Recovery of degraded and transformed ecosystems in coal mining-affected areas

847205-RECOVERY-RFCS-2018

Deliverable 5.1

Relevant market price data

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Executive summary

In this Deliverable, the relevant market prices for the scenarios considered for Figaredo Mine in Spain, Janina Mine in Poland, and Ema-Terezie in the Czech Republic, were specified and collected. Most-Ležáky Mine and Chabařovice Mine in the Czech Republic do not expect benefits in their foreseen scenarios.

When necessary, the areas involved in the market prices (in ha) and the total market prices are also presented in the Deliverable, together with the shares of Corinne Land Cover (CLC) classes in each scenario.

Also, prices of EU emission allowances were collected and analysed. To achieve consistency, the monetisation of all non-provisioning ecosystem services will build on the monetary valuation of the attribute with the most direct and market-related valuation possible: carbon sequestration, which will be evaluated using the EU Emissions Trading System, the world's first primary carbon market. The EU Emissions Trading Scheme (EU ETS) is the first primary carbon market in the world and the largest. The EU ETS was introduced in 2005 and has reduced emissions by around 43% in the sectors covered by emissions trading.

All the costs are presented in EUR/m^2 and EUR/ha to facilitate their comprehension, except the ones related to EU carbon permits, which are given in EUR/t CO_2.

1 Introduction

To develop the cost-benefit assessment of the different scenarios, it is necessary to quantify the costs of the alternative actions and the economic value of the ecosystem services provision to determine which options will deliver the most significant benefits concerning their costs.

Market values are derived, if available, from the information on individual behaviour provided by market transactions relating directly to the ecosystem service. In the absence of such information, price information must be derived from parallel market transactions associated indirectly with the good to be valued.

The main ways to collect relevant market prices differ according to the ecosystem services valuation technique selected:

1. Supply-based techniques: relate changes in the output of marketed goods and services to a measurable shift in ecosystem goods and services.
2. Demand-based techniques: to determine how much it costs to buy an ecosystem product or service or what its sales value is.
3. Cost-based techniques: the cost of replacing ecosystem goods or services with manufactured or artificial products, infrastructure or technologies.
4. Value transfer techniques use average willingness-to-pay values from existing and similar studies and adapt these to specific cases.

After collecting all the relevant market price data and determining when prices are distorted to correct distortions finding comparable products or services at undistorted prices in similar environments, the monetary values will be standardised to standard spatial, temporal and currency units, namely EUR per hectare per year, making the information comparable and accessible.

Under the coordination of UBER, each partner will be responsible for collecting data about relevant market prices in their own countries.

2 Relevant market prices

2.1 Figaredo Mine

Three were the scenarios proposed in the Figaredo Mine:

1. Fibre production.
2. Food production
3. Broad-leaved forest (landscape).

2.1.1 Fibre production

Fibre production through pine plantations to produce wood as raw material is always one of the ecosystem service alternatives traditionally considered in Asturias. The relevant CICES V5.1 code is 1.1.1.2, and the class is "Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic material)".

The ecosystem services indicator could be Forest productivity and the quantification method, m^3/ha/year. A similar one was used by Baró et al. (2017) in a study on ecosystem service bundles along the urban-rural gradient, although related to crop production.

It has not been possible to find a data source to quantify the ecosystem service as the development of pines depends on the specific climate. However, in Asturias, pine plantations have, on average, four trees per 10 m^2, equivalent to 300 trees/ha. After 30–40 years, each pine will produce 2 tonnes of wood with an actual price of 17 EUR/tonne.

The source of uncertainty in this valuation will mainly derive from the development of market prices for pine timber as a function of demand/supply and elasticity.

2.1.2 Food production

Food supply through cows reared for feed at the Figaredo mine can only occur on pastures. However, horses are raised for feed nowadays, although this is not as common as cows' cases. The corresponding CICES V5.1 code is 1.1.3.1, and the class "Animals reared for nutritional purposes".

The ecosystem services indicator could be livestock production and the quantification method livestock units/ha/year, as used by Baró et al. (2017).

