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

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Deliverable 4.3

Adequate discount rates

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Table of contents

List of Figures

List of Tables

Executive summary

In this deliverable, the appropriate discount rates to undergo the valuation of provisioning ecosystem services, including the costs incurred for developing them and the expenses needed to create non-provisioning ecosystem services, are proposed.

For this purpose, three different categories of goods were distinguished: (1) non-intensive natural goods production, such as familiar animal exploitation, familiar tree plantations, familiar agriculture, etc.; (2) intensive natural goods production, such as intensive animal farms, intensive forest exploitation, intensive agriculture, etc.; and (3) industrial goods production such as renewable energy production, industrial facilities, etc.

The proposed discount rates were then used in the Figaredo mining area case study and applied to calculate the value of two provisioning ecosystem services: fibre production, which refers to pine plantations to produce wood as raw material, and food production, which relates to cows reared for feed. Also, the actual costs of a non-provisioning ecosystem service, broad-leaved forest, were estimated.

After, the revenues of the three scenarios considered feasible for the Figaredo mining area (Fibre, Food and Landscape) were determined using the values of the non-provisioning ecosystem services calculated in *D4.2 Feasible valuation techniques*.

Finally, an exercise was carried out to estimate what the price of EU Allowances would have to be for the Landscape scenario to be chosen, being tantamount to allowing nature itself to set the price of EU Allowances in the Figaredo mine environment.

1 Introduction

Work package 4 aims to develop the formulation that will be used later for the cost-benefit assessment.

Task 4.3 will select the adequate discount rates for each case study within this work package.

As discounting is a critical issue in the economics of ecosystems, particular emphasis will be put on the choice of the discount rate for each case study, as there are no purely economic guidelines for choosing it. A variety of discount rates, including zero and negative rates, could be used, depending on the period involved, the degree of uncertainty, the scope, and the country of the project.

In general, a higher discount rate applied to specific cases will lead to the long-term degradation of ecosystems. However, a low discount rate for the entire economy might favour more investment and growth and environmental destruction.

Resource economics has a long tradition of applying a higher discount rate to the benefits of development and a lower rate to the environmental costs of that development, as presented in equation 1.

$$NPV(D) = -1 + D / (r + k) - P (r - h) \quad (1)$$

Where D is the value of development and P is the value of preservation. In this setup, a factor k is added to the discount rate applied to development benefits to reflect the depreciation of development benefits over time. In a similar vein, a factor h is subtracted from the rate of the discount applied to the benefits of preservation.

Here, h represents growth in the value of environmental services over time-based on increased material prosperity that augments willingness to pay for scarce nonmarket goods. No hard and fast rules can be applied to determine how much these discount rates should be adjusted.

In terms of the discounting equation, estimates of how well-off those will be in the future are the critical factor in how much we should leave the future.

2 Range of discount rates

The range of discount rates in the scientific literature is broad and justified according to different reasons.

Here are some examples of different proposed discount rates that, in most cases, are selected within a range of 1%-7%.

2.1 The Economics of Ecosystems and Biodiversity (TEEB)

The Economics of Ecosystems and Biodiversity (TEEB, 2010) dedicates one whole chapter to “Discounting, ethics, and options for maintaining biodiversity and ecosystem integrity” (Chapter 6).

In this chapter, they state that there are no guidelines that may help to select an adequate discount rate and that this selection may be an ethical matter about the future well-being and preserving life opportunities.

They also state that various alternative discount rates can be selected (including negative rates).

Moreover, they state that “a 5% discount rate implies that biodiversity loss 50 years from now will be valued at only 1/7 of the same amount of biodiversity loss today”.

TEEB also presents the Ramsey Discounting Equation to estimate the rate at which future monetary costs and benefits should have to be discounted (equation 2).

$$r = \rho + \eta \times g \tag{2}$$

Where ρ is the rate of pure time preference, η is the parameter that reflects the curvature of the utility function and g is the growth rate of per capita consumption.

Assuming a ρ value of near-zero and a η value of near one, then the discount rate should equal approximately the rate of growth g, which usually takes values between 1% and 2%.

