RESTORE –

Restoring Mineral Sites for Biodiversity, People and the Economy

across North West Europe

Work Package 4, Action 21

Economic Valuation Methods

▪ Overview of existing economic valuation methods to capture ecosystem service benefits of quarry restorations

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1 Economic Valuation and Ecosystem Services in RESTORE

The RESTORE project is developing a framework for the restoration of mineral sites to provide high net benefits for biodiversity, habitats and local people. One major aim of the project is to increase the impact of restoration investments on both society and environment by demonstrating opportunities to increase overall public welfare. To achieve this, RESTORE will showcase approaches and best practices of economic valuation of restoration investment options. The project will focus on the ecological, social and economic benefits that can be generated from mineral site restoration by analysing ecosystem services (ESS) at a number of selected case study sites. In essence, RESTORE will deliver guidance for policy makers to select the restoration option which delivers the greatest benefits relative to its investment and maintenance costs.

In contrast to the financial analyses that are conducted within enterprises (e.g. to decide whether or not to excavate raw materials), the benefits, and therefore the welfare impacts, of restoration investments need to be evaluated and captured using a different set of methods and indicators. While demand or supply curves and market prices can be used for the former, there is no such counterpart readily available in for the latter (the so called “valuation challenge”, see Hanley & Barbier 2009, pp. 206-213). Consequently, there is a rich body of theoretical and empirical papers in economic literature that deals with the issue of how to capture the benefits of environmental investments. There is a long tradition in economics to develop valuation approaches for non-market (public) goods to support decision making processes (Smith 2009). Due to this, there is a wide range of approaches that may be applicable to the RESTORE project. In order to be able to put monetary values on as many aspects of mineral sites restoration as possible, the scientific approach within the project will be site-specific with each restoration assessed and valued based on its unique circumstances. Despite this site-specific approach, there are two combining elements that frame the valuation within Work Package 4 (WP4) of RESTORE: site selection criteria and ecosystem services. The first element ensures we choose a representative set of restoration locations based on a set of defined criteria (substrate, location, starting point and alternative state) to enable transferability of results to other sites within North West Europe. The second element is the structure for our valuation approach. Within WP4, ESS will be used to guide the primary data collection, survey designs and also benefit valuation. This linking node was chosen, because benefits from ESS can be named and classified quite simply. Throughout the last decade many seminal publications helped to define a system of ecosystem services (ESS) that incorporate all the major factors that can be defined as creating benefits for society and nature (de Groot et al. 2002; Millennium Ecosystem Assessment 2005; Fisher et al. 2009).

2 Ecosystem Service Economic Valuation Methods

There is a wide range of existing economic valuation techniques to estimate the value of ecosystem services (McConnell & Walls 2005; TEEB 2010). In general, there are two main branches of economic valuation for public goods which are suitable to determine specific benefits: revealed and stated preference techniques (European Commission 2008).

2.1 Revealed preference approaches

Revealed preference methods are approaches that are based on market prices. They cope with the problem that for most public goods there are no market prices available (see1) by observing (market) behaviour and purchases caused by non-market impacts (TEEB 2010). In this way, these methods quantify the influence of preferences for non-market goods or services on actual markets for other goods (Pearce et. al. 2006). Therefore, revealed preference methods utilise an individual´s demand for private goods to infer their demand for public goods (Gronemann & Hampicke 1999). In contrast to stated preference methods (see 2.2) revealed preference methods cover only use values of the analysed goods. Two different approaches of revealed preference valuation for ESS have been identified from the literature - travel cost and hedonic pricing – and these are reviewed in more detail below.

2.1.1 Travel Cost Method

The travel cost method (TCM) is based on observed behaviour (TEEB 2010). Its basic assumption is that there is a relation between the use of a public good and the costs incurred for the use (Elsasser 1996). The TCM primarily derives the value for recreation sites from the costs expressed in the market for trips to the recreational areas. Thus, it is mainly used to determine values related to ecosystem services and biodiversity of public non market environmental goods such as national parks, beaches, woodland, etc. (TEEB 2010). To conduct a TCM the amount of visits per individual or household to a specific recreational site and the associated travel costs are required. This information is mostly gathered via surveys on site (Hanley et al. 2013). The travel expenses include monetary costs such as fares or petrol costs, wear and tear and depreciation of the vehicle, and so on. Furthermore, the cost of time spent travelling has to be considered. Here, opportunity costs appear, as time is a scarce resource that the household or individual could spend in other ways related to well-being (e.g. working). This leads to the conclusion that less time consuming trips to recreational areas should be more attractive and that the personal benefit of using the recreational sites, including the travel to it, must be at least as high as the personal benefit received by the alternative action. Therefore, wage rates are often used as values for the price of time when implementing a TCM approach. In reality, individuals can only imperfectly choose the number of hours they work, and thus time spent travelling is reported to be valued around a third and a half of the wage rate (Pearce et. al. 2006).

The application of the TCM can create a range of problems. The most significant is caused by multiple purpose trips, which creates the issue of identifying the part of the travel costs that are relevant for estimating the TCM. International tourists, for example, will not only visit a single recreational site a day but combine it with trips to other destinations. The same problem occurs in dense urban areas providing a lot of infrastructures such as shops, services, etc. According to Pearce et al. (2006), this complication can be overcome by asking visitors to estimate the proportion of enjoyment they derived from their entire trip that they would assign to the recreational area of interest, which reveals their approximate travel costs to the specific site. Additionally, TCM estimates the total economic value of all ecosystem services and biodiversity as well as other services of a site and does not allow the monetary quantification of single features of an area such as water quality, habitat and so on. Another important issue related to the application of TCM is that only use values are captured but non-use values are not covered.

2.1.2 Hedonic Pricing Method

The hedonic pricing method (HPM) is based on the assumption that prices for market goods consist of a combination of different elements, which together describe its character (Gronemann & Hampicke 1999). For the case of a private property this includes property characteristics (e.g. lot size, number of rooms), neighbourhood characteristics (e.g. property tax, crime rates), accessibility characteristics (e.g. distances to work, public transport) and environmental characteristics (proximity to open space, ESS provided by the green areas nearby). On this basis, HPM uses available information on the demand elements for a market good to identify the implicit price for the public good (Pearce et. al. 2006; TEEB 2010). In general, HPM is applied by the use of house, property prices and rents which are themselves influenced by factors such as location, size and number of rooms, and also by environmental qualities such as air quality, landscape, green spaces, recreation provision and water bodies. Hence, the values of ESS are reflected in property prices (TEEB 2010). For example, previous studies have demonstrated that properties next to a green space or water body are more expensive than those which are not (Crompton 2001; Luther et al. 2002; Mayor et al. 2009; Cho et al. 2009).

The first step in conducting an HPM is to collect relevant data on prices, characteristics and amenities of properties in order to identify marginal willingness to pay for each characteristic and amenity. Based on the gathered information, a hedonic price function is developed which describes the dependency of the property price on its factors. For the identified amenities, such as the proximity to sites providing ecosystem services, the implicit prices are estimated (Pearce et. al. 2006). The implicit price for an amenity is defined as the price difference of two properties with exactly the same amenity combination except for the amenity of interest. By this means, the implicit price reveals the value for a specific amenity, while the property price represents the total value for the property (Cansier 1993). Consequently, properties are considerably more expensive if they are in close proximity to a green space that provides higher environmental qualities than properties which have a green space providing low environmental qualities nearby.

