

LIABILITY & ENVIRONMENTAL DAMAGE, ASSESSING THE ECONOMIC VALUES: METHODOLOGIES, FRAMEWORK, CRITERIA, APPLICATION

2014

Ministry of Infrastructure and the Environment

REC CAUCASUS

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Liability for Environmental Damage, Assessing the Economic Values: Methodologies, Framework, Criteria, Application

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CONTENTS

LIST OF ABBREVIATIONS

ALRI	Acute lower respiratory infection
ANWB	The Royal Dutch Touring Club (
As	Arsenic
Cd	Cadmium
CENN	Caucasus Environmental NGO Network
CH4	Methane
CIA	Central intelligence Agency
CO2	Carbon Dioxide
COD	Chemical oxygen demand
CP	Cardiopulmonary
Cr	Chromium
Cu	Copper
CVM	Contingent Valuation Method
DALY	Disability-Adjusted Life Year
dB(A)	Decibel exposure level of noise
DPM	Dundee Precious Metals
ECON	Environmental costs of different types of waste
EECCA	Eastern Europe, Caucasus and Central Asia is a block of countries that includes Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.
EEX	European Emission Exchange
EFTEC	Environmental economists from economics for the environmental and science
EIA	Environmental impact assessment
ESIA	Environmental and Social Impact Assessment
EV	Economic Value
GDP	Gross domestic product
GHG	Greenhouse gas
Hg	Mercury
HPP	Hydropower plants
ICZMC	Integrated Coastal Zone Management Committee
IVM	The Institute for Environmental Studies
K	Kalium
LC	Lung Cancer
MER	The Netherlands Commission for Environmental Assessment
N	Nitrogen
NH3	Ammonia
Ni	Nickel
NO2	Nitrogen dioxide
NOx	Oxides of nitrogen
N-TOT	Nitrogen compounds
O2	Oxygen
OECD	The Organisation for Economic Co-operation and Development
P	Phosphorous
P1	Price of product 1 per unit
PAC	Pollution Abatement and Control
PAC's	Polycyclic aromatic compounds
PAH	Polycyclic aromatic hydrocarbons
Pb	Lead
PM	Particulate matter
PM10,	Fine particles less than 10um in diameter
PM2.5	Fine particles less than 2,5um in diameter
PPP	Purchase power parity
P-TOT	Phosphorous compounds
Q1	Quantity of product 1
RIVM	National Institute of Public Health and Environment
RIZA	Institute for Inland Water Management and Wastewater Treatment
RR	Relative risks

SO2	Sulphur dioxide
TME	Institute for Applied Environmental Economics
TCM	Travel cost method
TRI	Toxic Releases Inventory
UNEP	United nations environment programme
VOC	Volatile organic compounds
VOL	Value of life
VSL	The Value of a Statistical Life
WB	World Bank
WHO	The World Health Organisation
WTP	Willingness to pay
Zn	Zinc

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UNDP Georgia

WWF Armenia

NGO Green Movement

Ltds “Madneuli” and “Kvartsiti”

Ltd “Euromines”

1 INTRODUCTION AND BACKGROUND

The Regional Environmental Centre for the Caucasus (REC Caucasus) is an independent, non-for-profit organisation, established to assist in solving environmental problems as well as development of the civic society in the countries of the South Caucasus.

The mission of the REC Caucasus is determined as to assist in solving of environmental problems in the Caucasus region through the promotion of co-operation at national and regional level among NGOs, governments, business, local communities and all other environmental stakeholders in order to develop a free exchange of information in line with the principles of the Aarhus Convention; offer assistance to all environmental NGOs and other stakeholders; and increase public participation in the decision-making process, thereby assisting the states of the Caucasus in the further development of a democratic civil society.

REC Caucasus contributes to the improvement of the Caucasus environment by facilitating, introduction and implementation of global, European, regional and national environmental policies and by providing a gateway for dialogues, networking and cooperation among environmental stakeholders and partners at global, regional, national and local levels.

The report has been prepared by REC Caucasus within Project "Improvement of Environmental Liability Regime" that is aimed at providing best methods and combination of methods to be applied under national liability regimes for valuation of actual damage caused to the environment by economic activities.

The report reflects the key sectors of economic activities that are increasingly vulnerable towards over exploitation of natural resources in Armenia and Georgia, the economic values of environment and nature, methods, framework approach for sectoral identification of monetary valuation methods for environmental damage and natural resources, selection monetary valuation techniques and pilot activities covering key economic sectors of Armenia and Georgia.

1.1 Environmental Liabilities and Monetary Valuation of Damage

Methods to assess the monetary value of damage caused by environmental pollution and use of natural resources are surveyed in the context of the enhancement of liability regimes in the Caucasian region.

What exactly is meant by "Environmental liability for environmental damage" is not just a legal question, but also a more philosophical question. From a legal point of view, one may argue that liability is limited to breach of regulations which are explicitly defined. For example, if a factory breaches emission-limits (continuous or temporarily), the factory is be liable for the damage. The public authorities represent the "environmental interest" and penalises the factory. In a more philosophical approach, one may argue that any polluter should be liable for the pollution caused, whether it is within legal boundaries or not. Actually, this more philosophical vision has been implemented by taxing pollution in many countries.

Liabilities can be classified in the as follows:

- Liability for the environmental damages caused by industrial accidents. This relates to incidents with large environmental and social-economic impacts due to for example explosions, large industrial fires, spill of pollution through wide areas due to breaking a dam of a tailing. Such kind of liability is regulated (in the EU) by the Environmental Liability directive (DIRECTIVE 2004/35/CE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage);
- Liability for environmental damage due to a breach of permit/legal provisions. In most countries environmental law includes the possibility to penalise the enterprises that are in breach with their (environmental) permits. The penalty may involve a prison sentence for responsible individuals or a fine. Often, the level of punishment for an environmental offence is based on the same principals as in criminal law: the level of the sentence is based on the severity of the offence, and the minimal and maximal punishment/penalty is determined in (by) laws. Through this (legal) generalisation of punishment/penalties, there may be some relation with the actual or potential environmental damage caused by non-compliance, but it is clear that in such

approach, the punishment/penalty will not be based on a comprehensive economic assessment of the environmental damage on a “case by case” approach. In a civil case, a more precise damage assessment may be the base for compensation payments (in relation to the actual damage);

- Liability for the use of natural resources or pollution of the environment. Normally, an enterprise that makes use of natural resources (wood, mining, water, etc.) or emits (some) pollution in the environment will need a permit (in which should be described what is permitted). Even if the use of natural resources or the pollution remains within the boundaries of the permit, it may be obliged to make a payment for the extraction of natural resources or for the pollution caused by the production process. This can be a resource tax, an environmental charge, a pollution tax or charge etc. at national or regional/local level.

In all of these cases, the liability is somehow connected to monetary damages caused by pollution and/or resources, due to:

- an (industrial) accident causing environmental damage;
- excess use of natural resources or excess pollution (breach of permit);
- or “regular” use of natural resources or “regular” pollution.

In these different cases of liability different approaches will be needed to assess the monetary value of damage caused by pollution and exploitation of natural resources.

In the case of accidents or non-compliance with permits/legal provisions, the environmental damage needs to be assessed on specific parameters.

For specific investment projects, the assessment of the damage needs to be case-specific and may be an integral part of the Environmental Impact Assessment (if there is a legal obligation to carry out) or the environmental permit. This study gives some guidance towards such integration, but does not aim at describing how such integration can be achieved.

Concerning “regular” pollution or use of natural resources a more generic approach is normally followed.

1.2 Valuating pollution and natural resources

- In Chapter 2 the theoretical framework for the assessment of values of pollution and natural resources is briefly discussed. Two main issues are the so-called “external effects” and “total economic value”.

There is a variety of methods to assess the economic value of natural resources.

- In chapter 3 an overview of different methods will be presented and evaluated, in the light of the overall objective of the project. In Annex 3 examples of parameters, formula’s, data and application of these techniques are given.

- In chapter 4 a framework approach is proposed to select the most appropriate valuation techniques for the various different sectoral environmental issues.

- In Chapter 5 selection criteria and issues that need to be taken into consideration when applying valuation techniques are summarised.

- In Chapter 6, the framework developed is illustrated by application in two pilots studies:
  - The Khudoni Hydro Power Plant in Georgia;
  - the Kapan gold mines in Armenia.

Additional – in the annexes 2 and 3 – the main sectors linked with environmental problems in Georgia and Armenia are summarised.

2 THE ECONOMIC VALUES OF ENVIRONMENT AND NATURE

2.1 Introduction

The economic valuation of environment and nature is based on valuation by (groups of) human beings. This implies that the intrinsic value of the environment can only be valued in monetary terms if human beings do mind about environment and are willing to spend money on environmental protection. If human beings do not care at all for environment even the richest ecosystem would have no monetary value.

Two main issues will be discussed:

- So called “external effects”;
- “Total economic value”.

2.2 External effects

In “day-to-day” market economics, markets determine prices and quantities of products and services. Theory says that due to the market, an optimal mix of products and services is demanded and supplied, leading to the highest possible welfare (given the physical production and consumption limitations).

However, for products and services that are not sold on the market, no direct market price information is available, making it difficult to optimise the supply and demand of such services. But although no prices exist for “a forest”, “biodiversity”, “pollution”, it is obvious that many individuals attach a certain value to such non-priced goods and services.

Even before environmental problems became visible and well understood, economic theory had to deal with the problem of non-priced goods and services and the optimal supply and demand thereof. This leaded to the concept of “externalities” (or external effects). This also became a key concept in valuation of natural and environmental resources. Externalities can be described as follows (Wikipedia):

> In economics, an externality is a side effect from one activity which has consequences for another activity but is not reflected in market prices. Externalities can be either positive, when an external benefit is generated, or negative, when an external cost is generated from a market transaction.

An externality occurs when a decision causes costs or benefits to stakeholders other than the persons involved in the economic transaction (for example, a transaction which results in pollution of the atmosphere would involve an externality). In other words, the decision-maker does not bear all of the costs or reap all of the gains from his or her action. As a result, in a competitive market, too much or too little of the good will be consumed from the point of view of society. If the world around the person making the decision benefits more than he does, such as in areas of education, or safety, then the good/service will be underprovided; if the costs to the world exceed the costs to the individual making the choice in areas such as pollution or crime then the good will be overprovided from society's point of view.

So the valuation of pollution and environmental resources should be seen as a part of the economic theory on externalities:

- positive externalities occur in case natural habitats create an economic benefit for certain consumers (that don’t pay directly for it): the vicinity of a forest, lake, etc. will create additional value to the ones that benefit from the vicinity of the natural habitat;
- negative externalities occur in case pollution or noise is emitted in the environment, changing the physical environment for consumers in a negative way.

As externalities, by definition, are not traded on markets, the value of the externality needs to be estimated making use of a variety of methods, developed and applied over the last 40 – 50 years.

2.3 Total Economic Value

The environment represents various sorts of economic value for human beings:

- water: to drink, to cook, to clean, etc.

- air to breath, as essential ingredient in many energy –conversions, etc.
- land/space to live, transport, to produce, recreate, etc.
- (building) materials: wood, minerals, etc.
- energy: fuels, wind, sun, water;
- a heritage for our children and future generations;

The following table classifies the "total economic value", which indicates what kind of values - attached by human beings to the environment – can be distinguished.

Use and non-use values can be distinguished. Use values are often easier to assess than non-use values. In general it can be said, that the more to the right in the schedule for calculating the total economic value of environmental resources, the harder it will be to assess the economic value and the less certain the estimates of these values are.

Table 2.1
Economic taxonomy for environmental resource valuation

Total Economic Value				
Use Values			Non-use Values	
Direct Use	Indirect Use	Option Value	Bequest Value	Existence Value
Outputs directly consumable	Functional benefits	Future direct and indirect values	use and non-use value of environmental legacy	value from knowledge of continued existence
• food • biomass • recreation • increased living comfort	• health • flood control • storm protection • nutrient cycles • carbon sequestration	• biodiversity • conserved habitats	• habitats • prevention of irreversible change	• habitats • species • genetic • ecosystem

source: based on EFTEC/RIVM, 2000.

Direct Use

Direct use is the most obvious value category, as the economic benefits can be calculated by making use of market information. The outputs of the resource can be directly consumed:

- a forest may yield annually a certain amount of wood that can be sold or used for heating and construction;
- pastures provide space for some livestock
- a lake provides fish to fisherman;
- enjoying nature (recreation).

Pollution may have influence on the "direct use" values: a polluted lake will produce less consumable fish than a clean lake, a forest in "top condition" will have a higher direct use value than a degraded one. On the longer run, climate changes may also affect direct use values. This may be positive if the climate change induces higher agricultural outputs, but the opposite may also occur if agricultural yield diminish due to climate change or due to additional mitigation measures to compensate climate change effects (like higher sea level).

Indirect use

Indirect use of natural recourses relates to functional benefits, the outputs provide a social benefit from ecosystem functioning.

For example, forests and wetlands provide water purification and flood protection, erosion protection or carbon sequestration, clean air, etc.

Many studies show that cleaner air (a natural resource) leads to less respiratory diseases and considerably less mortality. So health costs can be influenced positively by improving air quality. There is also evidence that agricultural output is (positively) affected by nearby natural habitats.

Option use value

Option value relates to the cases where individuals are willing to pay for the future use of the resource (e.g. future visits to national parks, clean surface and ground water, avoiding of erosion to enable future use of pastures).

Two types of non-use value of environment can be distinguished:

Bequest values

This reflects the publics' willingness to pay to ensure future generations to enjoy the same environmental benefit in the years to come. This relates to the willingness to pay for preserving existing habitats, species and ecosystems. It also includes the willingness to pay to prevent for irreversible changes (for example: extinction of species).

Existence value

This non-use value reflects the "moral" or philosophical reasons for environmental protection, unrelated to any current or future use. It is related to the for example the scientific society and the value from knowledge of continued existence of species, habitats and ecosystems.

Apart from direct use all other values are an expression of external effects.

3 METHODS

3.1 Introduction

There is a wide range of methods to estimate the monetary value of natural and environmental resources. Here we give a brief overview of some important methods used. Basically the methods can be subdivided into two categories:

- **Revealed preferences techniques**: These link the (change in) quantity of an environmental resource, to a (change in) market price that can be observed in reality;
- **Stated preference techniques:** These are methods that determine preferences directly from consumers, by using various types of questionnaires or experimental set-ups.

Applying "revealed and stated preferences techniques" is often costly. Questionnaires/ experiments need to be designed, (large amount of) data need to be collected, processed and analysed. That is why in many cases, so called "Benefit Transfer" is applied, making use of outcomes of detailed, comparable studies and local data sets/indicators.

In this chapter the main valuation techniques will be briefly discussed. In Annex 4 guidance is given on parameters, formulas, data-needs and applications of the most common techniques.

3.2 Revealed Preferences Techniques

3.2.1 Market prices and quantities

The most obvious way of measuring the value of environment is to see how much crop, fish, wood, livestock, etc. can be obtained by sustainable use of the natural habitat. By surveying crops, woodcutting, cattle breeding, etc, of the population, in combination with (local) market prices, the direct use value for the inhabitants can be measured.

But it is also possible to valuate ecosystem-services (water purification) if the purifying potential of an eco-system can be assessed and (shadow) prices for alternative purification can be calculated empirically.

This method can be used to valuate natural habitats like forests, wetlands, etc. But it also can be used to assess “health benefits”. The (negative) effect of for example air-pollution can be assessed by isolating the costs of medication, doctor visits, hospitalisation, etc. in case of illness due to environmental pollution (air/water). These cost-factors are also based on market prices.