2.2 Benchmarking discount rates in restoration evaluation

Wu & Chen (2017) stated that low discount rates favour ecosystem restoration instead of economic activity because restoration activities imply benefits in the far future.

They proposed a discount rate decision support system according to which the chosen discount rates will be within the range of 1.0%-3.5%.

Addressing original damage components and discount rates, they present the following values:

- Defensive cost: 3.5%.
- Primary restoration: 3.5%.
- Assessment cost: 3.0%.
- Interim loss: 3.0%.
- Permanent welfare: 1.0%.

For permanent welfare, they distinguished the following values:

- Recreational service (sporting, sunbathing, swimming): 2.1%.
- Regulation service (biodiversity): 1.3%.
- Cultural service (festival or sporting activities): 1.0%.
- Provisioning service (fishery production): 2.4 %-3.0%.
- Existence value (non-integrity of the ecosystem): 1.7%.

Thus, the range goes from 1.0% for permanent welfare to 3.0%-3.5% for provisioning services such as fishery production.

2.3 Benchmarking loss given discount rates

Scheule & Jortzik (2020) provided alternative discount rates for computing loss given results using historical bank data.

The average risk premium from 2008 was around 6.0%, while the risk-free rate given by global credit data (GCD) from 2009 was around 1.0%, corresponding to the Euro Interbank Offered Rate (EURIBOR).

The Capital asset pricing model (CAPM) states that the shareholder discount rate will be the one presented in equation (3).

$$r = riskfree\ rate + average\ risk\ premium\ rate = 1.0\% + 6.0\% = 7.0\% \quad (3)$$

2.4 Resource Equivalence Analysis

Shaw & Wlodarz (2013) proposed to use a social discount rate of 3%, which is the most prevalent in the United States, while in Europe, the social discount rate varies from 3%-6%.

The rate is even higher in developing countries (10%-12%).

3 Ecosystem services valuation

According to the valuation methodology described in *D4.2 Feasible valuation techniques*, while provisioning ecosystem services will be valued in RECOVERY using market prices that will be discounted using appropriate discount rates, 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).

3.1 Valuation of provisioning ecosystem services

The valuation of the provisioning ecosystem services, including the costs incurred for developing them, should be done by calculating their net present value (NPV) over a sufficiently long period.

A horizon of 70 years or more is proposed to consider that the residual value could be equal to zero.

It is then necessary to define the discount rates used in the calculations. We will propose using different discount rates according to the goods produced by the provisioning services.

We will distinguish between three main categories of goods:

1. Non-intensive natural goods production, such as familiar animal exploitation, familiar tree plantations, familiar agriculture, etc.

2. Intensive natural goods production, such as intensive animal farms, intensive forest exploitation, intensive agriculture, etc.

3. Industrial goods production such as renewable energy production, industrial facilities, etc.

3.1.1 Non-intensive natural goods production

Considering such a long horizon (70 years) and the fact that the average reference rate of the European mortgage market in 2020 was around 2%, and the average inflation rate was around 1%, the nominal rate for non-intensive natural goods proposed should be about 2%, which is equivalent to a real/constant rate of 1%.

This value is equivalent to a moderate rate of growth, according to TEEB (2010), and is equal to the lower limit of the range proposed by Wu & Chen (2017) for permanent welfare.

It is also equivalent to the risk-free rate, according to Scheule & Jortzik (2020).

Real/constant euros are recommended to facilitate calculations, assuming that product prices may maintain a constant value in 2020 real/constant euros in the coming years.

Although by the end of 2021, inflation has increased considerably as a consequence of the effects of the Covid-19 pandemic and the Ukrainian invasion by Russia, it is logical to assume that interest rates should increase by a similar amount, so it would not be wrong to adopt the same 1% as in 2020 as the real rate in the European mortgage market.

Some examples are provided for valuating provisioning systems in the Figaredo mining area in Spain (Figure 3-1).

Figure 3-1. Figaredo mining area after the initial restoration of the waste heaps.

3.1.1.1 Fibre production

In this case, fibre production refers to pine plantations to produce wood as raw material, which 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 pine depends on the specific climate. However, a monetary valuation is feasible and could be done using timber prices that appear in the production, consumption and foreign trade of timber and timber products (Spanish Ministry of Agriculture, 2018).