There are some issues involved in the practical application of HPM. Like TCM, only use values can be measured. Furthermore, a large data set as a basis for the valuation is needed, which is often expensive and time consuming to create (TEEB 2010). Data can also be biased related to the individual's extent of knowledge of the property market. As a lot of individuals are taking part in the property market the resulting house purchase data will mostly be gathered from many overlapping markets. Finally, due to the collection of property characteristics which cannot be separated accurately another problem occurs: multicollinearity. This relates to the issue that some characteristics or amenities co-vary (e.g. the proximity to green space, a visual characteristic, is often related to recreation provision, a physical characteristic), making it difficult to separate their individual effects on the total price of the property. As a result, a clear cut identification of implicit prices is not possible any more (Pearce et. al. 2006).

2.2 Stated preference approaches

As the name suggests, stated preference approaches are survey-based. A questionnaire is developed to create a hypothetical payment scenario. Thus, a market and demand for ecosystem services is simulated revealing willingness to pay (WTP) or willingness to accept (WTA) for hypothetical changes in the provision of ecosystem services (TEEB 2010). Within the questionnaire, the good itself, the institutional context and the way it would be financed is described (Stewart & Kahn 2009). Further, a random sample of people is asked directly to express its WTP for a hypothetical change in the ecosystem service. To minimise bias, the respondents need to answer questions as realistically as possible. This can only be achieved if the good that is valued is honestly explained so that the respondent can make an informed answer. By this means, the amount of respondents willing to pay for a certain improvement can be identified revealing the attractiveness of the improvement. In contrast to the revealed preference methods, stated preference methods are able to capture non-use values and are applicable before and after an intervention (Pearce et. al. 2006).

2.2.1 Contingent Valuation Method

The contingent valuation method (CVM) is by far the most popular stated preference method for valuing ESS (Pearce et. al. 2006). The development of a questionnaire forms the key element of every CVM study. Beside an adequate format and wording, the questionnaire should be piloted before its implementation to correct main drawbacks and problems. Questions should be focused on conservative WTP questions, instead of WTA questions that generate upward biased prices (Arrow et al. 1993). Also, a “no-answer” option should be provided and people should be asked to state what their reason is for not stating any WTP (Bateman et al. 1993). Regarding the specifics of the WTP question, Arrow et al. (1993) suggest using a referendum setting, in which people only vote with “yes” or “no” for a specific amount of money presented by the interviewer.

Generally there are three basic parts in most CV surveys:

First, data on users/visitors of a specific site is collected. For this, use frequency, usage and users’ attitudes are surveyed (Pearce et. al. 2006). On the one hand, respondents are asked to give information on their use frequency and reasons for using/visiting the site. In addition, users´ opinions on features and characteristics of the featured ecosystem services in question may be surveyed. Further, respondents are asked to state what kind of new investment they would like to be implemented next. This question allows the interviewer to become acquainted with users’ conceptions and preferred investments for future developments of the public good. Additionally, it leads over to the WTP section of the questionnaire by revealing the underlying factors for WTP.

Second, the WTP scenario is presented. On the basis of respondents` attitudes and ideas for new investments, their WTP is investigated in few different questions which may cover if (general WTP) and, when yes, how much respondents are willing to pay (absolute WTP) and reasons for no general WTP.

Finally, socio-economic characteristics are recorded. In this part of the survey respondents are asked about their socio-economic status. Information such as origin, age, education and occupation are collected in this section to get a more detailed overview of their private circumstances.

If users state a general WTP, they are asked what annual amount they would be willing to pay into a hypothetical fund, which tax they would spend more money on or any similar payment vehicles, i.e. measures that structure how the provision of the good is to be financed. To support respondents with their decision, a payment card can be used, allowing respondents to declare every kind of amount (Gronemann & Hampicke 1999). Respondents not willing to pay are asked why this is the case. This approach enables interviewers to see whether expectations of users and inhabitants are being fulfilled and where further investments could be targeted. Furthermore, it helps to estimate if future investment may be financially supported by users when respondents´ needs and suggestions are taken into account. Additionally, the determinants of the WTP are explored by gathering users´ data, such as information on socio-economic characteristics, frequency of usage and opinions.

2.2.2 Choice Modelling

Choice modelling (CM) is a stated preference method which was originally popular in marketing and transport applications (e.g. REFS). More recently, it has grown in popularity among environmental economists due to its ability to capture use and non-use values (Morrison & Bennett 2000). A choice modelling application includes a survey, similar in structure and content to CVM (see section 2.2.1), which presents investment alternatives to be chosen by respondents. The trade-offs respondents make can be quantified, and values related to the attributes of the alternatives can be revealed (TEEB 2010). Although CM is quite similar in its application to CVM, there is an important difference in that CM respondents are asked to pick their preferred options within a series of scenarios, to rate or to rank them (Stewart & Kahn 2009). This enables policy makers not only "to uncover the value of the total change in a multi-dimensional good" (Pearce et al. 2006, p. 126) as in CVM, but also to estimate the change in each of the attributes of the good.

In CM applications the main characteristics of the good in question are identified by using focus groups to define the attributes of the good that are likely to be affected by a specified policy action (Pearce et al. 2006; Stewart & Kahn 2009; Hanley et al. 2013). It is most important that the chosen attributes (e.g. water quality, wetland area, animal species conserved, etc.) are related to some kind of monetary costs, if economic values are to be estimated, and that they are meaningful with regards to the preferences of the target interviewees. It should be possible to change the chosen attributes by the responsible authority (Hanley et al. 2013). Next in this procedure, the attributes are given certain levels which should be realistic, feasible and cover the variation of respondents` preferences. One of the attribute levels is generally the "status quo" (Pearce et al. 2006). Afterwards, the different levels of the attributes are used in an experimental design to create choice sets that present respondents with investment alternatives. Every choice set usually contains three or more options (Morrison & Bennett 2000). On the basis of the choice sets a survey procedure is selected to measure individual preferences and related benefits. Variants of CM are named after their ways of measuring respondents' benefits: Choice experiments, contingent rating, contingent ranking and paired comparisons (Table 1; Pearce et al. 2006).

Table 1: Main choice modelling alternatives

Type of CM	Approach
Choice experiments	Choose between two or more alternatives (where one is the status quo)
Contingent ranking	Rank a series of alternatives
Contigent rating	Score alternatives on a scale of 1-10
Paired comparisons	Score pairs of scenarios on similar scale

Source: adapted after Pearce et al. 2006

A choice experiment (CE) includes alternative, differing with regard to attributes and levels, and respondents are asked to choose their most preferred (see table 1). One of the alternatives is to keep the current situation. In a contingent ranking experiment the base of presented alternatives, described by various attributes and levels is the same as in CE, but here interviewees should rank the options. Contingent rating demands the respondents to access the different scenarios on a semantic or numeric scale (e.g. 1-10). The paired comparisons exercise takes the contingent rating principle one step further by requesting respondents to select their preferred alternative out of a set of two scenarios and to score it as in contingent rating (Pearce et al. 2006).

2.3 Benefit Transfer

Benefit transfer describes the usage of economic research data gathered mostly from a revealed or a stated preference study, which was conducted at a certain place and time, the "study site", to make predictions of welfare estimates for another site, the "policy site", for which primary information is not available (Rosenberger & Loomis 2001; Ready & Navrud 2005; Wilson & Hoehn 2006; Johnston & Rosenberger 2010; TEEB 2010). As a result, benefit transfer is only applicable "if a study already exists that valued a good similar to the good in question" (Ready & Navrud 2005, p.196).