3.2.2 Dose response function and valuation of morbidity, mortality

This method is often used in studies that aim to estimate the monetary damages of environmental degradation, for example through pollution of the air by fine particles, sulphur dioxide, nitrogen oxides and volatile organic compounds. It has been successfully applied in EU studies on air-pollution (ExternE). It requires large datasets, establishment of dose-response function (for mortality, health, loss of crop and real estate). Moreover, it requires valuation of mortality, putting a monetary value on life, which is not undisputed.

The WHO and other institutions have established methods to estimate health impacts (morbidity and mortality) of for example particulate matter or lead. These methods apply concepts like:

- DALY’s (Disability-Adjusted Life Year, which can be thought of “one lost year of "healthy" life”). DALY’s can be estimated for Premature mortality, Chronic bronchitis, Hospital admissions, Emergency room visits, Restricted activity days, Lower respiratory illness in children, Respiratory symptoms;
- “IQ-points lost” due to elevated lead-blood levels in children.

Although the physical effects of pollution can be formalised in mathematical relationships between pollution and effects, the economic valuation of these effects depends on local income and cost levels. Effectively this means that in a poor country life is less valued than in a rich country.

3.2.3 Dose response function and loss to crop and real estate

Another example of dose-response functions is the loss of crops due to air/water/soil pollution, depending on crop and many other geographical/environmental circumstances.

It is also known that acidification and other air pollution leads to additional cleaning costs and accelerated decline of buildings/structures, sometimes leading to high restoration costs.

3.2.4 Hedonic pricing

Hedonic pricing involves the use of large data sets in which the value of property (houses, land) is observed and compared with environmental factors. By statistical analyses the environmental or nature valuation attributes in the price of property can be separated from other attributes.
For example, the price of property decreases by 0.5% by an increase of the noise level with 1 dB(A)).

This method is mostly applied to noise, but it can also be applied to nature, vicinity of open water by looking at values of property in relation to the distance to natural areas or water.

3.2.5 Travel cost method

Part of economic behaviour can be measured implicitly by looking at how individuals spend their money and time. The Travel Cost method aims at measuring travel costs (for example to visit a protected natural area) and time (and value this economically) and (sometimes) the economic spin off (consumptions in the region, costs of accommodation).

3.2.6 Prevention costs

Applying preventive measures is a way to mitigate negative effects of economic developments for the environment.

For example, in OECD countries, it is common that industries apply the “Best Available Techniques” to ensure minimal impact on the environment. This comes at certain costs which make it possible to calculate the costs of pollution prevention.

Passages for animals, tunnels, deviation or longer routes of road (to prevent cutting off part of a natural area) are examples of measures to protect nature. The costs of such measures can be related to economic values of the nature protected.

The costs of preventing pollution (up to levels regulated) and preservation of natural habitats can be regarded as the (minimal) value of damage to the environment due to pollution or the protected habitats.

It is important to recognise that prevention costs are related to environmental standards or environmental targets (like pollution reduction but also biodiversity preservation). This implies that – if limits are changed, for example more stringent – the costs of preventive measures will increase and thus the value “automatically” changes accordingly.

3.2.7 Compensation costs

The loss of a natural habitat can - theoretically spoken – be fully compensated by creating a new natural habitat that can be compared with the old habitat. In practice, this is not for 100% possible, depending of the type of land used for compensation and the influence on the natural habitat.

The costs to compensate the loss of natural habitat can be assumed to be – at least – the value of the natural habitat in question.

3.2.8 Opportunity Costs method

The opportunity costs of a resource, is the value of the next-highest-valued alternative use of that resource. For a natural area this may be agricultural use, use as a road, and in some cases economic development (industry, housing). The opportunity costs of nature thus will depend largely on location and (for agriculture) fertility. In the Netherlands natural area is valuated at about €20.000 per ha (CBS), agricultural land costs €30.000 – €40.000, industrial €100.000 - €200.000 and housing €2.000.000 - € 5.000.000 per ha. If statistics on actual prices of land-transactions are available, such assessment can also be made for the Caucasus.

This kind of valuation sheds a light on the importance of “nature”. Central Park in New York is surrounded by the most expensive real estate in the world. Still every government of New York could suppress the temptation to sell the land to the highest bidder. The 341 ha would have an enormous value if brought on the market. Implicitly, this means that “nature” in such an metropolitan environment is highly valued.

3.3 Stated Preferences Techniques

For certain environmental problems – like preservation of biodiversity or future environmental benefits - it is difficult, controversial or impossible to assess the monetary environmental damage by means of revealed preferences techniques. In such cases revealed preferences techniques can be used to acquire information on monetary environmental values.

Stated preferences can be used instead of revealed preferences techniques (for “direct and indirect use values” (see table 2.1), but more important also for “option use values” and “non-user values” (which principally cannot be assessed by means of revealed preferences techniques).

Since the 1970’s various techniques have been developed to forecast individual (economic) choices. Initially, these techniques were applied mainly in marketing research, later also applications were used in transport and environmental economics.

By far the most commonly used stated preferences technique in environmental economics is the so called “Contingent Valuation”, which will be discussed briefly in the next section.

3.3.1 Contingent Valuation (CVM)

This method aims at measuring the willingness of individuals to pay for environmental services, nature protection, etc. Most critical with this method is the way in which is explained what exactly has to be valued by the respondents and realistic monetary choices. A limitation is the “income restraint” (poor people will be less willing to pay, so average income levels influence outcomes of the studies). An advantage is that it can be used to valuate difficult to measure non-user values of non-traded goods and services.

CVM is a survey-based, stated preference, methodology that provides respondents the opportunity to make an economic decision concerning the relevant non-market good. Values for the good or service are then inferred from the induced economic decision. The CV method is in use for over 30 years.

CVM is one of the most advanced and the most used techniques for environmental valuation. In contingent valuation researches, precise questionnaires are developed, aiming to obtain a direct answer from the individuals questioned.

The essential part of the questionnaire is information about the willingness to pay for a certain environmental benefit, or willingness to accept compensation for a forgone benefit, or an incurred cost. The contingent valuation questionnaire should define:

- environmental good – that has to be evaluated by the respondent – itself;
- the institutional context of its consumption (how is the externality “consumed” by respondents);
- and the way of paying for it (privately, publicly).

Although the questions are related to a hypothetical situation, the respondents are expected to behave as if they are in a real marketplace. Respondents state the preferences in a form of a bidding game. Econometric techniques are used to analyse the obtained results. Accuracy of conclusions is closely related to the construction of the questionnaire. That is the reason why a precise procedure should be applied (Arrow et. al. 1993).

A wide variety of CV studies have been carried out on a wide range of environmental and nature issues:

- preserving biodiversity;
- (water and nature) recreation;
- water supply and supply of sewerage;
- increased access to natural habitats, etc.

On the internet, various sites give summaries and overviews of the results of CV-studies.

3.4 Benefit transfer

Benefit transfer is a method that aims at using results of earlier studies to put a value on environmental resources and nature. The outcomes of the studies that can be used in benefit transfer can be of any type of the here above described methods.

The main reason for the application of benefit transfer is that fundamental research is in most cases quite costly, whereas in certain cases benefit transfer can produce reliable results at much lower costs.

To apply benefit transfer successfully the following three criteria apply (Boyle and Bergstrom (1992)):

1. Similarity of the environmental good or service to be valued;
2. Similar demographic, geographic, economic and social characteristics, or the ability to adjust for these kinds of parameters statistically (King & Mazzotta, 2004). EFTEC/RIVM mention the following potential adjustments (p. 127):
   - average income;
   - population size and characteristics;
   - background conditions;
   - level of impacts (i.e. concentrations), and
   - other determinants;

3. Evidence of sound economic and statistical methodology applied in the preliminary study or studies.

A fourth criterion can be added:

4. Use if possible more than one reference study to have an idea of credibility and reliability. Nowadays a large amount of benefit assessments is available for any kind of environmental problem.

The advantage of benefit transfer compared to more fundamental research method is the saving of time (quick results) and costs. The disadvantage is the potential lack of credibility (especially when using results from EU or US and transfer them to other countries in very different stages of development) and the lack of "local evidence" (benefits assessments based on local interviews/assessments).

3.4.1 Application of benefit transfer

Benefit transfer can be applied for any environmental problem for which studies are available.

The applicability of benefit transfer depends very much on the kind of environmental damages that have to be valued and in which context. A few examples show this:

Air pollution

By means of the analysis of large data sets on air-pollution (PM_{10}, $PM_{2.5}$) and mortality and morbidity standardised formula's for the estimation of the costs of morbidity and mortality have been developed.

Specific (regional, local, nation-wide) data on air-pollution (concentrations of PM_{10} and $PM_{2.5}$), population data (affected population, age-class, death rate and the frequency of cardiopulmonary and lung cancer death causes), income and local cost factors form the input to the estimation of monetary damages due to air pollution.

So called DALY's[1] are estimated for Premature mortality ($PM_{2,5}$), Chronic bronchitis (PM_{10}), Hospital admissions (PM_{10}), Emergency room visits (PM_{10}), Restricted activity days (PM_{10}), Lower respiratory illness in children (PM_{10}) and Respiratory symptoms (PM_{10}) by means of standardised formulas.

Basically, this methodology can be applied in any country or region for which sufficient data is available on the essential issues.

Valuation of natural habitat

Especially when it comes to very specific assessments, it will not be easy to apply a sound "benefit transfer". Each ecosystem will have its characteristics for which the valuation often differs from other – comparable - ecosystems. But there are common issues that are normally used in ecosystem valuation:

- Direct use values: timber, firewood, other natural products, fish, hunting, recreation;
- Indirect use values: nutrients, agricultural productivity, water management, carbon sequestration;
- Non-use values: option, bequest and existence values.

For most of the direct use values it is logical to assess local factors (like wood production, sustainable fishing levels, etc.), for others, results of earlier studies may be analysed and used (with care) to complete the assessment.

In case a natural habitat will be modified due to economic activities (for example a dam, or a road) the valuation needs to include a comparison of the "old" and the "new" situation to assess damages (or needed level of compensation by i.e. mitigation).

[1] The disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.

(Illegal) waste landfills

Negative external effects due to environmental pollution influence property prices. Many studies have been carried out to establish the relationship between for example traffic and industrial noise and property prices (see for example (EFTEC/RIVM, 2000) or (TME, 2004)), but also for the influence of the vicinity of clean surface water (Brouwer et al, 2007).

In the USA, a hedonic pricing study has been carried out on the influence of landfills on property prices (Ready, 2005), This meta-analysis shows that lower-volume landfills decrease adjacent property values by 2.5%, on average, with a gradient of 1.2% per mile. This means that in the area around a landfill property values are lower:

- adjacent area = 3,14 (Π) * 1,62 (square km/square mile) = 8,038 km^2
- area from 1 – 2 miles distance: 3,14 * 1,62 (square km/square mile) x 3 = 24,11 km^2.

If information is available on (illegal) landfills, property affected and property prices, the negative influence of dumpsites on the value of property can be estimated.

Unit damage costs approach

This is a particular type of benefit transfer, in which (physical) pollution is valued at “unit damage costs”. These unit damage costs are derived from specific studies, by combining total damage caused by pollution divided by the amount of pollution. Alternatively, unit damage costs are derived from prevention cost studies (total costs to prevent pollution to a certain level).

To apply unit damage costs estimates, the amount of pollution needs to be known. To assess local unit damage costs, corrections are necessary on for instance: price level and inflation, concentration of pollutants in the environment, population density.

It is a rough, but fast method, with a minimum of data requirements and which produces credible results and gives indications of the magnitude of the monetary damages.

3.5 Overview of methodologies and applicability

The following table gives a summary of the findings on the different methodologies and their categorisation in their applicability in liability regimes.

Table 3.1 Overview of methodologies and applicability thereof to assess monetary value of damages to the environment and the extraction of natural resources

Method	Application	Comments
Market prices and quantities	Direct use values of natural habitats (crop, cattle, fishing, materials like wood, clean water)	Most credible results due to use of market prices, should be used if possible. Sometimes quantities difficult/costly to assess.
Dose Response function	Direct use values: health effects of pollution (fine particles, other smog, heavy metals), effects on habitats, crops and buildings (acidification, water pollution)	Needs to be linked with values of life, crops, habitats. Applied in many studies. Can be used with relative little data.
Travel costs	Direct use value (recreational)	Requires large amounts of data. Values sometimes difficult to separate from other purposes of trips.
Hedonic pricing	(implicit) Direct and indirect use value of property (living noise free, near biodiversity)	Requires large amounts of data and specialist statistical analysis
Prevention costs	Direct/indirect use values and non-use values for nature valuation and pollution (reduction)	Gives rough first estimate, preferably accompanied by other "evidence"
Compensation costs	Nature valuation (direct, indirect and non-use values)	Gives rough first estimate, preferably accompanied by other "evidence"
Opportunity costs	Nature valuation (direct, indirect and non-use values)	Gives rough first estimate, preferably accompanied by other "evidence"
Contingent Valuation	Use and non-use values of natural habitats and environmental pollution	Sometimes difficult to know which values are measured. Most adequate when other methods fail. Only method that is used to explicitly assesses non-use values
Benefit transfer	Can be used for any assessment of the value of nature or benefits of environmental protection	Produces credible results with relatively little data requirements. The transfer must be based on thorough comparison and correction between the original and the "transfer" country/region.

This scheme is the starting point for developing a framework approach to assess environmental damages in different sectors.

3.6 Discussion

Even when applying sophisticated methods to assess the value of natural and environmental resources, there always remains area for discussion on the results of valuation studies. Benefits are often less obvious than costs, and thus results of benefit studies are less precise than cost estimates (although also evidence exists that costs estimates are not very accurate and in certain cases overestimate costs of policies by factors (IVM, 2006)).

Benefits/damages measured by the researcher may be linked to more than one of the benefit/damage categories depending on what exactly is valued by the method:

- when applying a willingness to pay study, the respondents will have at least some difficulties in understanding what they are asked to value (recreational use, existence value, option value, etc.;). Also, it can be assumed that the understanding of the value of money for each individual differs;

- when applying a hedonic pricing study (mostly based on differences in prices of property), part of the additional value due to environmental benefits may relate to living comfort (including recreational opportunities and silence), partly to non-user values (when people with large gardens also promote nature protection).

Results also may be biased or disputable:

- when applying a dose-response functions with "value of life" estimates, discussion on applying monetary valuation of mortality will affect the credibility of the result, also the uncertainty on dose-response relations;

- if various negative effects on the environment are valued, there is a risk of "double counting", for example if damages due to air pollution are valued by taking into account the different air-pollutants (SO_2, NO_x, VOC, NH_3, PM_{10}/ $PM_{2,5}$) it may be that certain negative health effects are due to a cocktail of pollutants, rather than the sum of negative effects linked with the various different substances.

4 FRAMEWORK APPROACH FOR SECTORAL IDENTIFICATION OF MONETARY VALUATION METHODS FOR ENVIRONMENTAL DAMAGE AND NATURAL RESOURCES

4.1 Introduction

The purpose of the framework approach is to guide the user of the framework towards the most appropriate techniques to valuate environmental damage and natural resources. Basically, the framework should give guidance for the valuation of each type of environmental damage or natural resources, for each relevant sector.

To classify all types of valuation of damages and natural resources, a distinction is made between (i) economic sectors and (ii) the types of environmental issues. This results in 3 matrices, which will be discussed below:

1. The first matrix confronts economic sectors with <u>pollution</u> of air, water and land (the 3 main media in environment);

2. The second matrix focuses on the valuation of the (main) "<u>other environmental effects</u>" induced by economic sectors, which includes: waste (management), noise and effects on biodiversity, nature and landscape;

3. The third matrix deals with the valuation of the use of air, water, land, nature and waste as a <u>resource</u> for the various economic sectors.

