

# POTENTIALS

RFCS AM PROJECT

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

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## **Deliverable 4.2**

Economic, social, and territorial impact assessment

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## Executive summary

This Deliverable undergoes impact assessments of the before selected and developed business models, all of them based on Eco-industrial parks with a virtual power plant; on a generic case in fact an economic impact assessment, a social impact assessment and a territorial impact assessment. These assessments are supplemented by current relevant further aspects in relation to the respective assessments.

The essential aim of these assessments has been to support the update and re-adoption of territorial just transitions plans (for the coal regions in transition identified by the European Commission under the Coal Regions in Transition Initiative, now called Just Transition Initiative).

In the first place, an economic impact assessment is developed for a generic Eco-industrial park (with a virtual power plant) of 100,000 m<sup>2</sup> in liberated areas different from waste heaps, consisting in a photovoltaic installation, an unconventional pumped hydro energy storage, a geothermal energy generation plant, a green hydrogen plant, and a molten salt plant as an alternative for energy storage.

Only in the case of the green hydrogen plant, the expected net present value (NPV) is negative as the investment is not feasible unless a specific subvention is obtained for developing the green hydrogen plant. For the rest of the investments, the internal rate of return (IRR) is always higher than 13% (geothermal plant and molten salt plant), reaching a 16% in the case of the virtual power plant.

A sensitivity and uncertainty analysis on the previous financial outcomes revealed that the install capacity of the PV plant, the investment on the PV plant, and the capacity factor (% of time that the PV plant is used) are the most sensitive variables. After modelling these variables, the IRR distribution after the Monte Carlo analysis achieves a mean of 17.95%, being sensitively higher than the calculated 16%. Thus, the calculated IRR can be considered robust.

In the second place, a social impact assessment is developed, starting with an analysis of job losses in the mining and power plant sector in European regions in transition due to closure, with a specific focus on Poland, Spain, Greece and Germany. It is followed by discussing the requalification needs of the workers in order to be able to work in the new circumstances. Finally, the assessment focuses on the efficiency of creating Eco-industrial parks in these areas after the mine closure has taken place, concerning the creation of new jobs and energy production.

The general qualifications for both coal miners and renewable energy sources workers occupied in the eco-industrial parks, focusing on photovoltaics and wind turbines, have been identified based on the results presented in the Erasmus+ project RES-SKILL and categorized according to: (a) the knowledge level, (b) the technical skills, and (c) the soft



skills (non-technical qualifications), with analogous job profiles being deducted. A specific focus was put on analysing job opportunities and requalification needs in eco-industrial parks. It is followed by an specific assessment of pumped hydro storage systems, due to their relevance for Greece.

In the third place, a territorial impact assessment using a modified Territorial Efficiency, Quality and Identity Layer Assessment (TEQUILA) approach is developed, aiming to evaluate ex-ante the efficiency of the proposed policy and the measures based on it to improve territorial cohesion, encompassing impacts across regions in terms of the economic competitiveness, environment and climate change, land-use and society.

The experts of the POTENTIALS project partners have set up an extensive list of 17 “direct result indicators” for the relevant scenario outputs. In further discussions about the application on the territorial impact assessment, this list of indicators has been condensed to the measurable sub-criteria of the TEQUILA approach and affiliated sub-weights by expert judgements.

After completion of this conceptual preparatory work, a demonstration of the application of a territorial impact assessment via the proposed modified TEQUILA approach follows. Two examples of the scenario business models identified in the POTENTIAL project, both focusing on the model of the eco-industrial park: one example is combined with hydrogen production and the other example is combined with biofuels production. Due to the value scores used, the positive territorial impact and therefore the contribution to territorial cohesion is considerably higher in the Eco-industrial Park with Green H<sub>2</sub> plant, with a total value score 3.42. The Eco-industrial Park with Biofuels production achieves a total value score 2.85. The largest difference was in the dimension Territorial Quality and the smallest difference in the dimension Territorial Identity (with the dimension Territorial Quality quite exactly in the middle).

The Deliverable finishes by explaining how to analyse the jobs created in supported entities from structural funds as well as a focus on a site specific scenario for Germany: biofuels.

## 1 Introduction

Work Package 4 is to justify the selection of business model choices and their adaptation according to the expected transition process to update and re-adopt territorial just transition plans.

Specific objectives are:

1. To support the update and re-adoption of territorial just transition plans, show how these synergies can be used to develop new business models, define concrete prospects and transition plans from different implementation scenarios, and justify the business model choices.
2. To undergo an economic impact assessment to determine the economic diversification potential, the likely commercial viability, and the added value of the proposed business models.
3. To undergo a social impact assessment, analysing the expected job losses and requalification needs.
4. To undergo a territorial impact assessment to analyse the potential territorial impact of the business model proposals.

Within this work package, *Task 4.2 Assessing the economic, social, and territorial impact*, comprises the activities to be carried out to develop:

1. An economic impact assessment (including CAPEX, OPEX, cash flows and expected financial outcomes) to determine the economic diversification potential, the likely commercial viability and the added value of the proposed business models that, in addition, should be permissible by planning authorities.
2. A social impact assessment, analysing the expected job losses and requalification needs, to avoid inflicting a substantial economic upheaval in the coal regions in transition identified by the European Commission under its Coal Regions in Transition initiative.
3. A territorial impact assessment to analyse the potential territorial impact of the business model proposals and anticipate the scenarios' consequences on regions and local communities.

The assessment related to the territorial dimension should limit the risk of “causing an unbalanced territorial or spatial distribution of costs and benefits for different

regions”, with the explicit goal of providing information on the territorial distribution of impacts for the different business models.

## 2 Eco-industrial parks (with virtual power plant)

According to *Deliverable 4.1 Business models choice justification*, Eco-industrial parks (with virtual power plant) are the most appropriate and exciting business model choice for coupled end-of-life coal mine sites and coal-fired power plants along with surrounding residential/industrial areas. They may be complemented with a green hydrogen plant, according to their high TRL, provided that specific economic subventions are obtained to achieve balanced financial results.

Eco-industrial parks (with virtual power plant) have the second mean in the evaluation of actions, high TRLs of the technologies involved (photovoltaic/wind and geothermal), no problematic requirements regarding the European taxonomy, an exciting contribution to the circular economy and a high level of sector coupling. In the second place, they may be complemented with a green hydrogen plant and even with a molten salt plant to undergo energy storage.

Developing district networks for the surrounding residential/industrial areas allows for integrating renewable sources such as geothermal and photovoltaic into these centralised systems. District networks will help increase photovoltaic deployment by producing synergies concerning transforming heating/cooling customers into prosumers or customers with excess electricity from solar panels on their roofs. The aim is to maximise the number of business opportunities and thus the impact on employment.

**Eco-industrial parks for the POTENTIALS project can be defined as:**

*Eco-industrial parks (with virtual power plant) as an integrated alternative to be developed within coupled end-of-life coal mine sites and coal-fired power plants along with surrounding residential/industrial areas for sustainable renewable energy generation (geothermal and photovoltaic/wind), storage technologies, circular economy contributions and synergies for reducing waste and pollution by promoting short-distance transport and optimising the park's material, resource, and energy flows, producing the goods needed for the industrial transition in Europe and cooperating to its achievement.*

*Eco-industrial parks should be based on district networks that allow multiple energy sources to be connected to various energy consumption points, helping to increase photovoltaic deployment by transforming heat and power energy customers into prosumers or customers with excess electricity from solar panels on their roofs. Eco-industrial parks should be supported by pursuing financial privileges and other benefits to boost and diversify the area's economy, attracting external investment: tax exemptions for industries, access to preferential credits from National authorities, European Investment Bank, and others.*

### 3 Economic impact assessment

To determine the economic diversification potential, the likely commercial viability and the added value of the Eco-industrial parks (with virtual power plant), an economic impact assessment ((including CAPEX, OPEX, cash flows and expected financial outcomes) will be developed.

To achieve this goal, a generic case economic assessment of a Virtual Power Plant was developed to determine the likely commercial viability of the project and the economic added value. Wind and circular economy technologies have not been considered in this assessment due to the site-specific circumstances that apply to these technologies.

The main barriers to developing new renewable energy production facilities are grid access capacity and transmission and distribution network connections. However, coupled end-of-life coal mine sites and coal-fired power plants are usually connected to the grid via overhead lines. They are typically connected to medium voltage lines through substations. The lines enter directly into the substations equipped with metering equipment, transformers, and other protective equipment. In this way, they can be easily adapted to inject electricity into the grid. Moreover, these connections facilitate the installation of electrolyzers for producing green hydrogen.

The economic impact assessment will be developed for a generic Eco-industrial park (with a virtual power plant) with the following characteristics:

1. A photovoltaic installation in a 50 ha waste heap area with an installed capacity of 1 MW/ha, thus totalising 50 MW.
2. An unconventional pumped hydro storage calculated to cover half of daytime energy production by photovoltaic plus a 10% safety margin, with around half of the daytime hourly energy production twice the time, resulting in an installed capacity of 200 MWh-10 MW.
3. A geothermal energy generation plant of 4 MW producing 5,000 MWh of heating and 2,000 MWh of cooling per year.
4. A Green hydrogen plant with PEM technology electrolyzers of 2.5 MW.
5. An eco-industrial park of 100,000 m<sup>2</sup> will be developed in liberated areas different from waste heap areas.
6. Finally, a molten salt plant with an installed capacity of 300 MWh-50 MW will be considered as an alternative for energy storage.

## 3.1 Virtual power plant

### 3.1.1 Photovoltaic plant

Extracting coal generates vast residues during excavation, including overburden, interburden or waste rock. These large amounts of extractive waste from excavation generated at extraction sites are managed on heaps.

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.

Given that the areas occupied by waste heaps after many years of exploitation are usually huge, it is possible to consider different rehabilitation and subsequent user actions. One alternative is to use these areas for renewable energy generation: photovoltaic. This will require the application of rehabilitation techniques that will facilitate the geotechnical stability of the renewable energy generation structures in addition to restoring the land.

Solar photovoltaic panels are currently the most widespread type of solar photovoltaic technology. Panels can be used individually, or several can be connected to form arrays. Because of this modular structure, photovoltaic systems can be built to meet almost any electric power need. The cost of manufacturing solar panels has plummeted dramatically in the last decade, making them affordable, with a lifespan of roughly 25 years.

A photovoltaic installation in a 50 ha waste heap area with an installed capacity of 1 MW/ha, thus totalising 50 MW, will be considered for the example.

**Table 3-1** presents the photovoltaic parameters for a 50 ha waste heap area with an installed capacity of 1 MW/ha, a capacity factor of 30%, which corresponds to the percentage of time that the installation is used per year, and 50% of energy to be stored and the rest to be sold. Magellan & Barents, S.L., and HUNOSA facilitated these data.

### 3.1.2 Unconventional pumped hydro storage

Energy storage is necessary to maintain a competitive supply of electricity. Storage can absorb excess electricity generation and re-inject it later, effectively reducing curtailment due to excess generation or demand constraints. It can do this in a market or a vertically integrated environment.

**Table 3-1. Photovoltaic deployment parameters**

Parameter	Value
Installed capacity	50 MW
Estimated investment (plant life: 25 years)	20 M€
Capacity factor (% time of use of the installation per year)	30%
Daily production (50 MW x 30% x 24 hours)	360 MWh
Fraction of energy to be sold, the rest to be stored	50%
Daytime energy sold (360 MWh x 50%)	180 MWh
Daytime energy price	40 €/MWh
Daytime revenue (180 MWh x 40 €/MWh)	7,200 €
Photovoltaic annual revenues (7,200 € x 365)	2.63 M€
Annual expenditure (staff, maintenance and overheads)	0.50 M€

The great majority of global electricity storage capacity deployed today is pumped hydro due to its favourable technical and economic characteristics. The unconventional pumped hydro storage using dense fluids has similar efficiency to conventional pumped hydro but with a yield of up to three times more, depending on the density of the dense fluid.

It allows large-scale storage unlocking the potential of renewable energies, taking advantage of coal mines' deep infrastructure but without the need to operate in a non-flooded mine. On the other hand, the pump/turbine and electrical equipment are on the surface, representing easy maintenance. The galleries eliminate the need for a bottom pressure vessel, with pressure relatively stable and close to that due to overburden.

Unconventional pumped hydro storage has a smaller footprint and higher energy density than conventional pumped hydro energy systems. The system uses a high-density fluid and allows for different configurations where upper and lower reservoirs may be at the same elevation, for example, on the surface above an underground mine.

The energy storage capacity is proportional to the fluid density for a given reservoir or tank volume. For example, when the high-density fluid has a density of 3x, the system's energy storage capacity is three times that when water is used. It is due to the mass flow rate being about three times more than water. Alternatively, the system can produce the same energy output using less fluid volume and a lower height differential between the upper and lower reservoirs.

Thus, coal mines’ deep infrastructure is very suitable for designing a system to satisfy output requirements: large height differentials and very deep galleries that eliminate the need for a bottom pressure vessel, with pressure relatively stable and close to that due to overburden.

**Table 3-2** presents the unconventional pumped hydro storage parameters calculated to cover daytime energy storage plus a 10% safety margin, with around half of the daytime hourly energy production twice the time (approximately 16 hours), resulting in an installed capacity of 200 MWh-10 MW. Magellan & Barents, S.L. facilitated these data.

**Table 3-2. Unconventional pumped hydro storage deployment parameters**

Parameter	Value
Installed capacity	200 MWh-10 MW
Estimated investment (plant life: 50 years)	5 M€
Roundtrip efficiency	80%
Daytime energy storage (360 MWh x 50%)	180 MWh
Nighttime energy production (180 MWh x 80%)	144 MWh
Nighttime energy price	70 €/MWh
Night-time revenues (144 MWh x 70 €/MWh)	10,080 €
Annual revenue for Disrupted pumped hydro (10,080 € x 365)	3.68 M€
Annual expenditure (staff, maintenance and overheads)	0.15 M€

### 3.1.3 Batteries

Although unconventional pumped hydro storage can perform rapid ramping, avoiding photovoltaic curtailment and loss of load, it needs several minutes to respond to signals.

Thus, batteries should be used but only for short periods. As batteries have proven to be remarkably rapid in responding to signals (from sub-seconds to seconds), with costs declining notably while technical parameters such as degradation rates and energy density keep improving, they will play a vital role in the flexibility of the energy storage system.

High-power batteries would be used for brief periods, with an estimated investment of 1.5 M€ for an installed capacity of 200 MWh-2 MW and an annual expenditure of about 0.05 M€. This information was obtained from Pacific Northwest National Laboratory (2022).



### 3.1.4 Cashflows calculations

Table 3-3 presents the cash flows for the first three years, using constant 2022 euros, annual depreciation of 5% and working capital of about 9% of operating revenues.

**Table 3-3. Cash flows calculation for the Virtual Power Plant (k€)**

Item	2022	2023	2024
Capital expenditure	(26,500)		
Working capital	(565)		
Operating revenues		6,310	6,310
Operating expenses		(700)	(700)
Depreciation (20 years)		(1,325)	(1,325)
EARNINGS BEFORE INTEREST AND TAXES		4,285	4,285
Taxes (25%)		(1,072)	(1,072)
NET INCOME		3,213	2,700
CASH FLOW (Net income + Depreciation)	(27,065)	4,538	4,538

### 3.1.5 Financial outcomes

Considering an 8% capital cost, the expected financial outcomes for 25 years will be:

$$Net\ Present\ Value\ (NPV) = -27,065 + \frac{4,538}{(1 + 0,08)} + \frac{4,538}{(1 + 0,08)^2} + \dots + \frac{4,538}{(1 + 0,08)^{25}} = 21,991\ k€$$

$$Internal\ rate\ of\ return\ (IRR) = 16\%$$

$$Payback\ Period\ (PP) = 9\ years$$

## 3.2 Geothermal plant

Geothermal energy is a renewable source that harnesses the heat from inside the earth, in our case, through the water that floods the mines. From a certain depth, the temperature of the subsoil is constant regardless of the season. Thus, a continuous and accessible energy source is available all year round, just a few metres away from us. The water temperature alone is not useful for heating and cooling. However, it can be processed in a geothermal heat pump, transforming the energy from low to high temperature, becoming suitable for these purposes.

The heat pump usage for space heating and cooling powered by solar or wind energy can be considered renewable technology. Technologies for direct uses, like district heating or geothermal heat pumps, are widely used and considered mature. As the heating and cooling demand in Europe represents about half of the EU’s final energy consumption, the importance of this energy in bringing down the barriers to clean energy uptake in Europe is high. On the other hand, generating electricity is more inefficient than heating and cooling as, for this purpose, high or medium-temperature resources are needed.

**Table 3-4** presents the parameters for a 4 MW geothermal energy plant producing 5,000 MWh of heating and 2,000 MWh of cooling per year. Most of the data was obtained from HUNOSA.

**Table 3-4. Geothermal energy deployment parameters**

Parameter	Value
Installed capacity	4 MW
Estimated investment (plant life: 20 years)	1.5 M€
Thermal energy supplied (heating)	5,000 MWh
Thermal energy supplied (cooling)	2,000 MWh
Energy produced per kWh of electricity consumed	4.5 kWh
Electricity cost (from Virtual Power Plant)	55 €/MWh
Heating energy sale price	0.07 €/kWh
Cooling energy sale price	0.05 €/kWh
Annual expenditure (staff, maintenance and overheads)	75,000 €

**Table 3-5** presents the cash flows for the first three years, using constant 2022 euros, annual depreciation of 5% and working capital of about 9% of operating revenues.

Finally, considering an 8% capital cost, the expected financial outcomes for 20 years will be:

$$Net\ Present\ Value\ (NPV) = -1,541 + \frac{236}{(1 + 0,08)} + \frac{236}{(1 + 0,08)^2} + \dots + \frac{236}{(1 + 0,08)^{20}} = 776\ k€$$

$$Internal\ rate\ of\ return\ (IRR) = 13\%$$

$$Payback\ Period\ (PP) = 11\ years$$

**Table 3-5. Cash flows calculation for geothermal energy (k€)**

Item	2022	2023	2024
Capital expenditure	(1,500)		
Working capital	(41)		
Operating revenues		450	450
Operating expenses		(160)	(160)
Depreciation (20 years)		(75)	(75)
EARNINGS BEFORE INTEREST AND TAXES		215	215
Taxes (25%)		(54)	(54)
NET INCOME		161	161
CASH FLOW (Net income + Depreciation)	(1,541)	236	236

### 3.3 Green hydrogen plant

Eco-industrial parks (with virtual power plant) may be complemented with a green hydrogen plant, according to their high TRL, provided that specific economic subventions are obtained to achieve balanced financial results.

Mine water represents an essential raw material for producing green hydrogen by electrolysis. This process needs up to 18 tonnes of water - not counting losses - to produce one tonne of hydrogen. Water treatment systems typically need about two tonnes of impure water to produce one tonne of purified water.

In other words, one tonne of hydrogen needs not nine, as usually stated, but 18 tonnes of water. If losses are considered, the ratio is nearly 20 tonnes of water for every tonne of green hydrogen.

The Green hydrogen plant will be designed with a 2.5 MWe of electrical power dedicated to hydrogen generation; the electrolyser will allow a nominal flow rate of 500 Nm<sup>3</sup> H<sub>2</sub>/h (0.012 kg H<sub>2</sub>/s = 1078 kg H<sub>2</sub>/day). The purity of the H<sub>2</sub> generated will be 99.998%, and the operating range is between 5 and 125% of the nominal H<sub>2</sub> flow rate.

The hydrogen produced will be sold to power electro-intensive industries or companies nearby.

Table 3-6 presents the Green hydrogen plant parameters. These data were obtained from DURO FELGUERA, S.A. and HUNOSA.

**Table 3-6. Green hydrogen plant deployment parameters**

Parameter	Value
Installed capacity	2.5 MWe
Estimated investment (plant life: 15 years)	5 M€
Functioning hours of the installation for one year	6,000 h
Annual hydrogen production	270,000 kg/year
Operating expenses (personnel, maintenance, repairs)	250,000 €
Electrical consumption of the plant	3 MWh
Hydrogen sale price	7 €/kg
Electricity cost (from Virtual Power Plant)	55 €/MWh

Table 3-7 presents the cash flows for the first three years, using constant 2022 euros, annual depreciation of 6.7% and working capital of about 9% of operating revenues.

**Table 3-7. Cash flows calculation for Green hydrogen plant (k€)**

Item	2022	2023	2024
Capital expenditure	(5,000)		
Working capital	(170)		
Operating revenues		1,890	1,890
Operating expenses		(1,240)	(1,240)
Depreciation (15 years)		(333)	(333)
EARNINGS BEFORE INTEREST AND TAXES		317	317
Taxes (25%)		(79)	(79)
NET INCOME		238	238
CASH FLOW (Net income + Depreciation)	(5,170)	571	571

Finally, considering an 8% capital cost, the expected financial outcomes for 15 years will be:

$$\text{Net Present Value (NPV)} = -5,170 + \frac{571}{(1 + 0,08)} + \frac{571}{(1 + 0,08)^2} + \dots + \frac{571}{(1 + 0,08)^{15}} = -283 \text{ k€}$$

$$\text{Internal rate of return (IRR)} = 7 \%$$

Thus, the investment is not feasible unless a specific subvention is obtained for developing the Green hydrogen plant. This is why we will suppose that receiving a 50% subvention of the total investment is possible, which aligns with Big Ticket projects within the Research Fund for Coal and Steel (RFCS). So, taking into account a subvention of 2.5 M€, the new expected financial outcomes will be:

$$\text{Net Present Value (NPV)} = -2,670 + \frac{571}{(1 + 0,08)} + \frac{571}{(1 + 0,08)^2} + \dots + \frac{571}{(1 + 0,08)^{15}} = 2,217 \text{ k€}$$

$$\text{Internal rate of return (IRR)} = 20 \%$$

$$\text{Payback Period (PP)} = 7 \text{ years}$$

### 3.4 Eco-industrial park

Developing a business park to attract industry is timely, and it can take at least four years, and this has a financial cost of planning and execution of the work. A typical industrial park of 100,000 m<sup>2</sup> will have 10% of the area for green space and 30% for roads and general facilities if the shapes are not complicated. Table 3-8 presents the Eco-industrial plant deployment parameters. SOGEPSA, an industrial land promotion company in Asturias, Spain, facilitated these data.

**Table 3-8. Eco-industrial park deployment parameters**

Parameter	Value
Total area available	100,000 m <sup>2</sup>
Estimated time for development	Four years
Percentage of green areas over total area available	10%
Percentage of reads and auxiliary services over the total area	30%
Available area for industries	60%
Sale price	60 €/m <sup>2</sup>
Cost of execution related to the total area available	10 €/m <sup>2</sup>
Planning cost to be developed during the first two years	100,000 €
Drafting of the project during the third year	100,000 €

Table 3-9 presents the cash flows for all the years of the investment, using constant 2022 euros.

**Table 3-9. Cash flows calculation for Eco-industrial park (k€)**

Item	2022	2023	2024	2025	2026
Capital expenditure	(50)	(50)	(100)	(1,000)	
Operating revenues					3,600
Taxes (25%)					(600)
CASH FLOW	(50)	(50)	(100)	(1,000)	3,000

Finally, considering an 8% capital cost, the expected financial outcomes will be:

$$Net\ Present\ Value\ (NPV) = -50 - \frac{50}{(1 + 0,08)} - \frac{100}{(1 + 0,08)^2} - \frac{1000}{(1 + 0,08)^3} + \frac{3,000}{(1 + 0,08)^4} = 1,229\ k€$$

We assume the end-of-life coal mine and the coal-fired power plant own the land.