Again, finding a data source to quantify the ecosystem service was impossible. However, in Asturias, one ha for feeding cows for meat production can generate around 900 EUR every two years, with 300 EUR/year of additional feed costs such as dry grass and feed. The cost of buying a cow ready for insemination is about 1000 EUR, plus an insemination cost of 60 EUR. The cow will be productive for 14 years.

The source of uncertainty in this valuation will derive from the changing market for beef prices as a function of demand/supply and its elasticity.

2.1.3 Broad-leaved forest

A broad-leaved forest, similar to those already present in the region's landscape, was the third scenario selected, also called Landscape.

Based on several trials, an optimal plantation from a forestry perspective was designed with a density of 250 trees/ha in the case of a broad-leaved forest. The species used to reconstruct an Asturian broad-leaved forest stand out for their low mortality. They adapt to all types of terrain, and their soil requirements are much lower than those of other species: *Fraxinus excelsior* (36%), *Betula alba* (36%), *Acer pseudoplatanus* (20%) and *Ilex aquifolium* (8%). In the case of pines, an optimal plantation was designed with a density of 300 trees/ha.

No provisioning ecosystem services are foreseen from the Broad-leaved forest, so no market prices apply.

2.2 Janina Mine

Three scenarios were proposed in Janina Mine:

1. Increasing the natural and recreational potential.
2. Increasing the economic potential.
3. Increasing the natural, recreational and economic potential.

2.2.1 Increasing the natural and recreational potential

Considering the recommendations for future planning and development of the post-mining landscape, five types of land rehabilitation and ecosystem restoration actions will be proposed for the scenario I, as follows:

- Space for green urban areas (low vegetation of dry-loving grasslands and flower meadows),
- Transitional woodland-shrubs,
- Natural grasslands,
- Area for sports and leisure facilities (walking and cycling paths, sports fields and outdoor gyms),

- Water bodies.

The share of particular land use types in Scenario I are presented in Table 2-1.

Table 2-1. Share of CLC types on Scenario I in Janina Mine

Land Use	Area (ha)
Green urban areas	5.52
Transitional woodland-shrub	19.96
Natural grassland	19.97
Sports and leisure facilities	7.34
Water bodies	15.72

No market prices are foreseen in this scenario, as no commercial goods will be produced besides that. However, to maintain this area possibility, a small fee for visitors could provide an income for reclaimed and restored land.

2.2.2 Increasing the economic potential

This scenario focuses on increasing its economic potential due to location advantages, the possibility of using large areas with solar energy plants (photovoltaic panels), and the available capacity for locating mining waste. The share of particular land use types in scenario III is presented in Table 2-2.

Table 2-2. Share of CLC types on scenario II in Janina Mine

Land Use	Area (ha)
Dump sites (current mining settlement)	11.99
Construction sites (photovoltaic farm)	50.1
Industrial or commercial units	6.42

The solar energy generated from photovoltaic panels was calculated using the Power Systems Programme. The following data were made for the calculation of energy yields:

- Module efficiency of solar panel: 20.5 %,
- Peak power Watts of solar panel: 535 Wp,
- The number of solar panels per one ha: 1870 (1 GWp).

The calculated electricity yield of a PV installation per hectare was estimated at 0.85 GWh/year and 42.6 GWh/year for a PV installation located on 50.1 hectares under Scenario II.

The photovoltaic geographical information system was used to estimate: https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html (Figure 2-1).