In the matrices, the main environmental issues with potential negative economic impacts are summarized at sectoral level. This means that for each sector and each problem, different valuation techniques may be applicable. Each sectoral problem – within an assessment of the economic valuation of damage and use of natural resources – will need the use of the most suited techniques.

In the next sections an overview will be given of the most common environmental issues of each of the sectors, and these issues will be linked by means of examples to the applicable valuation techniques.

4.2 Pollution of air, water and land

The first matrix concerns the valuation of pollution of air, water and land due to activities of the different sectors.

	pollution of: air	water	land
Agriculture	CH_4 NO_2 NH_3	P N Cod	pesticides, etc.
Mining	PM SO_2 NO_x VOC Heavy Metals	heavy metals	waste dumps
Industry	CO_2 NO_x SO_2 PM H Metals	Cod N P Heavy metals etc	soil contamination, dumps
Energy, hydropower		if organic and toxic materials are not removed	
Energy, thermal	CO_2 NO_x SO_2 PM H Metals	thermal	soil contamination, dumps
Energy, nuclear		thermal	soil contamination
Energy, solar			
Energy, wind			
Construction	PM SO_2 VOC		
Transport	PM SO_2 NO_x VOC Heavy Metals		
Waste services	PM Dioxins smell	leachate	dumps
Households	PM	sewage	
valuation methods	Benefit transfer - unit damage costs	Benefit transfer - unit damage costs	Market prices
	Dose response function	Dose response function (mortality/morbidity due to diarrhea etc.)	Hedonic pricing
	Contingent Valuation	Prevention costs	Benefit transfer
	Prevention costs	Market price	Prevention costs
			Compensation costs

Air-pollution

The negative effects of air-pollution cannot be underestimated. Air pollution causes negative health effects, damage to crops, nature and cultural heritage. A variety of methods can be applied to assess the economic damage due to air pollution:

- Benefit transfer – unit damage costs: this technique can be applied if sectoral (annual) emission levels of the relevant pollutants are documented or can be estimated in a credible way. In the above table this means that this technique can be used in all relevant sectors.

- Dose-response functions: in case ambient concentrations of air pollutants are known (especially for PM_{10} and $PM_{2.5}$), this technique can be used to assess impact on (human) health (mortality, morbidity) by estimating lost DALY's due to mortality and morbidity and the costs of illness. As ambient concentrations are due to a cocktail of air-pollutants from different sources, this technique can be used for inter-sectoral pollution, or in other words: damages can be linked with the air pollutant, but not (directly) with sectors (also because air-pollution is in principle trans-boundary). To apply this technique, data on ambient air concentrations are needed, an estimate of the exposed population, the age structure of the exposed population, and the frequencies of certain health conditions that occur due to air-pollution(crude death rate and Cardiopulmonary (CP) and Lung Cancer (LC) mortality (% of all deaths));

- Dose-response functions: in case of exposure of the population to heavy metals (mining, metallurgy, traffic) the damages to health (IQ of children under 14) can be assessed by means of lead blood-levels. If these are known, the potential economic losses due to lower IQ can be assessed;

- Dose-response functions: Agricultural productivity may be influenced by air-pollution (acidification: SO_2, NO_x, NH_3, VOC). By means of crop specific formulas (linked with deposition levels of air-pollutants) the productivity loss can be assessed. Combined with total crop and market prices of the crop, the monetary damage can be assessed;

- Prevention costs: The costs of (technical) measures to reduce air-pollution levels to the legal standards (or the ecological standards) give an indication of the value of the environmental damage. Whether this is an under- or overestimation of these values, will depend on the values that the human society attaches to "clean air". Implicitly, the implementation of legal standards (and permit specific regulations) and the costs of implementation express the (minimum) willingness to pay to avoid the environmental damages.

Water-pollution

Water pollution diminishes the economic value of water resources and has adverse effects on health, fish-stocks, biodiversity, etc. Many different methods can be used to assess different aspects of water pollution:

- Benefit transfer - unit damage costs: This technique can also be applied in case of water pollution, if sectoral (annual) discharge levels of the relevant pollutants are documented or can be estimated in a credible way. In the above table this means that this technique can be used in all relevant sectors;

- Dose response function (mortality/morbidity due to diarrhea etc.): In case of water borne diseases, dose-response functions can be used to estimate the lost DALY's due to mortality, morbidity and costs of illness. Key parameters are: share of young children (under 5 years old) in population, mortality rate for these children and the share of diarrhea in total child mortality. For morbidity the total number of cases of diarrhea needs to be known (health statistics) for the child population (<5 years) and the rest of the population, etc.

- Prevention costs: The costs of (technical) measures to reduce water-pollution levels to the legal standards (or the ecological standards) give an indication of the value of the environmental damage. Whether this is an under- or overestimation of these values, will depend on the values that the human society attaches to "clean water". Implicitly, the implementation of legal standards (and permit specific regulations) and the costs of implementation express the (minimum) willingness to pay to avoid the environmental damages due to water pollution;

- Market price: In some specific cases market prices can be used to estimate the value of damage. For example, clean (surface and ground) water have a certain (regional or local) market price or market value. In case the water is polluted the market value of the polluted water will drop (as the use of it is limited or additional costs must be made to purify the water). The price difference together with the volume of the water, will result in a (minimum) estimate of the value of the damage.

Soil-pollution

If soil gets polluted, the potential use will be limited, thus reducing the value. Contaminated soil may also have a negative effect on the value of neighbouring property. There are several methods to assess the value of soil pollution:

- Market prices: The value of land is in general known for a great variety of types of land. The value of land depends on it geographical characteristics (location, productivity, etc.). Deterioration of land due to pollution will affect productivity and thus the value of the land. So the most direct way of valuing contamination of land is to compare prices before and after the pollution took place (leaving all other parameters the same).

- Hedonic pricing: the vicinity of a waste dump may have a negative effect on the price of neighbouring land. By means of hedonic pricing techniques the drop of land value due to the vicinity of the landfill can be isolated from other – value explaining – factors.

- Benefit transfer: By means of using the price-differentials between "clean" and "contaminated" land surveyed in earlier studies (i.e. EFTEC, 2001) assumes a 10% drop in value due to contamination) an estimate can be made of the damage due to land-contamination, by multiplying the value-depreciation (10%) with the price of land (in a certain function like industrial, housing, agriculture, etc.).

- Compensation ad prevention costs: A proxy for the value of environmental damage in case of contamination of land can be derived from an estimation of compensation or prevention costs. Preventive costs include at least the costs of measures that would prevent soil contamination from happening (this may be liquid proof floors/pavement in case of potential risk of soil contamination). It also may include "clean up" costs, which comprise a.o. rinsing, biological treatment, thermal treatment, etc.

4.3 Other environmental effects: waste, noise, biodiversity/nature/landscape

The second matrix concerns the valuation of negative effects of waste, noise and (loss of) biodiversity, nature and landscape, due to activities of the different sectors.

	other environmental effects:		
sector	**waste**	**noise**	**biodiversity, nature, landscape**
agriculture	manure waste		trade off with nature, loss due to monoculture
mining	tailings		destruction of natural habitat
industry	ash	industrial noise	
energy, hydropower			loss of ecosystem, fish migration
energy, thermal	ash	industrial noise	
energy, nuclear	Radioactive waste		Genetic modifications
energy, solar			
energy, wind		turbulence noise	bird accidents, loss of landscape
construction	construction waste		
transport		traffic noise	Disturbance,
waste services	ash dumps		landscape
households	household waste		
valuation methods	Benefit transfer-unit damage costs	Hedonic Pricing	Compensation costs
	Hedonic Pricing	Benefit transfer-unit damage costs	Hedonic Pricing
	Prevention costs	Contingent Valuation	Contingent Valuation
	Market prices	Dose Response function	Market prices

Waste:

Waste pollutes soil, water, air. Storage requires land. There are various methods to assess the negative impacts waste can have on environment:

- Benefit transfer – unit damage costs. In various studies an attempt is made to assess "unit damage costs" per tonne of waste. This is done by estimating the emissions of CH_4,CO_2, PM_{10}, dioxins, PAC, PAH by means of (standardised) emission factors for the amounts of waste dumped on certain types of landfills (sanitary or not, on fire or not, illegal dump or "back-yard" burning). By applying unit damage costs for the pollutants from EU-countries (taking into account a correction-factors for amongst others purchase power, population density, pollution density) the damage due to these emissions can be assessed. This method can be applied in case of landfill or incineration of municipal waste, if it is possible to estimate emissions in the waste-management chain. In case of (excess) manure an estimation can be made of "run-off" emissions of nutrients (N, P, K), which will cause damage to groundwater resources. This damage can be valued by means of unit-damage costs and quantities.

- Hedonic pricing: This method can be applied if the relationship between the prices of property can be linked to the vicinity of a landfill. This requires a large amount of data and sophisticated statistical techniques. Alternatively, the results of earlier studies (i.e. in the US, Ready, 2005) can be used, which estimates the drop of value of property at 2,5% for land located within a mile of the landfill, and of 1,2% for property located between 1 and 2 miles from the landfill;

- Prevention costs: If it is difficult or impossible to assess emissions from the waste-management chain, an estimation of prevention costs will give some guidance on the (threshold) value of the environmental damage. For example, the costs of safe storage of radio-active waste can be assessed, by summing the needed initial investments and the (discounted) operational and maintenance costs for the period the storage must be kept safe. Prevention costs can also be calculated for other types of waste, giving a threshold value for the (potential) environmental damage;

- Market prices: In some cases "market prices" give an indication of damage. For example, if ashes are dumped on a landfill, whereas there is an opportunity to use ashes instead of other building materials (i.e. sand, cement) the market price of the (potentially) replaced building materials can be used as a proxy estimate of the damage due to landfilling ashes. In case of mining tailings/construction waste, these may (or may not) represent a certain economic value (if processing of the tailings/construction waste would be profitable). This – unused – value can be regarded as a threshold proxy for the damage of landfilling tailings. In case of groundwater pollution due to excess nutrients in manure, it can be argued that the value of the groundwater resources is diminished due to this pollution, limiting the use of these resources. By comparing the prices of clean and polluted groundwater, an indication of the value of the damage can be derived.

Noise:
Noise disturbs the well-being of human beings. Noise levels above dB(A) 50 are found to have adverse effects on property prices and health.

- Hedonic pricing: By means of meta-analysis of data on property values/sales-prices and characteristics of property (a.o. the noise classification), the influence of noise on property prices can be assessed. Many such studies have been carried out, and the conclusion is that property value drops by between 0.2% up to 3% per dB(A) noise (above 50 dB(A));

- Contingent valuation: Contingent valuation is an alternative for hedonic pricing. It measures the willingness to pay (WTP) of individuals/families to reduce noise levels by 1 dB(A). In such WTP-study, it is important to choose the most appropriate experiment settings, as to achieve credible results;

- Benefit transfer: In case a credible result can be used from for example hedonic pricing or WTP studies, this method can be used, if information is available on the distribution of the (to noise exposed) population, divided in different exposure classes (i.e. population exposed to 50-55 dB(A), 55-60 dB(A), etc.);

- Dose-response functions: The adverse health effects of exposure to noise has been studied in various EU Member States (Berry, 2009). It is clear that there is a relationship between noise and increased prevalence of acute myocardial infarction and other cardiovascular diseases, transient sleep disturbance and hypertension. But not in all cases there is consensus on the quantification of these relationships, making it disputable to apply this technique (alone) in assessing the value of these adverse health effects.

Biodiversity, nature and landscape
The loss of biodiversity, natural habitats and ecosystems and the disturbance of landscape results in loss of economic values. The following methods can be applied.

- Compensation costs: In case a natural habitat is transformed for use in another function (agriculture, hydropower, industry, housing, etc.) the damage can be evaluated by means of assessing the costs of creating an equivalent natural habitat. It must be realised that such compensation can never be 100% comparable with the eco-system lost/compensated). This technique can be applied in case of mining (destruction of habitats), hydro-power (replacing lost eco-system at other place), any shift in land-use of (former) natural habitats;

- Hedonic pricing: This technique can be used if it is possible to isolate the environmental factor in the relationship with the prices of property. This may be true for landscape and vicinity of nature: such factors will be included in the preferences of (some) property owners, being very "visible". However, for the more complex concept of biodiversity loss, it will be hard to arrive at credible results through hedonic pricing;

- Contingent valuation: A well designed experiment can determine preferences (and thus willingness to pay) for biodiversity conservation. It can as well measure use values as non-use values (as far as a human preference can represent the intrinsic natural value of biodiversity). A main issue is the explanation in the questionnaire of what exactly the respondents need to value: which factors of biodiversity should be explained and taken into account?

- Market prices: In some cases market prices and quantities can be used to assess the value of nature/biodiversity. For example, there exists a certain "ecological" balance between agricultural land and natural habitats, for instance for (ground) water management it may be essential that a certain percentage of the land is not used for agricultural purposes. Also, for some crops, the vicinity of natural habitats increases agricultural productivity. If in a certain area it is possible to quantify this relationship (productivity as function of percentage area covered with nature) the economic value of the additional productivity can be used as a proxy for the value of the natural habitat. Another example can be used for hydropower plants: if these diminish fish stock and re-productivity thereof and this can be quantified, the market price of fish can be used to assess the loss.

4.4 Use as a resources of air, water, land, nature and waste

The third matrix concerns the valuation of use as a resource .due to activities of the different sectors.

	use as resource:				
	air	**water**	**land**	**nature**	**waste**
agriculture	CO_2	ground /surface water extraction	agriculture land use	agricultural productivity, fish	organic waste as fertiliser
mining		rinse	sites, dumps	Minerals, building materials, fossil fuel	
industry		process water	industrial sites		Recycling of secondary materials
energy, hydropower		as medium	water basins	kinetic energy	
energy, thermal	(O_2)	cooling	Sites, storage		
energy, nuclear		cooling	Sites, storage		
energy, solar				solar energy	
energy, wind	(Wind)		site	kinetic energy	
construction			commercial areas	Timber, cement, ,stones, sand etc.	
services			commercial areas		secondary materials trade
transport			roads		
waste services			dumps		Recycling of secondary materials
households	(health)	basic survival need	Living space	recreation, firewood, forest products	
valuation methods	Market prices	Market prices Hedonic pricing Compensation costs Benefit transfer	Market prices Hedonic pricing Opportunity costs Benefit transfer	Market prices Hedonic pricing Prevention costs Contingent Valuation Travel Costs Benefit transfer	Market prices Benefit transfer

Air:

(Clean) air has, as a resource – until now – a limited direct economic value. Oxygen is for free, in some particular cases (greenhouses) CO_2 maybe produced (at certain costs by burning fuel). The wind is used by windmills to produce electricity, but there are no payments for wind (maybe implicit, by prohibiting certain structures in the vicinity of windmills). Clean air has certainly an indirect value for human beings, as polluted air has negative health effects (which – as explained earlier – can be valued).

- Market prices: In case CO_2 is used in a greenhouse to increase yield, the (positive) value of CO_2 is equal to additional crop value due to additional CO_2 minus the costs of the production/transport of CO_2.