### 3.5 Molten salt plant

Another possibility is complementing the Eco-industrial parks (with a virtual power plant) with a Molten salt plant as a storage option.

According to Roper et al. (2022), molten salts are mainly used for thermal energy storage when connected to a concentrated solar power (CSP) plant due to their excellent properties for heat retention, as could be the case in Spain.

However, the retained heat can be also used to provide electricity. In the case of delivering electricity, it is necessary to transform the heat via Rankine or Brayton conversion cycles. This poses a problem that must be analysed on a case-by-case basis, and much research is still needed. However, power-to-heat-to-power energy systems using molten salts may give a total end-use ration of 87.4%, corresponding to a 68.2% heat and 19.2% power, according to Bauer et al. 2021.

Thus, the TRL of power cycle coupling is still relatively low, precisely because of limited modern research, as well as because of the existence of still many chemistry challenges such as corrosion, tritium generation, and materials compatibility; the high radiation/high-temperature environment that is necessary for this technology posing a problem on the reliability of mechanical valves; the sensitivity of commercial instrumentation and control (I&C) technologies to this environment; the modelling challenges in reactor systems, etc.

Geyer (2022) also stated that with thermal energy storage systems using the technology of sensible heat (e.g., molten salts, rock material, concrete), today’s market readiness is R&D/pilot.

Thus, to obtain accurate economic data for this type of installation is extremely difficult. For developing this deliverable, we used data from Ponciroli et al. (2021) and Turchi & Heath (2013).

**Table 3-10** presents deployment parameters for a molten salt plant. The nameplate capacity (MWh) corresponds to the Total battery energy content (100% charge or “usable energy”), with usable energy divided by power rating (in MW) reflecting the hourly duration of the system.

In this specific case, and due to the plant’s capacity, 80% of the energy produced by the photovoltaic plant will be stored. However, calculations will not be repeated for the complete Virtual power plant, and we will consider that the energy is bought at 40 €/MWh.

**Table 3-10. Molten salt plant deployment parameters (adapted from Ponciroli et al., 2021; Turchi & Heath, 2013)**

Parameter	Value
Installed capacity	300 MWh-50MW
Nameplate capacity	300 MWh
Estimated investment (plant life: 20 years)	6 M€
Roundtrip efficiency (RTE)	80%
Daytime energy storage (360 MWh x 80%)	288 MWh
Electricity cost (from Virtual Power Plant)	40 €/MWh
Nighttime energy production (288 MWh x 80%)	230 MWh
Nighttime energy price	70 €/MWh
Night-time revenues (230 MWh x 70 €/MWh)	16,100 €
Annual revenue (16,100 € x 365)	5.88 M€
Annual expenditure (staff, maintenance and overheads)	0.50 M€

Table 3-11 presents the cash flows for the first three years, using constant 2022 euros, annual depreciation of 5% and working capital of about 9% of operating revenues.

**Table 3-11. Cash flows calculation for Molten salt plant (k€)**

Item	2022	2023	2024
Capital expenditure	(6,000)		
Working capital	(529)		
Operating revenues		5,880	5,880
Operating expenses		(4,705)	(4,705)
Depreciation (20 years)		(300)	(300)
EARNINGS BEFORE INTEREST AND TAXES		875	875
Taxes (25%)		(219)	(219)
NET INCOME		656	656
CASH FLOW (Net income + Depreciation)	(6,529)	956	956

Finally, considering an 8% capital cost, the expected financial outcomes for 20 years will be:

$$\text{Net Present Value (NPV)} = -6,529 + \frac{956}{(1 + 0,08)} + \frac{956}{(1 + 0,08)^2} + \dots + \frac{956}{(1 + 0,08)^{20}} = 2,857 \text{ k€}$$

$$\text{Internal rate of return (IRR)} = 13 \%$$

$$\text{Payback Period (PP)} = 11 \text{ years}$$

Thus, the molten salt plant can also be considered an attractive investment.

### 3.6 Sensitivity and uncertainty analysis of the Virtual power plant

The last step of the economic impact assessment is the sensitivity and uncertainty analysis of its variables. Sensitivity analysis involves studying how model input uncertainty can be apportioned to different sources of uncertainty in model inputs, indicating exactly how much the NPV or IRR will change in response to a given change in a single input variable, other things held constant.

A Monte Carlo simulation is typically used when conducting an uncertainty analysis on critical variables. This simulation approach involves a computerised mathematical technique that allows one to account for risks involved in quantitative analysis and decision-making. Monte Carlo simulations furnish decision-makers with a range of possible outcomes and with the probability that they will occur for any course of action.

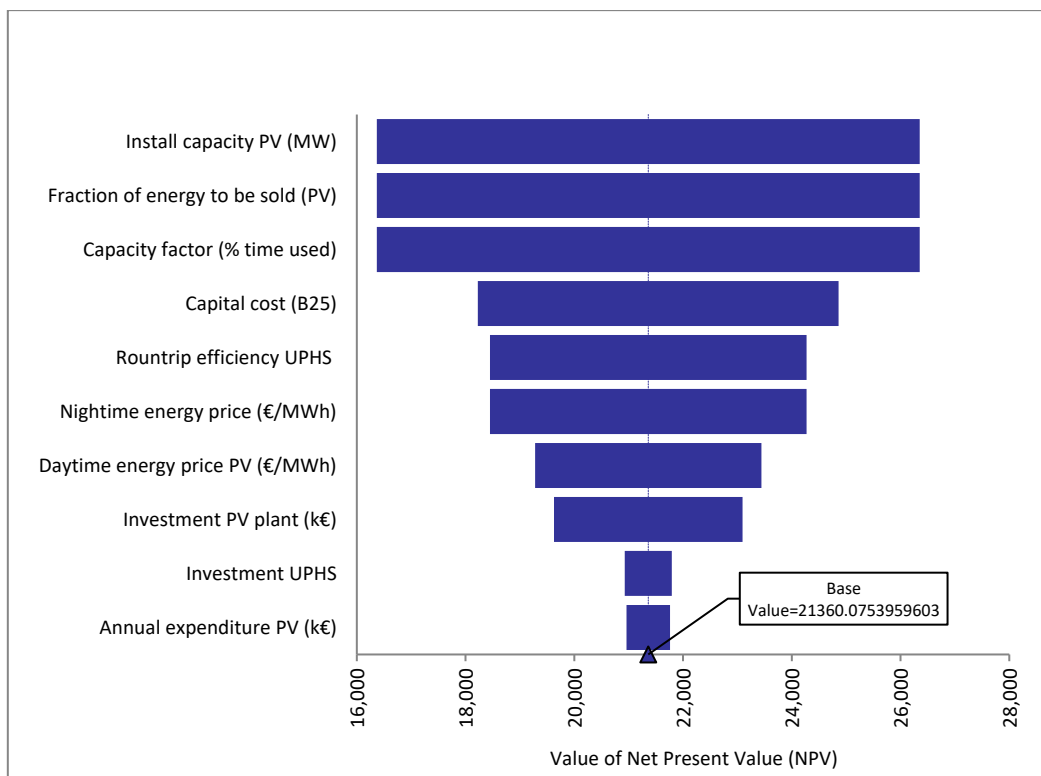


The programme used to undergo the sensitivity and uncertainty analysis will be @RISK from Palisade Corporation (Ithaca, New York), which UNIOVI and GIG usually use for these purposes.

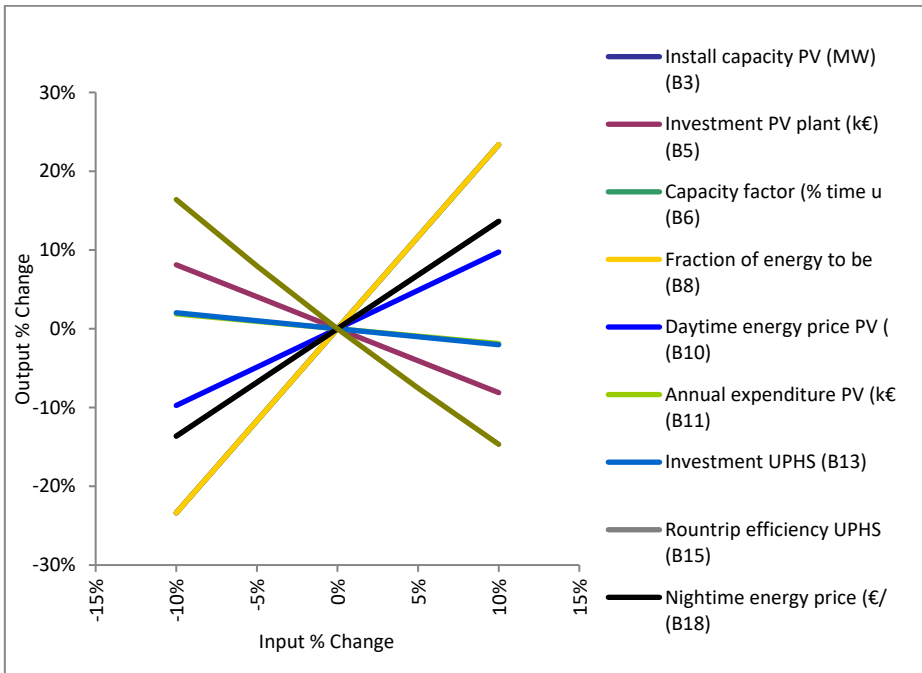
### 3.6.1 Sensitivity analysis

Figure 3-1 presents the Tornado Graph of the Net Present Value (NPV), and Figure 3-2 illustrates the same information in a Spider Graph. According to this information, the most sensitive variables for the Net Present Value (NPV) are in order of importance:

1. Install capacity PV (MW).
2. Fraction of energy to be sold (PV).
3. Capacity factor (% time used).
4. Capital cost (B25).
5. Roundtrip efficiency UPHS.
6. Nighttime energy price (€/MWh).
7. Daytime energy price PV (€/MWh).
8. Investment PV plant (k€).
9. Investment UPHS.
10. Annual expenditure PV (k€).

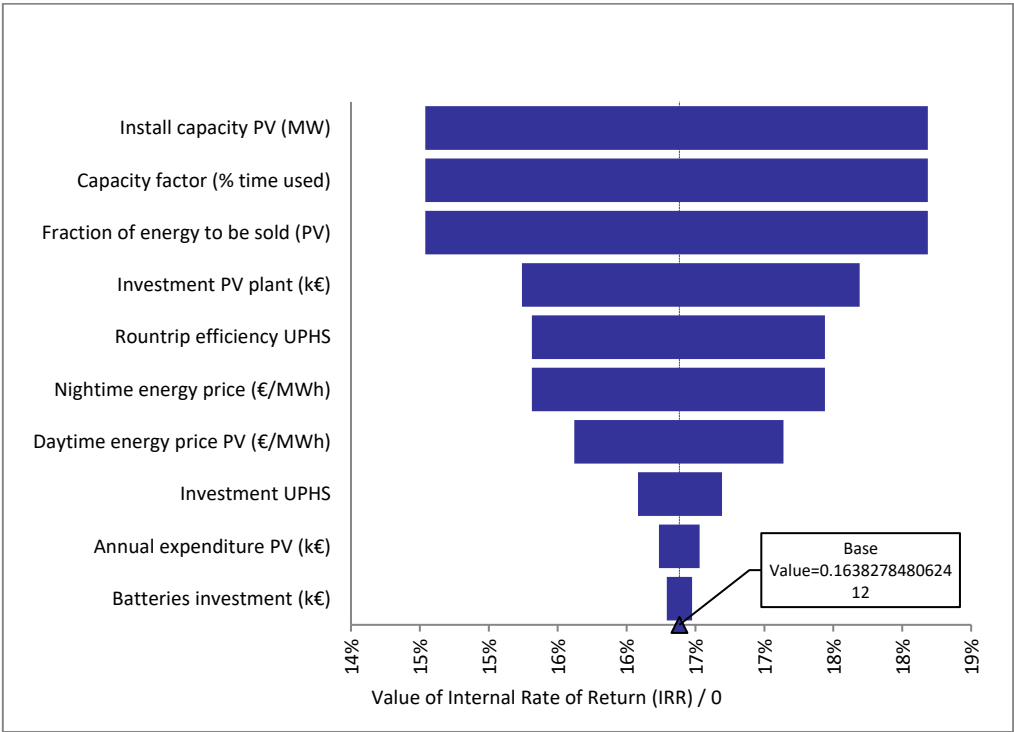


**Figure 3-1. Tornado Graph of the Net Present Value (NPV)**



**Figure 3-2. Spider Graph of the Net Present Value (NPV)**

On the other hand, **Figure 3-3** presents the Tornado Graph of the Internal Rate of Return (IRR), and **Figure 3-4** shows the same information in a Spider Graph.

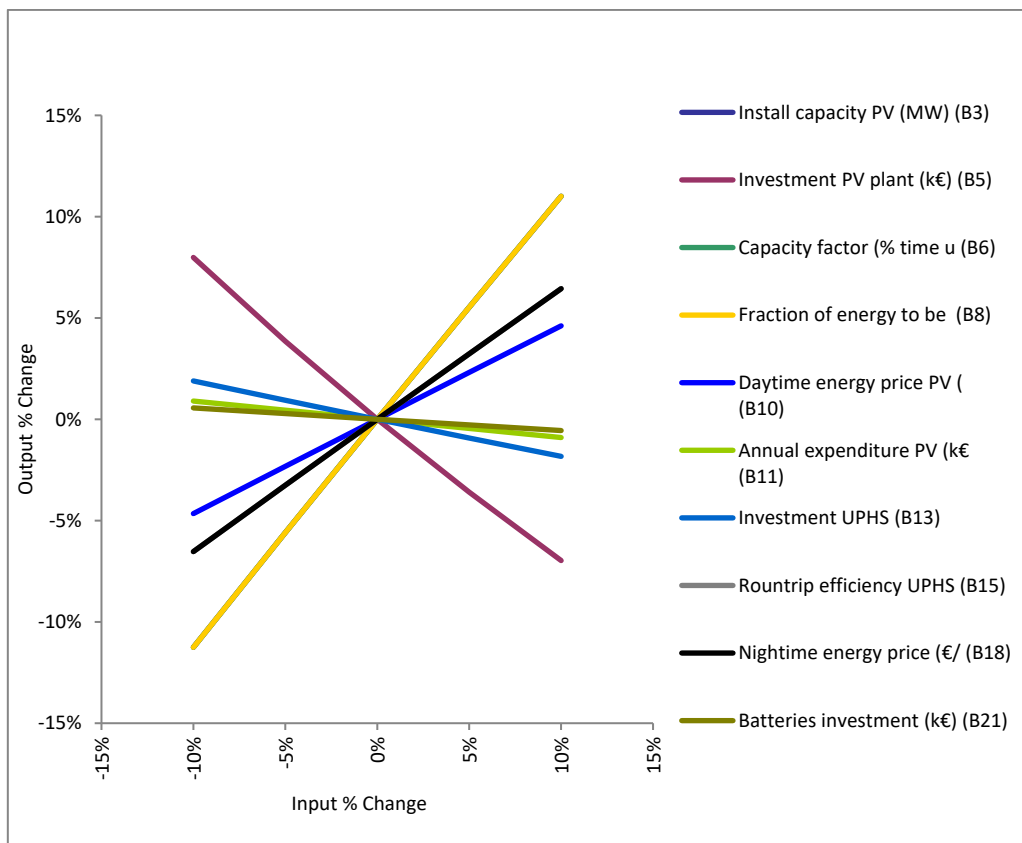


**Figure 3-3. Tornado Graph of the Internal Rate of Return (IRR)**

According to this information, the most sensitive variables for the Internal Rate of Return (IRR) are in order of importance:

1. Install capacity PV (MW).
2. Capacity factor (% time used).
3. Fraction of energy to be sold (PV).
4. Investment PV plant (k€).
5. Roundtrip efficiency UPHS.
6. Nighttime energy price (€/MWh).
7. Daytime energy price PV (€/MWh).
8. Investment UPHS.
9. Annual expenditure PV (k€).
10. Batteries investment (k€).

Thus, both analyses are similar, mainly in the seventh first sensitivity variables, which are eight if we include the capital cost necessary for the NPV calculation.



**Figure 3-4. Spider Graph of the Internal Rate of Return (IRR)**

### 3.6.2 Uncertainty analysis

To develop the uncertainty analysis, we will model the three most sensitive variables with specific distribution functions according to the intrinsic characteristics of the variables.

#### 3.6.2.1 *Install capacity PV (MW)*

The install capacity will be modelled employing a normal distribution. This distribution can be used to represent the uncertainty of a model's input whenever it is believed that the input is itself the result of many other similar random processes acting together in an additive manner (but where it may be unnecessary, inefficient, or impractical to model these detailed driving factors individually).

The Normal distribution is a symmetric continuous distribution unbounded on both sides and described by two parameters ( $\mu$  and  $\sigma$ , i.e. its mean and standard deviation). The Normal distribution can often be justified regarding a mathematical result called the Central Limit Theorem. This loosely states that the resulting distribution is approximately Normal if many independent distributions are added together. The distribution, therefore, often arises in the real world as the compound effect of more detailed (non-observed) random processes. Such a result applies independently of the shape of the added initial distributions.

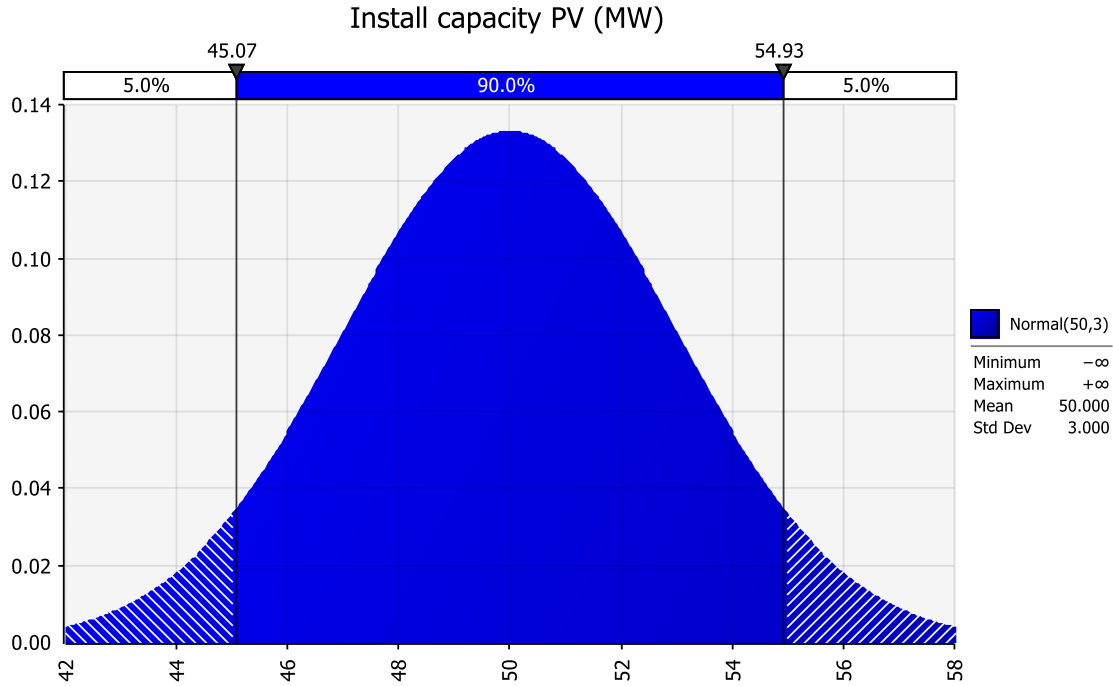
Examples could include the total number of goals scored in a soccer season, and the amount of oil in the world, assuming that there are many approximately equal-sized reservoirs, but each with an undetermined amount of oil.

In our case, we will use a  $\mu$  of 50 MW and a  $\sigma$  of 3 MW, resulting in the distribution presented in [Figure 3-5](#).

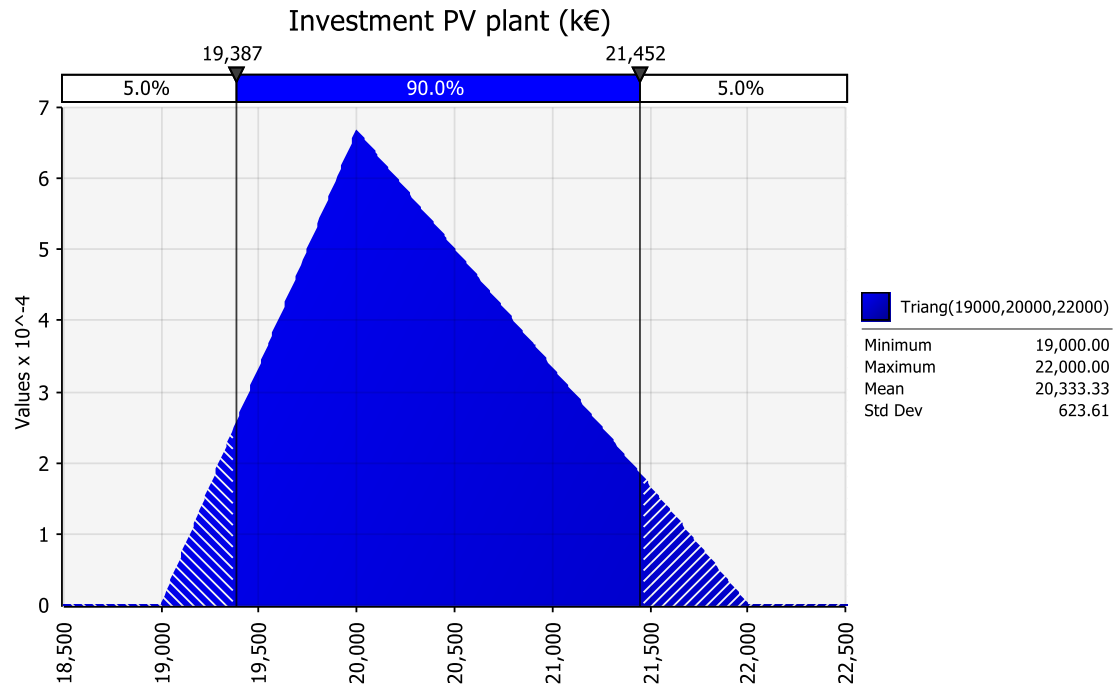
#### 3.6.2.2 *Investment PV plant (k€)*

We will consider that the photovoltaic plant's investment will vary according to a triangular distribution that uses three easily identifiable values to describe a complete distribution.

Our case, as presented in [Figure 3-6](#), it specifies a triangular distribution with three points — a minimum (19,000 €), most likely (20,000 €), and a maximum (22,000 €). The direction of the "skew" of the triangular distribution is set by the size of the most likely value relative to the minimum and the maximum.