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. Thus, at an actual price of 17 €/tonne, pine production can have a net income over 35 years of about 10,200 €/ha.

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.

Regarding the costs of tree planting (300 trees/ha), they are presented in Table 3-1. The planting holes have to be sanitised, and topsoil must be added. Then, during the first months after planting, maintenance and watering must be carried out, followed by annual maintenance for at least five years, which includes the following tasks: weeding around each plant for a perimeter of about one metre, hand weeding around the tree, weeding, breaking up large clumps, fertilising with slow-release fertiliser, giving each tree a minimum of 150 g of fertiliser, and checking the condition of the stakes. Trees should be planted with a tutor and protective netting. In addition, it is advisable to rinse once a week in the warmer season, with a water supply of about 35 litres per watering plant.

Table 3-1. Pine tree plantation and maintenance costs. Source: HUNOSA.

Item	**€/m^2**	**€/ha**
Tree plantation (300 trees/ha)	0.204	2,040
Clearing and cleaning/year	0.045	450
Slow-release fertiliser/year	0.020	200
Watering/year	0.013	130

Although the first step is always to develop slope stability to achieve a suitable final slope configuration, hydroseeding must be carried out in each mined area. Both slope stability works, and hydroseeding are sunk costs, as in all cases, they have to be incurred and cannot be recovered, so they should not be considered in the cost-benefit assessment.

To determine the revenues of this scenario, according to the costs and payments previously analysed, the NPV of the provisioning ecosystem service could be calculated:

Equation (4) presents the NPV per ha of a pine plantation. The cost of tree planting (300 trees/ha) was estimated at 2,040 €/ha, and the costs of clearing and cleaning, slow-release fertiliser and watering at 780 €/ha/year, which should take place over the first five years. After 35 years, each pine tree was considered to produce 2 tonnes of timber which, at a real price of 17 €/tonne, represents 10,200 €/ha. The residual value in year 70 is assumed to be zero.

$$NPV_{Pine\ trees} = -\,2{,}040 - \frac{780}{(1+0.01)} - \ldots - \frac{780}{(1+0.01)^5} + \frac{10{,}200}{(1+0.01)^{35}} - \frac{2{,}040}{(1+0.01)^{36}} - \ldots + \frac{10{,}200}{(1+0.01)^{70}} = 2{,}386\ € \qquad (4)$$

3.1.1.2 Food production

In this case, food supply refers to cows reared for feed at the Figaredo mine, which can only occur on pasture. However, horses are also reared for feed, which is not as common as cows. The corresponding CICES V5.1 code is 1.1.3.1, and the class "Animals reared for nutritional purposes". The indicator of ecosystem services could be livestock production, and the quantification method of livestock units/ha/year, as Baró et al. (2017).

Again, finding a data source to quantify this ecosystem service was impossible. A monetary valuation can still be made using market prices for beef cows (Spanish Ministry of Agriculture, 2020).

However, in Asturias, 1 ha is usually contracted for 100 €/year. On the other hand, a similar area for feeding cows for meat production can generate around 900 € every two years, with 300 €/year of additional feed costs such as dry grass and feed. The cost of buying a cow ready for insemination is about 1,000 euros, plus an insemination cost of 60 euros. 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.

Equation (5) presents the NPV per ha of feeding cows for beef production. The cost of buying a cow ready for insemination is about 1,000 euros, plus an insemination cost of 60 euros. The cow will be productive for 14 years. The cow will generate meat (a calf) for around 900 € every two years, with 300 €/year of feed costs such as dry grass and feed. The residual value in year 70 is also assumed to be zero.

$$NPV_{Food} = -\,1{,}060 - \frac{300}{(1+0.01)} + \frac{(900-300)}{(1+0.01)^2} + \ldots - \frac{(900-300-1060)}{(1+0.01)^{14}} - \frac{300}{(1+0.01)^{15}} + \ldots - \frac{(900-300)}{(1+0.01)^{70}} = 3{,}323\ €/ha \tag{5}$$

3.1.2 Intensive natural goods production

In the case of intensive natural goods production, we propose a real/constant discount rate of 3%-3.5%, which corresponds to the lower value of the interval that was presented by Shaw & Wlodarz (2013) for Europe, and with the upper value of the interval proposed by Wu & Chen (2017).