Recent research distinguishes commonly between two types of benefit transfer: unit value and function transfer (Johnston & Rosenberger 2010). The first approach is suitable when the hypothesised impacts of the policy site can be measured in independent, non-overlapping units which are identified through review of previous valuation studies for that good (Ready & Navrud 2005). To guarantee high validity, the study and policy sites should be similar and in close proximity to one another. By doing so, it is ensured that benefit values from a study site can be easily projected unit by unit to a policy site. When the context of the study site is different to the one of the policy site, function transfer may increase the reliability of the benefit transfer. A value function predicts the benefit values of the project site on the basis of the measurable characteristics of the study site. By knowing the significant factors affecting WTP for the study site (e.g. income, age, opinions, etc.) this information can be used as a function to assess the benefits of the policy site (Pearce et al. 2006; Ready & Navrud 2005).

As function transfer is dependent on several conditions regarding study site attributes and data, a meta-analysis which combines value estimates from different studies can provide more flexible value functions with greater applicability. The general opinion in the literature is that function transfers are typically more accurate than unit value transfers (Johnston & Rosenberger 2010). Both types of benefit transfer are subject to two categories of errors: measurements errors and transfer errors. The first are within the original study and reveal differences between a true underlying value and a primary study value. The latter may occur within the transfer process. They are also called generalization errors as they can be caused by "the correspondence between sites and populations, the commensurability of non-market goods and policy contexts, and the benefit transfer method applied" (Johnston & Rosenberger 2010, p. 486).

Due to its relative simplicity in relation to primary research, benefit transfer is commonly conducted worldwide by agencies and institutions to assess the economic benefits and costs of development projects to justify investments (Wilson & Hoehn 2006). Benefit transfer offers a time-saving and inexpensive option to support policy progress instead of conducting original studies when benefit estimates are required (TEEB 2010). Therefore, benefit transfer is often the only feasible alternative to estimate the monetary benefits of environmental goods and services, although "the use of primary research to estimate values is generally preferred" (Johnston & Rosenberger 2010, p.479). Despite its increasing importance for policy making, practitioners are still seeking for official guidance or best practice standards on how to apply benefit transfer (Wilson & Hoehn 2006). Here, the scientific discussion and the practical use of benefit transfer for policy analysis are not perfectly linked with each other (Ready & Navrud 2005). While academics have produced many papers on the use of function transfer and other approaches to reduce transfer errors and improve validity, practitioners are interested in less complex but easier accessible concepts and guidance which are conducive to benefit transfer applications (Johnston & Rosenberger 2010).

2.4 Cost Benefit Analysis (CBA)

In many studies on the welfare effects of policy measures, the valuation methods presented are just one step in a wider analytical framework: the cost benefit analysis (CBA), or social cost benefit analysis if extended for distributional aspects (SCBA). As its name is indicating, this framework is a concept which concentrates on the net effects of policy measures. So it takes into account not only the possible benefits for society and nature, but also the costs that accrue due to policy implementation (Brent 2006). In the RESTORE case these basic concept of a CBA becomes important. It is not only essential to compare benefits of alternative environmental investments. It is even more important to ask, which investment is generating the highest "value for money".

The CBA is characterized by a standardized stepwise procedure (Hanley & Barbier 2009):

1. Project/Policy Definition
2. Identification of Physical Impacts of the Policy/Project

3. Valuing Impacts
4. Discounting of Cost and Benefit Flows
5. Applying the Net Present Value Test
6. Sensitivity Analysis

Steps 1 and 2 refer to the definition of the issue that should be analysed and to the need to have a fixed amount/magnitude of change versus the status quo ante. More interesting, the third step is the heart of a CBA when looking at the work that needs to be done individually and is case sensitive. Here, the valuation methods that have been discussed so far are implemented to end up with a list of monetary values for the benefits of a project over its lifetime or the time horizon that is under consideration.

Following the valuation, a CBA also looks at the costs of a project (implementation, maintenance, etc.) to use them in a fully scoped appraisal. All price information on benefits and costs is then discounted using a social discount rate (step 4). Step 5 is the primary result of a CBA. By looking at the net present value, which is the sum of all discounted benefits minus the sum of all discounted costs, the CBA ends at this stage with an explicit decision on the social profitability of policy measures: As long as the benefits outweigh the costs, a project can be classified as providing additional welfare to society (Hanley et al. 2013). When comparing a set of different policy option, the CBA results can guide the decision on which of these to take. For this, the decision maker should compare the absolute net benefits, cost-benefit ratios and also break-even time projects need to reach a surplus status (Pearce et al. 2006).

In a final step a sensitivity analysis is obligatory, because many variables that are used in a CBA change the results when they are only slightly altered. This is especially relevant to discount rates, time horizons and, in the case of environmental CBAs, the WTP values and their capture.

3 Economic Valuation and Mining

Valuation of environmental and socioeconomic benefits in monetary terms has gained importance over the last decade by playing an increasingly significant role in decision-making (Damigos 2006). However, economic valuation methods have been rarely applied to the mining industry so far because decisions in this sector are determined primarily by the financial gains earned by mining/excavation. Quarry restoration and aftercare programmes do not contribute further to profit for the mining industry, and consequently companies often choose restoration options with low cost expenditure based on financial analysis, and neglect landscape aesthetics and other environmental and recreational benefits (Damigos & Kaliampakos 1999; 2003a).

Nevertheless, there are some examples of case studies where economic valuation has supported the decision making progress (e.g. Larondelle & Haase 2012, who modelled post-coal mining scenarios in Germany). Damigos (2006) emphasizes the particular potential for valuation studies in the mining sector. On the one hand monetary valuation techniques should be applied to project appraisal, on the other hand to environmental liabilities.

The following section presents some examples of contemporary experiences of economic valuation in the mining sector. Firstly, we present published economic valuation studies that have collected and provided data, differentiating between those estimating negative external effects produced by mining activity, and those valuing restoration options and recreational benefits after mining activity. We then describe studies that use methods to transfer existing benefits to a chosen mining site without surveying on site. A summary discussion of the presented studies and economic valuation methods that have been used so far on mining concludes this section and highlights the relevance and use of economic valuation techniques for mining site restoration. Table 3 gives an overview of the selected studies and is attached at the end of the chapter.

3.1 Measuring negative external effects of mining activities

As purely financial computation of an open-cast site neglects environmental costs, in 1992/93 Trigg and Dubourg carried out a *social cost-benefit analysis (SCBA)* using a prospective open-cast coal mining site in the Trent Valley in North Staffordshire, UK. They used the case study in order to evaluate the relation of financial profit and possible environmental costs and appraise the development proposal. First, the total financial profit of the potential site had to be estimated. Based on national figures and investigations on site, assumption about the output of coal, that can be produced, financial costs of mining including the long gestation process, the market price of coal considering the international competition, as well as the period of production of 8 years were met with the result that the site has a total discounted profit of £7.8 million applying the Treasury discount rate of 8%. Benefits generated by development and restoration such as employment or creation of nature reserves were neglected due to the fact that open-cast coal mining is much less labour intensive than deep mine production and that there are already nature reserves close by. Second, the environmental costs such as noise, dust, adverse visual impacts, reduced amenity and recreational possibilities or long-term environmental damage were valued to be comparable with the expected profits by using a *hedonic pricing approach* (other methods were ruled out due to their limitation, cost-intensity or complexity). Thus a survey of seven estate agents with specialized knowledge of the Trent Valley area and impacts of other opencast coal mining sites on the housing prices was undertaken. The interviewees were asked to estimate the impact of the prospective site on house prices in the area, the areas affected and the extent of price falls. As the experts agreed that the “site would have an adverse effect on house prices” (Trigg & Dubourg 1993, p. 1119) they also predicted house prices could fall by between 10% and 40% depending on the location. Combined with values of the housing stock extracted from council tax registers and under consideration of government subsidies influencing house prices, the estimates of the survey were used to aggregate the overall effect to £5.1 million for the rental from the total loss in housing stock for the whole time of site development and production. Moreover, some of the interviewees considered a recovery of house prices in case of a quarry restoration. In total, the profits were estimated to be higher than the monetary measured environmental costs, so that the study assessed a net benefit of £2.7 million. However, Trigg and Dubourg noted an underestimation of the environmental costs as the study did not contain non-use values and does not analyse “the full menu of environment impacts” (Trigg & Dubourg 1993, p. 1121). For instance, it did not include the involvement of non-residents that use the site (Trigg & Dubourg 1993).