**Figure 3-5. Normal distribution of the PV install capacity**



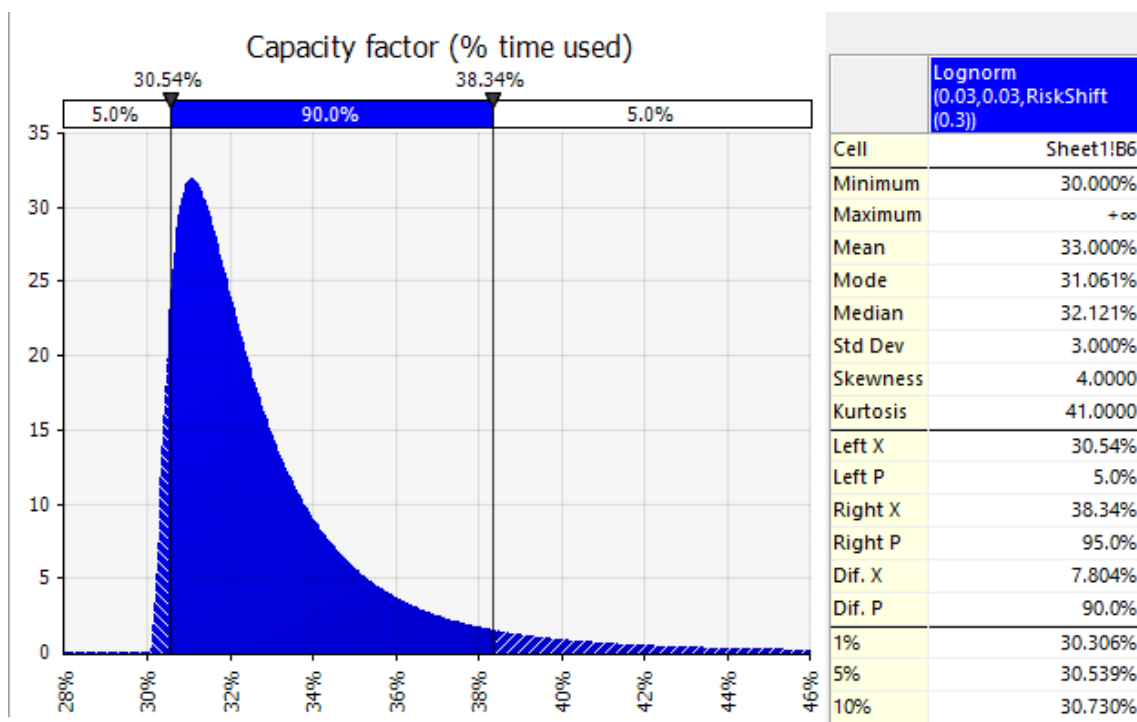
**Figure 3-6. Triangular distribution of the PV plant investment**

This distribution is perhaps the most readily understandable and pragmatic distribution for basic risk models. It has several desirable properties, including a simple set of parameters, including the use of a modal value, i.e. a most likely case. There are two main disadvantages of a Triangular distribution. First, when the parameters result in a skewed distribution, the outcomes may be over-emphasised in the direction of the skew. Second, the distribution is bounded on both sides, whereas many real-life processes are bounded on one side but unbounded on the other.

### 3.6.2.3 Capacity factor (% time used)

To undergo an uncertainty analysis, the capacity factor or the percentage of time of use of the photovoltaic installation per year will be modelled employing a Lognormal function, as it is one of the functions that better models natural phenomena.

In this case, **Figure 3-7** specifies a lognormal distribution with a mean of 33% and a standard deviation of 3% with skewness of 4 and a kurtosis of 41.



**Figure 3-7. Lognormal distribution of the capacity factor**

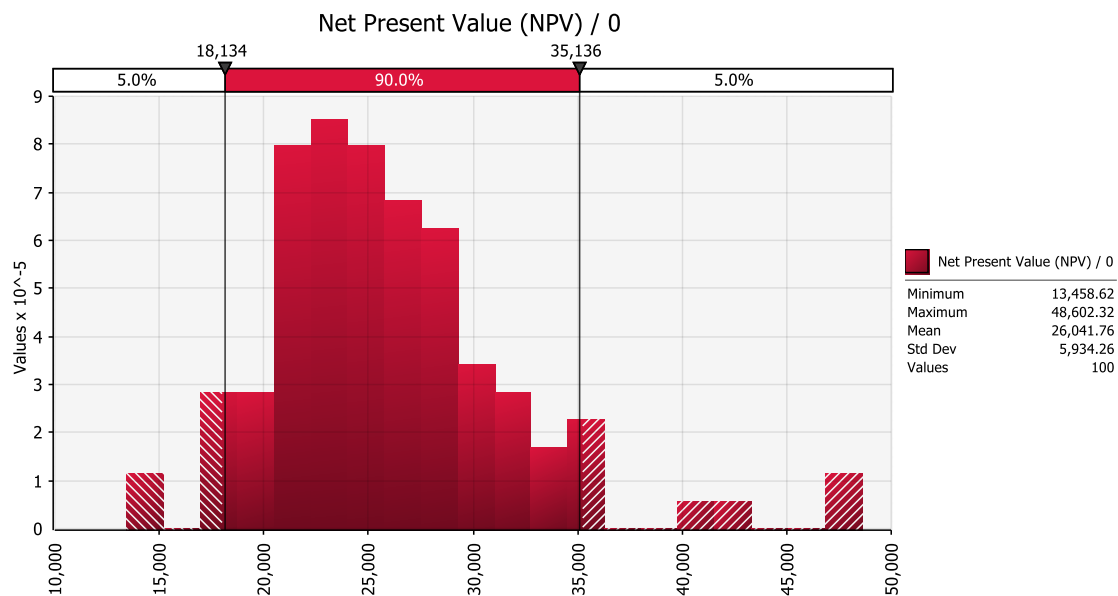
The arguments for this form of the lognormal distribution specify the actual mean and standard deviation of the generated lognormal probability distribution. Like the Normal distribution, the Lognormal has two parameters ( $\mu, \sigma$ ) corresponding to the mean and standard deviation. Just as the Normal distribution results from adding many random processes, the Lognormal arises by multiplying many random processes.

The logarithm of the product of random numbers equals the sum of the logarithms. In practice, it is often used as a representation of the future value of an asset whose value in percentage terms changes randomly and independently. It is often used in the oil industry as a model of reserves following geological studies whose results are uncertain.

The distribution has some desirable properties of real-world processes. These include that it is skewed and has a positive and unbounded range, i.e., from 0 to infinity. Another valuable property is that when  $\sigma$  is small compared to  $\mu$ , the skew is slight, and the distribution approaches a Normal distribution; so any Normal distribution can be approximated by a Lognormal by using the same standard deviation but increasing the mean (so that the ratio  $\sigma / \mu$  is small), and then shifting the distribution by adding a constant amount so that the means match.

### 3.6.2.4 Net present value (NPV) distribution

Figure 3-8 presents the Net present value (NPV) distribution obtained after the Monte Carlo analysis. As can be observed, the mean obtained (26,042 €) is much bigger than the NPV calculated (21,991 €). Thus, it can be stated that the estimated figures are robust, and there is a high probability of achieving the calculated NPV or higher.



**Figure 3-8. Net present value (NPV) distribution**

3.6.2.5 Internal rate of return (IRR) distribution

Figure 3-9 presents the Internal rate of return (IRR) distribution after the Monte Carlo analysis. Again, the mean of 17.95% is sensitively higher than the calculated 16%. Thus, the calculated IRR can be considered robust, as with the NPV.

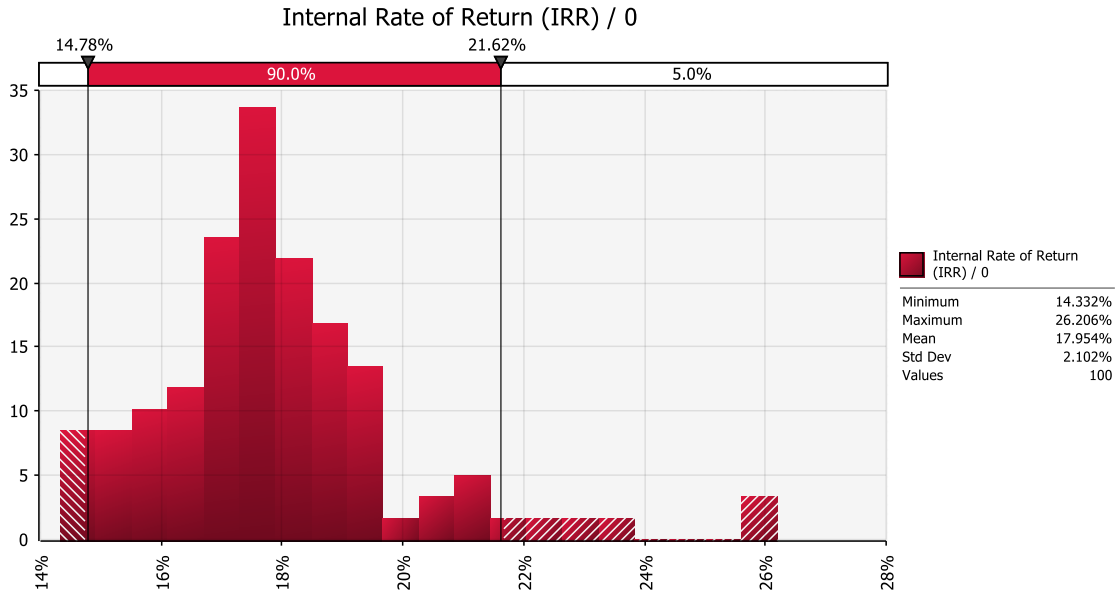


Figure 3-9. Internal rate of return (IRR) distribution



## 4 Social impact assesment

The term social impact refers to the results brought to human population, related to changes caused by public or private actions, regarding their way of living, working and organizing in order to be able to survive and strive as members of a society. Social impact is not limited only to actions, but also comprises any change that is associated with norms, values, and beliefs, which exist and control the way the population within the society thinks and acts (Environmental Impact Assessment Review, 1995).

Mancini and Sala (2018) used a total of 50 global studies in order to compile a list that comprises the most usual social impacts identified in the coal sector. Based on the studies, a total of 6 distinctive categories were identified as the following: 1) economy, income and security, 2) employment and education, 3) land use and territorial aspects, 4) demography, 5) environment and 6) human rights.

The social impact will be determined in areas that are currently in coal-out phase, to assess and estimate, the social consequences that are likely to follow due to closure of coal mines and power plants, from an employment and requalification point of view. An assessment of the expected number of job losses will be determined as well as a definition of the requalification needs for the employee in order to find new jobs.

The aim of the social impact assessment is to provide solutions to the upcoming unemployment in the coal regions in transition and avoid inflicting a substantial economic upheaval. Potentials will propose the best solutions to the expected job losses, which can be adapted by the employees in order to achieve a smooth transition and re-adoption of the territorial transition regions. In addition, it will determine the benefits of using Eco-Industrial Parks as a potential business model for the areas in transition after the closure of mines and the job opportunities that could arise.

The first part of the social impact assessment will focus on the number of potential job losses in the mining and power plant sector in European regions in transition due to closure, with literature data. In the second part, the requalification needs of the workers will be discussed in order to be able to work in the new circumstances. The third part will focus on the efficiency of creating Eco-industrial parks in these areas after the mine closure has taken place, concerning the creation of new jobs and energy production.

### 4.1 Job losses

The global temperature has reached values that are considerably higher compared to those before the Industrial Revolution (Walker and King, 2009). In order to stabilize the temperature at  $\sim 2^{\circ}\text{C}$ , a 50% to 85% decrease in greenhouse gas emissions has to take place by 2050 (IPCC, 2007).

The European Union (EU) has set the goal to reduce the greenhouse gas emissions to at least 55% by 2030 aiming at zero emissions by 2050 (Foltynowicz, 2020). However, the effects of COVID-19 pandemic had a negative impact on the economies and societies of all EU-member states, as well as on the target for GHG reduction that was set by the EU (Foltynowicz, 2020).

To support and alleviate these negative effects, the EU has developed the Just Transition Fund through the Just Transition Mechanism (JTM), setting as primary objective to “leave no one behind” (The Just Transition Mechanism, 2020). The Fund aims to mitigate the socio-economic costs over the transition period and support economic projects, especially those that include the production of clean energy. The overall goal is to make local economies less dependent on the coal and lignite mining industry and support the repurposing of these areas (The Just Transition Mechanism, 2020). Countries searching to gain economic benefit from the Fund, for coal regions during the transition phase, were asked to submit Territorial Just Transition Plans (TJTP) that can justify their demands.

The main actions, concerning the lowering of greenhouse gas emissions, is the closure of coal and lignite mines and focus towards Renewable Energy Sources (RES). Although the green energy from RES is environmentally friendly, it could lead to high unemployment in the coal industry. Poland, Spain, Germany and Greece are amongst the European countries that will be highly affected by the transition, as almost 75% of the current electricity obtained due to burning of coal (Dias et al., 2018) will be replaced by RES. In particular, coal regions in Greece and Spain, with low GDP when compared to the national average, are likely to be more affected by additional job losses (Dias et al., 2018) in the coal sector than others.

A high number of employees, related to direct jobs in the coal mines and power plants and indirect job losses in areas and industries dependent from the mining activity, will be at risk to be laid off (McDowall et al., 2023). It is estimated that the number of jobs lost in the coal sector, due to mine and power plant closure, can get up to ~ 160 000 by 2030 (Dias et al., 2018). To avoid the unemployment, many workers from the coal and mining sector in these countries will try to relocate in the search for new jobs, whereas others will try to find jobs in the renewable energy sector, based on their developed skills (Witajewski-Baltvilks et al., 2018). The relocation of workers is going to have an enormous impact on the regions that are coal dependent as the economy is mostly based on coal and the workers that live in those areas (Government of Spain, 2019).

Employment data based on Eurostat (Dias et al., 2018), Table 1, show that Poland, Spain, Germany and Greece are some of the countries in Europe with a high number of direct jobs in the coal sector. Poland is at the top of the list, as almost half of the total coal sector employees in the European Union belong in this country. Germany is second after Poland, with Spain and Greece following. The coal industry also has an impact on the

creation of indirect jobs related to the coal activities. It is estimated that a total of 215,000 indirect coal jobs exist based on 2015 data (Dias et al., 2018). Poland occupies again the second place with an estimate of ~ 88,000 employees, followed by Germany 34,000 (Dias et al., 2018). Taking into consideration the above estimates and the numbers presented in **Error! Reference source not found.**, the total amount of jobs in Europe related to coal is close to 450,000.

**Table 4-1. Jobs in coal power plants and coal mines in top 10 countries in Europe (Dias et al., 2018)**

Country	Jobs in coal power plants	Jobs in coal mines	Total
Poland	13.000	99.500	112.500
Germany	10.900	24.700	35.700
Czechia	3.600	18.000	21.600
Romania	3.600	15.000	18.600
Bulgaria	2.700	11.800	14.500
Spain	3.300	3.400	6.700
Greece	1.600	4.900	6.500
United Kingdom	4.100	2.000	6.100
Slovakia	500	2.200	2.700
Italy	2.400	300	2.700
<b>Total</b>	<b>45.700</b>	<b>181.000</b>	<b>226.700</b>

In the previous decades, most of the jobs in this sector were lost due to economic reasons, high cost for extractions when compared to the sale price of the product, and not that much as a result of laws and policies implemented to help with climate change mitigation. This is totally different to the phenomenon observed today, as the Regulation on the Governance of the Energy Union and Climate Action (EU) 2018/1999 required that all Member States submit National Energy and Climate Plans (NECPs) for the period 2021 – 2030 (European Commission, 2019), in order to achieve zero greenhouse gas emissions by 2035.

Due to the high number of employees in the coal sector (**Error! Reference source not found.**), these countries are considered to be some of the most vulnerable and at risk from the decline in fossil fuel industry activity. A total of 130-140,000 direct jobs are expected to be lost by the year 2030 in the coal sector, as a result of closure of mines and power plants, due to impact of mitigation policies (Galgóczi, 2019). **Table 4-2.** (McDowall et al., 2023) shows a list with the regions that are considered most vulnerable based on the percentage of job losses by 2035. Greece and Poland have some of the most vulnerable coal dependent regions, in terms of risk of job losses, with Western Macedonia being at number 1 and Silesia at number 2.

To confront the difficulties brought by the closure of coal mines and power plants, each of the previous mentioned European countries submitted Territorial Just Transition Plans (TJTP) that will be implemented in order to achieve de-lignitization, energy transition and repurposing of the regions that are currently in the coal transition phase. The replacement of coal with RES for the production of green energy will help with the expected decline of coal jobs as most of employees can be reskilled and find jobs in the renewable energy sources sector due to the experience and knowledge gained while working in the coal and mining industry (Dias et al., 2018; Christiaensen et al., 2022). In addition, the implementation of RES does not only help with the job losses but on also provides employment that is I paid and in most cases under better conditions (please see section 4.1 for further details)

**Table 4-2. Most vulnerable regions based in the percentage of job loss by 2035 (McDowall et al., 2023)**

Rank Vulnerability	Region, Country	Major sectors	Share of region's jobs lost in 2035
1	Western Macedonia, Greece	Coal mining	4.5%
2	Silesia, Poland	Coal mining, ICE manufacture	3.7%
3	SE Bulgaria	Coal mining, refineries	1.7%
4	SW Oltenia, Romania	Coal Mining, ICE manufacture, oil and gas extraction	1.2%
5	Moravian-Silesia, Czech Republic	Coal mining, ICE manufacture	1.7%
6	NE Czech Republic	ICE manufacture, Coal Mining, refineries	1.8%
7	NE Scotland	Extraction of oil & gas	1.8%
8	Piemonte, Italy	ICE manufacturing, oil extraction	1.0%
9	NW Czech Republic	Coal mining	1.0%
10	Lower Silesia, Poland	ICE manufacturing, coal mining	0.9%

#### 4.1.1 Poland

From the beginning of the 90's until today, about 300,000 jobs related to coal mining were lost in Poland, which currently shares half of the total number of coal related jobs in Europe (**Error! Reference source not found.**) Christiaensen et al. (2022). In 2020, the approximate number of coal miners working in the coal industry was 80,000 (EUROACTIV, 2020). In the same year, the Polish government declared 2049, as the date for phasing out coal for the country (Taylor, 2021). By the year of phasing out, the total

number of jobs is expected to decline by 31,000 (Sartor et al., 2018). When it comes to the coal power sector, the number of jobs will fall by 2030 to 23,000 differing from 29,000 jobs in 2010, whereas by 2049, 12,000 additional jobs are expected to be lost (Sartor et al., 2018). In 2015, a total of 26 coal mines operated in Poland corresponding to 21 in hard coal and 5 in lignite sites. At that time, the jobs were mostly found in the hard coal sector, specifically in Silesia, which was responsible for a total of 82,700 out of 91,600 jobs (Galgóczy, 2019).



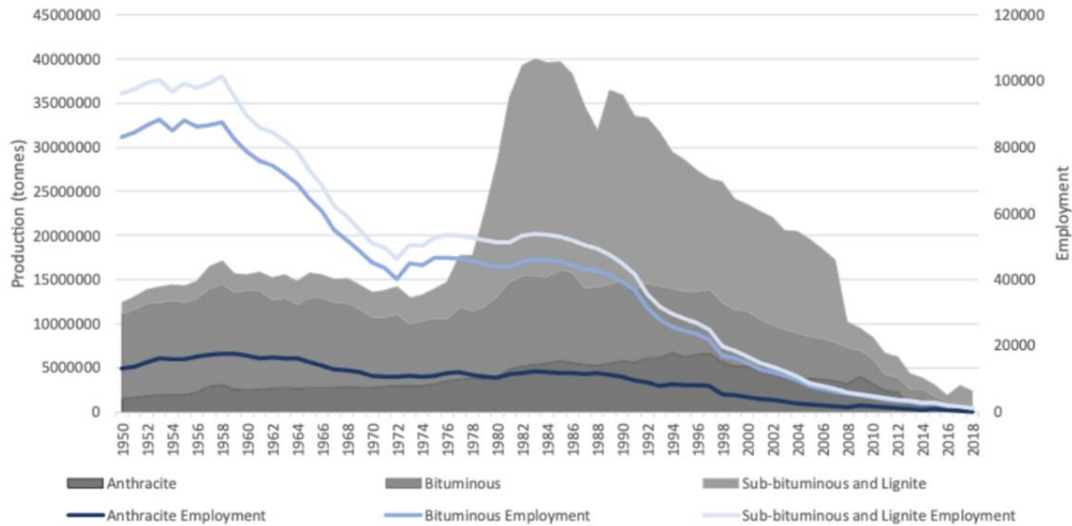
**Figure 4-1. Employment in hard coal and lignite in top European countries (Christiaensen et al., 2022)**

When it comes to lignite, most jobs were found in the Lodzkie region with a total of 4,900 out of 8,900 (Galgóczy, 2019). As of 2021 hard coal is extracted in Silesia, Lesser Poland and Lublin, whereas lignite is extracted in Greater Poland (i.e., Wielkopolska), Lower Silesia, and Łódź (Christiaensen et al., 2022). Although these coal and lignite regions are responsible only for 1% of the total employment in the country, their economy is heavily coal-dependent. For example, the Silesia region is amongst the most vulnerable coal-dependent regions in Europe with an expected job loss of 3.7% by 2035 (McDowall et al., 2023) or 15,000 to 18,000 jobs that could be lost by 2030 (Christiaensen et al., 2022).

#### 4.1.2 Spain

In 1990, 45,200 workers were employed in the coal sector in Spain (Institute, J.T., Spain, 2022). At that time, the areas were heavily coal dependent as most of the economy had its roots in the coal sector. From 2008, more than 8,000 jobs were lost in the coal mining sector (Figure 4-2, Wong and Maxwell, 2022), with the most affected areas being

Asturias, Teruel (Aragon), as well as León and Palencia (Castilla y León) (European Union, 2021). In 2018, the number of workers in the coal sectors was decreased to 1,833 people that were hired at nine companies across the country (Institute, J.T., Spain, 2022).



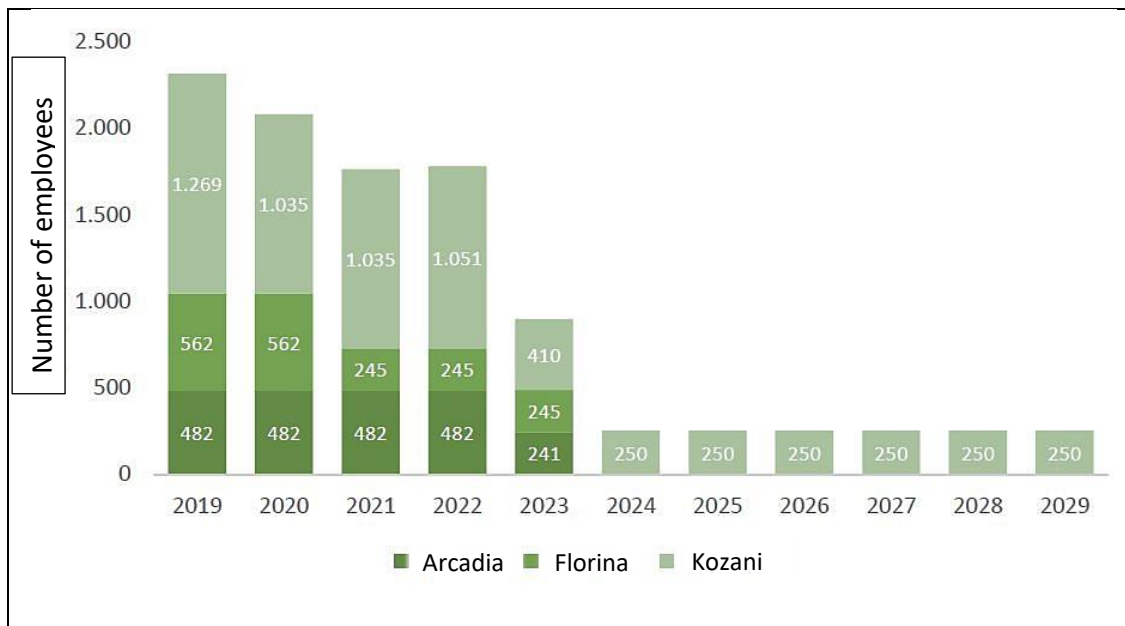
**Figure 4-2. Employment and production in coal and lignite in Spain (Wong and Maxwell, 2022)**

In Spain, only 15 coal-fired thermal power plants were still working during 2019, whereas eight of them requested to shut down by the end of the year. The remaining power plants employ more than approximately 2,500 workers for the operation and maintenance processes (Institute, J.T., Spain, 2022).