Water:

Other than air, water traditionally has an economic value: consumers, industries pay in general for water supply, farmers may need to invest in water storage (and thus add value to water) and in some countries pay for water (irrigation). But in many cases the "water-market" is dominated by public institutions that are responsible for water management and supply:

- Market prices: In valuation of water resources, market prices often give a good indication of the economic value. In certain countries, farmers have to pay for (additional) water supply (and are willing to do so if added crop value is higher than the price paid for water). Consumers and industries in general also pay a certain price for water, or sometimes for the right to extract water. In case water-management is in public hands pricing may not always be too obvious (no direct relation to for example use of water);

- Hedonic pricing: The value of water resources (certain aspects like vicinity, recreational and landscape value) can be estimated by means of hedonic pricing. The problem with this kind of hedonic valuation will be that in case of water, it will definitely not value all aspects of water (i.e. quantity fresh water available), thus only gives a partial estimate;

- Compensation costs: In certain cases compensation costs can be used to assess the value of water resources. For example: if groundwater resources diminish, this can be compensated by inject (pre-treated) surface water, the costs of treatment, transport and injection are a proxy for the value of the original groundwater resources. Another example is if a wetland has a function for water-purification. This potential can be valued by assessing the costs to purify an equivalent amount of water by means of wastewater purification techniques.

- Benefit transfer: In case local values for water resources cannot be obtained easily, comparable data from other areas can be used.

Land:

The value of land is linked with the economic use of land: the more wanted a piece of land is (for a function like crop production, industrial site, road, living space), the higher the prices are.

- Market prices: These can - in most cases - be used as the basis for the valuation of land. But it can be that this market is distorted(a little) due to: speculation(will lead to too high prices on market) or limitation of functions by permitting/land-use policy (which will limit use value to designated use). But also other external effects can influence the real value of land. In case of market-distortion or external effects, additionally other techniques can be applied to complete the picture;

- Hedonic pricing: As already mentioned, the value of land may be influenced negatively in case of landfills. Such (additional) external effects on value can be roughly assessed by means of hedonic pricing;

- Opportunity costs: as mentioned, the value of land may be limited due to land-use policy. A way to assess the potential value of land, one can look at potential land-use options with higher values. For example: the value of a park in the centre of town may be comparable to land-prices for nearby construction sites (which in general have a high price), the value of a natural habitat near a suburban district with large houses may be comparable with the prices of such suburban land;

- Benefit transfer: If in certain cases exact prices cannot be observed easily, general market information or information from other studies/data-sources in combination quantities land involved can be used as a proxy to assess the value.

Nature:

The use of nature as a resource is as old as mankind. Nature offer mankind abundant resources. Some of them depletable (fossil fuels, minerals, etc.), some of them undepletable (biomass in all its variety). Of course, market prices reveal some of nature's (economic) values, but as market prices merely reflect current (short term) preferences, additional methods are needed to assess the value of nature's resources.

- Market prices: To assess the value of nature or natural habitats, in general many values are derived from market prices. Direct use values of nature, like the value of wood (timber, firewood), other forest and nature products, fish, hunting game, recreation, can all be assessed by means of market prices and quantities.
  For minerals (mining), the value of the extracted materials is an indication of the value (although it is difficult to make a statement if current price-levels on the world market reflect enough the depletion of resources).
  Market prices can also be used to assess indirectly the value of kinetic energy stored in water (hydropower), by assessing the energy potential of the hydropower plant (and the economic value thereof) in combination with the costs to capture that power (by means of a dam, etc.): the potential profitability of the dam (due to a higher market price of electricity than the costs to generate it by means of hydropower) gives a good proxy of the value of the kinetic energy stored in water.
  "Market prices" for CO2 (as in the EU-trading system) can be used to assess the value of carbon sequestration;

- Compensation/prevention costs: In case nature has a function that otherwise should be dealt with by human technology, the costs of such measures (i.e. water management) can be used as a proxy for the value of the provision of this service by nature.
  An example of the use of compensation costs is in case a natural habitat is transformed to an industrial site, housing, etc. (another function). The costs to replace the natural habitat elsewhere, is a proxy for the value of that habitat.
  In a longer term perspective, compensation costs can also be used for assessing the "real" value of the extraction of for example metal-ores. This value would consist of the costs of recycling (including collection/separation/processing) to "replace" the depletable resources;

- Travel costs: These can be used to (mainly) assess the recreational value of nature;

- Contingent Valuation: To assess option and non-use values of nature, contingent valuation can be used. This implies a well set-up experiment, that investigate the willingness to pay of current population to maintain the eco-system and to avoid irreversible changes (loss of biodiversity): basically a valuation of the intrinsic values of nature by human beings (which by definition does not include all aspects of the intrinsic value);

- Benefit transfer: Benefit transfer can be applied if basic data (relative prices, income, quantities, reliable study results) are available and credible, and research would be costly.

Waste:
Waste originates from and can also replace the use of natural resources. That is why waste is included in a system that valuates environmental resources.

- Market prices: Recycling has always been an issue. Market prices of raw- versus recycled materials and the inventiveness of mankind, currently determine to what extent materials are recycled. Resource prices on the world-market fluctuate constantly and are difficult to predict, making it difficult to assess the quantities that are or can be "economically" recycled (i.e. at break-even or profit). But also much depends on the local situation: if there is no demand for secondary materials (due to a lack of infrastructure) waste materials which can have a second life may be "wasted";

- Benefit transfer: In the EU, due to recycling policies (setting minimum standards for recycling) some material are recycled that otherwise would not be (economically) recycled. This means that for some materials (like plastics), the "ecological value" is found higher than the actual market value. In such case, by means of benefit transfer (higher) resource prices can be used as proxy.

5 SELECTION OF MONETARY VALUATION TECHNIQUES

As discussed in the last section, in most cases more than one valuation technique can be applied. This means that for each case to be investigated, the most appropriate techniques need to be selected. Selection criteria are:

- Kind or type of damage:
    - due to (large) industrial accident;
    - due to (incidental) breach of permitted emission/pollution levels;
    - due to continuous pollution (pollution of air, water, land by stationary and mobile sources);
    - due to continuous use of natural resources (water, minerals mining, logging, etc.);
    - due to modification of land-use (road-construction, hydropower, land reclamation, etc.).

- The use of valuation results:
    - for penalties in case of excess pollution (breaching standards);
    - for assessing “right price” of pollution (in case it is decided that polluters will also have to pay some form of compensation (pollution taxes), even if their pollution is within legal limits/standards);
    - for assessing the “right price” for the use of natural resources (a distinction should be made between renewable and non-renewable resources);
    - for permitting purposes (for example Environmental Impact Assessment to assess monetary environmental values for different alternatives (in which case the alternative with more mitigation measures will produce lower damages)).

- The level of “sophistication” needed:
    - It can be argued that for certain applications, a high level of credibility is needed (i.e. for EIA purposes, assessing penalty levels, etc.). In such cases a more “sophisticated” technique may be preferred, which indicates the use of specific, basic valuation techniques rather than benefit transfer;
    - In other applications (i.e. taxation) it may be more important that the assessed values give an order of magnitude (indication of damages) rather than a very precise number. In such case benefit transfer may be the right choice. The (indicative) levels calculated then may form the input in the discussions on how tax-levels should be set.

- Practical issues:
    - If the valuation results are used to be incorporated in the taxation regime of a country or region, it should be investigated to which extent an appropriate tax-base is available. For example, it may be almost impossible to assess (on individual basis and at reasonable costs) the emissions of a motor vehicle. In such case the emission-levels (which cause the contribution of an individual vehicle to overall air-pollution) cannot qualify as tax-base. In such case a “second best” option needs to be investigated (i.e. an annual tax based on pollution characteristics or volume of engines of a vehicle, a surtax on fuels, etc.).

- The costs:
    - Application of any of the valuation techniques will require more or less inputs. A fundamental research will require a large amount of inputs, whereas benefit transfer only requires the use of already existing quantitative information;
    - Costs are to be evaluated in view of the purpose of the use of research results. If the results of the research are to be used for a specific issue, probably specific, fundamental research will give the most credible results. If the research aims at more general results, probably the use of benefit transfer may give satisfactory results at relative low costs.

6 PILOTS

6.1 Introduction

Two pilots have been studied to illustrate the application of the methodologies described in this report. For Armenia the mining sector, and in particular the existing gold/silver mine near Kapan situated within the south eastern region Syunik has been studied. For Georgia the hydropower sector, and in particular the Khudoni Hydropower Project in the northern region of Georgia, has been studied.

For both projects an inventory – based on existing (local) documents and international studies – is made of the potential impacts. Next, data are analysed in order to assess the possibility to quantify the potential economic impacts.

Given the time constraints, not all potential impacts could be quantified, nor was field research an option. The calculations of the impacts are (mostly) based on “benefit transfer” (although other methods may be used to assess the original results). Given large uncertainties, the calculations should be regarded as “illustrative”: explaining a potential approach and indication of data to be used. Where relevant, recommendations are given to refine the calculations (and the data used).

6.2 Kapan gold mine

In Armenia some 400 mines are currently active, including about 30 base metal and precious metal mines. The type and location of a mine determine the environmental impact and risks.

The Kapan gold mine is situated in the Syunik marz, in the south-eastern part of Armenia near the border with Azerbaijan. The mine is owned and operated by DPM (Dundee Precious Metals). The complex consists of the underground Shahumyan mine, with both rail and mechanized diesel transport systems, two primary crushing stations and ore stockpiles, a processing plant and various infrastructure facilities that were built to support the operation. Two types of concentrates are produced: one copper concentrate with high concentrations of gold and silver and a zinc concentrate with lower concentrations of gold and silver.

In 2012 the mine produced 21 843 ounce (619 kg) gold, 449 092 ounce (12 732 kg) silver, 1.114,3 tonnes copper and 6,996.8 tonnes zinc. Production costs were US$ 69,10 per tonne (excluding royalties) and US$ 76,45 per tonne (incl. royalties). As in 2012 509 000 tonnes of ore were processed, the annual production costs were US$ 38,9 million (€28,8 million), including US$ 3,7 million royalties. The gross profit of the Kapan mine was US$ 3,4 million (€2,5 million in 2012).

The mining company had plans to extend the productivity of the Shahumyan underground mine by converting it into an open pit mine. This would extend current production levels from 500,000 tonnes of ore per year to 1 million–10 million tonnes of ore per year. Where circumstances permit, open cast mining is generally an easier and cheaper way of operating a mine. On the other hand, open cast mining creates a greater environmental impact and interferes much more with land use and settlements.

In the following the main information on the possible environmental impacts and applicable valuation techniques is summarised.

Climate

The mining operation cause greenhouse gas emissions, due to the use of fuels, transport and indirect emissions (electricity) and also the use of materials. For the mine in Kapan the GHG emissions are estimated at 22.880 tonnes per year (excluding so called Scope 3 emissions due to the use of materials).

A proxy of the damage caused by 1 tonne of CO_2 is given by the current prices for EU emission allowances, which is about € 4,5 per tonne[2].

Water use

[2] EEX, 2012. European Emission Exchange (www.eex.com)

Large amounts of water – 2,4 million m3 - are used to process the 509.000 tonnes of ore. Main source is river water (2,2 million m3), the rest is supplied by the municipal system. Fresh water is a valuable resource (for drinking water production or agriculture), and therefore has an intrinsic value, even if this is not reflected in a market price. Through economic analysis of alternative uses of fresh water (in agriculture, other industries and for drinking water production) a proxy for the value of fresh water can be estimated. Based on a study for Serbia, a "shadow price" for water of between €0,04 - €0,07 per m3 (price level 2010) has been used to express the value of fresh water (see TME, 2004)[3].

Waste water discharge

Apart from water that vaporises all water used is somehow discharged. Of the water supplied by the municipal system 175.000 m3 (90% of supply) is discharged as domestic waste water. It is not clear if this waste water is collected in a sewer or discharged in the river.

DPM states the annual discharge of about 20.800 m3 of industrial waste water. This cannot describe the complete water balance, as 2,2 million m3 is taken from the river for flotation. It seems more likely, that the discharge form ore processing is around 2 million m3 per year.

No information is available on the quality of the waste water discharges or the presence of any pre-treatment before discharging. So it is not possible to quantify the potential negative environmental effects of the discharges.

In this case the only way to assess the (negative) economic value of the discharges is to assess the "prevention costs" technique. Treatment of sewage in OECD countries costs around €1 per m3 (with a wide range), treatments costs of industrial waste water are in general lower (due to composition and specialised treatment equipment). It may be reasonable to assume that prevention costs in this case (large amounts of wastewater, with low concentrations and basic treatment (ponds)) would be in the range of €0,10 per m3 to €0,25 per m3.

Risk of underground unwanted changes in hydro-geological balance

In the mining process each year about 685 tonnes of blasting agents are used. Such underground explosions may cause changes in the hydrology of groundwater resources (Jermouk Development Centre, 2013). To make an economic assessment of this risk information is needed on:

- relative risk of an event, causing unwanted changes in the hydro-geological balance (% chance that such event happens in any year, for example "once per thousand years");
- the adverse effects on the (ground)water resources, and affected quantities;
- the economic value of the water resources.

Whether such risks exist near the Kapan mines is not known. Also no information is available on the potentially affected (ground)water resources. This makes it impossible to carry out an economic assessment of this (potential) risk. If such assessment should be made

Risk of uncontrolled discharge of waste water (breaking or flooding of dams)

Dams of tailings may cause large risks if not constructed and maintained well. In Kolontár, Hungary, on 4 October 2010, a dam-wall collapsed causing the flooding (1 million m3) of an area of 400 ha agricultural land, destroying 300 houses and causing a damage of at least € 115 million (BIO Intelligence service, 2012). If such risk exists near the Kapan mine is not known, but 3 minor floodings are reported by the company (DPM, 2013). To assess the potential economic damage of such event, information on:

- relative risk of an event, causing a dam break (% chance that such event happens in any year, for example "once per thousand years");
- the economy in the surrounding area is needed (activities, income, (agricultural) output, etc.);
- the potential area of impact of such an event.

As these parameters are not available without further study, no economic assessment is made of this risk.

[3] The price of drinking water in Belgrade - € 0,30 per m3 (price level 2003) – is the starting point for this calculation. Production costs of drinking water (withdrawal) are estimated at about 10%, costs of distribution (pumping, costs of the network) 90%.

Air pollution
Air pollution may be caused by the diesel engines of the (transport) equipment and machinery of the mine. In 2012, 2,68 million litres of diesel were used.

To what extent heavy metals are spread in the environment (due to blasting, wind erosion of tailings, etc.) is not known, no data are available on that.

For the economic valuation of air pollution caused by the mine, the focus is on SO_2 (caused by diesel). The amount of SO_2 emitted can be estimated assuming an S-contents in diesel of 0,8%. With a specific weight of diesel of 0,84 kg per litre, SO_2 emissions per litre diesel are:

0,8%* 0,84* 2 = 13,44 gr SO_2/litre diesel.

The damage costs due to SO_2 are derived through “benefit transfer”. In the Netherlands, 1 kg SO_2 causes a monetary damage of between €4,5 and €11,25 (price level 2010). To convert values to Armenian economic circumstances they must be multiplied with a factor expressing the GDP in both countries[4]: US$42.900/US$5.900 = 0,1375.

Tailings
Tailings may cause various environmental risks: contamination of the air (windborne dust), water, and soil (runoff and dust deposition). In Kapan, in 2012, in total 492.000 tonnes of tailings were stored on site (DPM, 2013). There is no indication of the potential risks linked with the tailings.
An indication of the potential damage of tailings can be derived from “unit damage costs” of tailings (per tonne). The simplest way is to assess the “prevention costs” (how much does it cost to store tailings in such a way that they have no negative impact on the environment). But also, a comparison can be made with unit damage costs (“benefit transfer”) connected with waste management, taking into account the specific characteristics of (inert) tailings. This would lead to “unit damage costs” of between €1 - €20 per tonne (WB, 2011, p. 43-46).