In the context of a potential taxation for mining activities, a study was undertaken in 1999 in order to estimate “the level at which an aggregate tax should be set to account for externalities [such as noise, dust and mud] from quarries” (Willis & Garrod 1999, pp. 77-78). Hence, the study measured the value of externalities to local residents from quarry operations at the Aycliffe hard rock quarry in County Durham, UK, which was chosen as a case study because it was considered representative with a typical range of externalities. A stated preference *CE* was used to reveal the WTA compensation for the change in quarry externalities amongst the residents. This choice experiment “permitted respondents to trade-off decreases in [local council] tax against changes in the number of days they are subject to environmental disamenities” (Willis & Garrod 1999, p. 84). Thus 49 choice sets were created, each defining two scenarios that differed from each other in the face of the attributes describing the number of days with noise disturbance, as well dust and mud on public highways produced by the quarry activity, and a specified reduction in council tax. Whereas at least one of these attributes was higher in the second scenario than in the first scenario, the reduction in council tax was higher. A randomly chosen series of four choice sets were presented to the respondents, and they were asked to choose one scenario for each choice set based on their preferences for externalities as well as their WTA compensation. Moreover, the respondents were informed about the quarry activity in Aycliffe and interviewed about their attitude to the quarry in particular and the environment in general. Taking into account the amount of average council tax payment and number of days per year the quarry worked, the survey revealed that the value of one less day of noise, dust and mud ranged between £1.38 and £3.54 per household, corresponding to an annual value of £433.32 to £1111.46. The total disamenity value was £175,061 to £449,070 considering all affected households. Given the quarry’s annual output, the study recommended a tax on aggregates production of £0.41 to £1.05 per tonne (Willis & Gerrod 1999).

Commissioned by the British Department of the Environment, Transport and the Regions (DETR) London Economics published a study in 1999 dealing with environmental costs and benefits of the supply of excavation materials using CVM. The aim of the study was also intended to derive estimates for the economic values of the environmental impact of quarrying to inform whether further measures such as tax increase were necessary to reflect the costs in the prices. The open-ended *CV* contained two surveys analysing the WTP and WTA, which were applied at eight rock and eight sand and gravel quarries. First, 7300 local people who lived within a five-mile radius of the selected quarries, were asked how much they would accept as compensation for continuing quarry operation, and how much they would be prepared to contribute towards the closure of the quarry in their vicinity. The survey identified local environmental costs of £0.34 per tonne of rocks and £1.96 per tonne of sand and gravel extracted by quarrying. Second, a national interview was undertaken addressing quarrying in National Parks asking 1019 people in the UK about their WTP for the closure of quarries in Yorkshire Dales and Peak District National Parks (LE 1999). The environmental costs of National Park quarries generated by this study were £10.52 per tonne and thus much higher than the local environmental costs. Both audiences were asked to consider two scenarios: One for continuing extraction and one for early termination of quarrying. However, each option included assumptions identified as unrealistic by the Quarry Product Association and thus inapplicable for a contingent valuation. Moreover, contrary to its title, the study focused on environmental costs while neglecting valuation of benefits. The case study was criticised by the Quarry Product Association, which suggested that 16 sites could not be considered representative, given that the total number of rock, sand and gravel quarries in the UK exceeds 1500 (QPA 2000).

The *CVM* was also used in a study conducted during the 1980s in Kentucky, USA. In order to measure the economic benefit of preservation instead of further extraction, WTP of wetlands preservation from surface coal mining was recorded. In the face of expanding the mining industry in the area, households were asked about their WTP for a hypothetical “Wetland Preservation Fund” to avoid further development for the surface coal mining. Instead of asking for a stated amount, graded dollar values were used and respondents had to agree or disagree. Mean WTP was US$12.67 or US$6.31 per household per year (Whitehead 1990).

3.2 Valuing quarry restoration and recreational benefits

The studies presented in Section 3.1 centre on the environmental costs of quarrying and, therefore, do not survey benefits generated by quarry restoration. However, there are also studies bringing restoration options and benefits into focus.

A case study from the late 1980s in Colorado dealt with environmental assets, as an abandoned mine still released hazardous substances to a nearby river and groundwater, causing environmental issues. By use of the *CVM*, a county-wide household mail survey was undertaken to find out about people’s annual WTP for 10 years to clean up and restore the river section affected by mining. Mean WTP per year and household was US$70. Additionally, mean WTP for water based and non-water based activities along the river section were identified as US$73 and US$51 per year and household within the county. In addition, hedonic property analysis was integrated on county level, which showed that vicinity to the river affected the property value negatively (Rowe et al. 1985; Kopp & Smith 1993; Damigos 2006).

During the late 1990s and early 2000s, two survey-based economic valuation studies related to the mining sector were applied in Greece. Both involve ex-ante assessments of restoration plans for a selected quarry, which underlined the unique character of each site. The first survey was the first attempt to introduce monetary benefits of reclaiming abandoned quarries to the Greek public and local authorities, and focused on the P. Viaropoulos quarry located in the centre of Athens, which had been abandoned since the late 1970s. The aim of the study was “to measure abandoned quarries’ reclamation benefits in monetary terms, using residents’ WTP for the implementation of remedial measures on the ground of a *contingent valuation method* survey” (Damigos & Kaliampakos 2003a, p. 256). Due to high density and lack of green infrastructure in the centre of Athens, the study was centred on free space orientated restoration alternatives. Over a two-month period, 200 adult residents in the surrounding municipality were interviewed face-to-face about their WTP for each of the three following restoration options that were presented by photographs in 1998 to 1999: (1) reforestation, (2) total backfilling of the area, and (3) reforestation, partial backfilling, reforestation and installation of new land uses including recreation, sport and parking facilities (Damigos & Kaliampakos 1999; 2003a; 2003b). Mean WTP values showed a significant preference for the latter alternative that offered a high degree of variety in land uses; Scenario 1 reached a mean WTP of €30.75 per year, scenario 2 €49.47 per year and scenario 3 €58.20 per year, even though the second alternative show the lowest rate of refusing to pay (Damigos & Kaliampakos 2003a). Besides the CVM, the study also used *TCM and HPM*. As *TCM* is limited in ex-post analyses, it was necessary to assume that the value of neighbouring recreation represents the “’lower’ limit of the recreation value of the site after the rehabilitation” (Damigos & Kaliampakos 2003b, p. 359). Excluding respondents that arrived by foot, the travel costs varied from €0.29 to €1.47 (Damigos & Kaliampakos 2003b). Due to the lack of adequate data the *HPM* was modified using the “fuzzy Delphi method” (Damigos & Kaliampakos 2003b, p.360). Thus, twelve experts were asked to estimate the effect of a rehabilitation of the quarry site on property prices. Later the average of all estimates was presented to the experts, allowing a revision of their statements (Damigos & Kaliampakos 2003b). The results of this analysis reached 35 times higher values compared to mean WTP results (Damigos 2006). However, Damigos and Kaliampakos (1999) underlined the importance of non-use values in terms of quarry restoration, which HPM as well as TCM cannot estimate. Damigos also pointed out that the results originally surveyed ex-ante might be useful in terms of benefit transfer for other ex-post valuations (Damigos 2006).