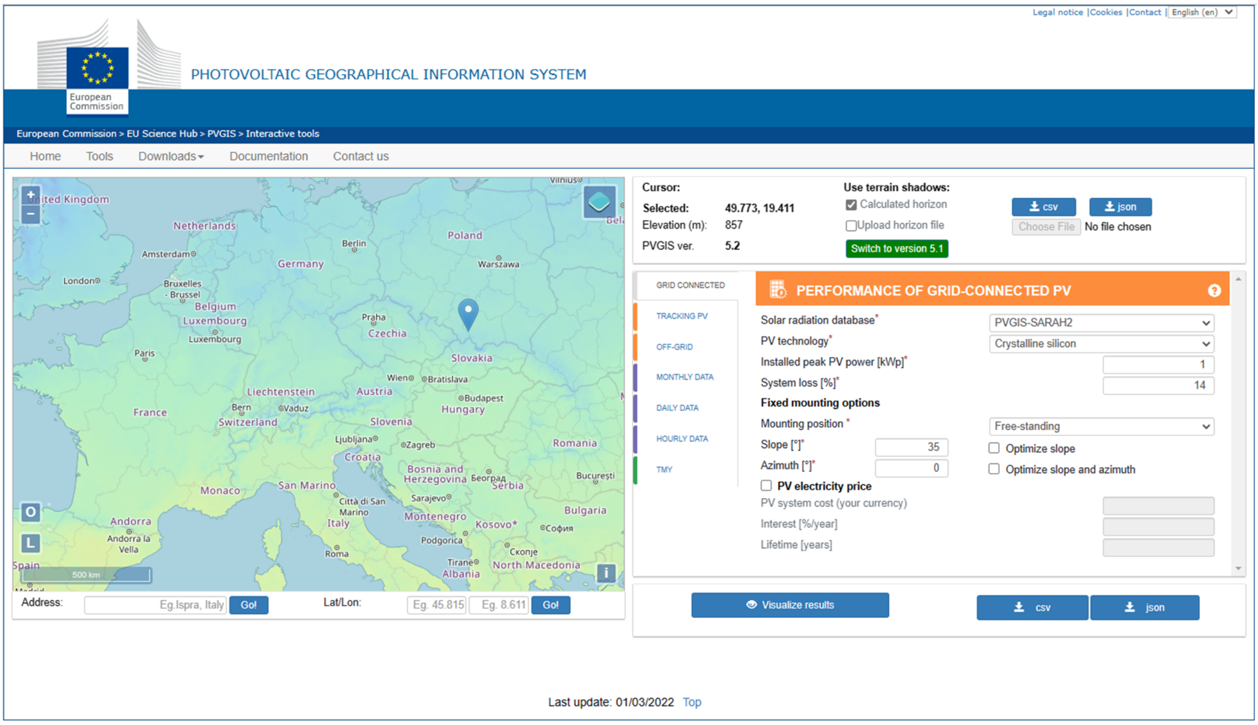

Figure 2-1. Photovoltaic geographical information system. European Commission

Figure 2-2 presents the studied area's monthly energy output from the fixed-angle PV system (see Annex I).

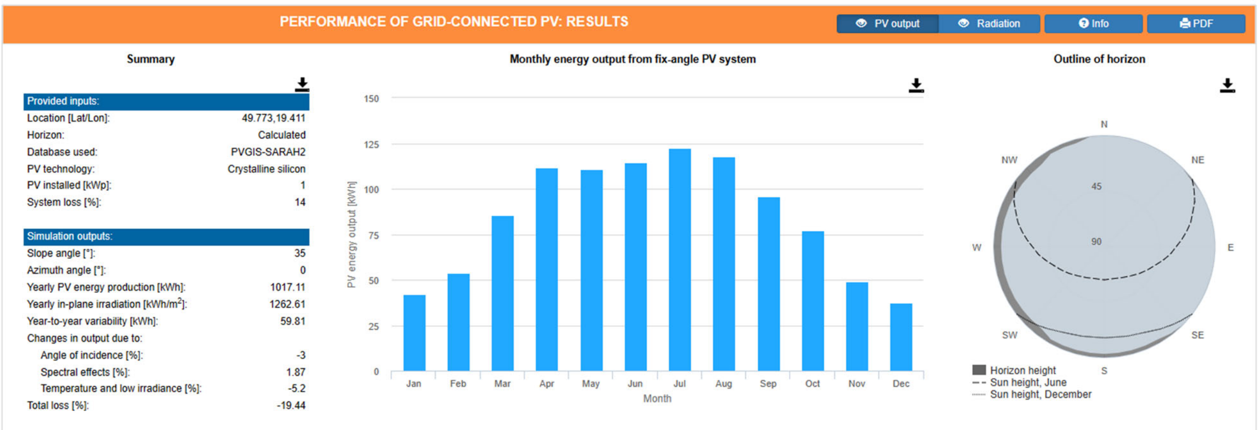

Figure 2-2. Monthly energy output from fix-angle PV system

Figure 2-3 presents the monthly in-plane irradiation for the studied area's fixed angle (see Annex I).