Another way is to assess the potential drop in value of nearby real estate (applying “benefit transfer” based on an original “hedonic pricing” study). Applying the latter method means that it is assumed that property values near tailings drop by 1,5% in a zone of 32,1 km2 (see annex 4, hedonic pricing). If we assume an average property price of €2.500 per ha, the value will drop by €37,50 per ha for in total 3.210 ha.

Hazardous waste
According the sustainability report of DPM in 2012 1.134 tonnes of hazardous waste were transported off-site (with no recycling). Another 202 tonnes are treated and disposed off on site.
The damage costs of untreated hazardous waste can be estimated by “benefit transfer”. It has been estimated that damage unit costs for hazardous waste were € 414 per tonne (price level 2000) in the Netherlands (TME, 2004). To convert values to Armenian economic circumstances they must be multiplied with a factor expressing the GDP in both countries: US$42.900/US$5.900 = 0,1375, a correction for inflation (2000->2010) leads to 23% higher values, which leads to “unit damage costs” for hazardous waste of €70 per tonne of hazardous waste.

Destruction of natural habitat
According to the environmental reports of DPM, there is no obligation to have biodiversity management plans in place. Near the mining site there are no protected areas or areas of high biodiversity value. Mine closure plans are in place for the reclamation and rehabilitation of those sites.

On the other hand DPM reports they have encountered a Red List species of plant called Paeonia Tenuifolia on the site, which now is monitored and protected by a fence.

Open pit mining in the future may have larger adverse effects on the local ecosystem, but are at this moment unpredictable.

[4] The estimate of the damage caused by SO_2 is based on the calculation of DALYs. Regional differences between the value of DALYs is based on differences in income levels.

To assess potential damage due to destruction of habitats due to open pit mining, the value of the ecosystems/habitat can be assessed by means of "market prices" (as explained in annex 4). The current information on these plans is not sufficient to make such an assessment.

Cultural heritage

On the site a few archaeological artefacts have been discovered, currently being investigated by archaeological experts in Armenia. To ensure proper management, drilling sites and roads will continue to be developed under the direction of a supervising archaeologist. No assessment is made of the economic values thereof.

Resettlement of population of Shahumyan

Due to the potential development of an open pit mine 280 inhabitants of the Shahumyan village had to be resettled. They al opted for financial compensation (no information on the magnitude of the compensation).

Overview of potential economic value of environmental damage of Kapan mines

In the following table, the potential economic value of environmental damage of the Kapan mines is summarised, by category. As the assessment is illustrative, the results are uncertain, they may be lower (if too high "unit costs" are used in the assessment) or (much) higher than the values shown. Such an uncertainty range is normal for this kind of assessments (see i.e. Worldbank, 2011).

Table 6.1 Overview of the potential economic value of environmental damage caused by exploitation of the Kapan mines, illustrative assessment

Issue	Amount		price		annual		total	
Climate, CO_2-equivalent	22.880	tonne/y	€ 4,50	per tonne	€	102.960	€	2.522.520
Water use, river	2.230.800	m3/y	€ 0,04	per m3	€	89.232	€	2.186.184
Water use, municipal	197.188	m3/y	€ 0,04	per m3	€	7.888	€	193.244
Water discharge, other	1.791.860	m3/y	€ 0,10	per m3	€	179.186	€	4.390.057
Water discharge, industrial	208.140	m3/y	€ 0,10	per m3	€	20.814	€	509.943
Water discharge, sewer	175.548	m3/y	€ 0,10	per m3	€	17.555	€	430.093
Diesel	2.680.477	litres/y						
SO_2	36.026	kg/y	€ 0,62	per kg SO_2	€	22.493	€	551.080
Tailings	492.563	tonne/y	€ 1	per tonne	€	492.563	€	12.067.794
Rock dumped	64.384	tonne/y	€ 1		€	64.384	€	1.577.419
Hazardous waste, transported	1.134	tonne/y	€ 70		€	79.352	€	1.944.133
Total					€	1.076.427	€	26.372.466

Source: The assessment has been done by international expert of the project

It can be seen that the issues studied would in total lead to an economic damage of about €1 million per year, or €26 million in total[5]. It seems that waste issues cause over 50% of this total, water related issues about 30%, and climate 10%.

In comparison with the total annual output of the mine – about € 30 million in 2011 – the damage would be around 4%. Compared to profits - € 2,5 million (2011) – the damage would be over 40%, compared to royalties paid - € 2,8 million in 2011 – the damage would be slightly lower than 40%.

So, the overall conclusion can be that the economic value of environmental damage is significant in relation to the turn-over and profits of the mining operation.

[5] If annual damages are calculated, total damage can be assessed by calculating the Net Present Value of annual damages over a period of for example 100 years, with a discount rate of 4%. This leads to a 24,5 times higher value for the total damage and vice versa.

To improve the robustness of the assessment and thus reduce the ranges of uncertainty (for example as part of a Cost-Benefit analysis), various partial studies can be carried out. Such partial studies could focus on improving the “unit costs” estimates used in the assessment (by means of questionnaires, statistics, collecting information on pollution of wastewater discharges, etc.) as well as the quantified impacts.

6.3 Khudoni Hydro Power Project

In Georgia, hydropower is the main source for electricity production (> 50% of installed power). To increase independency from imports as well as to support economic development, half a dozen hydro power plants (HPP’s) are planned or under construction. The type and location of a hydro power plant determine the environmental impact and risks.

The Khudoni hydropower plant is the next step in implementing the Cascade Master plan on the Enguri River (north of Georgia, near the border with Abkhazia). It has been planned upstream of the already existing Enguri HPP (realised in the 80-ties). Construction activities started in 1979 and were stopped in 1989. Since the independency of Georgia hydropower was chosen as main source for electricity production and plans to finalise the construction of the Khudoni project have been developed. The Khudoni HPP is designed to have a 200 meter high dam and should create a reservoir of 364,5 million m3 flooding an area of 528 ha. Consequently, about 1.000 – 2.500 inhabitants have to be relocated (MER, 2013, Kochladze, 2013)[6]. The installed power is 702 MW, the expected annual production 1.500 million kWh per year (CENN, 2011).

In the following the main information on the possible environmental impacts and applicable valuation techniques is summarised.

Climate

Although HPP in general have a beneficial climate impact, HPP still may produce considerable amounts of Greenhouse gasses (GHG). For comparable HPP plants the HGH emissions may be between 50 and 120 gr/kWh produced.

A proxy of the damage caused by 1 tonne of CO2 is given by the current prices for EU emission allowances, which is about €4,5 per tonne.

Water quality

With a mean river flow of 114 m3/sec and a reservoir volume of 364,5 Mm3, the average water retention time is 37 days. Water quality problem usually increase with increasing retention time. Khudoni’s retention time is very short; water quality problems related to retention time are not to be expected (MER, 2013).

Risk of uncontrolled discharge of water (breaking of dam)

Dams of HPP’s may cause large risks if not constructed (i.e. include measures to withstand earthquakes) and maintained well. To assess the potential economic damage of such event, information on the economy in the surrounding area is needed (activities, income, (agricultural) output, etc.) and an assessment needs to be made of the area of impact of such potential event. As these parameters are not available without further study, no economic assessment is made of this risk.

Habitat

The partial flooding of the Enguri Gorge, will inevitably have negative impacts on the unique and coherent identity of upper Svaneti. There is a fear that the “together with the existing Enguri Dam and the Vardnili cascade, the proposed Khudoni and Nenskra dams will have devastating impacts on the Enguri Gorge. The cumulative impact of the HPPs on the environment and the climate within the region, in conjunction with global climate change processes, will accelerate the melting of *(nearby)* glaciers and negatively affect the unique biodiversity and water quality both in Svaneti and the South Caucasus region.” (Kochladze, 2013).

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[6] MER, 2013 estimates 256 families have to be resettled, whereas Kochladze, 2013 concludes that if the regional centre function of Khaisi (with 850 families), other small settlements also will need resettlement.

The ESIA proposes to improve degraded forest around the reservoirs, to compensate the inevitable losses in biodiversity. The Netherlands commission for Environmental Impact Assessment (MER, 2013) advices instead, that "it would be appropriate to look for the most valuable biodiversity hot spot areas in the entire valley. These areas should be turned into protected areas and thus will be preserved for the future. A combination with preservation of the cultural heritage of the valley is recommended, also with an eye to the economic potential (tourism) of such measures."

To assess the damage, the most obvious way is to assess the area impacted (which is larger than the 528 ha flooded, in the calculation1000 ha is assumed) and to establish an average economic value of the area (as explained in annex 4). In the calculation it is assumed that the annual value of the area is about € 200/ha (based on Worldbank, 2011).

Waste dump

A waste dump for 7 million m3 of solid waste is proposed in the Khaishura Gorge, to store inert construction materials (including rocky subsoil) dumped over a length of 4 to 5 km. There is currently no detailed design and management plan for this dump, nor an impact assessment on landscape, ecology, erosion, etc. (MER, 2013).

An indication of the potential damage of this dump can be derived from "unit damage costs". The simplest way is to assess the "prevention costs" (how much does it cost to use or store the ineret materials in such a way that they have no negative impact on the environment). But also, a comparison can be made with unit damage costs ("benefit transfer") connected with waste management, taking into account the specific characteristics of (inert) waste. This would lead to "unit damage costs" of between €1 - €20 per tonne (WB, 2011, p. 43-46).

Impact on agriculture

There are concerns about possible changes in the micro-climate near the planned dam (Kochladze, 2013). A complaint heard ever since the Enguri HPP was built is that humidity has increased in surrounding areas: "Fruits have rotten and orchards been destroyed. Even apple trees do not give fruit as they used to… Damp has risen to the point where we cannot get our laundry dry and we get slush instead of regular snow". There is no indication given of the economic impact or impact on agricultural output in the region.

That such potential impact could have a significant damage cost, is clear if we for example assume that agricultural output drops by 10%, whereas agriculture in the Samegrelo-Zemo Svaneti region provides 20% of the regional income (Geostat, 2013). Per capita income in the region (2011) is GEL 3164 per year. This equals, adjusting for purchase power, € 2.450. So per capita income for the affected population in this example would drop by 10%*20%*€2.450 = € 49.
In the calculation it is assumed that about 2.500 inhabitants will be affected (= about the number of the relocated inhabitants).

Fish migration

As the Khudoni dam is upstream of the already existing Enguri HPP, fish migration (as far as it concerns species from the Black Sea) is already blocked by the Enguri HPP (MER, 2013). Therefore, no assessment is made of such potential damages.

Cultural heritage

The flooding of the upper Svaneti region will flood the village of Khaishi. The flooding has wider implications, as Khaishi represents an administrative centre. It will also affect a dozen other small villages. The resettlement can cause the fragmentation of the already minority Svan ethnic group that populates the Zemo Svaneti region (comprising up to 14.000 people). The Khudoni project is a challenge for the Svans to maintain their existing forms of cultural expression.

A way to assess the economic value of this loss of cultural is to estimate the potential income linked with their culture (i.e. tourism, books, products), which would give an indication of the "willingness to pay" for the Svan culture (Kochladze, 2013). No specific information is known on this kind of income, but at national level the tourist sector accounts for 6,7% (2011) of total economic output (Geostat). So a

1% loss of (overall) income for the Svan ethnic group might not be a unreasonable assumption. This would mean a loss of income of €25 per capita for 14.000 people.

Overview

In the following table, the potential economic value of environmental damage of the Khudoni HPP is summarised, by category. As the assessment is illustrative, the results are uncertain, they may be lower (if too high “unit costs” are used in the assessment) or (much) higher than the values shown. Such an uncertainty range is normal for this kind of assessments (see i.e. Worldbank, 2011).

Table 6.2 Overview of the potential economic value of environmental damage caused by exploitation of the Khudoni HPP, illustrative assessment

Issue	amount		price/value			annual	total
Climate, CO2-equivalent	75.000	tonnes CO2/y	€	4,50	per tonne	€ 337.500	€ 8.268.750
Habitat	1.000	ha	€	200	per ha/year	€ 200.000	€ 4.900.000
Waste dump	7,1	mln ton	€	1	per tonne	€ 289.796	€ 7.100.000
Impact on agriculture	2.500	inhabitant					
	2%	income	€	49	per inhabitant	€ 122.500	€ 3.001.250
Cultural heritage	14.000	inhabitant					
% of income	1%	income	€	24,50		€ 343.000	€ 8.403.500
Total						€ 1.292.796	€ 31.673.500

Source: The assessment has been done by international expert of the project

It can be seen that the issues studied would in total lead to an economic damage of about €1,3 million per year, or €31 million in total[7]. It seems that the cultural heritage and climate issue cause each slightly more than 25% of this total, waste related issues about 20%, and ecological concerns about 15% and the impact on agriculture about 10%.

In comparison with the total annual output of the HPP (assuming a price of €0,05/kWh) of €75 million, the damage would be around 1,7%. Compared to total construction costs (US$1.125 billion= €830 million) the total damage would be over 3,8%.

So, the overall conclusion can be that the economic value of environmental damage is significant in relation to the turn-over of and investments in the HPP.

[7] See for explanation why a factor of 24,5 is used in annex 3 and paragraph 6.2.

ANNEX 1: SECTORS GEORGIA

Identification of key sectors of economy with significant damage caused to the environment in Georgia.

To identify key economy sectors having significant influence on environment official statistics have been first searched related to share of different sectors of economy in GDP formulation which is as follows:

- Other sectors - 25,2%;
- Trade - 18,9%;
- Industry - 16,9%;
- State administration - 13,5%;
- Transport and communications - 9,3%;
- Construction - 8,2%;
- Agriculture, hunting and forestry - 8,0% .

For identification of key economic sectors having significant negative influence on environment we were focused sectors with potential damage of different components of environment (land, water, air) at the same of which forestry from agriculture sector and mining from industry were selected.

Forestry
Forests in Georgia cover around 40% of total country area (about 3 million hectares) and perform significant ecological (soil and water protection, climate regulation) and economic (fuel wood supply for energy sector, wood processing and non-wood forest products sector, tourism sector, etc.) functions. In proper forest management seriously affect vegetation, wildlife, soil and watershed areas and climate.

Mining
Main environmental problems caused by mining are related to air, water and land pollution, forest degradation and increase of erosion and landslides.

Therefore, both selected sectors present source of damage to all components of environment.
It is possible also to think about damage caused by other sources from energy sector like Thermal power plants, which are mainly source for air pollution. Regarding of Hydro power plants the problem is the stage of their construction (therefore activity is covered by construction sector) when serious damage to different environmental components is expected due to lack of general environmental, social and economic criteria for their construction. After construction there are no precedents of identification and calculation of any damage caused to environment out of them.

ANNEX 2: SECTORS ARMENIA

Key sectors of economy/economic activities that are increasingly vulnerable towards overexploitation of natural resources and damage caused to the environment

It is evident that as a result of economic activity environmental damage is being caused in the form of environmental pollution, reduction of natural capital.
For Armenia the key sectors of economy/economic activities that are increasingly vulnerable towards overexploitation of natural resources and environmental pollution are.

1. Mining, More than 670 mines of solid minerals, including 30 metal mines, with confirmed resources are currently registered in the state inventory of mineral resources. Among these around 400 mines, including 22 metal mines are exploited.

The aggregate lands allotted to mining companies in Armenia total 9.700 ha, with 8.275 ha of faulted soil and 1.400 ha of tailing facilities lands. Due to the active exploitation of deposits of Armenia, the soil of adjacent areas are highly contaminated with heavy and toxic metals such as copper, molybdenum, mercury, arsenic, vanadium, selenium, cadmium, etc.