The second study analysed WTP for different restoration options for the Prosotsani quarry in north-western Greece using the *CVM*. The study concentrated on the attitude towards quarrying in order to find out determinants of preferences regarding quarry restoration. The selection of interviewees also included tourists and visitors, as respondents were chosen randomly in the city centre of Drama. Results from the study showed attitudes towards quarrying did not depend on whether respondents ever visited the site, whereas WTP was dependent on their attitudes. The most preferred restoration alternative was the greening of slopes with trees, followed by greening of slopes only with low vegetation, building a theatre place, and creating an ethno-botanic garden. Significantly less desirable were commercial alternatives such as a factory, a fun park or a commercial centre (Papadopoulos et al. 2012). As the study was conducted relatively recently it shows the relevance of economic valuation of restoration scenarios for the current discussion.

Another study in north-western Greece, in Kavala, the neighbouring municipality of Drama, dealt with attitudes towards an abandoned marble quarry as well as quarry restoration preferences. Without applying any economic valuation methods, the presented restoration alternatives were comparable with the study in Drama. However, the results differed, as afforestation was the most desirable followed by building an open-air theatre, creating an ethno-botanic garden, a shopping centre and a zoo. Greening of slopes not necessarily covered by trees was only the sixth most preferred option. Moreover, the study revealed that respondents preferred certain alternatives but did not intend to visit natural recreation based restoration sites (Hasanagas et al. 2009). However, comparing both studies, it is striking that attitudes towards abandoned quarries and restoration preference might differ for each site.

A similar approach to the examples from Greece was undertaken in Eastern German Lusatia Region where several open brown coal pits were flooded to create a ‘lake district’ for recreational use by 2018. Due to the soil conditions and a regional scarcity of water there was a high risk of acidification in the lakes which resulted in restrictions for swimming and thus for recreational use. Prior the study, recreational benefits had not been investigated, even though the concept of the restoration project focused on recreational use. Hence, the study attempted to derive an economic valuation of these non-market values by using the open-end *CVM* (Lienhoop & Messner 2008). Respondents were asked about their WTP for two restoration scenarios addressing the water quality of the lakes and infrastructure for recreational use such as beaches or hiking trails (UFZ 2009). They were asked for annual donations for 10 years into a hypothetical “fund that will help finance the development of the lake-district and its recreational infrastructure” (Lienhoop & Messner 2008, p. 968) in order to reveal a feasible way of paying. One scenario described nine core lakes with good water quality, good infrastructure and multiple possibilities of use (1); the other included only six of the nine lakes with good and three with poor (acidic) water quality limiting their use (2). For scenario 1 mean WTP was €18.96 per year whereas for scenario 2 it was €15.94 per year. The procedure included a pre-test consisting of face-to-face interviews of on-site visitors that were carried out in order to gather information about travel distances to locate the zone of attraction. The interviews were feasible because part of the lakes were already completed and in use. Based on the results of the pre-test, 1,500 questionnaires were distributed to households and face-to-face explanations of the two scenarios were made. In this manner, users on site as well as users at home and non-users could be reached. By asking for respondents’ distance to the lakes, it was also possible to account for this during analysis. The results showed a higher mean WTP for a distance more than 50 km even though the authors emphasized that it can be assumed that these visitors do not visit the lake-district frequently, but value the experience more due to its rarity. Furthermore, the study took account of the region’s socio-economic context, as Lusatia Region faces a drastic structural change because of the loss of the mining industry. Therefore, respondents were also asked to value potential improvements to the regional economy as a result of the quarry restoration in order to investigate the impact of these “fuzzy future benefits” (Lienhoop & Messner 2008, p. 971) which cannot fully traced back to restoration. Since total WTP means are significantly higher, if respondents – especially in non-user’s decisions – are influenced by these fuzzy future benefits, they play a decisive role for values priced (Lienhoop & Messner 2008).

Whereas the previous study's mean WTP revealed preferences and interests in the restoration site, a prior ex-ante survey undertaken in the region for a similar restoration site, the Cottbuser Ostsee, in 2004 determined a much lower WTP of €4.39 per year and household (Ahlheim et al. 2004). Contrary to the other studies presented, the focus on recreational aspects and benefits of both surveys in this Region are striking, attach importance to the users of the restoration site, and give examples of compatibility of CVM in the restoration of abandoned quarries.

3.3 Economic valuation using Benefit Transfer

There are also studies that did not survey primary data for a specific site because of a lack of time and resources. Instead, these economic valuation studies adopted a benefit transfer methodology, and some of these studies are described in detail below.

In Northern Greece, an assessment of a gold mining investment, the Perama gold project, was undertaken in order to estimate its social worthiness, as protests against gold mining projects are more intense than against other mining activities, and negative impacts on the environment and quality of life are considered as significant and long-lasting. In the context of a *SCBA* the overall impact of a mining project on sustainable development was assessed, considering these negative impacts as well as local and national economic benefits. To value external effects the *benefit transfer method* was applied. After carrying out an environmental impact assessment to quantify the environmental impacts, literature and study sites with similar environmental impact and socioeconomic characteristics were selected using an online database. Thus 323 studies were finally selected, of which 28 referred to mining activities. The primary economic studies applied different evaluation methods such as CV, HP or *TCM*. The study considered the three following different scenarios to estimate the cost of the environmental impacts of the project: (1) An approach estimating all externalities simultaneously, (2) an additive approach assessing environmental impact separately considering landscape alteration, biodiversity, surface water, ground water, air pollution and noise pollution, and (3) an approach considering the case of a major environmental accident. Due to differences between the study and policy site, different currencies and inflation, values were adjusted using the Power Purchasing Parity Index and the Consumer Pricing Index. The range of estimates derived from the studies is shown in Table 2).

Table 2: Estimated costs per annum for each scenario for the local and neighbouring area or a broader area

scenario	Costs for the local and neighbouring area	Costs for broader area
(A) simultaneous approach	€1.32 million	€9 to 13 million
(B) additive approach	€1.4 to 49 million	€9 to 12 million
(C) the case of a major accident	€4 to 182.5 million	

Source: Damigos 2006

Moreover, the social cost-benefit analysis revealed a mean Social Net Present Value (NPV) of €45.9 million. Thus, the total benefit of the project surpassed the total costs the investment was considered socially worthy. Taking into account a major environmental accident, the Social NPV was estimated to be € -310 million, even though its probability is very low (Damigos 2006; Damigos & Kaliampakos 2006).