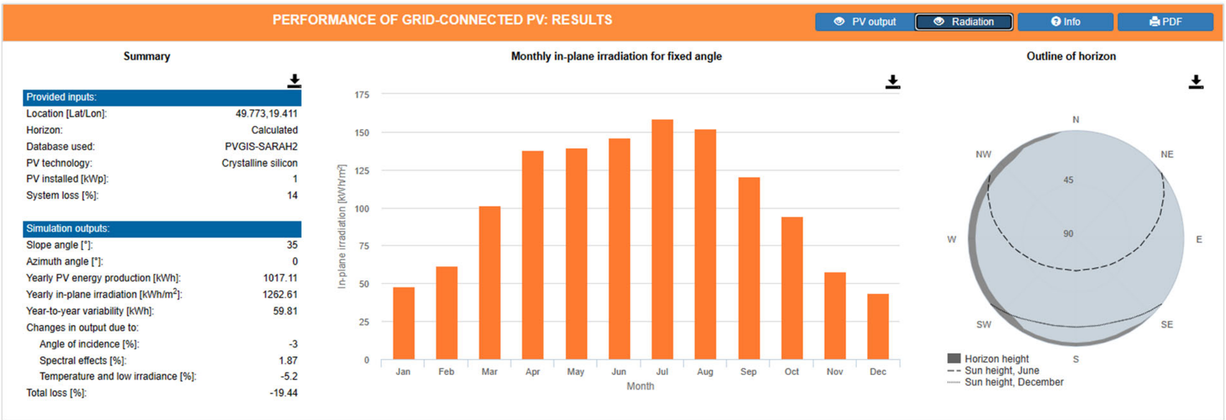

Figure 2-3. Monthly in-plane irradiation for fixed angle

According to scenario II, the calculated energy production was based on Poland's assumed electrical energy market price at the 2022 year of 68 085 EUR/GWh.

The approximate capacity of coal mining settlement for waste management is approximately 380 000 m^3. The cost of unit fee rates for storage of mine wastes on landfill is 2.25 EUR/m^3.

The total market prices for scenario II are presented in Table 2-3.

Table 2-3. Market prices for Increasing the economic potential in Janina Mine

Item	EUR/m^2	EUR/ha	Area (ha)	Cost (EUR)
Construction sites			**50.1**	**2 899 400**
Electrical energy production/GWh/year	5.79	57 872	50.1	2 899 400
Dumpsite (mining settlement)			**11.99**	**855 000**
Depositing mining waste (once)	7.13	71 309	11.99	855 000
TOTAL INCOME				**3 754 400**

According to scenario II, the total market prices were estimated at 3 754 400 EUR. The estimated electrical energy production using PV installation is 2 899 400 EUR/year.

2.2.3 Increasing the natural, recreational and economic potential

Scenario III assumes the development of a multifunctional area constituting the basis for establishing a business, producing energy from renewable sources and spending free time in areas with specific natural values. Scenario III considers transforming the sedimentation tank into a semi-natural water reservoir and creating spaces occupied by low vegetation and shrubs.

Considering the recommendations for future planning and development of the post-mining landscape, four types of land rehabilitation and ecosystem restoration actions were proposed for scenario III, as follows:

- Space for green urban areas (low vegetation of dry-loving grasslands and flower meadows).
- Transitional woodland-shrubs.
- Natural grasslands.
- Area for sports and leisure facilities (walking and cycling paths, sports fields and outdoor gyms).
- Construction sites (photovoltaics farm).
- Industrial or commercial units.
- Waterbody.

The share of particular land use types in scenario III is presented in Table 2-4.

Table 2-4. Share of CLC types on scenario III in Janina Mine

Land Use	Area (ha)	Share (%)
Green urban areas	7.36	10.7
Industrial or commercial units	4.45	6.5
Transitional woodland-shrub	18.97	27.7
Construction sites	4.55	6.6
Sports and leisure facilities	6.14	9.0
Natural grasslands	17.09	24.9
Water bodies	9.96	14.5

This scenario uses southern slopes for energy production from photovoltaic panels (about four ha). The highest efficiency of installation on slopes with such exposure dictates the solution. In this case, yearly PV energy production at 1MWh/ha is achievable (based on the results of the photovoltaic geographical information system).