3.1.3 Industrial goods production

Finally, in the case of industrial goods production, as in this case, there is usually an external investment trying to achieve capital returns, we propose a real/constant discount rate of around 6.0%-7.0%, which is coincident with the upper value of the interval proposed for Europe by Shaw & Wlodarz (2013) or with the benchmarked rate proposed by Scheule & Jortzik (2020).

Of course, these values will be acceptable when the industrial goods production risk can be considered average.

3.2 Valuation of non-provisioning ecosystem services

Regarding ecosystem services different from provisioning services, we hypothesise that no discount should be applied to these ecosystem service values, as they do not represent real cash flows but timeless values (see deliverable 4.2).

Nevertheless, there could be investment costs that will have to be considered and appropriately discounted, as in the case of selecting as a scenario the planting of a broad-leaved forest in the Figaredo mining area.

Based on several trials, in the case of a broad-leaved forest, an optimal plantation from a forestry perspective was designed for the Figaredo mining area with a density of 250 trees/ha. The species that 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%).

Regarding the costs of tree planting (250 trees/ha), they are presented in Table 3-2. Again, the planting holes must be sanitised, and topsoil must be added.

Then, during the first months after planting, maintenance and watering must be carried out, followed by annual maintenance for at least five years, which includes the following tasks: weeding around each plant for a perimeter of about one metre, hand weeding around the tree, weeding, breaking up large clumps, fertilising with slow-release fertiliser, giving each tree a minimum of 150 g of fertiliser, and checking the condition of the stakes.

Trees should be planted with a tutor and protective netting. In addition, it is advisable to rinse once a week in the warmer season, with a water supply of about 35 litres per watering plant.

Table 3-2. Broad-leaved forest plantation and maintenance costs. Source: HUNOSA.

Item	**€/m²**	**€/ha**
Tree plantation (250 trees/ha)	0.170	1,700
Clearing and cleaning/year	0.045	450
Slow-release fertiliser/year	0.020	200
Watering/year	0.013	130

Equation (6) presents the NPV per ha, or the actual cost per ha, of planting a broad-leaved forest with a density of 250 trees/ha. As in the case of the pine tree plantation, clearing and cleaning, slow-release fertiliser, and watering should take place over the first five years and at the same price of 780 €/ha/year (Table 1).

$$NPV_{Broad-leaved\ forest} = -\,1{,}700 - \frac{780}{(1+0.01)} - \frac{780}{(1+0.01)^2} - \ldots - \frac{780}{(1+0.01)^5} = -\,5{,}486\ €/ha \quad (6)$$

4 Ecosystem services valuation in the Figaredo mining area

To determine the revenues of the three scenarios considered feasible for the Figaredo mining area: pine plantations for the production of wood as raw material (Fibre), feeding of cows for beef production (Food), and reconstruction of a broad-leaved forest similar to those already present in the landscape of the region (Landscape), firstly and according to the costs and payments previously analysed, the NPV of the provisioning ecosystem services will be calculated.

Considering the non-provisioning ecosystem services value of the different scenarios per ha calculated in D4.2, Table 4-1 presents the pairwise comparisons with upper and lower bounds for the alternative scenarios and the ecosystem service obtained per ha for the three scenarios considered.

Table 4-1. The ranges of values per ha for the different scenarios.

Scenarios	Lower bound	Mean	Upper bound	E.S. value
Landscape	0.87	0.93	0.99	15,154 €
Fibre	0.49	0.60	0.71	9,777 €
Food	0.47	0.57	0.67	9,288 €

Finally, Table 4-2 presents the total value of the different scenarios per ha using the average percentage of the ranges of values shown in Table 4-1.

Table 4-2. The total value of the different scenarios per ha.