#### 4.1.3 Greece

In Greece, the employment in the lignite mining and electricity production sector is focused mainly on three regional units, namely Kozani, Arcadia (Megalopolis) and Florina. The areas of Kozani and Florina belong to Western Macedonia region, where the lignite mines and lignite-related activities are mainly located at Ptolemaida and Amyndeo. Compared to Greece as a whole, the highest proportion of employees in Kozani, Florina and Arcadia are occupied in the primary sector, including mining, energy and water supply, as well as in the construction sector. These are the dominant economic activities in these areas and affect directly the local and regional economy. In 2017, the total jobs in this sector reached 7,280, the vast majority of which was in the Kozani region (i.e. 5,443 jobs). Arcadia region is the second region in this sector with 1,000 jobs, followed by Florina with 840 jobs. The total number of jobs in the sector have met a significant decrease of 20.6% compared to 2008, where the jobs accounted up to 9,170 (IOBE, 2020).

The majority of those employees are permanent or temporary staff of Public Power Corporation (PPC SA). The number of direct employees in lignite mines and lignite plants of PPC SA in 2019, accounted up to 7,200, most of them being occupied in the mines. Employment forecasts were conducted by PPC SA for both the lignite power plants and the lignite mines in the regions of Arcadia, Florina and Kozani, for each year of the period from 2020 to 2029, on the view of the planned closure of lignite mines and power plants. The results revealed the greatest employment losses in the period 2023-2024, as seen in the graph below (Figure 4-3; IOBE, 2020).



**Figure 4-3. Graph of the estimated employment forecasts in the lignite mines and power plants for the period 2019–2029 (data estimated by IOBE, 2020)**

Data for the year 2015 show that, apart from the job occupations in the lignite mines and power plants, that were approximately 4,900 and 1,600 respectively for the Western Macedonia region, there is also a significant number of indirect jobs, related to lignite-mining activities. These jobs are already facing challenges with the lignite-closure and the green transition. Data provided by the EURACOAL (2015) demonstrate that in 2015, the number of indirect jobs in lignite mining activities accounted up to 2,438 at a regional level. An estimation conducted by Alves et al. (2018), revealed that the number of indirect jobs in the coal-related activities in Greece corresponded to 1,843 and 4,166 at an intra-regional and inter-regional level respectively. Another study conducted in the same year by the European commission, presents that the direct employment related to coal mining activities (mines and power plants) amounts to 5,681 people in Western Macedonia region (TCG-WM, 2018).

Pavloudakis et al. (2019) reported that up to this date, PPC holds the largest number of employees related to coal mining activities in Western Macedonia region, providing approximately 6.3% of all coal-related jobs and 45.9% of the direct job opportunities in the secondary sector (Pavloudakis et al., 2019). Statistical data from 2019 showed that 2,446 employees with indefinite-term contracts were occupied in the lignite mines of PPC SA, as well as in the PPC SA headquarters in Athens. These numbers reveal a 12% decrease in the number of employees compared to 2014, and a 55% decrease compared to 1994, which is attributed mainly in the gradual lignite retirement (Pavloudakis et al., 2019).

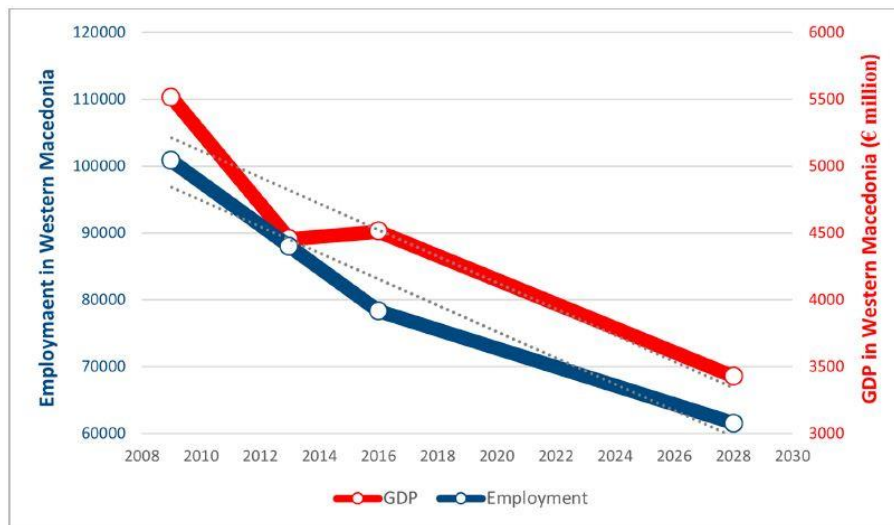
In order to assess the accurate number of direct and indirect coal-related job losses due to the closing of lignite mines, and the effect in the employment at an inter-regional and intra-regional level, it is important to entirely comprehend the lignite value chain. According to Pavloudakis et al. (2019), the lignite mining sector in Western Macedonia region is depended on: (a) excavating sub-contractors (including ten companies), (b) the owners of equipment such as trucks and excavators, (c) the repair and maintenance sub-contractors for the equipment (five companies and several local small and medium-sized enterprises (SME)), (d) the concrete and asphalt producing companies and the sub-contractors of steel and concrete construction works (five companies and numerous SME), (e) the suppliers of equipment and apparatus such as explosives, and (f) SMEs providing other services, such as labor transportation and catering supply. Regarding the latter, it is estimated that the total number of employees of all sub-contractors and service providers that are placed upstream of mines in the lignite value chain is 2,000. (Pavloudakis et al., 2019).

Rovolis & Kalimeris (2016) assumed a transition plan for lignite mines and power plants retirement and evaluated the losses for Western Macedonia region, considering the operation of the new Ptolemais V and Meliti II power plants for a smooth transition. Their research outcomes showed a negative impact with an investment loss of 2.5 billion euros for the operation of the plants, and 70% job losses (Rovolis & Kalimeris, 2016; Pavloudakis et al., 2019). A research based on Hellenic Statistical Authority data for the period 2000–2016, revealed that for every million ton of lignite produced, 185 lignite-related jobs are preserved and 725 new are created (equivalent to a ratio of 1:3.9; Sotiropoulos et al., 2020; Pavloudakis et al., 2020).

Figure 4-4 presents the employment reduction (job losses) and the GDP reduction in Western Macedonia region as predicted assuming that lignite mines will close by 2028. The results indicated that there will be a loss of approximately 21,000 direct and indirect jobs, which corresponds to a 24% employment decrease compared to 2013 (Sotiropoulos et al., 2020; Pavloudakis et al., 2020). Ziouzos et al. (2021) mention that more than 25% of local occupations are related to lignite mining activities, which will be lost during the transition process. From a financial point of view, the GDP loss will be 9 billion euros from 2013 to 2028, with an estimated annual decrease of 26% (equals to



an annual loss of approximately 1.2 billion euros; Sotiropoulos et al., 2020; Pavloudakis et al., 2020).



**Figure 4-4. Forecast of the employment reduction (job loss) and the GDP reduction in Western Macedonia region during the lignite phase-out, assuming that lignite mines will be closed by 2028 (Sotiropoulos et al., 2020; Pavloudakis et al., 2020)**

The region of Western Macedonia was stated to have 3,200 employees working in the lignite sector (mining and power production) in 2020, owned by PPC SA. Additionally, around 2,000 indirect jobs in satellite companies for observation and operational needs of the PPC SA were reported (Ziouzios et al, 2021; Karasmanaki et al., 2020). During the lignite phase-out as planned for 2023, these direct and indirect jobs will face crisis and the majority of them will be lost. Unemployment in those fields and other occupations related to the lignite value chain has already been remarkable since 2021 (Ziouzios et al, 2021; Karasmanaki et al., 2020). The results of the coal phase-out will be noticeable in the local community, since the 10% of the local employment is linked to the lignite industry either directly or indirectly, but also at least 34% of the Gross Value Added (GVA) is attributed to the lignite sector (Eurostat statistics; Ziouzios et al., 2021).

#### 4.1.4 Germany

In Germany, during 2015 there were approximately 10,900 jobs in coal power plants and 24,700 occupations in the coal mines (accounting up to 35,700 in total; Alves et al., 2018). Data provided by the EURACOAL (2015) reveal that in 2015, the number of indirect jobs in lignite mining activities accounted up to 21,06% (15,700 jobs related to hard coal mining activities and 5,316 related to lignite mining activities) at a regional level. The number of indirect jobs in coal-related activities of Germany were 14,089 and 34,366 at an intra-regional level and at an inter-regional level respectively (Alves et al., 2018). The same study, reported that in 2015, the top-ranked regions of Germany,

regarding the number of coal-related direct job occupations included Münster (with approximately 10,000 jobs), Köln (with 5,700 jobs), Düsseldorf (with 4,600 jobs), Brandenburg (with 4,500 jobs) and Dresden (with 3,400 jobs; Alves et al., 2018).

Later for the year 2018, the number of direct jobs that could be affected by ceasing all coal-related activities was approximately 20,000, with many more indirect job losses, according to the Labor Union for the Mining Chemical and Energy Industries (IGBCE). The majority of them was associated to regions based mainly in the industrial activity, such as Lusatia, with 8500 job occupations, and Rhineland, with 9903 jobs in 2018, as reported by DEBRIV (the federal German association of all lignite producing companies and their affiliated organizations; Bartholdsen et al., 2019).

Niebuhr (2019) presented data regarding lignite-related employment numbers for three mining regions in Germany; (Chile, 2019) Lausitzer Revier, Mitteldeutsches Revier, and Rheinisches Revier (Niebuhr, 2019; Richwien et al., 2018). The estimations regarding the job losses from lignite retirement accounted to approximately 20,000 direct jobs related to coal mining and energy production, while the number of indirect job losses was estimated to be around 36,000. At a regional level, it will bring a structural change in the coal-mining regions, such as mandatory industrial transition and career change with creation of new jobs, due to mandatory shift to other income alternatives, in order to compensate loss caused by phase-out (Niebuhr, 2019).

According to Vassiliadis (2019), lignite mining in Germany in 2018 was related to 60,000 direct and indirect jobs that will be lost during the phase-out coal. Statistical data for the year 2020 (Statistik der Kohlewirtschaft, 2021; Markard et al., 2021), revealed that 19,500 employees were still occupied in lignite-related direct jobs, while hard coal mining has ceased since the last hard coal mine closed in 2018 (Markard et al., 2021). Apart from the job losses, mine closing will also cause structural disruptions in the industrial sector and in the economy of the country, since it is responsible for approximately 4 billion euro of value creation (Vassiliadis, 2019; Markard et al., 2021).

## 4.2 Requalification needs

Most of the coal and lignite mines will be considered inefficient as they are near the end of their license (Dias et al., 2018). As a result, the promotion of natural heritage through repurpose existing mines could be an important existing support instrument for employees in the coal and mining sector (Government of Spain, 2019). Other promising industries for coal and mine workers are the agricultural-food, through the growth of home products, and the touristic, through work in rural tourism, hotels and hostels (European Union, 2021). Although the vast majority of workers in the coal sector could find jobs in the renewable energy sources sector, they do not possess the required qualifications for the new jobs and there is a need to develop a training and reskilling plan for green energy jobs (Government of Spain, 2019).

#### 4.2.1 Necessary skills for the RES workers of the Eco-Industrial Parks

The necessary skills for RES workers occupied in the EIPs as defined by the POTENTIALS project, focusing on photovoltaics and wind turbines, have been identified and presented in the Erasmus+ project RES-SKILL: Reskilling coal industry workers for the renewables energy sector (2020-2023). After thorough research from the involved experts, they concluded that, apart from the specific knowledge and expertise, there are some specific characteristics and soft skills both coal workers and photovoltaics/wind turbines workers must obtain, and which can be developed and transformed in the case of coal employees to meet the requirements of the RES sector (RES-SKILL Project, 2020-2023).

The general qualifications both coal miners and RES workers should acquire, that can be modified or used as a leverage for the effective reskilling of the first into the RES sector are categorized in: (a) the knowledge level, (b) the technical skills, and (c) the soft skills (non-technical qualifications). In general, the knowledge level qualifications involve (RES-SKILL Project, 2020-2023):

1. Knowledge of mechanics, for the job positions that are responsible for the control, operation, repair and maintenance of machinery and tools.
2. Knowledge of computer and electronics, regarding job positions such as electrical and computer engineers or IT programmers, which are responsible for the operation and maintenance of electronic equipment (such as circuit boards and CPUs), as well as computer software/hardware.
3. Knowledge of building and construction, regarding skills related to materials and methods for the construction and maintenance of the infrastructures.
4. Qualifications regarding public safety and security sector, where employees need to obtain the required knowledge level of safety and security policies, measures, strategies, and equipment.

Similarly, both RES and coal employees need to acquire a series of technical skills, according to the profile of analogous job positions corresponding to each sector. These technical qualifications are identified to be (RES-SKILL Project, 2020-2023):

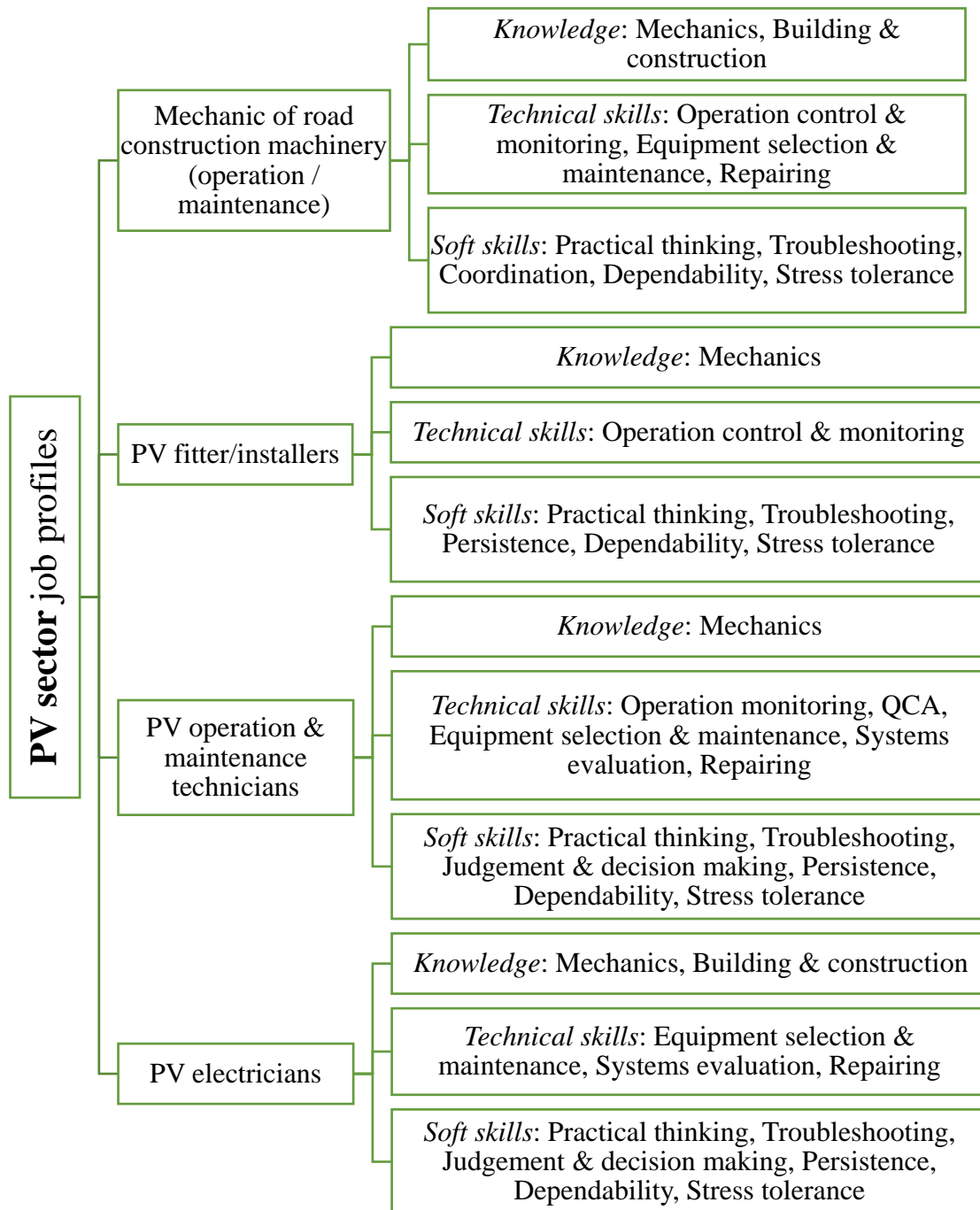
- i. Skills for operation and control of equipment and other systems, such as drilling in the case of coal mining, or PV fitters and installers in the case of photovoltaics. An additional technical skill to this field is the operation monitoring, which involves monitoring of equipment and systems to ensure smooth machinery operation process.
- ii. The evaluation of systems and system performance, for improving or assuring the accurate and effective operation, for achieving the targets. The system evaluation involves the capability of recognizing indicators that show the quality

- of the performance and actions that need to be taken accordingly to improve or maintain this quality.
- iii. The competence of selecting the right equipment and tools required for a specific task (equipment selection), along with technical skills for the equipment maintenance.
  - iv. Competence of Quality Control Analysis is required for job positions that conduct evaluation of quality and performance by running tests and reviewing products and services.
  - v. Lastly, technical skills that involve repairing of either machinery or systems in general.

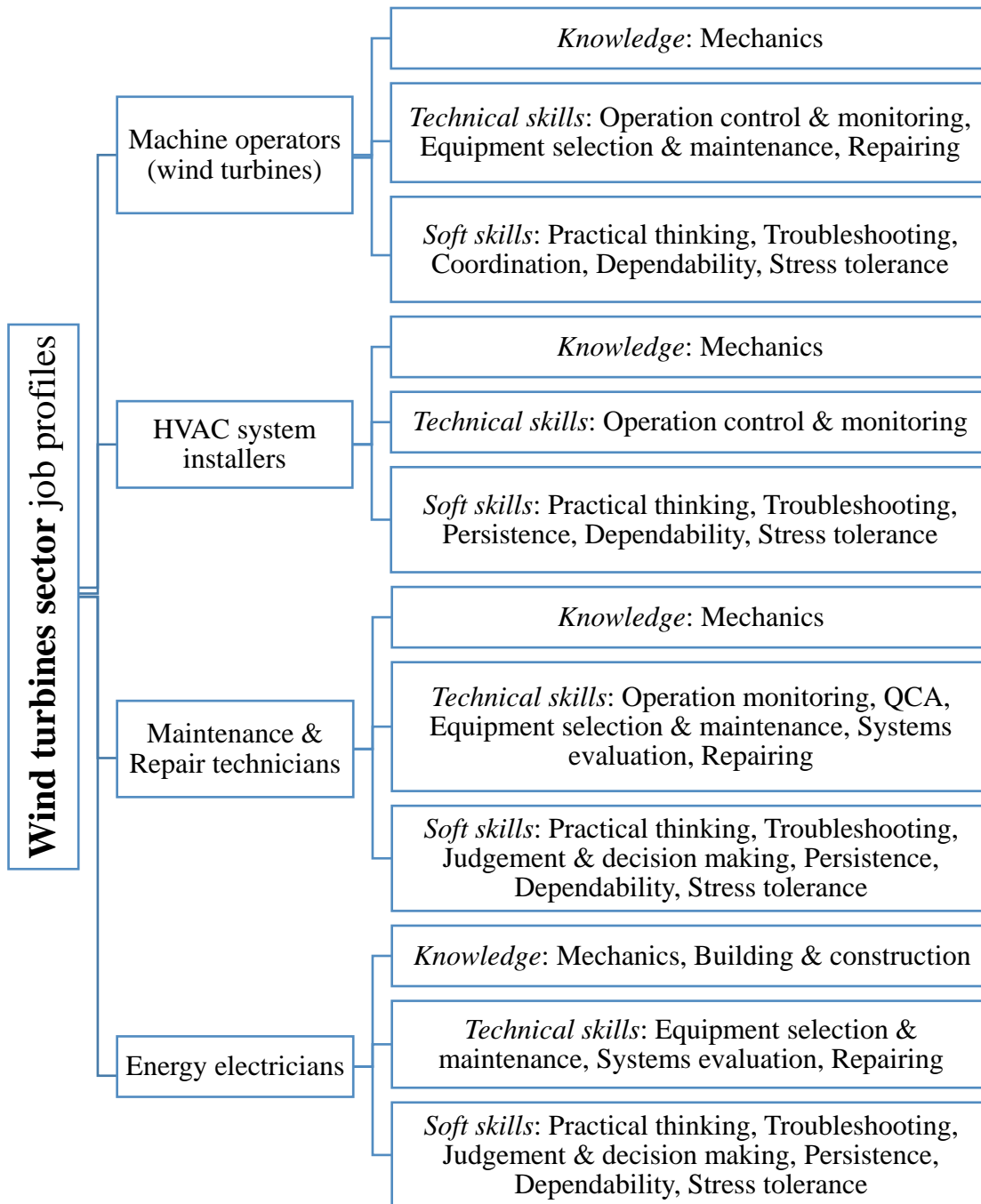
The soft skills that all employees need to acquire at a certain grade include stress tolerance, practical thinking, troubleshooting, judgement and decision making in order to be capable of finding causes of operating errors, as well as deciding the optimal solution with logic and considering all the outlays and benefits.

In addition, they need to obtain adaptability, in order to be able to adjust quickly in work changes, coordination with other workers, and reliability. They need to be able to instruct other workers and be sensitive to their coworker's needs and wellbeing, as well as be determined and persistent to inspire others and successfully face difficulties (RES-SKILL Project, 2020-2023).

The main job profiles in the photovoltaics and the wind turbine sectors are similar, and they go with a combination of the aforementioned knowledge requirements, technical skills, and soft skills. More specifically, these profiles and qualifications are presented in the following Figure 4-5 & Figure 4-6 (RES-SKILL Project, 2020-2023).