The rest components of cost market prices are the same as in Scenario I and Scenario II. The calculated electricity yield of a PV installation located on 4.45 hectares was estimated at 4.45 GWh/year under Scenario III. The total market prices for scenario III are presented in Table 2-5.

The approximate capacity of coal mining settlement for waste management is approximately 380 000m^3. The cost of unit fee rates for storage of mine wastes on landfill is 2.25 Euro/m^3.

Table 2-5. Market prices for Increasing the natural, recreational and economic potential in Janina Mine

Item	EUR/m^2	EUR/ha	Area (ha)	Cost (EUR)
Industrial or commercial units			**4.45**	**1 134 750**
Sale of real estate (once)	**25.5**	**255 000**	4.45	1 134 750
Construction sites			**4.55**	**309 787**
Electrical energy production/GWh/year	6.81	68 085	4.55	309 787
Dumpsite (mining settlement)			**11.99**	**855 000**
Depositing mining waste (once)	7.13	71 309	11.99	855 000
TOTAL INCOME				**2 299 537**

According to scenario III, the total market prices were estimated at 2 299 537 EUR. The estimated electrical energy production using PV installation is 309 787 EUR/year.

2.3 Ema-Terezie Mine dump complex

Three restoration scenarios were suggested for the case of the Ema–Terezie Mine dump complex in the Czech Republic:

1. **Recreation**: Scenario I is created by merging Wild Animal and "without any interventions" scenarios, which assumed only slight interventions in the area with a preference for extensive use. The mine dump complex is almost in the centre of the city of Ostrava, so it has significant potential for recreation and leisure–time activities. Excepting these recreational activities, support of ecological functions is also suitable and desirable for using the area (establishment and management of flower meadows, support of entomofauna, etc.). Part of Ema – Terezie area is characterised by non-interventional urban wilderness (CLC: Mixed Forest 313) and by a Broad-leaved Forest as typical native forest in the region: mainly *Betula pendula*, *Quercus robur*, *Sorbus aucuparia*, *Acer platanoides*, *Acer pseudoplatanus* and *Carpinus betulus* in terms of predominant ecological function. Nevertheless, this can be considered a mixed scenario of a Broad-leaved Forest and a physical recreation area. People can walk and enjoy nature observation around the area without developing specific infrastructure for physical recreation.

2. **Combination of land use intentions**: Scenario II is a combination of the using area for Housing (CLC: Discontinuous urban fabric 112), HorseTrails (CLC: Sport and leisure facilities 142), Pastures (CLC: Pastures 231) and ForestPark (CLC: Mixed Forest 313). It assumes ecological, hippo - tourist and partly extensive

agricultural use of the area. Horse breeding and riding are suitable on account of the riding school which currently exists here.

3. **Forest Park**: Scenario III is characterised in terms of the principal recreational function when a forest park (CLC: Mixed Forest 313) with equipment for outdoor sports and furniture is built on the territory of the mine dump complex. Support for ecological functions is not as crucial as in Scenario I.

The share of particular land use types in the three scenarios is presented in Table 2-6.

Table 2-6. Change rules for CLC land use classes from the three scenarios

Lad use	CLC 2006	Scenario I	Scenario II	Scenario III
Dumpsites	62.91	0	0	0
Discontinuous urban fabric	0	0	6.49	0
Sports and leisure facilities	0	0	15.85	0
Pastures	0	0	0.67	0.67
Mixed forest	0	62.91	39.9	62.24

2.3.1 Recreation

There are not any expected benefits for Scenario I. The logged material (trees) is supposed to be chipped and reused in the solved area.

2.3.2 Combination of land use intentions

There are not any expected benefits from Mixed Forest and Pastures (meadows) for Scenario II. The logged material (trees) is supposed to be chipped and reused in the solved area. Flowery meadows have no financial benefit, and fulfilling non-production functions are suggested. Grass will be composted or provided free of charge to the riding school.

Explanation of rent of the house calculation:

- There are planned ten houses per hectare.
- The monthly rent of one house is 1200 Euro per month, and it is 1200 x 12 = 14 400 EUR/year.
- The benefit from ten houses (built on one hectare) is 14 400 x 10 = 144 000,00 EUR/ha.