Scenarios	Mean	E.S. value	NPV	Total value
Landscape	0.93	15,154 €	– 5,486 €	9,668 €
Fibre	0.60	9,777 €	2,386 €	12,163 €
Food	0.57	9,288 €	3,323 €	12,611 €

As the difference between the fibre and food production scenarios is negligible (only 3.7%), both can be considered to bring similar value to society in the case of the Figaredo mine. Therefore, the selection between them should be based on the ease of undertaking, measured in the lower investment needed to realise the scenario. Food production should then be selected for the specific case of the Figaredo mine.

5 Estimating the price of EU Allowances prioritising biodiversity

An exercise was carried out to estimate what the price of EU Allowances would have to be for the Landscape scenario to be chosen. In a sense, this is tantamount to allowing nature itself (biodiversity) to set the price of EU Allowances in the Figaredo mine environment. The Landscape scenario is the one that prioritises biodiversity, as shown in Figure 5-1, where the ranges of values for this attribute are presented.

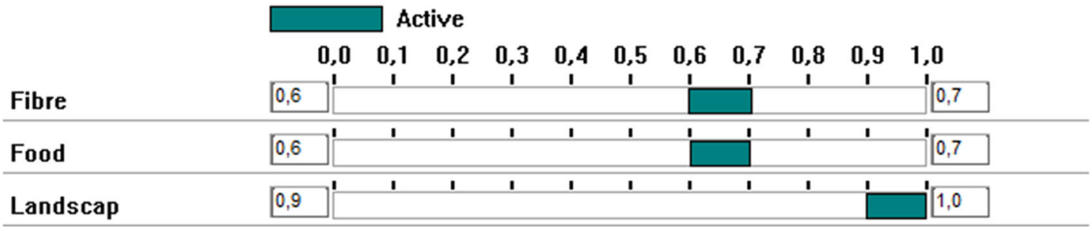

Figure 5-1. The ranges of values for attribute biodiversity.

For this purpose, and so that there can be no doubt about the preponderance between the different scenarios, it will be assumed that the value of the Landscape scenario should be at least 25% above the highest value of the other two scenarios. To achieve this goal, the total value of the Landscape scenario should be 38,268 €/ha, and its ecosystem services value should be 43,754 €/ha, as presented in Table 5-1.

Table 5-1. The updated total value of the different scenarios per ha.

Scenarios	Mean	E.S. value	NPV	Total value
Landscape	0.93	43,754 €	– 5,486 €	38,268 €
Fibre	0.60	28,228 €	2,386 €	30,614 €
Food	0.57	26,817 €	3,323 €	30,140 €

By dividing the value of ecosystem services in the Landscape scenario by 0.93, it is possible to obtain the updated total value of the highest potential contribution of ecosystem services in the Figaredo mine area: 47,047 €/ha. To achieve this result, it is necessary to value 68.31 t C/ha (equivalent to an above-ground carbon storage rate of 10.0) at 18,095 €. This would mean that the average sequestration value of 1 t C should be estimated at 264.90 €, which divided by the 3.67 t CO_2 contained in 1 t C, results in the emission of 1 tonne of carbon dioxide equivalent valued at about 72.18 € instead of 25 €.

This value of 72.18 € is very similar to the price of EU carbon permits on 17 December 2021, 73.5 € (Trading Economics, 2021), after the price escalation that coincides with phase 4 of the allocation of allowances under the EU Emissions Trading System (2015) that takes place from 1 January 2021 (International Carbon Action Partnership, 2021) (Figure 5-2).