In the course of the approval procedure for the extension of a sand and gravel quarry on current farmland in Ripon, Yorkshire Dales, UK, the operating company, Aggregate Industries UK, has undertaken a *CBA* in cooperation with International Union for Conservation of Nature and Natural Resources (IUCN). The valuation study aimed "to measure and quantify in monetary terms the impacts that the quarrying and [chosen] restoration operations will have on biodiversity and the ecosystem services provided to local communities and regionally" (Olsen & Shannon 2010, p. 5). Originally Aggregate Industries UK intended the study to identify the most efficient restoration option in ecological as well as economic terms among a range of alternatives. However, Olsen and Shannon (2010) suggested this was not possible, as valuing the difference in economic terms between renaturation alternatives (e.g. reed beds compared with wet grassland) is difficult. It would have required stated preference methods to quantify preferences and WTP for restoration options, and this was not realizable within the limits of the study's financial resources and time available. Instead, the company proposed the creation of an artificial lake surrounded by reed beds and wet woodlands as the final restoration option for Ripon City Quarry. The study compared its net benefits to those of the status quo scenario without extended quarrying. In order to gain the restoration's net benefit, the study identified and contrasted the most significant costs and benefits linked with quarry and restoration operation. Whereas costs included foregone agricultural output, associated ecosystem services, restoration activity and aftercare programmes, environmental costs considered by other studies focused were not included. The benefits covered profits from temporary excavation of sand and gravel, and post restoration ecosystem services such as flood control, carbon storage, biodiversity, the provision of habitat for wildlife and recreational opportunities. Due to the fact that collecting new empirical data exceeded resources and time, the study applied a *benefit transfer approach,* using estimates calculated in more detailed studies of similar sites in order to assess these ecosystem services in a monetary way. The study focused on studies that assessed a conversion of farmland into wetlands or man-made lakes. Annual WTP of £53.40 per household over a five-year period for enhanced biodiversity from new wetland habitats on existing farmland was estimated by a study by Christie et al. in 2004 in Northumberland. According to Olsen and Shannon (2010), the results were transferable, as the socio-economic characteristics of both regions were similar and the land-uses were the same, ignoring the short-term excavation. Due to little existence of transferable studies in terms of the recreational value, they used IUCN transferred estimates of a contingent valuation of, amongst other things, the WTP for boating activities in the Marston Vale Community Forest, in case a new lake was to be created (Maxwell 1994). Maxwell identified an annual WTP of £4.93 per resident, which was generalized for recreational value of the Ripon restoration site. The net benefit of the restoration scenario, which used a three per cent discount rate and 50 year time horizon, was significant, at £1.1 million. Including the profits from sand and gravel production the total value is estimated with £2,840,341. The most noticeable benefits arise from biodiversity (£1,415,917) and recreation (£356,330), while in contrast the highest costs are associated with foregone agricultural output at £721,761 (Olsen & Shannon 2010).

A study undertaken by Lafarge North America Inc. assessed the value of ecosystem services that are generated by different land management approaches for future reclamation of a limestone quarry in Presque Isle, Michigan, USA. After identifying key ecosystem services including erosion regulation, water purification, recreation and ecotourism as well as education the study valued those using different instruments (WBCSD 2011a; 2011b). First, erosion regulation and water purification were quantified, mapped and calculated by the use of a GIS based model, giving information about potential future avoided costs for erosion regulation services (Ozment 2012). Second, estimates for the recreational and educational services were generated within a *benefit transfer approach.* Potential monetary values related to fishing, hunting, wildlife viewing, and education services which are provided by wetland habitat changes were derived from the Wildlife Habitat Benefits Estimation Toolkit which contains WTP results of comparable site-specific studies (Kroeger et al. 2008; WBCSD 2011b). Nevertheless, these case studies do not necessary deal with quarry restoration, but habitat changes that are comparable to the restoration options. As a result the study revealed potential economic values for recreational and educational services between $2 million and $31 million over 10 years (Ozment 2012). Besides the significance for the specific future restoration of the Presque Isle Quarry, the study helps Lafarge North America Inc. to “restore more natural areas after mine closure to enhance local ecotourism and educations opportunities” (Ozment 2012, p. 3).

3.4 Discussion on economic valuation in mining

The selection of published studies presented shows that there are already a lot of examples for economic valuation related to mineral extraction, which allows highlighting the relevance and use of economic valuation techniques for mining site restoration. It seems that studies measuring external effects and environmental costs of mining activities are most common to date. In particular, WTA external effects for neighbouring residential areas are used frequently within these studies. By providing monetary values of negative side effects, which can be charged against the profits of mining activity, these studies facilitate admission procedures and decision-making regarding mineral extraction at specific sites. Thus, they can be used within the framework of a cost benefit analysis. Case studies from UK also show that economic valuation studies about external effects of mining activity can be used to reveal a potential taxation of mining products, which emphasizes the range of applications and addressees. However, they do not provide any decisions or solutions about the restoration and use after quarrying. Neither contributes further profits and both incur a financial loss for mining companies, but are of high interest for the environment and the public. Accordingly, economic valuation including non-use values and public preferences cannot be neglected in line with sustainable planning and restoration of mining sites. Hence, considering restoration options at an early stage and seeing restoration as a major part of the extraction process are advisable in order to increase acceptance among the public. The World Business Council for Sustainable Development emphasizes that studies including restoration plans facilitate future planning procedures and enable companies to build a reputation for environmental responsibility to improve their licence to operate (WBCSD 2011b). Presented studies show the possibilities of measuring benefits of restoration options in monetary terms. Environmental and recreational benefits in particular are measured to price the economic value of quarry restoration, which is important because qualitative estimations are difficult to compare to costs and profits and so are often neglected. Moreover, the comparison of the Greek case studies in Kavala and Drama reveal another advantage of using economic valuation methods: whereas the Kavala survey only investigated the preferences for different restoration alternatives, and also showed that despite preferring one option respondents do not intend to visit the reclaimed site, detecting the WTP as in the Drama study seems to be a more feasible approach to reflect local interest and value of the site. Moreover, it has to be considered that WTP also might be significantly influenced by cultural background or national history.

Currently, contingent valuation is often used in practice, yet this is not a standard approach in the mining sector. TCM and HPM are barely used in the mining sector due to their limitation to existing sites and the measurement of use values. Both, TCM and HPM are not suitable for ex-ante studies that optimise the benefits available under restoration.

Although primary research is always the best first strategy, it is a very time-consuming and expensive task. Hence, when primary research cannot be carried out due to limited resources, BT is the second-best strategy, as it can provide useful information for case studies that do not require a high degree of precision (Rosenberger & Loomis 2001; Damigos & Kaliampakos 2006). Thus, as the latter studies show, primary data of similar studies can be adopted. These case studies also demonstrate that data from studies dealing with valuation of recreational use of new habitats outside of the mining industry can also be used as long as sites are comparable and the survey does not concentrate on specific conditions given due to mining or restoration activity (e.g. Ripon City Quarry study or Perama gold project). Therefore, BT saves costs and might allow further surveys to be undertaken within the limits of the budget provided (WBCSD 2011b). Moreover, its structure is traceable so that BT is easily accessible for decision makers. Nevertheless, BT depends on primary research data, which is provided by databases such as Environmental Valuation Reference Inventory (EVRI) or Greek Environmental Valuation Database (GEVRAD), and it is vital that such data sets survey equal values or attributes to be transferrable. Furthermore, they need to be adjusted to the policy site. However, data sets rarely contain European case studies and the major part of available European economic valuation studies are confined mainly to Greek or British sites. Particularly in the face of valuing restoration options on basis of WTP, the scarcity or even lack of conducted and published studies in some European countries shows a certain need for action as preferences.