2.3.3 Forest park

There are not any expected benefits from Mixed Forest and Pastures (meadows) for Scenario III. The logged material (trees) is supposed to be chipped and reused in the solved area. Flowery meadows have no financial benefit, and fulfilling non-production functions are suggested. Grass will be composted or provided free of charge to the riding school.

2.4 Most-Ležáky Mine

For the case of Most-Ležáky Mine (Czechia), three restoration scenarios are foreseen:

1. **Recreation**: Physical recreation and free time activity with biking and hiking trails.
2. **Combination of scenarios**: Physical recreation and free time activity, biking and hiking trails, transitional woodland shrubs, and natural grassland.
3. **Nature**: transitional woodland shrub and natural grassland - leaving the area for more natural development without significant interventions in the landscape.

No market prices, as no commercial goods and services will be produced for any of the three considered scenarios.

2.5 Chabařovice Mine

For the case of Chabařovice Mine, three restoration scenarios were foreseen:

1. **Recreation**: Physical recreation, free time activity and leisure areas.
2. **Combination of scenarios**: Physical recreation, free time activity, leisure areas and biking trails.
3. **Sport**: Physical recreation and free time and biking trails.
4. No market prices, as no commercial goods and services will be produced for any of the three considered scenarios.

Again, no market prices, as no commercial goods and services will be created for any of the three considered scenarios.

3 EU Carbon dioxide emission allowances

While provisioning ecosystem services will be valued in RECOVERY according to market prices, non-provisioning ecosystem services will be quantified before their monetisation, using tables of coefficients for each land cover type derived from field experiments, following Bagstad et al. (2013).

Local scaling will be selected to transform non-provisioning ecosystem service values into a standard metric, an index between one and ten. Local scaling sets upper and lower bounds using locally measured performance values instead of global scales that may cause irrelevance of differences between local measures. Thus, all criteria performance values will have the same influence on the final scores of the alternatives if they are weighted equally, which will not be the case.

To achieve consistency, monetisation of all non-provisioning ecosystem services will build on the monetary valuation of the attribute with the most direct and market-related valuation possible: carbon sequestration, which will be evaluated using the EU Emissions Trading System, the world's first primary carbon market.

According to the EU Emissions Trading System, during 2019 and 2020, the period in which this research was initially developed, the average value of EU Allowances, which allows for the emission of 1 tonne of carbon dioxide equivalent, was about 25 EUR/t. As 3.67 t CO_2 contain 1 t C, the average value of sequestration of 1 t C can be estimated at 91.75 EUR/t.

An assumption is made that all non-provisioning ecosystem services weighted at 100% are worth the same, given that the specific values for each ecosystem service will come from the relative comparison between them.

No discount should be applied to the non-provisioning ecosystem service values, as they do not represent real cash flows but timeless values. An example will explain this assertion: the reconstruction of a broadleaved forest, the ecosystem service of climate regulation (temperature), the indicator of land surface thermal emissions and the quantification method of thermal emissivity.

Once the broadleaved forest is planted and during its growth to maturity, the thermal emissivity will decrease until it reaches a value considered stable. From this point on, the thermal emissivity can be assumed constant and will remain so for as long as the for-est survives. Considering that the forest will be maintained over time, the length of its growth period can be regarded as negligible concerning its total duration. Therefore, assuming that the average thermal emissivity is equivalent to its maturity can be considered acceptable.

A somewhat similar explanation would be given in the case of the ecosystem service of carbon sequestration, the indicator of carbon storage and the quantification method of above-ground carbon storage in t/ha.

Although the level of carbon storage would increase during the growth of the broadleaved forest, the overall effect on the environment is the ultimate sequestration of a certain amount of carbon. Regardless of whether this total sequestration occurs now or progressively over twenty years, and given that the sequestration will remain the same for many years to come, the overall effect on the environment is the sequestration of this total amount of carbon.

Therefore, if the intention is to value non-provisioning ecosystem services using the current price of EU emission allowances, the most straightforward and practical assumption is to consider their overall impact on the environment at the time of valuation without applying any financial discount, given their permanence over time.

The EU Emissions Trading Scheme (EU ETS) is the first primary carbon market in the world and the largest. The EU ETS was introduced in 2005 and has reduced emissions by around 43% in the sectors covered by emissions trading.