The mining sector is a main air polluter: Emission for 2011: SO_2 - 22.400 tonnes, PM 3.059 tonne, NO_x- 1.700 tonne, CO 2.700 tonne. Water resources are polluted by the mining sector with Ammonium nitrate, Sulphates , Nitrites, Nitrates, Suspended solids, Chlorides, Copper, Zinc, Cadmium Chrome, Molybdenum, Oil Products.

Tailings and land degraded by mining operations cover an area of 7.500 ha. A list of tailings is given below:

Name of tailings and location	Region	Status
Near Darakazmi village, on right tributary of Voghji, river	Syunik	Conserved in 1961
Near Pkhrut village, on right tributary of Voghji, river	Syunik	Conserved in 1969
On Voghji river	Syunik	Conserved in 1977
On Artsvanik river	Syunik	Operating
On Geghanush river	Syunik	Operating
On Davazan river	Syunik	Conserved in 1977.
Agarak No 1 gulch	Syunik	Operating
Agarak No 2 gulch	Syunik	Operating
Agarak No 3 gulch	Syunik	Operating
Near Dastakert on right tributary of Nazik river	Syunik	Conserved in 1968
Near Amulsar gold mine	Syunik	In the process of EIA
Neaq Hanqasar Molybdenum mine	Syunik	Passed EIA
Near Terterasar gold-polymetalic mine	Syunik	Operating
Near Akhtala town, on Nahatak river	Lori	conserved in 1988
On Dzoraget river	Lori	Passed EIA
Near Mghart gold mine area	Lori	Operating
Near Aragazap Village	Ararat	Operating
Near Tukhmanuk mining area	Aragacotn	2 – operated, 1 nagative EIA

Source: RECC

2. Water Resource Management, Despite the ongoing reforms and substantial investment in the sector losses in the of water supply and sewage systems continues to be high -70-80%. There is no adequate allocation of water between agricultural and hydropower sectors. Moreover, only a small part of the water price (0.03% of the fees for water supply instead of 1% accepted in the international practice) is earmarked for water resource management.

Main water polluters are: Water supply and sewerage system, 55.6%, manufacturing - 13.3%, energy - 8.2%, and agriculture -3.6%

3. Lake Sevan/groundwater Ararat basin, Water level rise of Lake Sevan over the period of 2001 to 2011 amounted up to 3.6m, but at the same time raising the water level has caused the need to address the management deficiencies of coastal areas-removal of vegetation from areas subject to flooding, deconstruction of buildings and other illegal buildings, relocation of transport infrastructure, in particular the roads.

The economic value of the water resources of Lake Sevan

Components of economic valuation	**Economic value**	**Economic Value**
	mln AMD	Mln USD
Value of direct use	*1.414.043*	*3366,8*
1.1.Objects of Fauna	9.500	22,6
1.1.1.Objects of fauna without fish and craw	60	0,1
1.1.2.Fish resources	1.120	2,7
1.1.3. Craw resources	8.320	19,8
1.2 Objects of flora without forest	515,1	1,2
1.3.Timber resources	7.860,7	18,7
1.4. land resources	352,6	0,8
1.5.Recreation potential	5.614,8	13,4
1.6. Water resources	1.390.200	3310
Use as an irrigation water	*1.390.200*	*3310*
Value of direct use without water resources	*23.843,2*	*56,8*
2.Value of indirect use (environmental value)	3.619,4	8,6
2.1.Accumulation of CO2	2.004,9	4,8
By forest	1.689,1	4
By other vegetation	315,8	0,8
2.2.water treatment function of wetlands	882	2,1
2.3.Health improvement of population by recreation	732,5	1,7
3. Value of Non-use	*927,4*	*2,2*
4. Value of availability	*11.343,1*	*27*
Total economic value	**1.429.933**	**3404,6**
Total economic value without water resources	**39733**	**94,6**

Source: Ashot Harutyunan 2005

The fish resources of the lake Sevan are at a critical level at the moment due to overexploitation and pollution. At this stage, system of measures ensuring necessary conditions for reproduction of fish fauna is not yet fully determined, which means that the problem of biodiversity conservation has to be also considered as a factor of poverty reduction in the region and food security. Besides this the unauthorized and unsustainable use of groundwater reserves of Ararat basin for fishery needs has led to serious environmental problems.

4. Agriculture, is the main land using sector in Armenia. Unfortunately, the current practice of land-use leads to the loss of soil fertility, erosion, salinisation and alkalinisation of soils. About 86.5% of Armenian lands suffer from different degrees of desertification.

5. Energy and Transport; Air pollution from mobile sources cover up to 90 % of all atmosphere pollution in Yerevan and the problem of reducing it requires integrated and targeted solution. From Stationary sources the most polluted city is Alaverdi which is polluted due to sulphur dioxide emissions from the metallurgical plant.

The energy sector causing maximum ecological damage to air pollution by stationary pollution sources: the share of this sector comprises 64,9% of total emissions.

6. Forest Management, Large-scale forest loggings and insufficient funding of reforestation activities, which started back from the period of energy crisis and continue up to this day, have led to the reduction of forest covered areas of the Republic and disturbance of the integrity of forests. Changes in the structure and organization of tree species has occurred in the forests, trees have lost their natural self-regeneration capacity, forest productivity has reduced.

7. Municipal and industrial waste, the negative impact of the existing condition of landfills and solid waste collectors on public health and the environment. Maximum ecological damage due to waste disposal is caused by mining, construction and municipal wastes. Main management problems are linked with the lack of legal framework, the availability of waste services and illegal dumping on large scale in rural areas.

ANNEX 3: VALUATION TECHNIQUES

Market prices

The most obvious way of measuring ecological values is to combine quantities of for example natural resources – like crop, wood, fish, cattle, etc. - with market prices. This method is mainly used to assess “direct use” values, but forms in principle the basis for all kinds of valuation techniques.

The Economic Value for one item/product/service can be calculated as follows:

EV = Q1 * P1

In which:
EV = Economic Value
Q1 = quantity of product 1
P1 = price of product 1 per unit

If more than one product is involved in the calculation, the Economic Value can be calculated as follows:

EV = ∑ Qi * Pi

In which:
EV = Economic Value
Qi = quantity of product i (i = 1 .. n)
Pi = price of product i per unit (i = 1 .. n)

It is important to record type of currency and pice level year.

The method of using “market prices” is often used to assess the (a part of the) value of natural habitats (wetlands, forests, pastures, etc.).

Application

To apply this method basically two types of information are needed:
- <u>production quantities</u> of marketable goods (on the precondition, that the level of production is “sustainable”, that is to say, does not exceed the carrying capacity of the natural habitat)
- <u>local market prices</u>.

To apply the methodology, first an overview must be made of the potential direct use values. This may include:
- firewood;
- wood for construction;
- crop growing (at small and integrated scale);
- non cultivated picking herbs, medical herbs, fruits, etc.;
- cattle breeding (also taking into account the carrying capacity);
- fish;

- hunting of mammals and birds;
- (clean) water extraction;
- recreation (or economic activities related to recreational activities).

The next step must be to assess quantities extracted or produced. If such data are not available through statistics, a representative sample of the population / beneficiaries of the natural habitat can be surveyed. Some knowledge in advance must be obtained to tailor the questions to the actual situation. This may be the way in which crop is produced, whether it is sold and at what price to whom (what market?), in case of own use, quantities must be estimated, the interviewer then needs to know what is the best way to communicate about such quantities (sacks, kg, other units) and if necessary establish rules of thumb (one sack means 20 kg, a bread is 600 gram, a cubic meter of wood equals 500 kg, etc.).

Key household information needs to be collected, as to enable statistical sound processing afterwards.

The sample must be large enough to be more or less representative for the population. This may involve several 100 interviews, to meet statistical demands. By comparing characteristics of the sample with the total population under investigation, the results of the sample can be magnified to the whole population.

Practise

Valuation of forest degradation in Kosovo

For Kosovo, the economic value of forests is estimated for direct use values (timber, firewood, non-wood forest products, hunting, and recreation); indirect use values (loss of plant nutrients, agricultural losses, protection of water reserves and water purification, as well as carbon sequestration); and option, bequest, and existence values (the option value of pharmaceutical products, biodiversity conservation, and cultural value; see table).

For each of these categories, the value was estimated for forests in good and degraded ecological condition (table).

The table summarizes the values per hectare of forest:

Table Value of forests, 2010 (€ per ha), low estimate

	Ecological condition		
Category	Good	Degraded	Difference
Timber	342	114	228
Firewood	1026	821	205
Non-wood forest products	1838	1470	368
Hunting	25	0	25
Recreation	123	0	123
Plant nutrients, agricultural productivity, and water management	613	490	123
Carbon sequestration	1356	1084	272
Option, bequest, and existence values	245	0	245
Total	5568	3979	1589

Source: World Bank, 2011.

Degradation costs between €1,589 (low estimate) and €1,858 (high estimate) per ha.

***Timber and firewood*.**

The average stock of wood in Kosovar forests in good ecological condition is estimated at 114 m3 per ha. On average, 10 percent of the wood can be used as timber, and the rest as firewood. The value of timber in the forest, before transport, processing, marketing, and use, is estimated at €30 per m3. The value of firewood is estimated at €10 per m3. The total value of a hectare forest in good ecological condition is thus €342 for timber + €1,026 for firewood = €1,368. In degraded forests the loss in value of timber is assumed to be 2/3rd of €342 and the value of firewood is reduced to 80 percent of €1,026—that is, €821 per ha.

***Non-wood forest products*.**
Natural forests produce a wide range of other products than wood.

International studies have identified values for grazing animals in forests, and collecting products like mushrooms and herbs. In Serbia, in the framework of the National Strategy for Sustainable Use of Natural Resources of 2005, it was estimated that annually €73 of non-wood forest products was harvested per hectare of forest, mainly based on the value of mushrooms/truffles, animal products (game), and plants, herbs and fruits harvested.

In Kosovo's similar forests, the value applied is €75 per ha for forests in good ecological condition, to take account of inflation in 2005–10. The net present value of annual revenues of €75 (for 100 years at a 4-percent discount rate) gives a total value of €1.838 per ha.

For degraded forests 80 percent of the above value is assumed—€60 a year per ha, for a total value of €1.470 per ha.

***Hunting*.**
The amount of hunting in Kosovo is unknown, but it is reasonable to assume that it takes place in Kosovar forests as it does in Serbian forests. As the potential benefits of animal products are already included in non-wood forest products, this evaluation deals with income from permits and licenses. Other studies (such as Turkey and others, 2005) adopt conservative estimates of about $1 per ha annually for such income. This assessment uses €1 for forests in good ecological condition for a total value of €25, based on the above net present value calculation. For degraded forests a zero value is assumed.

***Recreation*.**
No information is available on the economic value of forests for recreation in Kosovo. Some studies have looked at other countries and various forest types (see, for example, Pearce and Pearce 2001). In Europe, this assessment estimates that the average recreational value of forests is $80 per ha. Taking a conservative approach and correcting for income levels, currency movements, and inflation, a recreational forest value of an annual €5 per ha seems reasonable for Kosovo. This leads to a total recreational value of forests of €123 per ha.

Indirect use values.
Forests play a role in various natural cycles, reducing nutrient losses and erosion, regulating and purifying water resources, and sequestering carbon. It is hard to estimate a value for each of these categories in Kosovo. A conservative estimate of €25 per ha a year has been used for all categories together. The total value is €613 per ha. For degraded forests 80 percent of these values are assumed (€20 per ha a year, for €490 per ha total value).

***Carbon sequestration*.**
An ecological healthy forest can take up about 5 tons of carbon dioxide (CO_2) a year. With a CO_2 price of €11,25 the annual value of carbon sequestration is €55 per ha. The net present value is €1.356 per ha. For degraded forests 80 percent of these values are taken.

Bequest and existence values.

Bequest values are defined as the willingness to pay to preserve natural resource for future generations, while existence values are the values which are placed on for instance a forest even though individuals may never use it. The non-use functions of forests such as biodiversity, landscape, respect for the right or welfare of non–human beings including the forest ecosystem are considered under this category. As no specific information is available on Kosovo, a conservative estimate of these values of €10 per ha a year for forests in good ecological condition is assumed. For degraded forests a value of zero is assumed. This value is assumed to also include the option value of the forests.

Valuation of the Kolkheti wetlands in Georgia

In the period 2001 – 2005 a variety of studies have been carried out to assess the economic importance of the Kolkheti wetlands in Georgia.

Two major studies were carried out to assess the economic importance:
- a Cost Benefit study on the establishment of the Kolkheti national park (Arin);
- a study on Valuating resources in Black sea coastal wetlands (Neiland);

- a study on Resource Use in the Kolkheti National Park: Grazing, Logging, Fishing, Hunting (ICZMC).

All of these studies have mainly focussed on collecting data on the direct use values for the population living in or near the wetlands (in the "support zone").

All three studies have made use of questionnaires and interviews to assess economic use values for the population. By comparing the sample population with total population, estimates were made for the whole area (which was different in each of the three studies).

These data were then combined to assess "unit values" for wetland valuation. This was done by dividing the total use values per category for the study area by the area in hectares. Then the results of the three studies were combined, and the "best" estimates were selected of the three studies to arrive at a credible figure for the Kolkheti wetlands (expressed in € per ha annual value). The results of this are shown in the next table.

Table
Estimated direct and indirect use values of the Kolkheti wetlands, in € (2005) per ha.

(in)direct use	value (€ per ha)
Crop	168
Livestock	169
Fishing	237
Wood & wetland products	13
Hunting	9
Recreation and Tourism	0,51
Carbon Sequestration	3,03
Existence Value	0,94
Total	601

Source: estimate of international expert based on: Arin (2001), Neiland (2001) and ICZMC (2004)

The first 5 direct use categories were assessed by making use of market information. This information was gathered by field investigations, interviewing several 100's individuals about their social-economic situation in relation to the wetlands (crop, firewood, cattle, hunting, fishing, etc.) and (semi) market prices for these products. As such the average income from wetland products could be estimated per household. Next, the total income was assessed for the population under investigation, and finally, this total was divided by the number of hectares.

Use value of recreation was estimated on basis of a few assumptions about increased recreational activities and value added per additional (eco)-tourist. For carbon sequestration it was calculated how much carbon can be sequestered per year and this was multiplied by a "Carbon price" of US$ 10 per tonne C. Finally, the existence value has been estimated by making use of a WTP study in Georgia for biodiversity preservation in "strict" natural parks (closed to the public, only open for research) and attaching this number (GEL 2 per capita per year) to the Kolkheti wetlands.

Dose response function and valuation of mortality and morbidity

Introduction

The World Health Organisation (WHO) and other institutions have established methods to estimate health impacts (morbidity and mortality) of for example particulate matter.

Application

To apply this method a variety of information is needed (see for example (Dixons, 1997; Pope, 2002; Ostro, 2004). It follows 5 steps:

1. Ambient air concentrations of particle matter (PM_{10} and $PM_{2.5}$);
2. The exposed population;
3. Dose response functions, describing the relationship between exposure to certain ambient air concentrations and morbidity (illness) and mortality (death);
4. Assessing the physical health effects by combining information from step 1, 2 and 3;
5. Examination of the costs of morbidity and mortality.

The first type of information can be obtained from actual measurements (if existing). Also exposed population can be estimated by making use of statistical information.

To establish dose response functions, involves the analysis of large amounts of information about relevant parameters (concentration of pollutants, exposure (and who or what is exposed?), physical response in terms of number and type of morbidity and mortality cases).