Table 3: Overview of selected case studies

Year	Executer/ Author	Quarry site (type)	Location	Method	Object of investigation	Value
REVEALED PREFERENCE APPROACHES						
Travel Cost Method						
1998/ 1999	Damigos & Kaliampakos	Abandoned marble quarry	Athens, Greece	CVM, TCM, HPM	Ex ante assessment of restoration scenarios and their benefits	- TCM: €0.29 to €1.47 - Mean annual WTP (and aggregated WTP) for (1) reforestation: €30.75 (€248,245) (2) total backfilling of the area: €49.47 (€482,925) (3) reforestation, partial backfilling, reforestation and installation of new land uses: €58.20 (€524,440) - HP: €13,467,602.61
Hedonic Pricing Method						
Late 1980s	Kopp & Smith	Abandoned gold, silver and zinc mine	Colorado, USA	CVM, HPM	- River restoration due to hazardous substances - recreation activities	- Negative impact of environmental issues on property values - Mean annual WTP of US$70 per local household - Mean annual WTP for water based and non-water based activities along the river section of US$73 and US$51 per household
1992/ 1993	Trigg & Dubourg	Opencast coal mining site	Trent Valley in North Staffordshire, UK	SCBA, HPM	Environmental costs of an open-cut coal mining proposal	- House price fall between 10 and 40 % - aggregate the overall effect of - £5.1 million - net benefit of £2.7 million
1998/ 1999	Damigos & Kaliampakos	Abandoned marble quarry	Athens, Greece	CVM, TCM, HPM	Ex ante assessment of restoration scenarios and their benefits	- HPM: €13,467,602.61 - Mean annul WTP (and aggregated WTP) for (1) reforestation: €30.75 (€248,245) (2) total backfilling of the area: €49.47 (€482,925) (3) reforestation, partial backfilling, reforestation and installation of new land uses: €58.20 (€524,440) - TCM: €0.29 to €1.47
STATED PREFERNCE APPROACHES						
CVM						
1980s	Whitehead	Surface coal mining	Kentucky, USA	CVM	Wetlands preservation from expansion of excavation	- Mean WTP of US$12.67 or US$6.31 per household per year
Late 1980s	Kopp & Smith	Abandoned gold, silver and zinc mine	Colorado, USA	CVM, HPM	- River restoration due to hazardous substances - recreation activities	- Mean annual WTP of US$70 per local household - Mean annual WTP for water based and non-water based activities along the river section of US$73 and US$51 per household - Negative impact of environmental issues on property values
1998/ 1999	Damigos & Kaliampakos	Abandoned marble quarry	Athens, Greece	CVM, TCM, HPM	Ex ante assessment of restoration scenarios and their benefits	- Mean annul WTP (and aggregated WTP) for (1) reforestation: €30.75 (€248,245) (2) total backfilling of the area: €49.47 (€482,925) (3) reforestation, partial backfilling, reforestation and installation of new land uses: €58.20 (€524,440) - TCM: €0.29 to €1.47 - HPM: €13,467,602.61

Year	Executer/ Author	Quarry site (type)	Location	Method	Object of investigation	Value
1999	DETR & LE	8 hard rock and 8 sand and gravel quarries	UK (local); Yorkshire Dales and Peak District National Parks, UK (national)	CVM	External environmental effects of quarrying in residents vicinity and in National Parks; calculating a tax on the output of aggregates	- WTA continuing quarrying: local environmental costs of £0.34 per tonne of rocks and £1.96 per tonne of sand and gravel - WTP for the closure of quarries in National Parks: environmental costs of £10.52 per tonne
2004	Ahlheim et al.	Opencast coal mining sites	Lusatia Region, Germany	CVM	Recreational benefits of a reclamation project	- Mean annual WTP of €4.39 per household
2008	Lienhoop & Messner	Opencast coal mining sites	Lusatia Region, Germany	CVM	Recreational benefits of a reclamation project of a post-mining lake district	- Mean annual WTP per household for (1) nine core lakes with good water quality, good infrastructure and multiple possibilities of use: 18.96 € (2) only six of the nine lakes with good and three with poor (acid) water quality: €15.94
2012	Papadopoulou et al.	marble quarry	Drama, Greece	CVM	Attitudes and WTP for different restoration scenarios	- No WTP values published
Choice Modelling						
Year	Executer/ Author	Quarry site (type)	Location	Method	Object of investigation	Value
1999	Willis & Gerrod	Hard rock quarry	Aycliffe, County Durham, UK	CE	Environmental disamenities [Externalities from quarries (noise, dust and mud)]	- WTA of one day of noise, dust and mud ranges between £1.38 and £3.54 per household (annual value of £433.32 to £1111.46) - total disamenity value is £175,061 to £449,070 - tax on aggregates production of £0.41 to £1.05 per tonne
BENEFIT TRANSFER						
2006	Damigos & Kaliampakos	Potential Gold mine	Perama, Northern Greece	SCBA, BT	Social worthiness of excavation assed by externalities	- Estimated costs for the local and neighbouring area (and *for broader areas)* in million: (1) Simultaneous approach: €1.32 *(€9 to 13)* (2) Additive approach: €1.4 to 49 (*€9 to 12)* (3) In case of a major accident: €4 to 182.5 - mean social net present value of €45.9 million - Social internal rate of return of 35,5% - Major environmental accident: Social NPV of €-310 million
2010	Aggregate Industries UK & IUCN	sand and gravel quarry	Ripon, Yorkshire Dales, UK	CBA, BT	Net benefit of restoration option compared to the status quo (ecological and recreational benefits)	- mean annual WTP for restoration of £53.40 per household to enhance biodiversity - mean annual WTP of £4.93 per resident for the recreational value - net benefit of the restoration scenario is £1.1 million (£2,840,341 including profits from sand and gravel production)
2011	Lafarge North America Inc.	Limestone quarry	Presque Isle, Michigan, USA	BT	Ecosystem services of different restoration options	- potential economic values for recreational and educational services between $2 million and $31 million over 10 years

COST BENEFIT ANALYSIS						
Year	**Executer/ Author**	**Quarry site (type)**	**Location**	**Method**	**Object of investigation**	**Value**
1992/ 1993	Trigg & Dubourg	Opencast coal mining site	Trent Valley in North Staffordshire, UK	SCBA, HPM	Environmental costs of an open-cut coal mining proposal	- net benefit of £2.7 million - House price fall between 10 and 40 % - aggregate the overall effect of - £5.1 million
2006	Damigos & Kaliampakos	Potential Gold mine	Perama, Northern Greece	SCBA, BT	Social worthiness of excavation assed by externalities	- Estimated costs for the local and neighbouring area (and *for broader areas)* in million: (1) Simultaneous approach: €1.32 *(€9 to 13)* (2) Additive approach: €1.4 to 49 (*€9 to 12)* (3) In case of a major accident: €4 to 182.5 - mean social net present value of €45.9 million - Social internal rate of return of 35,5% - Major environmental accident: Social NPV of €-310 million
2010	Aggregate Industries UK & IUCN	sand and gravel quarry	Ripon, Yorkshire Dales, UK	CBA, BT	Net benefit of restoration option compared to the status quo (ecological and recreational benefits)	- mean annual WTP for restoration of £53.40 per household to enhance biodiversity - mean annual WTP of £4.93 per resident for the recreational value - net benefit of the restoration scenario is £1.1 million (£2,840,341 including profits from sand and gravel production)

Source: own illustration, compiled by the author

4 Applied economic valuation in RESTORE

RESTORE will develop ecosystem service valuation approaches for a set of restored mineral extraction sites, building on the methods and examples that were presented in Section 2 and 3 of this report. The framework for assessing ecosystem services will be based on the existing Toolkit for Ecosystem Service Site-based Assessments (TESSA) outlined in Peh et al. (2013). This methodology was developed originally to assess how ecosystem service delivery at a site-scale might vary in response to changes in environmental conditions arising from disturbance or development pressures.