The EU ETS has undergone several changes since its introduction in 2005. The implementation was divided into four phases, and phase 3 began in 2013 and lasted till 2020. Between 2019 and 2023, the number of allowances in reserve doubled to 24% of the allowances in circulation, significantly escalating Phase 3 prices in 2019 (from 5 to 25 EUR/t).

Finally, Phase 4, which started in 2021, coincided with a series of legislative proposals adopted by the European Commission on 14 July 2021, setting out how climate neutrality will be achieved by 2050. The proposals included an intermediate target of at least a 55% net reduction in greenhouse gas emissions by 2030, producing a vast price escalation to around 80 EUR/t.

Figure 3-1 presents the prices of EU carbon permits from 2012 till September 2022, adapted from EMBER (2021) and Trading Economics (2021).

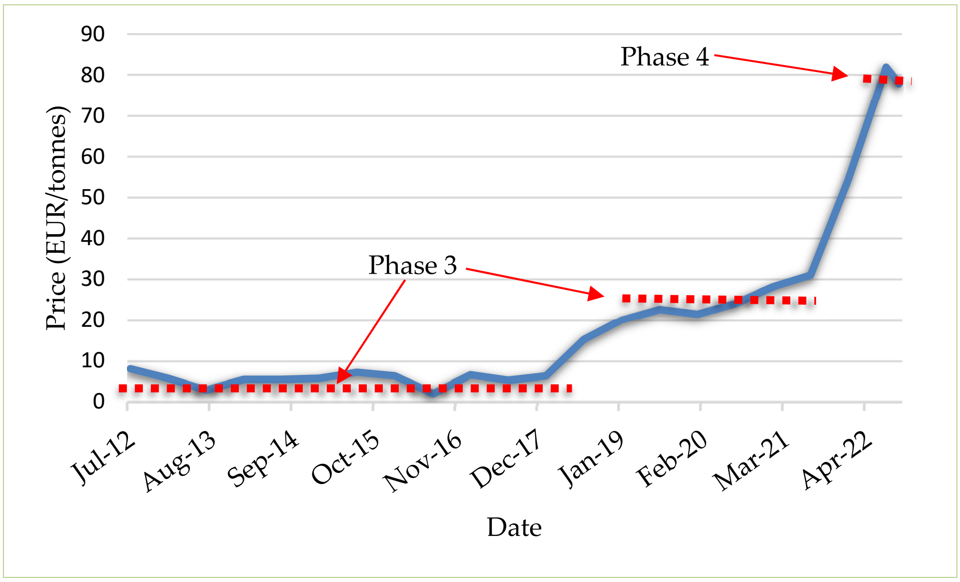

Figure 3-1. Prices of EU carbon permits from July 2012

4 Conclusions and lessons learned

In this Deliverable, the relevant market prices for the scenarios considered for Figaredo Mine in Spain, Janina Mine in Poland, and Ema-Terezie in the Czech Republic, were specified and collected, as Most-Ležáky Mine and Chabařovice Mine in the Czech Republic do not expect benefits in their foreseen scenarios.

Also, prices of EU emission allowances were collected and analysed. The EU Emissions Trading Scheme (EU ETS) is the first primary carbon market in the world and the largest. The EU ETS was introduced in 2005 and has reduced emissions by around 43% in the sectors covered by emissions trading.

The lessons relevant to RECOVERY from the collection of market prices can be summarised as follows:

1. In several cases, finding a data source to quantify the ecosystem services was not possible, so specific research had to be developed in the region to estimate market prices.

2. The sources of uncertainty in many valuations will derive from the changing market prices as a function of demand/supply and their elasticity.

3. For estimating the solar energy generated by photovoltaic panels, the Photovoltaic Geographical Information System from the European Commission (https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html) is a perfect tool.

4. EU carbon permit prices depend on the implementation phases of the EU Emissions Trading Scheme (EU ETS). Thus, the monetisation of non-provisioning ecosystem services should consider this fact.

5 Glossary

CAPM: Capital asset pricing model

CICES: Common International Classification of Ecosystem Services

CLC: Corine Land Cover

EIA: Environmental Impact Assessment

ES: Ecosystem services

EU: European Union

EURIBOR: Euro Interbank Offered Rate

GCD: Global credit data

HUNOSA: Hulleras del Norte, S.A.

