land use restrictions 0 %	No land use restrictions 0 %	Indifferent to land use restrictions 0 %		
	Waste heaps physical characteristics	Flat area, geotechnically stable 0 %	Inclined area, geotechnically stable 0 %	Landslides and/or wind and water erosion 0 %	Indifferent to waste heaps heaps physical characteristics 0 %	
	Waste heaps development constraints	Gas or fire hazards 0 %	Reclaimed or partially reclaimed waste heaps 0 %	Natura 2000 area or specific territorial development plan area 0 %	No development constraints 0 %	Indifferent to waste heaps development constraints 0 %
	Material type deposited on the waste heaps	Separate wastes 0 %	Inert waste 0 %	Indifferent to waste heaps material type 0 %		
	Flooding status of the mine	Non-flooded 0 %	Completely flooded 0 %	Partially flooded 0 %	Indifferent to flooding status 0 %	
	Pumped water chemistry / quality	Pumped water with hazardous substances 0 %	Pumped water with high content of mineral substances 0 %	Pumped water with low content of mineral substances 0 %	Indifferent to pumped water quality 0 %	