4.1 The TESSA tool

The TESSA methodology assesses the net ecosystem services provided by a site by comparing the current level of service provision to that expected under a plausible alternative state. For mineral extraction sites, this alternative state could be either: a) the historic land use of the site prior to extraction to which the site could have been restored following extraction, or; b) a different restoration end-use that could have been conceivably applied to the site.

The consideration of an alternative state means that the relative provision of ecosystem services at each site can be measured against other plausible restoration strategies. Therefore, the results generated by this project could be used as guidance by the minerals industry when planning restoration options at other sites in future.

In addition to the TESSA concept, RESTORE is widening this approach to a spatial planning perspective. For this, all sites in RESTORE will be valued based on a variety of possible alternative planning scenarios, in which one is always what TESSA calls the “counterfactual”. The valuation approaches will then aim at finding the most important aspects in those scenarios that lead to the best, i.e. benefit-maximising, results for people, biodiversity and economy. This objective can be summarized in two research questions that guide the whole valuation scheme:

1. Which is the best restoration alternative/scenario?

2. How exactly should the restoration alternatives/scenarios look like (in their components) to reach the highest net benefits?

By doing so, RESTORE helps practitioners and planners to decide what kind of restoration to do.

4.2 Assessment of ecosystem services using TESSA

At present, TESSA contains guidance for measuring the following classes of ecosystem services at a site-scale:

- Global climate regulation
- Water
- Harvested wild goods
- Cultivated goods
- Nature-based recreation

This section provides a brief overview of the different methodologies used to assess each ecosystem service class.

- *Global climate regulation*

  Global climate regulation refers to the exchange of carbon dioxide and other greenhouse gases between the atmosphere and the plants, animals and soil within ecosystems. Three components are considered in the TESSA methodology: carbon stored in plants and soil; carbon sequestered over time in plants and soil; greenhouse gasses (CO_2, CH_4, N_2O) emitted over time by plants, soils and animals. Data for these components are derived by combining local vegetation and soil samples with IPCC tier 1 estimates of carbon stocks for different habitat types.

- *Water*

  Water-related ecosystem services are often difficult to assess accurately without substantial time, effort and resource availability. TESSA advocates using existing data where possible to understand the water balance of a site (i.e. water provision), the degree to which it can store water and reduce peak river discharge (i.e. flood protection), and the capacity of a site to act as a pollutant sink (i.e. water quality improvement).

- *Harvested wild goods*

  Harvested wild goods include plants for food and medicine, animals hunted for food (including fish) or decoration (e.g. feathers), materials and fibres such as timber, and feed from an uncultivated area used for livestock. Data collection involves a workshop of key stakeholders and a questionnaire survey of harvesters. In north-west Europe, harvested wild goods are likely to be derived primarily from fishing or hunting of animals.

- *Cultivated goods*

  Cultivated goods can include food crops, livestock, products from aquaculture and plantation forestry, and biofuels. As with wild goods (above), data is collected through a workshop of stakeholders to establish general information on cultivation, and combined subsequently with existing data or a questionnaire survey of cultivators to understand the contribution of the ecosystem to the production of each cultivated good.

- *Nature-based recreation*

  Nature-based recreation summarizes the ecosystem benefits that accrue due to rest, recreation, relaxation and refreshment that people experience when they are using/visiting a restored mining site. Information on the volume and economic value of nature-based recreation of visitors to a site can be obtained through existing databases and studies, expert interviews, and new field surveys. In particular, interviews may be used to determine visitors' reasons for travelling to a site, their approximate spend per visit, and how their visitation frequency and valuation of the site might change under an alternative state. Using these data, the recreational value of a site can be assessed using a variety of techniques such as TCM or CVM.

4.3 Application of TESSA to RESTORE

TESSA will be used to assess ecosystem services provision at 10-12 mineral extraction sites across northwest Europe. In this applied part of the project, sites for ecosystem service assessment will be chosen based on the following criteria (Table 1):

- *Location (policy criterion)*

This criterion is defined to ensure that the study sites are well-dispersed spatially across North West Europe. Given the geographical and political scope of the project, study sites will be located in the UK, the Netherlands, Belgium and Germany. There may also be potential for additional study sites in France, Luxembourg and Ireland if suitable partner organisations can be identified.

- *Substrate (ecological criterion)*

Substrate type plays a key role in determining the final restored state of a site in terms of both vegetation communities and the provision of ecosystem services. For example, a restored limestone site may support calcareous grassland vegetation and provide aesthetic benefits, while a former gravel site on a river floodplain is more likely to be associated with reedbeds and flood alleviation.

The wide variety of minerals extracted across northwest Europe (limestone, sand, gravel, clay, granite, slate, etc.) makes it impractical to attempt to assess the ecosystem services associated with all substrate types. Instead, our sampling strategy will be limited to three primary substrate types (limestone, dry gravel/sand, wet gravel/sand) which a) are among the most common mineral types extracted in northwest Europe, b) differ markedly in their final vegetation communities and, potentially, provision of ecosystem services, and c) represent a range of potential restoration strategies.

- *Starting Point (valuation criterion)*

The active mining status of the quarry activities influences the alternative ways for economic valuations. All methods that deal with revealed preferences like the TCM can be used only if the restoration has already taken place and people already know the new area and use the site regularly. For the cases in which mining has not yet started or where it is still going on, all restoration options will be at least partly of hypothetical nature. Here, stated preference approaches need to be chosen to conduct surveys which ask people about their WTP on future scenarios of the mining site after mineral extraction and restoration phase.

- *Alternative state (overarching/combining criterion)*

As discussed above, the comparison of the current restored state with a plausible set of alternatives highlights the net gains and losses in ecosystem service provision arising from the chosen restoration strategy. Restoration for biodiversity conservation will feature all sites, but plausible alternative states are likely to differ between sites. Such alternative states may include restoration for agriculture, recreation, building development, or natural unmanaged vegetation succession, among others. In essence, the alternative state links with all three selection criteria. Depending on the location, substrate type and mining status, the amount and variety of possible alternative states is changing. So, depending of the levels in each of the criteria, a site-specific set of scenarios for alternative states will be developed.

4.4 Conducting the WP4 approach

According to the presented approach sites for ecosystem service assessments and economic valuation will be chosen under consideration of the site selection criteria. Each decision will be influenced by the technical expert panel (TEP), which contains international experts from the fields of minerals extraction, policy and planning, ecosystem services and economic valuation. The TEP will guide the conduction of the approach and give advice on the sites for investigation. Ecosystem service assessments for each site will be conducted using a combination of field data gathered by the RSPB and published literature values. This is essential to the innovative aspects of the RESTORE approach, because by creating individual base scenarios for the development of possible states and development options that will then be used in the survey based approaches, interviewees can use this information in their elicitation process. This will improve the whole process of economic valuation of mineral restoration options.

Valuation methodologies as described in chapter 2 will be tailored for each site based on the identified ecosystem service benefits of the alternative states and initial field results. Furthermore, the selection criteria “starting point” will mainly affect the choice of the specific valuation method. Relating to the possible methods that can be applied on a site, TCM or WTP approaches will be used exclusively or, if possible, mixed together to have the opportunity of comparing the results of competing valuation approaches. The overview of previous studies of ecosystem service valuation at mineral extraction sites (see chapter 0) will help to classify the results of sites applications and will inform the WP4 approach. By this means this report is important to partners as it clarifies the basic steps of the WP4 approach and gives background information on the relation of ESS and economic valuation techniques, which highlights the relevance of the work package for policy and practice in NWE.

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