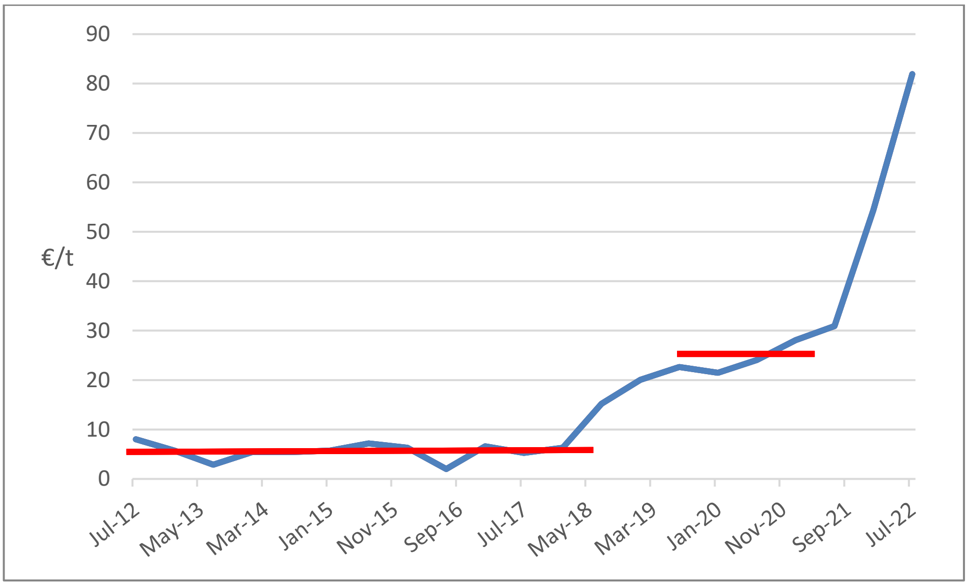

Figure 5-2. EU Carbon Permits (€/t). Adapted from EMBER (2021) and www.tradingeconomics.com.

6 Conclusions and lessons learned

The appropriate discount rates to undergo the valuation of provisioning ecosystem services, including the costs incurred for developing them, and the expenses needed to create non-provisioning ecosystem services, were selected in this deliverable.

They were classified according to three different categories: non-intensive natural goods production, intensive natural goods production, and industrial goods production, allowing for calculating the revenues of the scenarios considered feasible for the Figaredo mining area.

Based on this, the current price of EU Allowances was estimated by allowing nature to set the price in the Figaredo mine environment.

The lessons relevant to RECOVERY from the selection of the adequate discount rates can be summarised as follows:

1. Real/constant discount rates should be used in the calculations, as it will be challenging to consider adequate variations of the inflation rate over 70 years or more. Moreover, real/constant rates will allow using a common language despite the usual economic differences among European countries.

2. Non-intensive natural goods production, such as familiar animal exploitation, familiar tree plantations, familiar agriculture, etc., are proposed to be valued at a real/ constant rate of 1%, which is equivalent to the average reference rate of the European mortgage market in 2020. This value is equivalent to a moderate rate of growth, according to TEEB (2010), and is equal to the lower limit of the range proposed by Wu & Chen (2017) for permanent welfare. It is also equivalent to the risk-free rate, according to Scheule & Jortzik (2020).

3. Intensive natural goods production, such as intensive animal farms, intensive forest exploitation, intensive agriculture, etc., are proposed to be valued at a real/constant discount rate of 3%-3.5%, which corresponds to the lower value of the interval that was presented by Shaw & Wlodarz (2013) for Europe, and with the upper value of the interval proposed by Wu & Chen (2017).

4. Industrial goods production, such as renewable energy production, and industrial facilities, are proposed to be valued at a real/constant discount rate of around 6.0%-7.0% as there is usually an external investment trying to achieve capital returns. These values coincide with the upper value of the interval proposed for Europe by Shaw & Wlodarz (2013) or with the benchmarked rate proposed by Scheule & Jortzik (2020).

5. The values proposed for discounting industrial goods production should be accepted only when the industrial goods production risk can be considered average. In case the risk is over average, the discount rate should increase in the same proportion.

6. When the difference in the valuation between several scenarios is negligible, the selection between them should be based on the ease of undertaking, measured in the lower investment needed to realise the scenario.

7. The price of EU carbon permits varies over time, so in the valuation, it was used the average value during 2019 and 2020, which was relatively stable and coincident with phase 3 of the allocation of allowances. After the price escalation that coincides with phase 4 of the allocation of allowances under the EU Emissions Trading System that takes place from 1 January 2021, the consideration changed and, although not stable yet; it allowed us to estimate this carbon price by prioritising biodiversity over the rest of scenarios, something that was never done before.

7 Glossary

CAPM: Capital asset pricing model

CICES: Common International Classification of Ecosystem Services

CLC: Corine Land Cover

ES: Ecosystem services

EU: European Union

EURIBOR: Euro Interbank Offered Rate

GCD: Global credit data

TEEB: The Economics of Ecosystems and Biodiversity

NPV: Net present value

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