Although there are some theoretical problems (for example, to attribute a specific pollutant instead of a cocktail of pollutants to morbidity or mortality), in principle the methods to establish dose response functions are theoretically sound if used with caution.

Simplified approach

A simple, “quick and dirty” formula to estimate mortality due to air pollution, is established by (Dixon, 2000):

Mortality = 6,72 * 10^{-6} * (concentration of PM_{10} in µg/nm3) * (population)

For example:
- a city has 1.000.000 inhabitants;
- the concentration of PM_{10} in the air is on average 75 µg/nm3;

mortality can be estimated as:
- 6,72 * 10^{-6} * (75 µg/nm3) * (1.000.000) = 504 inhabitants per year.

In comparison with the more elaborate dose-response function explained in the next section, this is an underestimation by about a factor 2.

Health impacts of air pollution

Substantial scientific research demonstrates public health impacts from air pollution, and especially from particulate matter (PM). The key public health effects of PM are respiratory diseases and cardiovascular effects. According to WHO (2005), the following are attributed to short-term exposure to air pollution: respiratory and cardiovascular hospital admissions, emergency department visits, and primary care visits; use of respiratory and cardiovascular medications; days of restricted activities; work and school absenteeism; acute symptoms (wheezing, coughing, phlegm production, respiratory infections); physiological changes (such as lung function); and even death.

Effects attributed to long-term exposure include mortality due to cardiovascular and respiratory diseases; chronic respiratory diseases (asthma, chronic obstructive pulmonary disease, and chronic pathological changes); lung cancer; chronic cardiovascular diseases; and intrauterine growth restriction (for example, low birth weight at term; WHO 2005).
The following health assessment is based on air pollution by fine particle matter (PM_{10} and $PM_{2.5}$). This assessment follows five steps to quantify the health impacts of air pollution and their costs (approach based on Worldbank 2013/Ostro 2004).

Step 1: Monitoring data on air pollutants

To assess effects of air pollution on health, the first step is to collect data on ambient air concentrations of $PM_{2.5}$ and PM_{10}.
Ideally data should be used from monitoring stations in different kind of areas (urban, suburban, rural).

In the example, we assume (urban) ambient air concentrations of $PM_{2.5}$ of 40 µg/m3, for PM_{10} 75 µg/m3. These are relative high concentrations, but maybe representative for the Caucasus urban settlements. In a more advanced approach, differentiation can be made in exposure levels on different locations. For simplicity of the example, only one (high) level is taken.

Step 2: Determining the population exposed

The population that is exposed to air-pollution needs to be made. In the example, simply 1 million inhabitants are assumed to live under urban conditions outlined in step 1. If different exposure levels apply to different locations and inhabitants, adjustments can be made, if data allow.

Step 3: Assessing health impacts from exposure using epidemiological data

The third step is to determine the health impacts of exposure based on epidemiological scientific research of the exposure-response function between exposure to PM_{10} and $PM_{2.5}$ and mortality and morbidity.

Mortality
For mortality, the exposure-response functions for long-term exposure to $PM_{2.5}$ provided by Ostro (2004) are applied. The relating relative risks (RR)—that is, change of mortality rates—are calculated as follows:
- cardiopulmonary mortality, RR = exp[0,00893 (X-X0)], in the example 0,337[8];
- lung cancer mortality, RR = exp[0,01267 (X-X0)], in the example 0,509;
- and acute lower respiratory infection (ALRI) mortality in under-five children, RR = exp[0,00166 (X-X0)], in the example 0,105
- with X = current annual average $PM_{2.5}$ concentration for cardiopulmonary and lung cancer among adults and PM_{10} concentrations for ALRI among children, and X0 = target or baseline $PM_{2.5}$ concentration.

Mortality baseline data for Georgia/Armenia in the assessment are[9]:
- The crude death rate is 18 per 1.000 people;
- The share of cardiopulmonary mortality in total mortality is 66 percent;
- The share of lung cancer mortality in total mortality is 4 percent;
- The share of mortality due to acute lower respiratory infections in total mortality among under-five children is estimated at 12,5 percent.

Morbidity
Exposure-response coefficients (annual cases per 100.000 people) for PM_{10} from Ostro (1994) and Abbey and others (1995) are used, with Ostro (1994) reflecting a review of worldwide studies and Abbey and others (1995) providing estimates of chronic bronchitis associated with particulates (PM_{10}) (table A).

Table A. Urban air pollution exposure-response coefficients for morbidity health effects
Health impact (PM_{10}) Unit Impact per 1 µg/m3

Health impact PM_{10}	**Unit**	**Impacts per 1 µg /m3**
Chronic bronchitis	per 100,000 adults	0,87
Hospital admissions	per 100,000 pop.	1,2
Emergency room visits	per 100,000 pop.	23,54
Restricted activity days	per 100,000 adults	5.750
Lower respiratory illness in children	per 100,000 children	169
Respiratory symptoms	per 100,000 adults	18.300

Source: Ostro 1994; Abbey and others 1995

Baseline for PM concentrations
A baseline level for $PM_{2.5}$ of 7,5 µg/m3 is used (Ostro, 2004). Given a $PM_{2.5}$/ PM_{10} ratio of nearly 0,5 observed in Kosovo (see above monitoring results), the baseline level for PM_{10} is set at 15 µg/m3 (for large and for medium and small urban areas).

Step 4: Physical health impacts
The health effects of air pollution are converted to disability-adjusted life years (DALYs) to facilitate comparison with health effects from other environmental factors and between mortality and morbidity. A disability-adjusted life year is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. The DALYs per 10.000 cases for the various health impacts are in table B.

Based on the exposure-response coefficients, annual PM ambient air concentrations, and data on the exposed population, urban air pollution can be estimated (midpoint) annually to cause 1.348 premature

[8] Implying that 33.7% of cardiopulmonary mortality >30y is caused by PM.
[9] Partly based on WHO-statistics, partly rough estimates.

deaths, 420 new cases of chronic bronchitis, 720 hospital admissions, and 13.100 emergency visits. The health effects represent a loss of approximately 13.700 DALYs a year (table B).

Table B. Estimated health impacts of air pollution in Kosovo, 2010

Health impact	Case	DALYs /10,000 cases	Total DALYs
Cardiopulmonary mortality (PM 2.5) >30y	1.212	80.000	9.698
Lung cancer mortality (PM 2.5) LC > 30y	122	80.000	978
ALRI (PM10) <5y	14	340.000	481
Chronic bronchitis (PM 10)	420	22.000	920
Hospital admissions (PM 10)	720	160	12
Emergency room visits (PM10)	14.100	45	63
Restricted activity days (PM 10)	2.760.000	3	828
Lower respiratory illness in children (PM10)	20.280	65	132
Respiratory symptoms (PM 10)	8.784.000	0,75	659
Total			**13.770**

Source: International expert's calculations, ALRI = Acute lower respiratory infections.

These estimated cases can be much higher than the number of patients registered with respiratory diseases as not all persons with respiratory symptoms go to the doctor or hospital.

Step 5: Monetary effects of health impacts

The number of DALYs calculated in step 4 need to be multiplied by the value of a year of life lost. There are two approaches to valuation. The human capital approach values a life at the level of GDP per capita: if one year of a person's life is lost, society loses, at the very least, her contribution to production. This method provides a lower bound of a person's worth. An alternative method Is the Value of a Statistical Life (VSL), which provides an upper bound monetary value of health damages. It aims at measuring the willingness to pay to avoid death by observing individual behaviour when trading off health risks and money. In countries with a low GDP per capita, the VSL approach leads to generally gives higher monetary costs of mortality. Roughly spoken the VSL approach may lead to a 4 to 5 times higher valuation than the human capital approach.

In the example we apply the human capital approach, based on GDP at purchasing power. For Armenia and Georgia per capita GDP is estimated at about US$ 6.000 = € 4.400).

Total damage due to health impacts of air pollution in this example is:

13.770 DALYs * € 4.400/DALYs = € 60,6 million

Hedonic pricing

Hedonic pricing involves the use of large data sets in which the value of property (houses, land) is observed and compared with environmental factors. By statistical analyses the environmental or nature valuation attributes in the price of property can be separated from other attributes.
For example, the price of property decreases by 0.5% by an increase of the noise level with 1 dB(A)).

This method is mostly applied to noise, but it can also be applied to nature, vincinity of open water by looking at values of property in relation to the distance to natural areas or water.

Application

Applying hedonic pricing requires access to and capacity to process large amounts of real estate market information, environmental characteristics of property, etc. So normally, such projects can only be undertaken by statistically well-educated researchers.

Often, researchers make use of earlier estimates. For example, if the relationship between the value of property and a change in noise level of 1 dB(A) is established in general terms (for all property applicable), this relationship can be applied in other situations as well, if certain demands are met (see paragraph on benefit transfer for further reading).

Hedonic pricing is applied in only a few cases in nature protection (see (OECD)).

Practise

Assessing benefits of noise policy in the Netherlands

In 2000 a study on the benefits of environmental policy in the Netherlands was performed. Noise benefits were estimated in 2 ways: by assessing willingness to pay, and by means of hedonic pricing. In latter case, use was made of earlier estimates and combined with Dutch noise data.

The following table gives an overview of results from various hedonic pricing studies for traffic noise.

Road traffic noise valuation studies in Europe

Study	Country	% change of house price per dB(A)
Vainio (1995)	Finland	0.36
Haolomo (1992)		0.98
Weinberger et al (1991)	Germany	0.5 - 1.3
Collins and Evans (1994)	UK	0.65-1.28
Bateman et al (1999)	UK	0.20
Soguel (1994)	Switzerland	0.91
Pommerehne (1988)		1.26
Iten and Maggi (1990)		0.9
Saelensminde and Hammer (1994)	Norway	0.24-0.54
Grue et al (1997)		
Obos		0.24
Flats		0.21
Houses		0.54
Lambert (1992)	France	1.0

Although an average of between 0.6 – 0.8% can be determined from the above results, in the Dutch study an average value of 0.4 % change per dB(A) has been applied to assess the total damage of noise. The main reason is that most recent studies point at somewhat lower values.

This leads to following estimate of noise damage in the Netherlands.

Total noise damage for the Netherlands in 2010

Noise band	Average exceedance (in dB(A)	No of households (x 1000)	NDSI	Average house price	Damage Present value € million
51-55	3	2089	0,004	€ 124 921	€ 3 131,4
56-60	8	2197	0,004	€ 124 921	€ 8 782,9
61-65	13	1054	0,004	€ 124 921	€ 6 844,9
66-70	18	285	0,004	€ 124 921	€ 2 559,3
71-75	23	55	0,004	€ 124 921	€ 630,2
76-80	28	11	0,004	€ 124 921	€ 155,5
>80	32.5	1	0,004	€ 124 921	€ 24,1
TOTAL					€ 22 128,2

Source: EFTEC/RIVM

Influence of landfills on property prices

A hedonic pricing meta-analysis has been carried out in the United States on the influence of landfills on property prices (Richard, 2005). This study shows that lower volume landfills lower adjacent property values by 2,5 percent, on average, with a gradient of 1,2 percent per mile. This means that the areas around a landfill for which property values are lower (converting from miles to kilometres) are 8,0 square kilometres (km2) for up to 1 mile and 24,1 km2 for 1–2 miles or a total affected area of 32,1 km2.

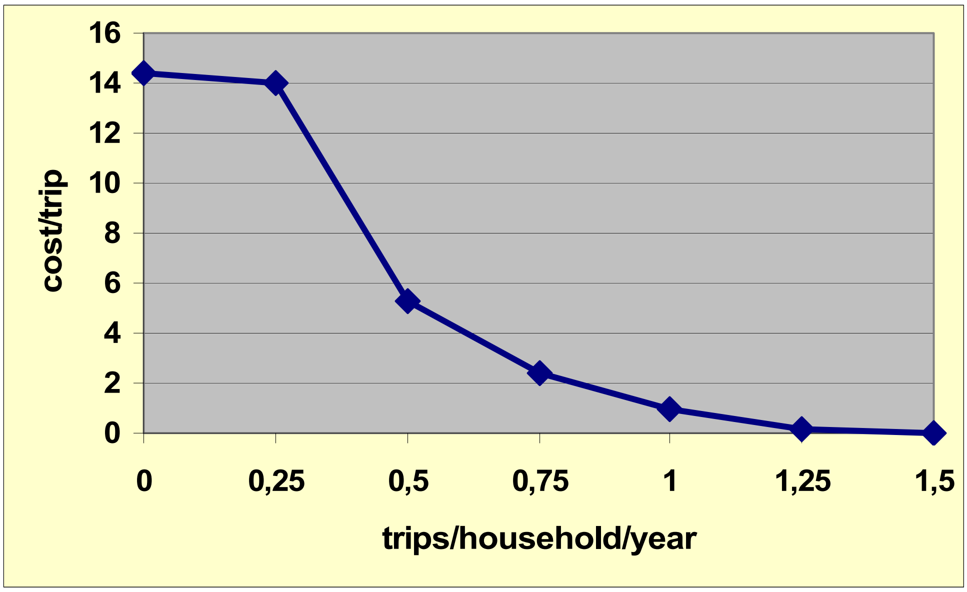
Travel cost method

Part of economic behaviour can be measured by looking at how individuals spend their money and time. Part of economic behaviour can be measured implicitly by looking at how individuals spend their money and time. The Travel Cost method aims at measuring travel costs (for example to visit a protected natural area) and time (and value this economically) and (sometimes) the economic spin off (consumptions in the region, costs of accommodation). As it measures the actual travel expenditures of individuals (as a function of distance) in relation to for example the visit to a natural habitat, the recreational value of the natural habitat can be measured.

The basic assumption behind this valuation method is that someone who has low expenditures to make a visit to the natural habitat, has a higher "consumer surplus" than the visitor of the habitat that pays a lot to get there (due to longer distance).

Application and practice

To measure travel costs, first a "demand curve" for visiting natural habitats must be estimated. This is done by collecting a lot of information of visitors of the site (number of trips per year, travel costs, distance to the site). As illustration a demand curve is shown in the figure. It basically shows the relationship between number of trips per household per year (x-axis) and the travel cost per trip (y-axis). It can be seen easily that increasing travel costs lead to less annual trips.



The next step is to calculated consumer surplus. It is clear that the consumers who make 1.25 visits per year, have much lower costs than the visitors who just make 0.25 visits or less per year. By integrating the demand curve between the actual costs of visits and that price at which the visitor rate would fall to zero (the y-axis), the consumer surplus is estimated. This leads to the following summary of results in the next table:

Table
Calculation of consumer surplus for a natural site

zones	zonal population	household trips	number of trips per household	average travel cost per household	average travel cost per trip	Consumer surplus per hh	consumer surplus per trip/hh	Total consumer surplus per year
1	10000	12500	1,25	0,16	0,128	2,6	2,08	26000
2	30000	30000	1	1	1	1,67	1,67	50100
3	10000	7500	0,75	1,83	2,44	0,94	1,25	9400
4	5000	2500	0,5	2,66	5,32	0,42	0,84	2100
5	10000	2500	0,25	3,5	14	0,1	0,4	1000
	65000	55000	0,85					88600

Source: OECD, Handbook of biodiversity valuation

The table shows that first zones have to be defined, next the population per zone needs to be assessed. Then per zone the number of household trips needs to be counted. This enables calculation of number of trips per household per year. Next, the average travel costs per household need to be assessed per zone (by taking into account distance, fuel costs, depreciation costs, bus ticket costs, “time” costs). This enables to estimate a “demand curve” (as shown above) and estimation of consumer surplus. By multiplying consumer surplus by the number of trips per year, total consumer surplus can be calculated. This total represents an estimate of the Willingness to Pay of visitors of the natural site for the “use-value” of the site.

costs

Prevention Introduction

Applying preventive measures is a way to mitigate negative effects of economic developments for nature. The costs thereof can be regarded as the value of the protected area or species, pollution prevention, improved life in general, assuming that the democratic process that leads to such measures and thus expenditures represents a “societal demand curve” for a clean environment.
Examples of such measures can be other, longer routes of road (to prevent cutting off part of a natural area), a tunnel, passages for animals. In industries it is implemented by installing environmental equipment or innovative, low polluting production technologies.