**Figure 4-5. The main job profiles for photovoltaic systems of the Eco-Industrial Park, along with the respective knowledge, technical skills and soft skills required for each job (data from RES-SKILL Project, 2020-2023)**



**Figure 4-6. The main job profiles for wind turbine systems of the Eco-Industrial Park, along with the respective knowledge, technical skills and soft skills required for each job (data from RES-SKILL Project, 2020-2023)**

As it can be observed from these two figures, and taking into consideration the knowledge, technical, and soft skills required for each job position, it is deduced that the analogous job profiles for PV and wind turbines are: (a) the “Mechanics of road construction machinery” (PV) with the “Machine operators” (wind turbines), (b) the “Solar PV fitter/installers” and the “HVAC system installers” for the wind turbines, (c) the “PV operation and maintenance technicians” and the “Maintenance and repair electricians” for wind turbines, and (d) the “PV electricians” and the “Energy electricians” for wind turbines. This relation between job profiles should help and make easier and more adjustable the process of employment in the Eco-Industrial Park since employees with similar profile knowledge and skills may be occupied in various similar jobs. Also, it allows former coal employees to have more choices when selecting alternative jobs during their career change that is inevitable consequence of the gradual coal mine closure.

Since the EIPs, as defined by the POTENTIALS project, may also include geothermal energy apart from PH and wind turbines, it is substantial to also present the job positions and the relevant necessary skills for geothermal energy industry workers. In general, geothermal energy creates a variety of direct and indirect green jobs, involving different specialties with different skills, educational levels and previous experience, and depending on the stage of the geothermal project they are occupied (Manijean and Saffache, 2017; Schütz et al., 2013).

The direct jobs are mostly related to the construction and maintenance of the geothermal plants, including manufacturing jobs, construction jobs, as well as operations and maintenance (O&M) jobs. These employees are responsible for conducting surveys and tests for potential geothermal drilling sites, for drilling geothermal wells after assessing the appropriate site. Their duties also include the design and build of the geothermal power plants, as well as for their smooth operation and maintenance, including replacement and repair of the equipment.

The indirect jobs are mostly related to providing services, tools, or other goods for the companies that are directly involved in the geothermal project. These are jobs related to the first stages of the geothermal project, before and during the exploration phase, such as geologists, biologists, hydrologists, geochemists and geophysicists, lawyers, paralegals, consultants and surveyors, engineers (geothermal engineers and drilling engineers), architects, as well as subcontractors for the majority of the workforce (Manijean and Saffache, 2017; Schütz et al., 2013).

In general, and depending on the occupation profile, the geothermal expertise personnel needs to obtain a minimum education of a Bachelor’s degree or postsecondary training, mechanical or manual dexterity qualifications, scientific skills and construction skills. In addition, it is important to acquire specific soft skills, such as troubleshooting, practical thinking, realizing and carrying out a variety of tasks

(multitasking), and other personality traits similar to those mentioned in the previous paragraphs regarding PV and wind turbines:

<https://firsthand.co/professions/geothermal-energy-industry-workers>

A survey conducted by Xu (2016) within the scope of KnowRES project, reported that there is a lack of skilled employees in the geothermal sector, especially regarding job positions such as supervisor drilling engineers, project managers, power plant managers, O&M managers. In order to cover this gap, adequate training and education of young employees and students in related technical or scientific university faculties should be taken into consideration. However, for a faster transition to green energies and a more imminent implementation of the EIPs scenario, the shortage in skilled employees may not be covered by training new employees alone (Manijean and Saffache, 2017; Schütz et al., 2013). Other measures should be taken into consideration, including reskilling employees of other sectors, such as coal, oil and gas sectors. These workers need to acquire flexibility and capability for adapting to change, such as working environment, duties and responsibilities (Manijean and Saffache, 2017).

According to Schütz et al. (2013), workers from the oil and gas sector are the optimal potential candidates for occupying such jobs, after sufficient training and reskilling. The authors note that the labor shortage in the drilling phase of a geothermal project may be covered by drilling engineers and other job profiles related with the drilling phase of the oil and gas sector. Regarding that the only extraction method of oil and gas is drilling; those candidates are highly skilled in this field. Therefore, the experience, skills and drilling techniques they obtain may be transferred to the geothermal sector with minor training (Manijean and Saffache, 2017; Schütz et al., 2013).

Other reskilling criteria to be included should concern the synergies of the EIPs, which include the storage technologies, circular economy contributions, synergies for reducing waste and pollution, as well as producing goods for the industrial transition, such as waste recycling. Some of the basic soft skills and technical skills regarding mechanics, operation and maintenance, repair and monitoring, may be common in all those sections and synergies involved.

### **4.3 Eco-industrial parks**

Eco-industrial parks (EIP) were firstly defined by the USEPA (United States Environmental Protection Agency) as “a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues including energy, water, and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only” (Lowe et al., 1995). This general



definition was modified as research proceeded, leading in EIPs today including clean energy production, industrial ecology, and waste management. Within this scope, it is deduced that EIPs involve both the green energy production and environmentally friendly industrial activity to minimize wastes and emissions, as well as the concept of circular economy and profitability to achieve the most effective industrial process for meeting demand and recovering value of energy (Perrucci et al., 2022).

For the POTENTIALS project, Eco-industrial parks with virtual power plants are defined as integrated alternative for sustainable energy generation technologies and circular economy synergies at coupled end-of-life coal mine sites and coal-fired power plants. Sustainable energy generation technologies for this project scenario include, primarily, photovoltaics (solar energy) and wind turbines, and secondarily geothermal energy for cooling/heating industries and companies that are involved in the EIP scenario. It can be deduced that EIPs with virtual power plants for their holistic implementation will include the surrounding residential and industrial areas.

Circular economy contributions will be included for promoting reuse and recycle, and consequently minimizing waste. EIPs will be accompanied by relevant synergies such as a molten salt plant, a green hydrogen plant, biofuels (production and combustion), or ancillary services provided by batteries. These synergies will further promote optimizing the EIP materials, resources, and energy flows, as well as meeting Europe's demand for goods from the industrial perspective of the just transition pathway. A significant advantage of the EIPs is the low energy storage demands and the possibility to cover the energy needs with batteries solely. Other synergies for EIPs should involve regional grids interconnecting various green energy sources to different consumption points, in order to transform heat and/or power customers into prosumers (simultaneously producers and consumers), or for customers with excess of electricity from solar panels on their roofs. This may further engage external investment, such as tax exclusions for involved industries, access to privileged recognitions from National authorities, and European Investment Bank.

For the optimal and most effective implementation of the EIPs with virtual power plant scenario, it is mandatory to develop a social network based on socio-economic and environmental criteria to achieve the optimum functional cooperation between energy producers and consumers, for a sustainable transition from coal industry to green alternatives. The furthest goal of this network is to increase the financial revenues and ecological status of the transitioning area (Martín Gómez et al., 2018; Wei et al., 2017; Zhao et al., 2018).

#### **4.3.1 Eco-Industrial Parks and Job Opportunities**

Renewable energy sources (RES), such as onshore and offshore wind and solar photovoltaics (PV), are constantly improving in terms of cost when compared to coal,

and are expected to be cheaper than the operation of existing coal and gas plants in the next decade. Specifically, Bloomberg New Energy Finance has estimated that the average cost of a PV power plant will decrease by 71% and wind energy will fall to 58% by 2050, compared to the 2017 price (BNEF, 2018). The economic advantage of RES to coal, in combination with the ethical consideration has led a number of investors to shift from investing into fossil fuel energy sources to turn their focus on more environment economic solutions such as RES. Such example is Glencore, considered the company with the most coal export in the world, that has declared no expansion in the coal business and maintain of its coal production at ~ 150m tones per year (Galgóczy, 2019; Hume, 2019). Rio Tinto is another example of coal companies that in 2018 was forced to run out of the coal industry after economic investment was stopped by banks and asset managers (Galgóczy, 2019; Hume, 2018).

After the application of the justification approach for business models in Deliverable 4.1 of POTENTIALS, and taking into consideration aspects such as: Green Deal policies, technical criteria, TRL, European taxonomy, synergistic potential, circular economy and sector coupling, the Eco-industrial parks (EIPs) was considered the most feasible business model choice for coupled end-of-life coal mine sites and coal-fired power plants. The business model includes technologies that can produce clean electrical energy that is enough to be considered sustainable, do not pollute the environment and can make use of waste as part of the circular economy synergies. Sustainable energy generation technologies for the EIPs include, primarily, photovoltaics (solar energy) and wind turbines, and secondarily geothermal energy for cooling/heating industries and companies that are involved in the EIP scenario.

Based on the data presented by Eurostat in 2017, the total amount of jobs in Europe was 219.8 million (Eurostat, 2018). Taking into consideration the data presented, the total jobs (direct and indirect) in the coal sector represent only a small number (~450,000) of the total amount of jobs. Although, the number is small, most of the jobs are located in regions within countries that are highly coal-dependent, thus having a huge impact on the local and regional economies in these countries. The need for immediate decarbonisation of the coal sector in Europe will have negative consequences on the employment in the highly coal-dependent regions, as many employees are going to be at the risk of losing their jobs. On the other hand, this will open new opportunities for friendly environment sources of energy to replace coal and create new jobs in the Renewable Energy Sector.

For example, in Guatemala, four former coal-dependent regions have become EIP zones. Specifically, in the region of Estanzuela more than 3,000 are expected to be created due to the transformation of the region from coal-dependent to EIR (Kechichian and Jeong, 2016). Another country that is a pioneer in the creation of EIRs is India. The Dr. A.P.J. Abdul Kalam Green Industrial Park in Nandigama Villag, located in the Medak District is an example of EIR that will provide social benefits to the population living in the area by

8,000 direct jobs, with the number of indirect jobs to be as high as 24,000 (Kechichian and Jeong, 2016). When it comes to actual numbers the creation of Devens Eco-industrial Park in 1993 in USA, Massachusetts is responsible for increase number of organizations in the region from 60 to 95 and the creation of 3,200 jobs for its residents (Veleva et al., 2015).

In Poland, the sectors with the greatest potential to provide job opportunities to coal works are the building, manufacturing, logistics, land remediation and RES industries. Specifically, in Silesia, which is considered a highly coal dependent region, the right economic investment could create total of ~ 85,000 by 2030, (Christiaensen et al., 2022). This number of jobs is considered to be sufficient to cover the jobs lost in the coal sector, after closure of mines and power plants takes place, and could even create more job opportunities. Another example is Wielkopolska region in Eastern Poland where analysis based on a pilot scenario suggests that a total between 12,000 and 22.000 jobs could be created, only in the energy sector (Christiaensen et al., 2022).

Giving the high potential of jobs created in the Energy sector together and taking into consideration different aspects mentioned above, Potentials suggests the transformation of regions coupled with end-of-life coal mine sites and coal-fired power plants into Eco-industrial parks with virtual power plants. The Eco-Industrial Park will have as primary energy technologies photovoltaics, wind turbines, and geothermal as secondary. This transformation can compensate the job losses in the mining sector by creating new jobs in the Renewable Energy Sector. The jobs created in potential sectors (particularly RES), could be suitable for former hard coal miners, simply based on the already skills developed while working in the coal and mining industry.

#### **4.3.2 Eco-Industrial Parks and Requalification Needs**

The right economic investment in transition regions, coupled with end-of-life coal mine sites and coal-fired power plants, with aim to transform them into Eco-industrial parks, will create a number of job opportunities for the residents living in these areas, especially those working in the coal sector. Such example is the Devens Eco-industrial park in Massachusetts, USA, which is responsible for the creation of 3,200 jobs for its coal residents (Veleva et al., 2015). In other parts of the world, estimates suggest that more than 3,000 are expected to be created in the region of Estanzuela, in Guatemala, 8,000 direct jobs in the Dr. A.P.J. Abdul Kalam Green Industrial Park in Nandigama Villag, in India (Kechichian and Jeong, 2016) and between 12,000 and 22.000 jobs in Wielkopolska region in Eastern Poland (Galgóczy, 2019).

Based on the data presented above, the expectation regarding the number of jobs opportunities EIPs can create is high and can prove to be sufficient to compensate for the abrupt decline in the number of employees in the lignite and related sectors (Galgóczy, 2019). Although this scenario seems to be ideal, a significant factor that has

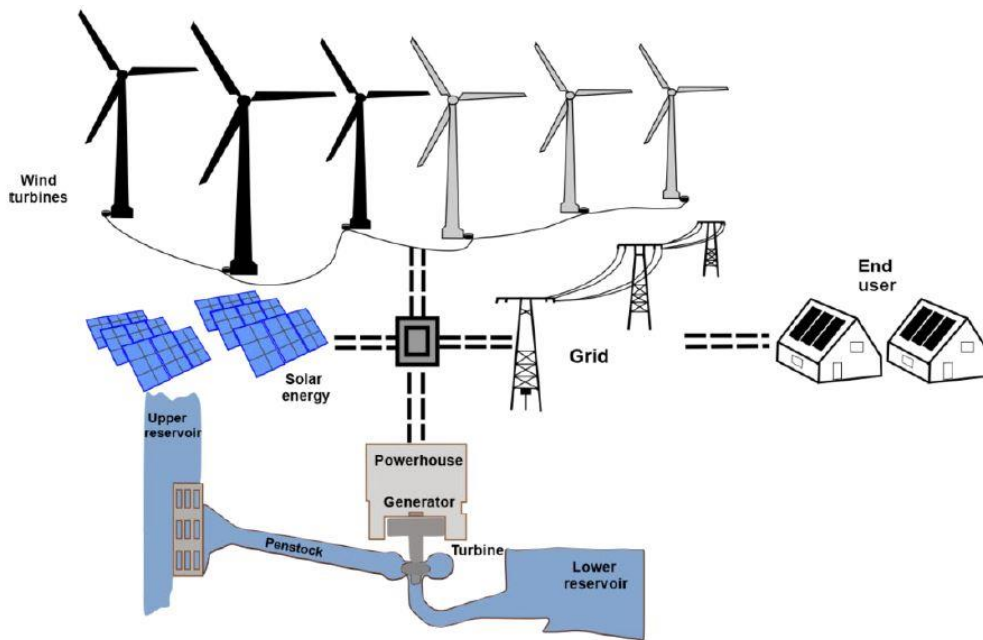
to be taken into consideration is the necessary requalification skills employees must develop in order to work in the RES field.

Although most of the employees, could be deployed and find jobs in the RES sector (based on the already skills developed while working in the coal and mining industry), they most probably do not possess the required qualifications; thus there is the need to develop a plan for training and reskilling employees from the coal and mining industry for green jobs (Government of Spain, 2019). Another significant factor towards the transformation of coal-dependent regions into EIPs is to educate and inform the residents living in these areas about the necessity for decarbonisation of the energy sector. It is necessary to help them accept and acknowledge the need for gradually ceasing of the coal mining activities, in order to be willing for a shift towards the RES sector, through employment training and reskilling for related job positions in this field.

The construction, manufacturing and energy sectors are considered the most suitable for replacing mining jobs, as the salaries offered are similar to those in the mining industry and there is no need for the development of additional skills. Data provided by the Labor Force Survey in Poland shows that about 75% of the workers from the mining business find immediate jobs in the manufacturing sector without the requirement of any skill development (Government of Spain, 2019). Additional activities that can replace mining are logistics and land remediation, which correspond to the necessity of environmental restoration of degraded mining areas, with the aim of opening up of new opportunities.

#### **4.4 Pumped Hydro Storage Systems**

Pumped hydro storage systems (PHS) or pumped storage hydropower systems (PSH), involve the utilization of gravitational energy for generation of electrical energy and vice versa, comprising of a system of hydroelectric energy storage. PHS systems comprise primarily a configuration of two water reservoirs at adequately different elevations, an upper water reservoir and a lower water reservoir (Figure 4-7). Due to their different elevation, the water flowing from the upper to the lower (discharge) can generate electrical power, passing through hydroelectric turbines. The PHS cycle is completed with the re-pump of water back to the upper reservoir (recharge) via water conduits (penstocks). Therefore, since the system requires power for the recharge of water, it utilises either electrical energy from the grid, or preferentially, excess of power from renewables, such as wind turbines and photovoltaic systems. PHS systems can be described as “giant batteries”, since they are able to release water from the upper to the lower reservoir for energy generation during high-demand periods, and store it in low demand periods, while the excess of renewable energy that is produced is used to recharge the water to the upper reservoir. (OEFRE, 2022; Breeze, 2019; Krassakis et al., 2023).



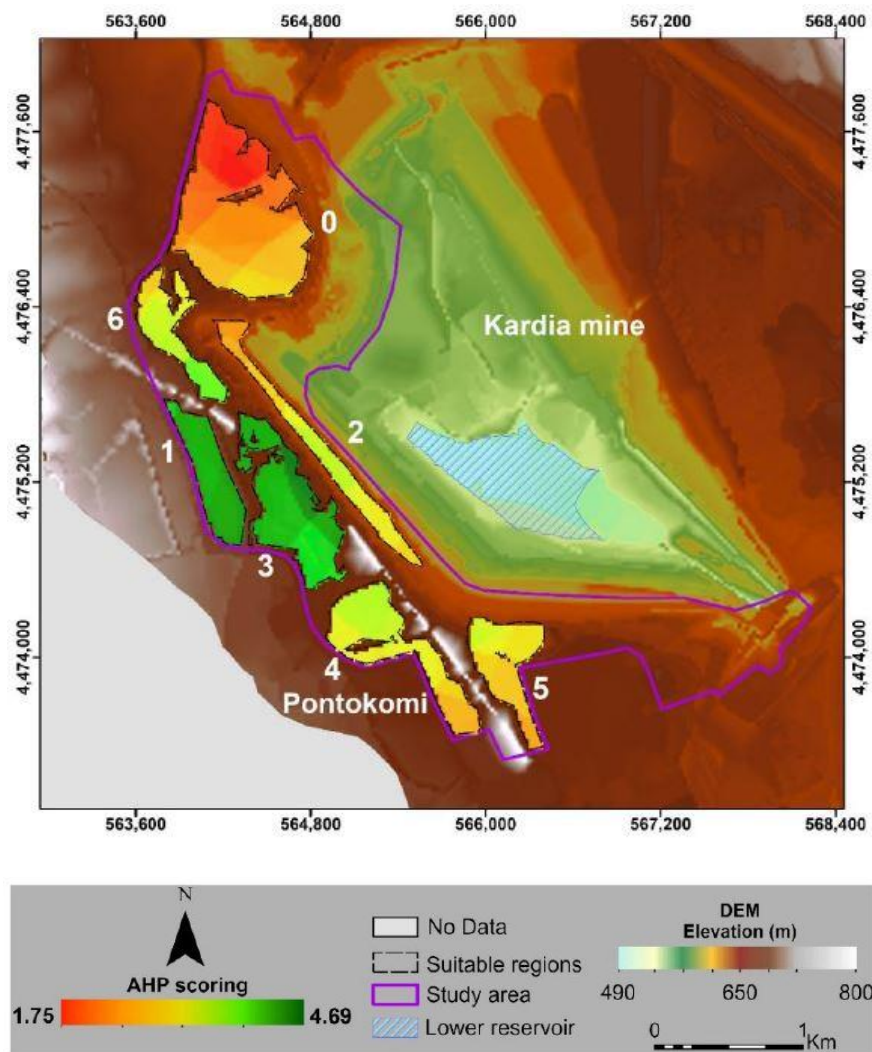
**Figure 4-7. Schematic representation of a pumped hydro storage system powered by excess energy from renewable energy sources (wind turbines and photovoltaics), from Krassakis et al. (2023)**

The storage capacity of a PHS system may vary depending on its specific characteristics (Hunt et al., 2020; Krassakis et al., 2023), while their typical cycle efficiency and energy storage efficiency range between 75–80% and 65–85% respectively (NHA, 2021; Krassakis et al., 2023). Compared to PHS systems, hybrid pumped hydro storage (HPHS) systems present an even more effective alternative, combining more than one RES (both solar and wind energy) and securing the energy availability and stability of the system (Voith, 2020; Krassakis et al., 2023).

In Greece, there is significant potential for the application of (hybrid) pumped hydro storage systems, due to the presence of natural, artificial, or open-pit coal lakes, as well as from the view of supporting renewable energies (wind and/or solar) that are already effectively applied throughout the country. Moreover, since most of the modern (H)PHS projects require the construction of one of the two reservoirs, ecological and topographical aspects need to be accounted for the feasibility of the project (Krassakis et al., 2023). In the majority of the Greek open pit coal mining areas, where the one of the two reservoirs may be an open pit lake, the topography allows the construction of a second reservoir at different elevation.

A recent example of a preliminary project of HPHS for repurposing open pit coal mines is implemented in Kardina lignite open pit mine in the area of Western Macedonia, Greece. The project is developed within the framework of ATLANTIS research project, and it examines the potential locations for the construction of an upper reservoir,

regarding that Kardias open pit mine will constitute the lower reservoir of the HPHS system. The experts examined the optimal location regarding specific indicators and parameters, while they also estimated the energy storage capacity for the probable HPHS location (Krassakis et al., 2023). Based on the methodology that they had implemented and developed within the ATLANTIS project, and in the subsequent publication (Krassakis et al., 2023), seven locations of the area were assessed as probable, with a potential energy storage capacity from 1.09 to 5.16 GWh. Two of those seven sites were assessed as being preferable, which have also been suggested by early techno-economic studies. In the following elevation map of Figure 4-8, these two areas are labelled as no.2 (upper tier excavation pad) and no.5 in the southeast, near the Kardias open pit mine (Krassakis et al., 2023).



**Figure 4-8. Digital elevation map of the Kardias open pit mine area, with the selected locations for the construction of an upper reservoir marked as “suitable regions”. The preferential ones are no.2 and no.5 (from Krassakis et al., 2023)**

The repurposing of the depleted Kardias open pit mine for an HPHS system was examined by PPC SA from a financial point of view. Their experts have presented a schematically model of the construction, for the utilization of the topography in order to create an upper reservoir lake in the mine face with the higher elevation, while utilizing the coal mine pit as a lower reservoir. According to Soumelidis (2022), the upper lake will be formed by acting as a drainage basin of the area. Therefore, rainfalls and a water pipe from lake, resulting in a positive input, will secure the water availability. Another significant advantage of the selected location is the proximity to the Lignite Power Station (1.500 m distance) that provides energy transmission infrastructure and allows the connection to the energy grid (Soumelidis, 2022; Krassakis et al., 2023).

According to PPC (Soumelidis, 2022), the maximum power during pumping and production will be 148 MW (11 h / 131 MW and 8 h / 130 MW respectively), with simultaneous operation of the units. The system efficiency is calculated to range between 72.6 % - 74.8 %, with losses attributed mainly to the pipe characteristics and to be mainly of hydraulic nature. The annual operation time is estimated to be approximately 200 days/year; the annual absorbed energy will be 288 GWh (11 hr. / day), and the annual produced energy 208 GWh (8 hr. / day). The total budget of the construction is estimate to rise up to 149 million euros. Since the project research is still ongoing (hydrogeological, road construction study, exploratory drilling and measurements), the final investment decision is planned to be taken in the middle of 2024, and the final delivery of the project is planned to start by the end of 2027 (Soumelidis, 2022).

Apart from the economic and ecological profits of the HPHS project, such as contribution to the total energy production, reduction of CO<sub>2</sub> emissions and natural gas (NG) consumption, it will also provide several new jobs in the regional community. It is estimated by PPC that the emissions rights cost that will be saved may cover the cost of approximately 50 new jobs per year (Soumelidis, 2022). The HPHS system will create several new job positions both in the hydropower system and in the supporting RES sector in Greece. Therefore, it may contribute to the gradual closing of coal mines both by the creation of new jobs, as well as by the repurposing of open pit coal mines, referring to the pit lakes. Existing employees in the coal industry, as well as graduates or new junior employees, may be reskilled to work in a PHS system, including the supporting RES units.