TEEB: The Economics of Ecosystems and Biodiversity

NPV: Net present value

PKÚ: Palivový Kombinát Ústí

PV: Photovoltaic

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Annex I

European Commission

Performance of grid-connected PV

PVGIS-5 estimates of solar electricity generation:

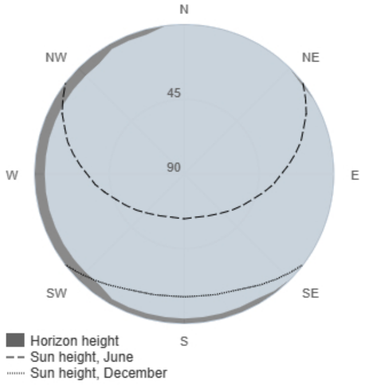
Provided inputs:

Latitude/Longitude:	49.773,19.411
Horizon:	Calculated
Database used:	PVGIS-SARAH2
PV technology:	Crystalline silicon
PV installed:	1 kWp
System loss:	14 %

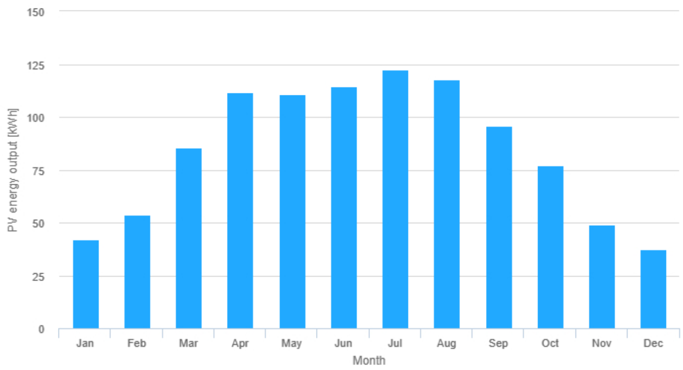
Simulation outputs

Slope angle:	35 °
Azimuth angle:	0 °
Yearly PV energy production:	1017.11 kWh
Yearly in-plane irradiation:	1262.61 kWh/m²
Year-to-year variability:	59.81 kWh
Changes in output due to:	
Angle of incidence:	-3 %
Spectral effects:	1.87 %
Temperature and low irradiance:	-5.2 %
Total loss:	-19.44 %

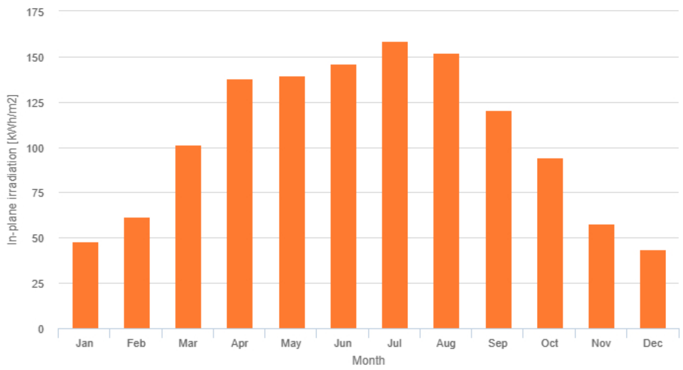
Outline of horizon at chosen location:



Monthly energy output from fix-angle PV system:



Monthly in-plane irradiation for fixed-angle:



Monthly PV energy and solar irradiation

Month	E_m	H(i)_m	SD_m
January	42.1	47.9	14.9
February	53.6	61.6	14.1
March	85.6	101.5	15.3
April	111.6	138.2	21.0
May	110.8	139.7	19.5
June	114.4	146.4	16.7
July	122.3	158.8	15.4
August	117.6	152.3	12.0
September	95.8	120.7	15.5
October	77.1	94.1	18.0
November	49.0	58.0	10.6
December	37.3	43.4	10.8

E_m: Average monthly electricity production from the defined system [kWh].

H(i)_m: Average monthly sum of global irradiation per square meter received by the modules of the given system [kWh/m²].

SD_m: Standard deviation of the monthly electricity production due to year-to-year variation [kWh].

Report generated on 2022/12/27