Reskilling employees will involve the transmission of knowledge and expertise gain both in the photovoltaics and wind turbines sector, regarding technical infrastructure knowledge, as well as in the PHS sector. Coal mining workers could be trained sufficiently in order to be able to cover related job titles. The first step of the training should involve education and learning, which is mandatory prior to practice training. Practice training could be conducted through intern courses in already existing hydro storage systems, as well as photovoltaic or wind turbine systems. Considering the

knowledge and expertise gap between coal workers and workers in the related HPHS industries, these steps are essential to bridge this gap. The required education and training for the upskilling of coal workers could be carried out either by EU or national funded programs, by governmental programs, or even by the involved industries themselves (RES-SKILL Project, 2020-2023).



## 5 Territorial impact assessment

Working Package 4.1 of the POTENTIALS Project on the business model choices justification has identified, among several prequalified alternatives, eco-industrial parks as the most appropriate and exciting business model choice for the considered areas. To select the most suitable and feasible action for the specific areas, the following aspects have been considered: Green Deal policies, technical criteria, Technology Readiness Level (TRL), European taxonomy, synergistic potential, circular economy and sector coupling. The conclusion of the previous chapter is that eco-industrial parks are the best action under examination to accomplish an integrated alternative for sustainable electricity generation technologies and circular economy issues. The main objective of such eco-industrial parks on former coal mining areas along with closely related neighboring industries is to provide sustainable energy generation technologies. These are able to comprise solar and wind energy production with energy storage and geothermal energy for cooling/heating to the companies /industries participating in the eco-industrial park, thereby reducing waste and pollution by promoting short-distance transport and optimizing material, resource and energy flows within the industrial parks. This concept may be complemented with a green hydrogen plant, if certain economic conditions are given. Sometimes there are territorial development plans that condition specific industrial development in the areas.

As represented, the project approach and the description of the most favorable action include already some special, self-explanatory territorial aspects. Beside these internal territorial aspects there are external territorial impacts for the economic, social and ecologic environment of the respective location and outside in the affiliated region. These aspects have to be made an object of a comprehensive Territorial Impact Assessment (TIA) before taking definite political and commercial decisions.

In the words of Edurado Medeiros, one of the protagonist of Territorial Impact Assessments in the European scientific sphere and editor of the one and only handbook on this subject: “Territorial impact Assessment (TIA) is a relatively ‘new kid on the block’ of policy evaluation”. Resting upon the holistic notion of territory, which encompasses multiple analytic dimensions (economy, society, environment, government, spatial planning), TIA is the most complex, yet with the policy evaluation procedure, the largest potential to assess projects, programs and policies” (Medeiros 2020).

A TIA may be helpful and is even necessary to fulfill the official claim of the European Court of Auditors (ECA) in its Special Report on EU support to coal regions (ECA 2022). The ECA Special Report provides an insight into the role of EU cohesion funds for the period 2014-2020 in the socio-economic and energy transitions in regions where the coal industry has been in decline. In this period the EU cohesion policy funds have been provided 12,5 billion euros to support the socio-economic and energy transition of seven audited European coal regions (in Poland: Malopolska and Silesia, Spain: Asturias and

Palencia and Leon, Germany: Lusatia, Czech Republic: Moravian Silesia, Romania: Jiu Valley). The central conclusion of this report is that the regional support in the time regarded “achieved little for climate transition” and had only “limited focus and impact on job creation and energy transition and that, despite overall progress, coal remains a significant source of greenhouse gas emissions in some Member States” (ECA 2022). Although the reduction in coal production inevitably led to a drop in the number of workers in the sector and EU-funded training was available to laid-off workers, the lack of data on their participation “meant that the auditors could not determine whether his helped them to find new jobs. Nor did the auditors observe any significant impact on renewable energy production capacity in the regions they examined.” Because the Just Transition Fund created in 2021 alone makes 19.3 billion euros available over the 2021-2027 period to regions and sectors most affected by the politically aspired transition to climate neutrality the auditors of the ECA, “therefore call for the new Just Transition Fund to be used effectively and efficiently to alleviate the socio-economic impact on coal regions” (ECA 2022). The European Commission has generally welcomed the ECA’s Special Report and accepted its recommendations.

Hence, the intended contribution of the POTENTIALS project to the mechanism and the measures of the Just Transition Fund (JTF) and especially the TIA concept in this project should concentrate on these claims.

European and national legislations, directives, policies as well as all the special projects based on these political measures have different effects on territories, depending on their geographical and environmental characteristics, their history, culture, demographic and socio-economic development. Territorial Impact Assessment (TIA) aims to better understand these differences and support evidence-based policy and decision making. Since the adoption of the European Spatial Planning Document (ESPD) in 1999 and the acknowledgement of Territorial Cohesion, as a general EU objective in the Lisbon Treaty 2007, TIA gained more and more attention. This led to different understandings and various approaches to TIA.

The study of Gaugitsch et al., in order of the European Committee of the Regions/Commission for Territorial Cohesion Policy and EU Budget (COTER) on the State of the art and challenges ahead for Territorial Impact Assessment (Gaugitsch et al. 2020), adopts a broad understanding of TIA and includes any methodology designed to assess territorial effects of legislations, policies and directives. This can be modelling tools using quantitative methodologies as wells as rather qualitative methodologies using expert judgements and participatory approaches and mixes of these tools. The file note of Gaugitsch et al. discussed selected TIA methodologies with the aim to further develop the assessment approaches possibilities to assess territorial impacts. There is also included a comparison with alternatives (or eventually supplementing) as Cost Benefits Analyses (CBA) or Enriched Environmental Assessments (EIA), Enriched Regulatory Impact Assessments (RIA) or Sustainable Development Impact Assessments (SDIA) and

other territorial foresight approaches. The selected variety shows the main advantages and limitations of TIA methodologies. After review, there are three main methodologies currently used at EU level for ex-post assessments (LUISA and RHOMOLO) and other TIA methodologies more useful for an ex-ante approach, as ESPON TEQUILA, ESPON QUICK CHECK or ESPON EATIA together with a discussion of main obstacles and main opportunities. Each tool is consistent with the EU Guidelines concerning Impact assessment (SEC(2009)92) and has specific characteristics and consequently different scopes of applications. Besides the use of distinctive methodologies or instruments, several European countries introduced strategies and guidelines to encourage assessing territorial impacts during policymaking processes and project development. Even while or after the policy making phase at the EU level has been completed, a TIA can explore the potential impacts of choices made during implementation at the national and regional level (Gaugitsch et al. 2020), as it is the case with the Just Transition Mechanism for the transition of the European coal regions and affected their locations. All these approaches have produced a useful richness of experiences and lessons learnt.

A prominent younger and very extensive example for a TIA is the Territorial Impact Assessment on Climate Targets of the European Committee of Regions in 2021 (COR 2021). It is not part of this report to discuss this kind of TIA, using the ESPON QUICK CHECK method for the assessment of selected economic and ecologic aspects in detail. Still, there have been some general conclusions that are of some relevance for the coal transition and the POTENTIALS project: Multi-level governance determines failure and success in climate action; winning and losing regions by the climate targets of the European Green Deal are not the same (coal regions are losing if not targeted and sufficiently supported in their transition); and distributing of know-how and funding among relevant actors is an important critical factor in this context.

## 5.1 TIA by the TEQUILA approach

Against this background, we propose a modified TEQUILA approach for this Deliverable of the POTENTIALS project as TIA. All possible methods highlight different challenges and solutions for TIA related to comprehensiveness, participatory approaches, data challenges and time perspectives of TIA. At the same time, TIA methodologies have to echoing the grown political and societal interest in the use of a more broad and holistic policy and project evaluation methods to assess the main impacts at all territorial levels. This is necessary to fulfill the ultimate goal aiming at promoting, directly and/or indirectly, positive territorial development trends and, ideally, territorial cohesion processes (Medeiros 2020).

The name TEQUILA is the acronym for *Territorial Efficiency, Quality and Identity Layer Assessment* and this approach aims to evaluate ex-ante the efficiency of a given European policy and the measures based on it to improve territorial cohesion, encompassing impacts across regions in terms of the economic competitiveness,

environment and climate change, land-use and society. The methodology has been tested with regards to the Common Agriculture Policy and the Common Transport Policy. A multicriteria analysis and, if available, forecast models or specific scientific-based examinations in combination with statistical values for comparison and aggregation serve as basis, by defining the most relevant indicators that help to measure the territorial impacts.

TEQUILA is the pioneering quantitative model for TIA, developed by Roberto Camagni, on the request for building an operational model for the ex-ante assessment of the territorial impact of EU policies, projects and regulations. It had been addressed by Camagni originally and directly to the ESPON (European Space Observatory Network) managing authority (Camagni 2020).

He proposed a rationale and definition of what could be intended as TIA. A prototype model and the connected software was built and applied the first time to the TEN (Trans-European Network) program in 2004-2006 on the level of attached NUTS3 regions in the EU. The convincing results achieved were followed by subsequent new and deeper studies, where the model was improved, simplified and implemented on EU transport and Agricultural Policies and at some EU directives in the environmental fields. TEQUILA is a multi-criteria model working on a quantitative base; however, it integrates in a statistically consistent way qualitative judgements by experts, when and wherever necessary (Camagni 2020).

The core of the TEQUILA approach are three summative macro-criteria (weighted by political preferences obtained from stated preference surveys among experts). These macro-criteria can be defined as the following: territorial efficiency, territorial quality and territorial identity (all adding up to the concept of territorial cohesion as the output for policy evaluation):

- *Territorial efficiency* refers to resource-efficiency with respect to energy, land and natural resources; competitiveness and attractiveness; internal and external accessibility of each territory.
- *Territorial quality* refers to the quality of living and working environment (including ecological aspects); living standards across territories; access to services of general interest, to knowledge and other resources.
- *Territorial identity* refers to enhancing “social capital”: developing a shared vision of the future; safeguarding local specificities, strengthening productive vocations and competitive advantages of each territory.

Given the differentiated nature of geographic territories, a generalized assessment of the impact of policies or projects on the overall EU territory does not make much sense.

On the other hand, a truly territorial assessment looking upon the specificities of a single region or areas would be much more interesting and even crucial if it is able to take into consideration the following insights (Camagni 2020):

- The *intensity* of the policy (or project) application may be different in the different regions, or even nul.
- Its territorial *impact* is likely to be different on the different regions, given their geographical and socio-economic specificities.
- The importance of the single criteria in the assessment methodology is likely to be different in various regions: different development stages, different histories and cultures, different shared values would determine different views concerning the relative relevance of impacts on growth, on environment, on social wellbeing, on competitiveness.

Therefore, a regionalized territorial impact model has been built for the assessment of policies, programs, projects and integrated schemes, keeping in mind the request for simplicity, operationality and transparency. In the case of quantitative assessment, the central formula is (Camagni 2020):

$$TIM_r = \sum_c W_c \times PIM_{r,c} \times S_{r,c}$$

where

TIM = *territorial impact* (total or for each dimension: territorial efficiency, quality, identity)

r = region, c = criterion or sub-criterion in the multicriteria analysis

$PIM_{r,c}$  = *potential impact* of policy or project (abstract) on region r and criterion c

$W_c$  = *weight of the criterion/subcriterion* c with  $0 \leq W_c \leq 1$ ;  $\sum_c W_c = 1$ .

$S_{r,c}$  = *sensitivity* of region r to criterion/sub-criterion c.

As Camagnis has explained, the rationale for the previous equation comes from traditional risk assessment procedure, where *risk* = hazard (= potential risk) x *vulnerability*. Similarly, the territorial impact is seen as the product of a *potential impact* (PIM) times a *sensitivity* indicator S, expressing the specificity of the region or the area and its preferences. Therefore,  $S_{r,c}$  is a set of regional or local characteristics, defining two main elements: the desirability D of the dimension/criterion in single regions/areas (technically: the territorial “utility function” indicating local preferences, measured by socio-economic indicators) and vulnerability V to impact (mainly geographic indicators):

$$S_{r,c} = D_{r,c} \times V_{r,c}$$

where

$D_{r,c}$  = desirability of criterion c for region r

$V_{r,c}$  = vulnerability of region r to impact on criterion c

The potential impact PIM is calculated through appropriate external quantitative models defining impacts on each criterion c and each region r, duly normalized as indicated above. D and V are designed as coefficients scaling up and down respectively the weight  $W_c$  and the  $PIM_{r,c}$  of a given maximum percentage. The quantitative indicators to be used for the *desirability* regional coefficient, e.g. a regional GDP effect, are in general the same used for impact, in their status form and not in their change consequent to the policy or project implementation. The *vulnerability* coefficient is mainly present in the environmental (or specific socio-economic) dimension/criteria and request ad-hoc indicators.

Regional receptivity (in case of positive effects of the policy or the project) could be quantified linking it to the quality of government or the project management, and utilized in case it is explicitly considered a plus in the allocation of funds; or due to experience it is set to 1 (neutral role).

The proposed “summative” evaluation procedure by the TEQUILA methodology (totally quantitative, totally qualitative or mixed) implies allowing compensation among criteria, namely those lower or even negative scores in one criterion may be compensated by higher or positive scores in another. Because this condition is not always socially accepted or acceptable, non-compensatory multi-criteria approaches have also been developed (Camagni 2020) - That demonstrates the already proven flexibility and modifiability of the TEQUILA methodology.

The TEQUILA methodology fulfills all requirements to develop an operational methodology for TIA set up by ESPON for ESDP and European cohesion policy, consistent with the guideline issued by the European Commission on the subject (Camagni 2020):

- To build an operational methodology for ex-ante impact assessment based on rigorous economic logic
- To be used for assessment of any EU policy, program, regulation or integrated projects with territorial impact
- Working at different geographical scales (from the EU as a whole supranational community about Nuts regions to local territories)
- Able to handle both quantitative measures and qualitative judgements

- Easy to build and operate, understandable by policy makers and the interested public
- Interactive, in order to be used in public meetings.

The TEQUILA methodology is rather comprehensive in assessing different perspectives of territorial cohesion. It uses predominantly statistical calculations and professional judgements performed by external researchers. Although this provides detailed results, the outcomes are not always easy to interpret by policy makers and by the public in particular due to the use of normalized scales and the summative macro-criteria (Gaugitsch et al. 2020).

Therefore, it is possible that further deliberations are necessary to simplify this approach for the political manageability of project plans.

In synthesis, the TEQUILA model introduces and applies itself a tailor-made version of a consolidated methodology, namely Multi-Criteria Analysis in its simplest forms, able to build in both an analytical and synthetic (“summative”) form of an ex-ante territorial impact assessment of EU policies, programs, measures or projects on European regions. Its flexibility, simplicity and transparency allows a utilization for differentiated policies or projects, utilizing at best the present availability of quantitative policy assessment studies in specific fields and integrating (or being substituted by that if necessary) in a consistent way qualitative expert judgements. It requires sometimes a bit of fantasy in connection with deeper sectoral and regional context, in order to devise the appropriate indicators, especially for the quality or immaterial dimensions of the territorial realm (Camagni 2020).

TEQUILA is particularly designed and equipped for comparative analyses and assessments of impacts of policy interventions and policy-supported projects, when the interest of administrations - from the European to the regional level – is “to have a picture at a glance” on relative impacts, both specific and summative, on a wide array of regions or for the selection of one project or more with different alternatives and territorial implications (Camagni 2020).

Gaugitsch et al. present the following factsheet on the main characteristics of the hitherto used TEQUILA models of ESPON including their demonstrated advantages and disadvantages (representation selected), as presented in Table 5-1.

**Table 5-1. Representation of the main characteristics of TEQUILA model after Gaugitsch et al.**

<b>Main characteristics</b>	<b>TEQUILA model</b>
<b>Intention</b>	The intention is to assess the efficiency of a given European policy (including measures based on it) to improve territorial cohesion, encompassing impacts across regions in terms of the economic competitiveness, environment and climate change, land-use and society.
<b>Main approach</b>	The general methodology – namely a Multi-Criteria Analysis – and the criteria taken into consideration for calculating the territorial impacts were consistent with the EU Guidelines concerning Impact assessment. The method is quantitative, integrating both quantitative assessment by forecast models (or scientific examinations) and qualitative assessment by expert opinion. Values can be normalized to 0-1 scale by different types of functions. Thresholds are to identify and to indicate values in a given indicator so poor not to be compensated by other indicators. Three “summative” macro-criteria (weighted by political preferences obtained e.g. from stated-preferences surveys) were defined, namely: territorial efficiency, territorial quality, and territorial identity all adding up to the concept territorial cohesion).
<b>Assessment method</b>	The territorial impact (TIM) is generally defined as $TIM = PIM \times D \times V$ , namely the product of a potential impact (PIM) (defined by each region using statistical indicators, forecast models or other evaluations) times an indicator of Desirability – D (in order to take into account the fact that, for example, a similar growth in employment has a different priority in advanced or lagging or otherwise problematic regions) times an indicator of Vulnerability – V (in order to take into consideration, for instance, of the higher vulnerability of urban areas to pollution or of natural areas to landscape fragmentation or of other challenges for the environment).
<b>Thematic fields covered</b>	All fields are covered since the assessment is comprehensive impacts on the economy and competitiveness impacts on environment and climate change impacts on society, on landscape and local identity TEQUILA was applied before for TIAs in Agriculture policies and Transport Policies in the ESPON TEQUILA project with data used from specialized databases and modelling tools by specialized research institutions for these fields (but it is in no way restricted to these thematic fields).



<b>Timing</b>	Ex-ante
<b>Advantages</b>	<p>The TEQUILA method includes all dimensions needed to assess the improvement of European territorial cohesion generated by a given policy, and then facilitates a comprehensive political discussion in relation how efficient it is in this respect.</p> <p>Transparent aggregation procedure of the method (possible) that can relatively easy be understood by decision makers and other stakeholders. The difference between scientific assessment of indicators and political choice of criteria and preferences among them is clear.</p>
<b>Disadvantages</b>	<p>Data scarcity and conceptual may produce controversial results ambiguity (as in all ex-ante methods) that are especially highlighted when displaying results in maps. Integrating results in graphics and aggregated by types of regions could reduce this possible disadvantage.</p> <p>Difficulty to use it on an ex-post evaluation mode. Can hardly be applied to assess territorial impacts of EU policies after their completion (this is not its genuine purpose because it is an ex-ante approach).</p>

## 5.2 A modified TEQUILA approach for the TIA in the POTENTIALS project

For the purpose of the TIA in the POTENTIALS project, a modified TEQUILA approach is presented. After intensive discussions, it has been concluded to develop a pragmatic tool that is as simple, applicable and employable as possible for deciders and stakeholders finally yet importantly for its integrability in Territorial Just Transition Plans. This approach will be supplemented by a special analysis of indicators for jobs created in supported entities.

Of course, in any way, the central idea and basic framework of the TEQUILA methodology, namely the division of the three dimensions of territorial cohesion by the above introduced macro-criteria territorial efficiency, territorial quality and territorial identity have to be implemented. They are represented by the weights  $W_c$  in the formula  $TIMr_c = \sum c \times W_c \times PIMr_{,c} \times Sr_{,c}$  and get all the same weight of one third (33%) or as a number in the formula; 0,333. This formula is in accordance with the most examples of the TEQUILA methodology in practice (Camagni 2020) and reflects the politically and societally acknowledged equality of these three dimensions for the territorial cohesion. Theoretically, it is readily possible to change these weights and give a different weight to certain macro-criteria due to political priorities.

More discussion has been necessary about the sub-components, respectively sub-criteria, of each macro-criteria of the assessment model. The sub-criteria represent the

different and measurable aspects relevant for the assessment and by that for the intensity of the impacts or, in other term, for the Sensitivity component of the formula Sr,c. The selection of the sub-criteria and the numbers given for them representing the weights assigned to single sub-criteria are the most sensitive elements in a multi-criteria analysis. They may be defined in multiple ways: through internal discussion among experts, through open discussions with policy makers and stakeholders, through Delphi procedures. Inside the model, the weights should be flexible in order to guarantee interactivity and, in all cases, they have to be perfectly transparent. Tests with changing weights allow the assessment of the sensitivity and stability of the outcome (Camagni 2020).

At first, the experts of the POTENTIALS project partners have set up an extensive list of 17 “direct result indicators” for the relevant scenario outputs. In further discussions about the application on the TIA, this list of indicators has been condensed to the measurable sub-criteria of the TEQUILA approach and affiliated sub-weights by expert judgements.

These collected sub-criteria and their sub-weights representing the Sensitivity component are a proposal and can be changed without a methodological problem by planning institutions, policy makers, stakeholders or alternative expert judgements in interactive meetings if new or better insights in the specific regional and territorial project circumstances are speaking for another selection, assignment and weighting.

As consequence of the deepened internal expert discussion and deliberation of the mentioned list of direct result indicators, some of the highlighted (sub-)criteria as “energy security degree”, “increased competitiveness of the region” and “potential to stimulate other business activities” are evaluated as pre-qualifications for the considered actions/micro-actions in the project. They are all designated to bring new energy production and business activity to locations with already end-of-life coal mine sites and coal-fired power plants. Other indicators as “energy efficiency” are not specific enough for the project and territorial impact or can be used as measurements of other sub-criteria as “patent applications to EPO” (European Patent Office) for innovations. Hence, in each case four sub-criteria remain for the three macro-criteria appropriately explained in the following way:

#### Territorial quality

- *Estimated low GHG emissions during the lifetime of the applied technology:* Because it is the aim of all projects connected to the European Green Deal (and so the POTENTIALS project) to pave the way to climate neutrality in the European Union and its territories, it is evident that the reduction of GHG emissions, measured in tons of CO<sub>2</sub> equivalent, is now a must-have and a very weighty criteria for territorial quality; metered sub-weight 0,4.

- *Reduction of (other) environmental impact:* The territorial quality reflected by aspects of the environment is not restricted to GHG emissions, but has to recognize all other environmental impacts of an action to the territory outside the location, especially in the context of environmental Life Cycle Assessments (LCA); it may be concentrated in this context on the pollution of air and water because other environmental aspects are recorded by other sub-criteria and can be measured by officially available indicators. It has to be taken into account that former coal activities had already to be in accordance to European legal standards for the environmental impact; metered sub-weight 0,2.
- *Environmental impact at the place of operation:* Environmental impacts are not restricted to the territory outside of the location but could happen also at the place of operation. This is especially the case for soil at the place and corresponding indicators; metered sub-weight 0,2.
- *Quality of offered services within the project, especially stability of energy supply.* Beside the environmental dimensions, the territorial quality is determined by the quality of offered services for the stability of energy supply. Above all, in case of the contribution to stability of the power supply for the surrounding industrial and/or residential areas, this could be measured by the specific SAIDI (System Average Interruption Duration Index); metered sub-weight 0,2.

#### Territorial identity

- *Capacity of renewable energy production:* A central question for the territorial identity of a former energy producing area as an area of (end-of-life) coal mining and coal power generation is certainly the question of the capacity of new energy production by renewable energies, measured by the power generation capacity in MW (Megawatt). It must be taken into account that the new capacity of more sustainable energy production on the same territory will be lower than the old capacity of coal energy because of the lower energy density of renewable energies as wind and solar power; metered sub-weight 0,3.
- *Energy users connected to the smart grid:* It is of similar importance for the territorial identity (as the capacity of renewable energy production) as an area of energy production how many energy users and their magnitude are connected to the smart grid by the new operations and their services to the grid; metered sub-weight 0,2.
- *New Jobs created by the operation (full-time employment):* Fundamentally important for the territorial identity and the subject of territorial cohesion in the affected region of closed coal mines and power plants is how many new jobs are

created by the new operations at the location, measured in full-time equivalents; metered sub-weight 0,4. (For a detailed view on how to count appropriately, the number of jobs created by supported entities see the special analysis in the next paragraph).

- *New (full-time) researchers:* Beside the new jobs in the (commercial) operations for energy production and services, the application of new and innovative technologies will require research and development and thereby establishing some new specific job opportunities for researchers that should be recorded separately because of their special quality, but measured also in full-time equivalents; metered sub-weight 0,1.

At least, for assessing the potential impacts of all sub-criteria in the region/territory, the component  $PIM_{r,c}$ , in the TIM formula  $TIM_r = \sum c \times W_c \times PIM_{r,c} \times S_{r,c}$ , by impact values, it is necessary to transform the presumed impact of each sub-criteria in value scores normalized on a common interval through a value function that should for practical purposes be assumed to be linear. The value scores are determined by expert judgements or the same assessment procedures as used for the weighting of the sub-criteria. Mostly applied in the TEQUILA methodology and also proposed here is an ad hoc scaling with defining a relatively simple scale, for example, and used in an interval between value scores of 0-5, which is easier to manage in operational terms and is only introducing a slightly higher level of subjectivity in the procedure as more complex scaling methods (Camagni 2020).

Against this background, an impact scale for the assessment of impact value scores for  $PIM_r$  in the interval 0-5, expressing impacts of the meaning, is stimulated here.

- |   |                     |
|---|---------------------|
| 0 | <i>no</i>           |
| 1 | <i>low</i>          |
| 2 | <i>medium-low</i>   |
| 3 | <i>medium</i>       |
| 4 | <i>medium-high</i>  |
| 5 | <i>high impact.</i> |

The higher the value score, the higher the quantified positive impact on the respective dimension of territorial cohesion. The sum  $TIM_r$  of all weighted value scores (by macro-criteria times sub-criteria) represents the whole (positive) impact on territorial cohesion. This can be also be considered in a differentiated way at each of the three dimensions: territorial efficiency, quality and identity in dependence of the selected sub-criteria. Of course, the collection of sub-criteria is tailor-made for the TIA purpose of the project and guided by political priorities, but this is done in a fully transparent and understandable modus operandi and open to sensitivity analysis of each component of the result. Taking all explained elements of the Territorial Impact Assessment by our

modified TEQUILA approach together, we get the TIA matrix presented in Table 5-2 for any action.

**Table 5-2. TIA matrix based on the research results.**

Macro-criteria/ Sub-criteria	Weight (macro-criteria)	Sub-weight (Sub-criteria)	Value Scores of sub-criteria 0-5 (PIM <sub>r,c</sub> )	TIM of sub-criteria (TIM <sub>c</sub> )
<b><i>Territorial Efficiency</i></b>	0,333			
Value Added		0,4		
Process/Product Innovations		0,3		
Recycled waste		0,2		
Space required		0,1		
<b><i>Territorial Quality</i></b>	0,333			
Lower GHG emissions		0,4		
Reduction of other environmental impacts outside the location		0,2		
Reduction of environmental impacts at the place of operation		0,2		
Quality of offered services		0,2		
<b><i>Territorial Identity</i></b>	0,333			
Capacity of renewable energy production		0,3		
Energy users connected to the smart grid		0,2		
Employment (number of jobs by the operation)		0,4		
New jobs for researchers		0,1		
<b>Summary TIM<sub>r,c</sub></b>				

After completion of this conceptual preparatory work, a demonstration of the application of a TIM via the proposed modified TEQUILA approach follows. Hereby, two examples of the scenario business models identified in the POTENTIAL project, both focusing on the model of the eco-industrial park. One example is combined with hydrogen production (Example A) and the other example is combined with biofuels production (Example B).

Here, the value scoring has been made consensually by a small circle of experts - and therefore using rounded numbers for the scores (and not averages or means) – **only for the purpose of exemplification and comparison in abstract cases**. These are **no definite**

assessments representative for the POTENTIAL project partners, because the recommendation is to do these assessments respectively to the value scoring for real projects in Just Transition Plans by the political and commercial deciders and their stakeholders in the concerning region. Besides that, it is essential to know all concrete conditions, specific circumstances and details of the plan at target locations (Table 5-3).

**Table 5-3. Example A – Eco-industrial Park with Green H2 plant**

Macro-criteria/ Sub-criteria	Weight (Macro-criteria)	Sub-weight (Sub-criteria)	Value scores of sub-criteria 0-5 (PIM <sub>r,c</sub> )
<b><i>Territorial Efficiency</i></b>	0,333		
Value Added		0,4	3
Process/Product Innovations		0,3	4
Recycled waste		0,2	1
Space required		0,1	3
<b><i>Territorial Quality</i></b>	0,333		
Lower GHG emissions		0,4	3
Reduction of other environmental impacts outside the location		0,2	5
Reduction of environmental impacts at the place of operation		0,2	5
Quality of offered services		0,2	3
<b><i>Territorial Identity</i></b>	0,333		
Capacity of renewable energy production		0,3	3
Energy users connected to the smart grid		0,2	1
Employment (number of jobs by the operation)		0,4	3
New jobs for researchers		0,1	2
<b>Total TIM<sub>r,c</sub></b>			<b>3,24</b>

The same procedure is done in the second example to get comparable TIM values. In this context, it is important to remember that the value scoring has been done by a small group of experts and is quite subjective and not representative for all POTENTIALS project partners (Table 5-4).

**Table 5-4. Example B – Eco-industrial Park with Biofuels production**

Macro-criteria/ Sub-criteria	Weight (Macro-criteria)	Sub-weight (Sub-criteria)	Value scores of sub-criteria 0-5 (PIM <sub>r,c</sub> )	TIM of sub-criteria (TIM <sub>c</sub> )
<b><i>Territorial Efficiency</i></b>	0,333			
Value Added		0,4	2	0,27
Process/Product Innovations		0,3	4	0,40
Recycled waste		0,2	1	0,07
Space required		0,1	2	0,07
<b><i>Territorial Quality</i></b>	0,333			
Lower GHG emissions		0,4	2	0,27
Reduction of other environmental impacts outside the location		0,2	3	0,20
Reduction of environmental impacts at the place of operation		0,2	4	0,27
Quality of offered services		0,2	3	0,20
<b><i>Territorial Identity</i></b>	0,333			
Capacity of renewable energy production		0,3	4	0,40
Energy users connected to the smart grid		0,2	1	0,07
Employment (number of jobs by the operation)		0,4	4	0,53
New jobs for researchers		0,1	3	0,10
<b>Total TIM<sub>r,c</sub></b>				<b>2,85</b>

Due to the value scores in these examples, the positive territorial impact (TIM<sub>r,c</sub>) and therefore the contribution to territorial cohesion is considerably higher in Example A (Eco-industrial Park with Green H<sub>2</sub> plant) with a total value score 3,42; than in Example B (Eco-industrial Park with Biofuels production) with a total value score 2,85.

The difference of 0,39 TIM score points in this TEQUILA model is composed by varying differences of the three dimensions what can be shown by direct comparison of the TIM in each macro-criteria (Table 5-5).

**Table 5-5. Comparison of the macro-criteria of the two TIM**

	Example A (Eco-Industrial Park with Green H <sub>2</sub> plant)	Example B (Eco-Industrial Park with Biofuels production)	Difference of TIM in each macro-criteria
Territorial efficiency	1,14	0,81	0,23
Territorial quality	1,26	0,94	0,32
Territorial identity	0,84	1,10	-0,26
Total TIM	3,24	2,85	0,39

By this comparison, we see the largest difference at the dimension Territorial Quality and the smallest difference at the dimension Territorial Identity (with the dimension Territorial Quality quite exactly in the middle).

Such an approach allows comparisons of all elements and at the same time professional discussion, from the selection of the sub-criteria and their sub-weights to the value scoring.

Of course, in this abstract, a comparison of the two examples has not taken into account if there is a site with neighboring industries having a relatively high demand of hydrogen and a low demand of biofuels. It is also accountable for factors, such as a local/regional industrial demand structure or very special circumstances and requirements of the infrastructure favoring the one or the other option what naturally would make a crucial difference in the assessment. This underlines the argument that the Territorial Impact Assessment of actions and projects as in the POTENTIAL project must be site-specific and the results depend less on the methodology, but on the conditions in reality.

Because of these results, every TIA approach and the modified TEQUILA model developed, presented and recommended here should be accompanied by a thorough inventory of the local/regional conditions and influencing factors as well as special investigations of critical factors. As the challenge of (more or less) unemployment and the creation of new jobs is a very critical factor in the general political and societal assessment of the coal transition in Europe, but is appearing in the TEQUILA model only as a sub-criterion, the elaboration of the Territorial Impact Assessment is supplemented by a special analysis of indicators for jobs created in supported entities.

### **5.3 Evaluation of jobs created in supported entities from structural funds**

For a holistic view of the object of investigation, according to the present deliverable and to complete the TIA approach, a possible approach for the evaluation of employment effects using structural fund measures is following. For this purpose, the



authors use above all the evaluation already presented by the EU itself with the associated methodology for a possible assessment of growth on the labor market.

Structural Funds, in turn, can play a key role here in the detailed consideration and analysis with regard to the employment factor. On the one hand, they create an effect on employment, so that emigration can be reduced by implementing appropriate countermeasures. On the other hand, depending on employment, it can also have a positive impact on the environment and boost GDP per capita. Even if other effects also come into play, the pure creation of new jobs is one of the top priorities. In general, a decision can be made between different employment effects, with the effects listed below having the greatest influence.

1. **Creation of new jobs (direct result):** These jobs are mainly temporary employment opportunities, such as for the necessary expansion of infrastructure through construction work or projects aimed at further training. Accordingly, the figures for depicting this form of jobs in person-years must be titled and the time limit must be made clear.
2. **Creation of new or conversion of existing jobs (direct consequence):** These jobs are created as a direct consequence of supporting measures from Structural Funds, such as for an SME (small and medium-sized enterprise). This potential therefore has a particularly positive effect on those who are involved in the measures.
3. **Creation of new or conversion of existing jobs (indirect consequence):** These jobs are also created because of corresponding Structural Fund measures, albeit only indirectly. This means, among other things, efforts to optimize infrastructure by expanding it, such as in the case of tourist attractions. Because of the improvement of this specific infrastructure, in the example (tourist attractions), for example, the waiting time is reduced due to increased vehicle use and a shorter overall travel time. As a result, a generally higher number of customers can then also be expected. This can be beneficial for the economic profitability of regions, especially during the vacation and holiday season, and this in turn can lead to an increase in employment due to the factors mentioned above.

For all forms of employment just mentioned, however, it is true that a realistic representation of employment is only possible if both **deadweight effects and relocation effects** are taken into account. Because these in turn influence the overall employment effect, so that it is weakened and corrected downwards. In the individual consideration, it becomes clear what can be understood by this: Individual measures or policies have to deliberately address targeted groups, such as the long-term unemployed. The higher the displacement effect to be generated here, the lower the

unemployment rate can be. Still, this is more of a substitution effect (sub-form of the relocation effect) and not the creation of new, previously non-existent jobs. In this respect, a differentiated view must be taken in. Therefore, the **deadweight effect** refers to those factors and impacts that would have arisen even without a measure or program. For this reason, they must not be included in the job evaluation in relation to new creation or conversion. The **relocation effect**, on the other hand, describes the fact that no new jobs are created when a measure is implemented, but existing ones merely adapt and change. This reduces the gross employment effect and must be deducted when considering possible effects because of Structural Fund measures.

In order to generate the creation of jobs in the long term, the evaluation of employment effects must be as precise as possible. At the beginning, it is sometimes easiest to depict the respective gross effects for the first comparison of data. However, this should only be done for the first step and for a better overview. As a result, the exact effects of the measures must be calculated, taking into account the deadweight effects and the relocation effects of the costs per workplace. Another important point is a transparent insight into the methods used to evaluate the numbers, because it should also be possible to recalculate and correct them afterwards, if necessary (MEN-D 2023).

*“In addition to quantifying the employment effect, it should be noted that the estimates of the program monitoring, the **interim or ex-post evaluation** must be verifiable (MEN-D 2023)”.*

It should be mentioned, that an **interim evaluation** is carried out while the measure is still ongoing and, if necessary, can provide information about needed changes and adjustments. The **ex-post evaluation** takes place long after the measure has been completed. The aim of this is to observe the effects that result from the measure and thus possibly make any necessary corrections to the calculated employment effects (MEN-D 2023).

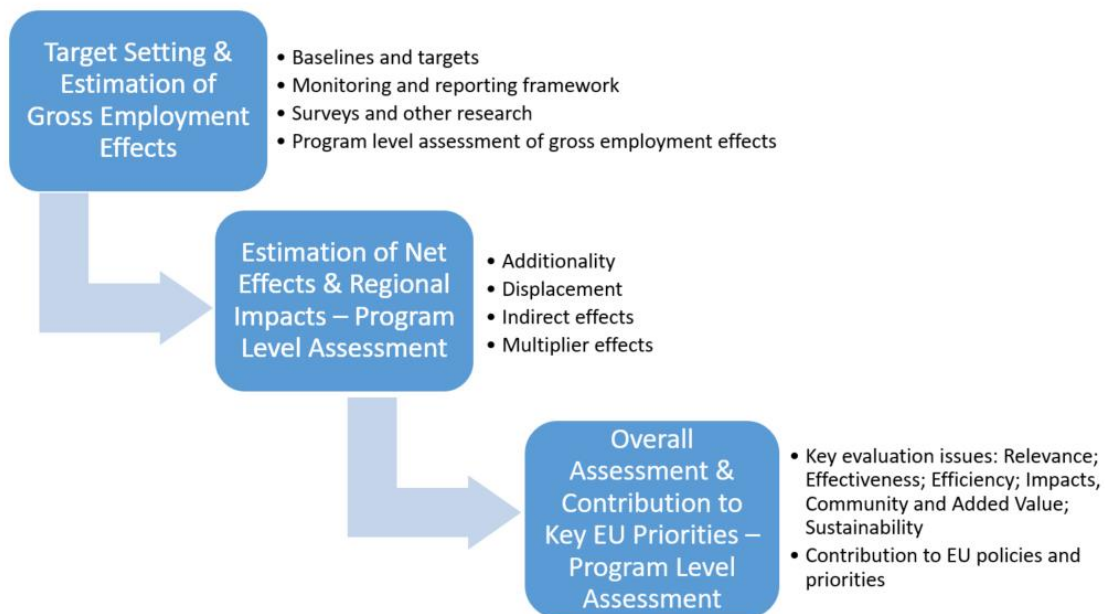
Based on the definitions made as a basis for further action, reference can now be made to the recommended approach for assessing employment effects by the **EU's MEANS manual No. 6** “Evaluating the contribution of Structural Funds to employment“, which specifies the current procedure, can be referred to here (MEN-D 2023; European Commission 2007). Accordingly, the authors (MEN-D 2023) summarize the standardized and recommended approach by the EU as follows:

- The measures of the funds serve as a starting point for measuring employment effects, whereby both the gross and the net employment figures should be taken into account. Furthermore, as already noted, a distinction must be made between newly created and merely converted jobs (due to the relocation effect).
- With regard to the gross employment effect, it should be noted that this is based on estimated values, which in turn are to be determined on the basis of the

material target values to be assumed. The general gain in employment is therefore also an estimated value, which is determined on the basis of previous experience and available results.

- In the case of the net employment value, on the other hand, the possible effects with regard to relocation, multiplication and deadweight must be taken into account as a matter of priority in addition to existing reports of experience.
- Regardless of which calculations and estimated values are involved, the precise composition of these must be disclosed in a transparent manner. In particular, if it is the case that effects (e.g. deadweight or relocation) could be identified, explanations are required. Accordingly, the underlying and used economic models for the calculations must also be explained. Finally yet importantly, when evaluating the impact of measures, it may not be primarily about direct employment effects, but rather about an increase in other factors that can ultimately contribute to an increase in these effects, too (e.g. tourism). An estimate of the change in possible employment effects should then still be made (MEN-D 2023; European Commission 2007).

A basic overview of the previously presented influencing factors for employment effects as well as the recommended procedure for an evaluation can also be found summarized in Figure 5-1 (based on European Commission 2007).



**Figure 5-1. Methodology in evaluating Structural Funds for Employment Effects (based on European Commission 2007)**

In addition to the steps already presented for the standard methodology in determining employment effects, the figure provides further necessary information and supplements:

In the *first step “Target Setting & Estimation of Gross Employment Effects”*, the Commission describes how to determine the respective starting values right at the start of a new program or measure. These help significantly to determine the associated employment effects, which means that this step should be carried out **ex-ante**, i.e. before the measure itself is implemented. For such an ex-ante assessment, several aspects must be taken into account: The starting point must be established from which the influencing factors for employment and unemployment take effect. Once the starting point has been determined, goals can be formulated. This is to ensure that the measure or program has a targeted and positive impact on employment. In addition, previous **cost-per-job data** can be useful to set new targets and calculate as realistically as possible.

In summary, this analysis of the planned program/measure serves to formulate a realistic objective for the assessment and creation of jobs, taking into account trends in unemployment and employment, but also the level of productivity and also geographical, sectoral and gender-specific distribution of jobs. Accordingly, it can be shown at the same time how many new potential jobs will be lost without carrying out the measure, although these jobs may be urgently needed for further regional development. This type of comparison of the added value to be generated is also called **counterfactual analysis**. It also makes sense to revisit this analysis carried out beforehand at a later point in time during the measure and to compare whether the initial calculations still seem feasible or whether an adjustment of the data is necessary.

During the measure, it is still important to carry out appropriate **monitoring** so that the objectives do not lose focus. It is helpful to set clear definitions and regulations that simplify data collection. On the other hand, it requires an authority to save and analyze data that arises in the course of the implementation of measures. By collecting and comparing this data on a regular basis, the achievement of targets is significantly increased. In this sense, previous Structural Funds have always supported the provision and implementation of such monitoring in the member states of the EU.

Another sub-point of the 3-step model according to the EU Commission are regular surveys, but also further research work on the effects of Structural Fund measures. The focus here is on assessing the quality, duration and type of structural funds. As a result, the influencing factors for determining the employment effects can be optimized. Despite the focus on the Structural Funds, it should not be forgotten that it could also make sense to include national programs depending on the situation, because these can have a supporting effect if necessary.

A last sub-step deals with the evaluation of the gross employment effects at the level of the program or measure. Because during the implementation as well as towards the end, **an assessment of the implemented objectives** should be made.

In addition to an evaluation of the monitoring data with regard to jobs created and their quality, this also includes the subdivision into age, gender and sector of the respective job. However, it also plays a role to what extent the jobs created are green jobs. The different existing effects of gross employment through the respective programs and priorities must be considered together and ultimately a comparison of the actual effects in combination with the goals set at the beginning must be made. This is the only way to make transparent which goals have been achieved and to what extent.

The *second step “Estimation of Net Effects & Regional Impacts – Program Level Assessment”* is a summary of the estimation of regional effects and the inclusion of net effects. Because it is not enough to only consider the gross effects, that would not be holistic. Accordingly, it should be supplemented by net effects and regional effects. In order to obtain this, the gross effects must be analyzed in their estimation with regard to several factors: **indirect effects, additionality and displacement**. Two types of measures are required for this: the use of external experts through appropriate input and the **formula for estimating net effects**:

$$\text{NET JOBS} = \text{GROSS JOBS} \times (1 - \text{DEADWEIGHT}) \times (1 - \text{DISPLACEMENT AND SUBSTITUTION}) \\ \times (1 + \text{SUPPLIER MULTIPLIER} + \text{INCOME MULTIPLIER}).$$

**Additionality** – Hidden behind this term is an evaluation of the direct correlation between the employment effects that can be determined and the Structural Fund measure. A distinction can be made here between three forms of additionality:

1. Absolute additionality: This form describes the case in which there would not have been any measurable employment effects without a corresponding Structural Fund measure.
2. Partial additionality: In this constellation, employment-promoting projects would have been continued even without corresponding measures from the Structural Funds, but the effects would have been significantly smaller and probably only became apparent much later.
3. No additionality – Deadweight: Here, the employment effects would clearly have occurred even without corresponding Structural Fund measures, since the necessary support for the continuation of projects would have been substituted from other sources.

Overall, it can be said with regard to the aspect of additionality that various methods can be used to evaluate which of the three forms is involved. For example, surveys can

be made and comprehensive feedback can be created. The point of criticism here is that it is possible to risk insufficient objectivity through preconceived opinions. Therefore, it is still advisable to draw a comparison between those groups that received support and those that did not. The difference between the two groups can then be used to draw conclusions about additionality. While the first method is much more common and may lead to distortions, the second method is much more accurate but also involves more costs. In this respect, it can be useful to see which measures have been rejected in advance. This is an indication that these would probably not have triggered any significant employment effects and that the previous projects do not need the support of these measures. Then the additionality can be classified here accordingly.

**Displacement** - This effect describes the success in favor of the existence of another eligible area. It is also about balancing positive employment effects against negative side effects due to displacement. On the other hand, there is **the substitution effect**. As already introduced, this is more about someone receiving a direct benefit based on another person or company that is not affected by the support measure (European Commission 2007). In concrete terms, this indicates several potential consequences:

- Gaps could arise between non-funded actors or programs and the European Regional Development Fund (ERDF) groups (European Parliament 2023; European Commission 2007). It should be noted that the ERDF has two major objectives. On the one hand, it is about investing in order to promote targeted employment and growth, which is intended to promote local economies and the labor market. On the other hand, within the framework of the EU, the territorial cooperation of the member states should move closer together and develop further together (European Parliament 2023).
- The so-called European Social Fund (ESF) in particular can increasingly lead to both displacement effects and substitution (The Federal Government, Germany 2023; European Commission 2007). This fund, in turn, is considered one of the central programs for promoting employment growth and has existed in the EU for over 60 years. Specifically, this fund includes the education of people and supports the achievement of greater equality of opportunity in employment. Therefore, the labor market should become fairer by supporting students in their start into working life, but also by promoting existing employees in their further training and by helping the unemployed to find work (The Federal Government, Germany 2023).
- The same risk of bias exists with regard to eligible and non-eligible groupings.

In summary, one speaks of the displacement effect when the creation of jobs would undoubtedly have occurred without the implementation of measures. Substitution, in turn, begins when an existing job is simply replaced by another. Because then no

completely new job will be created, but only a redistribution. If these two possible effects are now placed in a concrete context, for example in relation to the ERDF, this could be illustrated as follows: If an SME receives targeted support and can thus optimize its previous services, then this is at the expense of other competitors. The situation would be similar with regard to the ESF: If a targeted training of existing workers offers the possibility that this company improves and the performance is thereby increased, this means, conversely, a form of displacement for other competitors. According to estimates, the displacement effect can be classified at around 10-30%. Even if it has negative connotations, the effect can also bring positivity. Depending on the optimization through support, factors such as professional mobility can improve and at the same time contribute to economic restructuring being promoted. This then arises through the growth potential that transforms the transition from uncompetitive to competitive for sectors. Accordingly, a precipitation of the displacement effect must not only reflect the negative, but also the possible positive consequences.

#### 5.4 Indirect effects and multiplier effects

These effects aim to shed light not only on the net effects themselves, but also on the other indirectly generated effects through Structural Fund measures. There can be various indirect effects:

1. **Income multipliers:** Whenever new jobs are created and more income is generated than before, then the demand for more consumption in the form of goods and services inevitably increases. This has the after-effect that, in the medium term, new jobs will also have to be created in order to be able to meet the increased demand.
2. **Supplier effects:** This effect illuminates the other side compared to the previous income effect. This is about the business side, where support specifically leads to more orders for goods or more opportunities to offer services than before. Consequently, additional jobs are also needed here in order to cope with this increase.
3. **Other indirect effects on employment:** In addition, there are other indirect effects that have an impact. For example, if a region is to be made more attractive and measures and changes are made to increase the level of attractiveness, this can also have an impact on companies suddenly facing increased demand for their goods and services. In the time of the energy transition towards green transformation, this particularly affects the creation of green jobs.

Overall, the indirect effects as a result of direct employment effects are sometimes diverse and are not so easy to estimate in the course of a measure in the Structural Funds. The respective effects on local economies can be very individual, which is why

only rough estimates are possible here. A bottom-up approach or an econometric modeling technique is usually used to calculate an initial assessment.

After multiple investigations into the major ADI effects (additionality, displacement, indirect effects) mentioned in this second step "Estimation of Net Effects & Regional Impacts - Program Level Assessment", some benchmarks for classifying the precipitation of these effects can be identified Table 5-6. ) (European Commission 2007).

**Table 5-6. Classification of the ADI construct on the net employment effects (European Commission 2007)**

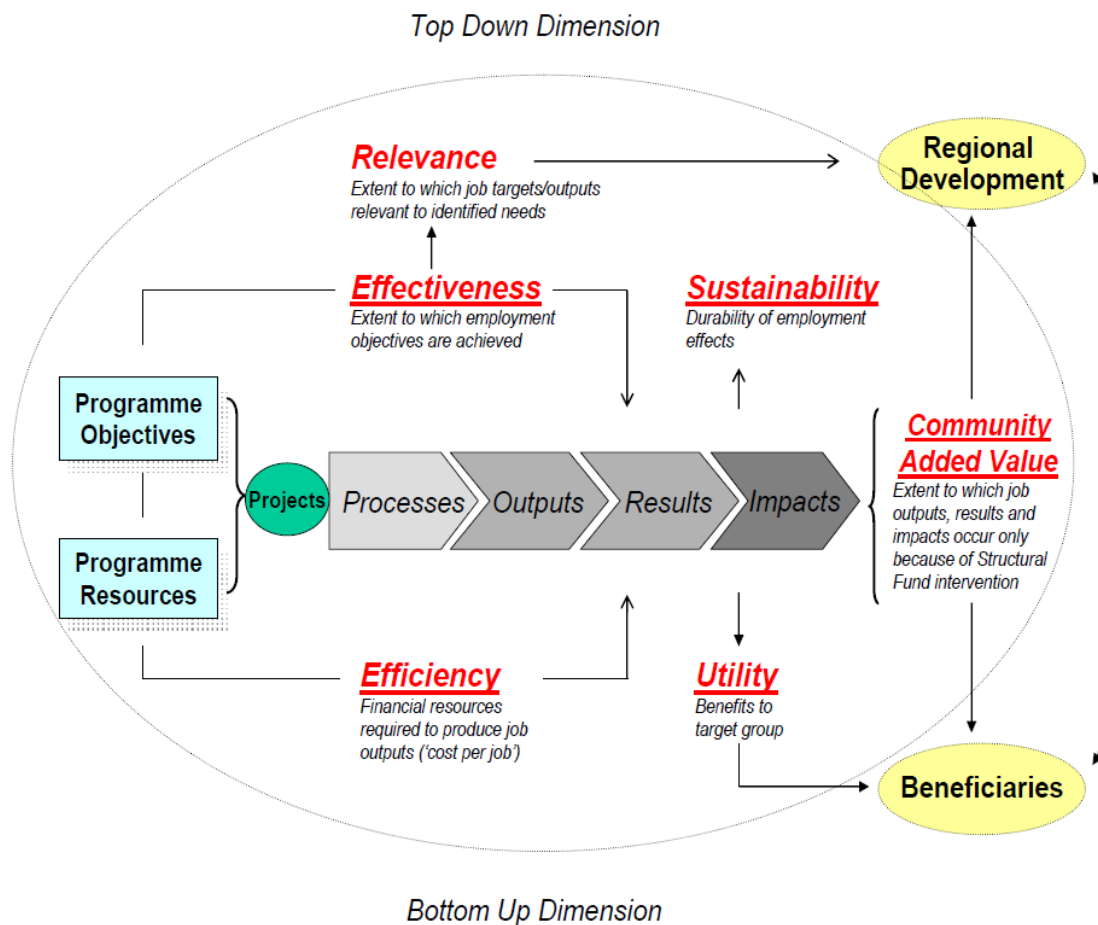
Job effects	A	D	I
Creation	High – 70-80%	Low – 10-15%	High – 1:1.5+
Savings	Low – 20-20%	High – 60-70%	Low – 1:1, lower
Training	High – 50-60%	Medium – 40-50%	Medium – 1:1.1-1.5

The third step “Overall Assessment & Contribution to Key EU Priorities – Program Level Assessment” rounds off the entire approach to determining employment effects. In this respect, this step should be taken **ex-post** and question several **key issues**. These questions focus on the influence of employment effects on the **labor market** and **regional trends** in development, as well as on the priorities of the EU, namely the **strategy for sustainable development and enlargement**, as well as the **Lisbon strategy** (European Commission 2007).

Behind the first-mentioned strategy for sustainable development, the main aim is to identify potential that contributes to a long-term increase in the quality of life for people and societies. Along with this, this project includes the responsible use of resources and the environment and grants innovation in a social context an important function for economic profitability and the associated prosperity. Among other things, topics related to climate change and the transition to clean energy, sustainable production and consumption, as well as optimization of the transport infrastructure, but also the preservation and use of natural resources play a major role (European Commission 2023a).

The other, the Lisbon strategy, is again an agreement reached by the governments of the EU. The focus here is on the goal of promoting the EU and thus its member states in terms of ecological, economic and social development together and as a unit. As a basis, sustainability in all aspects is a key element that must not be neglected and must be considered (Ivan-Ungureanu/Marcu 2006). The EU should then include these key elements in the ex-post analysis and evaluate them in various ways. For this purpose, the European Commission has created a corresponding overview of all factors to be included in its worksheet, which is shown in Figure 5-2 and is now explained in detail below (European Commission 2007).





**Figure 5-2. Overview of the general assessment under the consideration of the key issues (European Commission 2007)**

The first major evaluation point is that of **relevance**, which refers to dimensions relevant to employment that are caused by Structural Fund measures. In order to determine the actual relevance for the creation of jobs within the framework of pure measures or programmes, any possible benefit to individuals or companies must be included in addition to the jobs. Furthermore, a differentiation must be made as to how jobs are filled and equipped, i.e. with regard to gender, requirements or also the prerequisites for filling a position. Accordingly, the key question in this aspect is whether the jobs created can meet regional development and the needs of the regions and to what extent they do so. Therefore, it always plays a role whether the jobs achieved contribute to promoting equal opportunities or improving gender equality. The same applies to other disadvantaged groups, such as the long-term unemployed or minorities, so that the overall development of regions can be balanced in their existing disadvantages.

An aspect related to the relevance is the **effectiveness** in relation to the results of objectives to achieve specific employment impulses within a measure. There is no guarantee that the objectives of a measure can actually be successfully implemented

and that X number of jobs will be created. Therefore, it is not only crucial whether a specified reference value was achieved, but also whether the implementation to achieve this reference value made sense. So the key question in this context is how effective have the job creation measures been implemented been. Perhaps not enough care has been taken to ensure that displacement effects occur, for example, although there is a high level of additionality. Ex-post attention should be paid to the optimization of measures in their implementation and for future planning. In this way, it is also possible to identify which Structural Fund measures generally promise the greatest potential for success.

A third important aspect is represented by **efficiency**, which reflects the relationship between the price-performance ratio and the input and output of jobs, i.e. the respective costs that arise per job. In contrast to its predecessor, effectiveness, this point does not refer to the implemented targets with regard to the fulfilment of the estimated employment effects, but to the costs incurred. The focus is therefore on the extent to which the available funds were used sensibly in order to achieve the targets. However, this also means that the existing financial framework could perhaps have led to even more jobs if used more efficiently and to a greater overall effect. The reverse approach offers another perspective: Would it still have been possible to achieve the same values with fewer financial resources if the processes were optimized? In order to pursue this question, the gross and net costs per job are used as a basis and their results are then compared with other objectives with regard to selected priorities. An example of this would be the comparison to past programs in the same regions as a benchmark.

The fourth influencing factor that can be identified is the **impact**, which extends to the type and extent of net employment effects for a target region or target group. As can also be seen in the **Error! Reference source not found.**, bottom-up approaches for regions can preferably be used to determine the net employment effects of Structural Fund measures. Here, the already introduced consideration of the indirect effects, the additionality and displacement, which have a direct impact on the employment effects in their representation. Nevertheless, it is urgently recommended to include current trends for regional development, with factors such as sectoral job distribution, unemployment and productivity playing a significant role in relation to employment. As a basis for an estimate and evaluation to be carried out, comparisons should be made by carrying out an ex-ante and an ex-post evaluation for the respective region. The key question for the area of impact refers to the possible contribution to supporting desired regional trends and to what extent measures drive them forward or slow them down in the negative case. An applied bottom-up approach can only provide rough guide values as to how the effects will develop. Apart from that, the desired positive effects can sometimes only appear and increase after the completion of a measure, not necessarily during implementation and should therefore be given special consideration ex-post in the overall assessment of the influence exerted.

The penultimate factor to which the EU attaches particular importance is **community added value**. This should reflect the extent to which the employment effects achieved with the help of the Structural Funds exceed the possibilities of regional and national programs. In order to adequately assess the community added value of Structural Funds measures, two levels need to be included, the program and the respective region in which the program is implemented. With regard to the program, the community added value comes from the Structural Funds themselves. Most of the time, particular reference is made to the funding, which is guaranteed over several years, and this offers an advantage over national programs with less flexibility. The additional provision of possible funds also influences the creation of potential new jobs. However, this availability can also have a positive impact on supporting the private sector and promoting programs that otherwise could not receive funding. On the other hand, the added value can also be found in other aspects. For example, a measure can set its focus in such a way that it actively supports certain values, such as the goals anchored in the Lisbon strategy, and thus steers them in the direction desired by Europe. This then also leads to the targeted promotion of growth and employment in desired regions or can drive innovation to create new solutions and incentives for job creation. This offers great potential for community added value. The second level mentioned at the beginning includes the consideration of the region in its contribution to the community added value. This can be determined by measuring the gap between the employment effects before and after the implementation of measures. If the regional development trends are also included in a comparison, the added value also becomes clear.

The last major influencing factor is represented within the diagram by **sustainability**. In this context, this refers to the existence of employment effects, because the effects should last as long as possible beyond the Structural Funds measure. The idea behind a measure supported by the Structural Funds is that it should last as long as possible. Accordingly, this factor must be included in the assessment in the form of sustainability and the extent to which a measure can also promise long-term implementation of employment effects. A distinction is made here between temporary and permanent employment relationships. For example, temporary jobs are often created for the construction of infrastructure and construction sites for the duration of the construction, but these are eliminated after completion. This is not the case with permanent employment. Another aspect is the focus on employment effects in growth sectors, because this can also provide an indication of the possible long-term nature of jobs. Here, too, it should be remembered that it may be the case that some effects only appear or unfold after the completion of a measure and still have to be included in the evaluation in order to obtain a holistic picture.

This summary has illustrated the importance of the interaction of the six evaluation factors mentioned according to EU specifications for measuring the targeting of employment effects through Structural Fund measures. Furthermore, these evaluations should also flow into the priorities and the development of EU policies. Only in this way,

development can be promoted at EU level, but also nationally for the member states and their regions, and the scope of Structural Funds can be used in a strategically sensible manner (European Commission 2007).

In summary, it can be stated with regard to this approach to determining employment effects, that they play an essential role within the framework of EU policies. They help to measure the meaningfulness of the EU measures and at the same time to strengthen the community in every respect. These policies are, inter alia, the Lisbon Strategy, as well as the European Employment Strategy (EES) and the Sustainable Development Strategy (European Commission 2007). As the name for the EES suggests, the aim is to create jobs, but also to improve the overall situation of these jobs in the EU. The EES is divided into four main components: 1.) There are guidelines for employment, which are composed of joint agreements of the national governments of the member states, which were issued by the Council of the EU. 2.) There is a joint employment report in which both the employment situation in Europe is evaluated, the guidelines from the first point are implemented and finally an evaluation is made with regard to the central social and employment indicators. These are also issued by the EU Council, but are published by the Commission. 3.) Furthermore, the National Reform Programs (NRP) of the national governments are analysed in consultation with the Commission with regard to the overarching European goals. 4.) On the basis of this analysis of the NRP, country reports are published, which contain both the economic policy and individual recommendations for the respective countries based on their reports from the Commission (European Commission 2023b).

With regard to the approach to measuring employment effects, the EES is interesting because not only does it focus on the issue of employment in general, but also some key elements can be identified, assuming the various NRPs. In addition to the aim of reducing unemployment and, conversely, increasing employment, the further aim is to ensure equal opportunities in terms of gender, age and education. Besides the EES, but focusing on the Lisbon strategy, the focus here is particularly on investments that promise high growth potential. This is particularly true when national funds are limited and targeted Structural Fund measures can make a definite difference. In addition to material and infrastructure, this can also mean human capital or innovations and research opportunities. Nevertheless, the promotion of offers in the field of professional training is also important. With all these factors, it is always necessary to consider the connections to other EU policies and programs if Structural Fund measures are to be integrated. These should be in line with their own national objectives and the common objectives within the EU and there is in principle no contradiction to the aims of the European Green Deal (European Commission 2007).

Finally, regarding the introduction to the measurement of employment effects, it should be noted that the authors of this report have deliberately and extensively based themselves on the specified and officially recommended approach of the EU. As there is

only very limited literature for the concrete measurement of employment from Structural Funds measures, but also because this report is already aimed at the implementation of such measurements for the European framework, this report is part of an EU-funded project and in this respect, the authors refer to these documents and explain them sufficiently.

Following this very theoretically based consideration, there now follows a brief outline with practical reference to the topic of biofuels.

## **5.5 Site Specific Scenario: Biofuels**

The relevance of carbon capture and utilisation for a clean energy transition is evident, as its importance is highlighted in the European long-term strategic vision and the European Green Deal.

Besides switching from carbon-based to carbon-free energy sources, a common approach for solving this problem is to avoid emissions by implementing energy-saving measures or using more efficient technologies. In some industrial processes, emissions cannot be avoided entirely due to the nature of the process. Instead of being released into the environment as a waste product, the carbon dioxide stream can be recovered and thus be made usable for example as a CO<sub>2</sub> source for the production of synthetic fuels. Biofuels from CO<sub>2</sub>, also known as synthetic fuels, are a type of biofuel that is produced using the captured CO<sub>2</sub> and renewable energy. These fuels are often referred to as "power-to-liquids" or "power-to-gas" technologies. Liquid synthetic fuels produced from biogenic CO<sub>2</sub> or recycled carbon and hydrogen produced using renewable electricity are chemical long-term energy storage systems that have a very high energy density and can be used across sectors. The process of producing biofuels from CO<sub>2</sub> involves capturing CO<sub>2</sub> emissions from industrial processes or power plants and combining them with hydrogen that has been produced from renewable sources such as wind or solar power (see European Commission 2023c). The CO<sub>2</sub> and hydrogen are then converted into liquid fuels such as methanol, gasoline, or diesel using various chemical processes such as Fischer-Tropsch synthesis (U.S. Department of Energy 2023). This process can be carried out specifically using components and infrastructure of closed coal-fired power plant sites.

One of the most essential criteria for the further use of those closed conventional power plant sites for power-to-fuel purposes is the near distance to one or more available CO<sub>2</sub> point sources from neighbouring industries in the long term. Besides of that, criteria such as sufficient space for new build activities, the connection to renewable power plants, an electric grid or sufficient H<sub>2</sub> sources as well as the availability of transport logistics (vessel, train, truck) are relevant.

In the European research project (RFCS Grant Agreement number: 899512 - RECPP - RFCS-2019) "Re-purposing Coal Power Plants during Energy Transition (RECPP)" a detailed survey of infrastructure near decommissioned and operating coal-fired power plants was conducted. This survey covered more than 80% of the capacity of all coal-fired plants installed in the EU. The result of this survey shows that neighbouring industry is located within a radius of less than 50 km at about 40% of all coal-fired power plant sites considered. Thus, at many sites that are candidates for re-purposing, neighbouring industry can provide the required CO<sub>2</sub>-streams for the examined processes. Since these industrial processes are mostly continuous and operate year-round, they provide a reliable and nearly constant CO<sub>2</sub>-stream.

Further findings from the research project have also shown that parts of the old coal-fired power plant infrastructure can continue to be used for production of biofuels (EnergieVerbundTechnik 2023). This applies for example to the grid connection, the deionized water source and existing gas pipelines. In addition, the transport infrastructure can be useful to transport the final product to further customers and especially the carbon capture unit could profit from the big amount of free available areas. Possible steam sources of the old power plant can also be used for the planned processes. In addition, power plant sites already offer a large number of the resources required for carbon capture units and other plants needed for the production of synthetic fuels. With regard to CO<sub>2</sub> sources, in addition to the absolute amount of CO<sub>2</sub> that can be captured, the continuous occurrence of flue gas and the concentration are the most important factors. These conditions are met at those power plant sites that can use flue gas flows from a neighbouring industry.

In Germany several coal power plants have been already decommissioned and many more will be closed in the upcoming years due to the German coal phase-out. In 2019, the German government passed legislation to phase out coal-fired power plants by 2038 at the latest (The Federal Government, Germany 2023b). Many of these power plant sites, which have already been or will be decommissioned, are located close to neighbouring industry like waste incineration plants, biomass plants or the cement industry. This offers the advantages described above for conversion of the old site to a biofuel production site.

## 6 Conclusions and lessons learnt

The energy sector's necessity to shift from using coal as raw material to renewable energy sources will have a negative impact on employment, as many workers will be at high risk of losing their jobs. Poland, Spain, Germany and Greece occupy a spot in the top 10 most vulnerable countries in Europe, with Poland being at the top.

Therefore, during this coal retirement era, both direct and indirect employment forecasts must be conducted, involving all job occupations and industries that are linked to coal activities (mining and production), in order to have a comprehensive representation of the employment costs both at regional and national level.

The transformation of coal mines into Eco-Industrial Parks with sustainable energy from photovoltaics and wind turbines, could help mitigate climate change and reduce the unemployment created by the future closure of coal mines and power plants. Economic and territorial impact assessments should then be developed in order to select the most attractive business models to fight against this situation.

The lessons relevant to POTENTIALS from the economic impact assessment can be summarised as follows:

1. The financial outcomes of the virtual power plant are good, with an IRR of 16%, and the sensitivity and uncertainty analysis demonstrate that the estimated figures are robust.
2. The financial outcomes of the geothermal energy deployment are also positive. However, the IRR reduces to 13%.
3. The financial outcomes for a green hydrogen plant are adverse, and the investment is not feasible unless a specific subvention is obtained for its development. A 50% subvention aligning with Big Ticket projects within the Research Fund for Coal and Steel (RFCS) changes the green hydrogen plant into a desirable investment.
4. The financial outcomes from the molten salt plant align with the geothermal energy deployment, although obtaining accurate economic data for this type of installation is extremely difficult.

The lessons relevant to POTENTIALS from the social impact assessment can be summarised as follows:

1. It is estimated that a total of 160,000 coal related jobs are expected to be lost by 2030, due to closure of coal mines and coal power plants. With Poland, Germany, Spain and Greece being some of the countries in Europe with a high number of

direct jobs in the coal sector and thus among the most vulnerable countries in Europe addressing job losses in the coal sector.

2. For the effective employment of eco-industrial park scenarios, it is important to consider the option of reskilling employees previously occupied in the coal mining and energy production sector. The necessary skills include general qualifications both coal miners and renewable energy sources workers should acquire, that can be modified or used as a leverage for the effective reskilling of the workforce.
3. The construction, manufacturing and energy sectors are considered the most suitable for replacing mining jobs, as the salaries offered are similar to those in the mining industry and there is no need for the development of additional skills.

The lessons relevant to POTENTIALS from the territorial impact assessment can be summarised as follows:

1. A modified Territorial Efficiency, Quality and Identity Layer Assessment (TEQUILA) approach was highlighted as the most adequate to address the different challenges and solutions for territorial impact assessment related to comprehensiveness, participatory approaches, data challenges and time perspectives within POTENTIALS.
2. The extensive list of 17 “direct result indicators” for the relevant scenario outputs that was developed by the experts of the POTENTIALS project, has been condensed to the measurable sub-criteria of the TEQUILA approach and affiliated sub-weights by expert judgements.
3. These collected sub-criteria and their sub-weights representing the Sensitivity component are a proposal and can be changed without a methodological problem by planning institutions, policy makers, stakeholders or alternative expert judgements in interactive meetings if new or better insights in the specific regional and territorial project circumstances are speaking for another selection, assignment and weighting.
4. The positive territorial impact and therefore the contribution to territorial cohesion is considerably higher in an Eco-industrial Park with Green H<sub>2</sub> plant, with a total value score 3.42, than in an Eco-industrial Park with Biofuels production, with a total value score 2.85. The difference of 0,39 score points in this TEQUILA model is composed by varying differences of the three dimensions what can be shown by direct comparison in each macro-criteria.



## 7 Glossary

ADI – Additionality, Displacement, Indirect effects

AEL – Associated emissions levels

APV – Agrophotovoltaics

BAT – Best available technique

CCGT – Combine-Cycle Gas Turbine

CAES – Compressed Air Energy Storage

CSP – Concentrated Solar Power

DNSH – Do no significant harm

EIP – Eco industrial park

EPA – United States Environmental Protection Agency

ES – Ecosystem Services

EU – European Union

GHG – Greenhouse gas

GTP – Geothermal Technologies Programme

I&C – Instrumentation and control

ILUC – Indirect land use change

IT – Information Technology

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

MSP – Malten Salt Plant

NASA – National Aeronautics and Space Administration

NPV – Net Present Value

PHS – Pumped Hydroelectric Storage

PCBs – Polychlorinated Biphenyls

PV – Photovoltaic

R&D – Research and Development

RE – Renewable Energy

RE H&C – Renewable Heating and Cooling

RES – Renewable Energy sources

RFCS – Research Fund for Coal and Steel

RTE – Roundtrip efficiency

SMR – Small Modular Reactors

TIA – Territorial impact assessment

TRL – Technology Readiness Level

UNIOVI – University of Oviedo

UPHS – Unconventional Pumped Hydro Storage

VPP – Virtual Power Plant

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