A major drawback of this method, is that it gives an estimate of mitigation costs. Even assuming that the level of costs is in accordance with the societal preferences, it may underestimate the actual values of nature, clean air, water, etc. (as theory says that we should spend money on problems as long as the additional benefits are larger than the additional costs). But, in case an irrational decision has been taken (without democratic consultation) spending much money on small additional benefits, it also may be that the value is overestimated.

Therefore, it is recommended to use this method primary to make a first rough estimate.

Application and practise

Applying the method is relatively simple. One needs to identify the problem to be valued, and one needs to know (or estimate) expenditures to mitigate the problem.

An example of using prevention costs to value nature is the following:

The Dutch and Belgian governments almost agreed on re-activation of an old railway (“Iron Rhine”, from Antwerp to the Ruhr area). TME (2002) carried out a study on the potential economic damage due to this. Part of the Railway goes through a natural reserve the “Meinweg” of 1.800 hectares.

The value of this area was assessed in various ways, one of the methods was to estimate the damage (due to the railway) based on prevention costs. The preventive measure is the construction of a 5 km tunnel under the Meinweg area (which would largely solve the problem) would cost about € 115 mln. Divided by the area protected (1.800 hectares) the value of the Meinweg can be estimated at € 63.000 per hectare.

Compensation costs

Introduction

In some cases, a natural habitat is destructed due to the construction of a road, a harbour, industry, etc. Clearly, economical interests prevail in such cases. Theoretically spoken it is possible to create a new nature area that can be compared with the old area (although copying a natural habitat is not for 100% possible), as to compensate the loss of natural habitat.
The costs to compensate the loss of natural area can be assumed to be the value of the nature area in question (as a lower limit value).

As with prevention costs method, this method explains the value of a natural habitat by looking at the costs of replacing an existing value, rather than estimating the user and non-user values. Therefore, this method should only be used for a first rough estimate, if no other data is available.

Application and practise

If we take the example of the Meinweg (see paragraph on preventive costs) again, the following can be argued.
In this case we assessed the value of nature (per hectare) by estimating how much it would cost to create elsewhere the same kind of natural habitat. A study of ANWB (1992) estimates that to create one hectare of nature incurs costs to society of € 45.000/ha. Applying this to the 1.800 ha of the Meinweg, sets the value to € 81 million.

Opportunity Costs method

The opportunity costs of a resource, is the value of the next-highest-valued alternative use of that resource. For a natural area this may be agricultural use, use as a road, and in some cases economic development (industry, housing). The opportunity costs of nature thus will depend largely on location and (for agriculture) fertility. In the Netherlands natural area is valuated at about € 20.000 per ha (CBS), agricultural land costs € 30.000 – 40.000, industrial €100.000 - €200.000 and housing €2.000.000 - €5.000.000 per ha.

This kind of valuation sheds a light on the importance of "nature". Central Park in New York is surrounded by the most expensive real estate in the world. Still every government of New York could suppress the temptation to sell the land to the highest bidder. The 341 ha would have an enormous value if brought on the market. Implicitly, this means that "nature" in such an metropolitan environment is very highly valued.

But this example also shows the weakness of this approach: it may be so that a highly bio diverse habitat (almost) not accessible to mankind (pristine nature) may only have a fraction of the value of the less bio diverse Central Park.

Stated Preferences Techniques

For certain environmental problems – like preservation of biodiversity or future environmental benefits - it is difficult, controversial or impossible to assess the monetary environmental damage by means of revealed preferences techniques. In such cases revealed preferences techniques can be used to acquire information on monetary environmental values.

Stated preferences can be used instead of revealed preferences techniques (for "direct and indirect use values" (see table 2.1), but more important also for "option use values" and "non-user values" (which principally cannot be assessed by means of revealed preferences techniques).

Since the 1970's various techniques have been developed to forecast individual (economic) choices. Initially, these techniques were applied mainly in marketing research, later also applications were used in transport and environmental economics.

By far the most commonly used stated preferences technique in environmental economics is the so called "Contingent Valuation", which will be discussed briefly in the next section.

Contingent Valuation Method (CVM)

Introduction

Basically CVM aims at measuring the willingness of individuals to pay for environmental services, nature protection, etc. CVM is a survey-based, stated preference, methodology that provides respondents the opportunity to make an economic decision concerning the relevant non-market good. Values for the good or service are then inferred from the induced economic decision. The CV method is in use for over 30 years.

CVM is one of the most advanced and the most used techniques for environmental valuation. In contingent valuation researches, precise questionnaires are developed, aiming to obtain a direct answer from the individuals questioned.
The essential part of the questionnaire is information about the willingness to pay for a certain environmental benefit, or willingness to accept compensation for a forgone benefit, or an incurred cost. The contingent valuation questionnaire should define:

- environmental good – that has to be valued by the respondent – itself;
- the institutional context of its consumption (how is the externality “consumed” by respondents);
- and the way of paying for it (privately, publicly).

Although the questions are related to a hypothetical situation, the respondents are expected to behave as if they were in a real marketplace. Respondents state the preferences in a form of a bidding game. Econometric techniques are used to analyse the obtained results. Accuracy of conclusions is closely related to the construction of the questionnaire. That is the reason why a precise procedure should be applied (Arrow et. al. 1993).

Most critical with this method is the way in which is explained what exactly has to be valued by the respondents and realistic monetary choices. A limitation is the “income restraint” (poor people will be less willing to pay, so average income levels influence outcomes of the studies). An advantage is that it can be used to valuate difficult to measure non-user values or the value of non-traded goods and services.

A wide variety of CV studies have been carried out on a wide range of environmental and nature issues:

- preserving biodiversity;
- (water and nature) recreation;
- water supply and supply of sewerage;
- increased access to natural habitats;
- etc.

On the internet, various sites give summaries and overviews of the results of CV-studies.

Application

A Contingent Valuation study start with the design of a questionnaire. The questionnaire of course, should be tailored to the needs of the survey. This means that a precise description must be given of the kind of environmental goods or services that need to be valued by the respondents.

The design of the questionnaire would include the following issues (see for more details, paragraph 3.2.4):

- key descriptive statistics on the population interviewed:
    - age;
    - sex;
    - level of education;
    - household income;
    - size of household;
    - ownership of dwelling;

- a description needs to be prepared that details the benefits, that respondents are expected to enjoy if the measure to improve the environmental service or good is implemented;
- question(s) on whether the respondent would support the improved environmental service or good;
- a choice bid format has to be used, in which the payment for the environmental service may be for example:

- an increase in the per-person monthly tariff from the level households are already paying;
- an increased allocation of budget to a improve the level of environmental service;
- an increase in compensation for an individual who will not have access to the improved environmental good or service.

Respondents must be offered about ten possible bids (to be chosen in consultation with local experts).

By means of statistical analysis techniques (regression for example), the results of the questionnaire can then be interpreted.

When analysing the results of a CV study, It is important to assess what the expected hypothetical relationship will be between the willingness to pay for a service and certain parameters (like level of the bid; income, household size, gender, age, education, private interest). This can be used afterwards, when analysing results, to check whether the results are in line with the hypothetical expectations.

As this method is based on questionnaires, the method can be and has been applied to a variety of natural and environmental resources and environmental problems.

Practical examples

Willingness to Pay to be Connected to Sewerage as Required under the Urban Wastewater Treatment Directive in Lithuania, the case of Ukmerge

In this study (Bluffstone and DeShazo, 2006) the willingness to pay for extended environmental services, as a result of the implementation of the EU environmental directives on waste and wastewater, were surveyed. Here a summary is given of the results for the WTP for sewerage services.

The provision of sewerage in EU countries is regulated in the Urban Wastewater Treatment Directive. It has two major parts:

- The first part requires that wastewater treatment plants meet effluent concentration standards;
- The second part of the directive requires that sewerage be extended to all residents in towns with more than 2000 inhabitants, as long as costs are not “excessive.”

Since independence in 1990, Lithuania has been engaged in a program of wastewater treatment plant construction and upgrading. Like several other Lithuanian towns, Ukmerge has a treatment facility that probably already meets the requirements of the directive.

Sewerage, however, has received little or no attention, largely because it is believed that the individual septic systems commonly used are effective for treating small amounts of household sewage. Only sewerage was therefore considered, and only respondents who indicated they did not have sewerage services were surveyed. 42,6% of respondents said they did not have access to the sewage system.

A description of the services provided by the sewerage component of the Directive on Urban Wastewater Treatment was read to each respondent:

> "You have indicated that you are not connected to the municipal sewerage system. I would like to acquaint you with some of the potential benefits of connecting to the centralized sewer system. If you were connected, you would not need to service your private septic system or pit toilet. This would create a more sanitary environment in your yard. If you currently use a pit toilet, connection would allow you the opportunity to have indoor plumbing. Furthermore, there is little or no smell associated with centralized sewage systems."

Each respondent was then asked if they would support the program if they had to pay an additional monthly fee (on top of the tariff they already pay) ranging from €0,04 (0,20 litas) to €1,11 (4,90 litas) per person per month. The nationwide average per capita tariff is approximately €0,5 per month, but the cost is higher in Ukmerge because of debt service for the new treatment plant. Over half of those NOT connected indicated they would favour a program to extend sewerage at the bid they were offered.

The statistical analysis shows that the signs of all coefficients are as hypothesised and all estimates are also significantly different from zero, at least at the 10% level.

Respondents were asked for their maximum willingness to pay. Slightly over 35% said they were willing to pay zero for the program. Of particular interest is that 12% of all respondents in this group said they did not need sewerage. Another 38% said they were satisfied with the current situation. Most of the remainder focused on their inability to bear additional costs (34%).

Levels of Support for Extension of Sewerage at Various Tariff Levels

Proposed Additional Tariff per person per month	Estimated Percentage of Population that would Support the Sewerage Extension Program
0,18 euros (0,79 litas)	25%
0,04 euros (0,19 litas)	50%
0,01 euros (0,04 litas)	75%
0,002 euros (0,01 litas)	100%

The table suggests substantial household willingness to pay for sewerage services. Whether this figure is "enough," of course, depends on the costs. Half of respondents indicated a willingness to pay an additional €0,51 (2,24 litas) per person per year for sewerage services. If 20% of the Lithuanian people do not have sewerage services (a perhaps high figure), this means that the national willingness to pay for sewerage upgrading is approximately €400.000 per year.

How does that figure compare with the costs? The answer is rather badly. Beginning in 2011, it is expected that annualised costs will be approximately €42,5 million (187 million litas). Even with substantial income growth between the year 2000 and 2011, it is unlikely that the annual willingness to pay for sewerage will cover even 10% of the estimated annual costs. This finding suggests that sewerage extension is an area where subsidies will be necessary if it is to be provided as the directive requires.

Benefits of water quality improvements from different valuation studies

A study on the UNEP website gives an overview of the benefits of water quality improvement. Here the main results of some 10 studies from different regions in the world are shown. The unit shown in the table is the measured willingness to pay of individuals for improved water quality (Many of these studies used CVM to arrive at a figure

Study and region	Economic method used to measure benefits of water quality improvement a)	Annual benefits per individual
Michael et al. 1996 Maine, USA	Hedonic Model Measures changes in property prices	\$35 - 633
Needelman and Kealy, 1995. New Hampshire, USA	Discrete Choice Measures benefits for swimming	\$1.46
Bockstael et al. 1988 Chesapeake Bay, USA	CVM d) Measures benefits for swimming	\$48.35 - 198.86
Gren et al. 1997 Baltic Sea - Sweden	CVM - measures total benefits	\$392 - 758
Gren et al. 1997 Baltic Sea - Poland	CVM - measures total benefits	\$39 - 78
Sandstrom, 1996 Sweden	TCM e) - measures recreation benefits	\$21 - 48
Goffe, 1995 France	CVM - measures recreation and other benefits	\$31 - 42
Georgiou, 1998 UK	CVM- measures recreation benefits	\$8 - 9
Choe et al. 1996 Philippines	CVM measures public health and recreation benefits	\$0.40 - 1.63
Choe et al. 1996 Philippines	TCM - measures recreation benefits	\$1.5 or 2.08
Smil, 1996 China	Total benefit estimate - for fisheries only	\$0.13

Source: UNEP

Notes:

a) All values are annual except for the Needelman and Kealy, 1995 study which reports seasonal benefits, the Choe et al. 1996 study which reports monthly benefits and the Smil, 1996 study which is a one-time estimate.

c) Estimates were first converted to US Dollars, when in another currency. Then they were converted to 1997 US Dollars using the GDP Deflator. Data for exchange rates and GDP deflator are from Economic Report of the President 1998 US Government.

d) CVM is contingent valuation method.

e) TCM is travel cost method.

The results in the table show that there are considerable differences in outcomes. A not surprising difference is between richer and poorer countries. Whereas in rich countries benefits of improved water quality are at least valued at $ 8 per capita per year or (much) more, in developing countries (Philippines, China), the per capita benefits are much smaller (up to $2).
This can be explained by the income restraint that plays a role in CVM studies (the "bidding" needs to be adapted to local circumstances), the lower the average income, the lower the ability and thus willingness to pay.

Value of increased biodiversity due to cleaner water soils

In 2003, a postal survey with a response of about 1000 inhabitants of the Netherlands was held to assess the Willingness to Pay of the Dutch population for increasing biodiversity due to cleaning up polluted water soils (RIZA, 2004). The experiment was designed in such a way that three different types of questions were asked on the willingness to pay ("Open question", "Payment card" or "Dichotomus choice" format) to different groups of respondents.

The questionnaire was designed by experts and includes, background information and map on current water soils pollution problems and effects on biodiversity. Background questions on age, sex, income etc. were asked to see how good the sample matches with the Dutch population and corrections afterwards. Also questions on how much households think that they currently pay per year were asked to check the current cost-knowledge. It appeared that on average, respondents though that they paid about € 180 per household per year (whereas in reality a household pays about € 500 per year for water supply, sewerage and sanitation).

The willingness to pay question is introduced by the following choice:
- Option 1 (no cost): no extra water soil sanitation, and possible further decrease of biodiversity (without quantifying this);
- Option 2: extra water soil sanitation, leading to an increased biodiversity n and around the water (without specifying this).

In most questionnaires, the increase of biodiversity was not specified, but in some of the "payment Card"-type questionnaires, it was stated that the increase would be 25%, in others that it would be 50%.

Average willingness to pay per household per year for an increase of biodiversity in and around surface water in the Netherlands as a result of the sanitation of polluted water soils

	Open Question	Payment Card	Payment Card	Payment Card	Dichotomous Choice
	ns	ns	25%	50%	ns
Average WTP per household per year (€)	69,9	48,9	52	50,8	56,8
Standard error	9,5	6,3	6,3	5,5	4,8
Median value	50	40	35	35	
Range (min-max)	0-600	0-500	0-600	0-300	1-250
Number of observations	92	104	115	113	388

Source: RIZA

Explanation: ns: no specification of increase in biodiversity; 25%: 25% increase in biodiversity; 50%: 50% increase in biodiversity

The results show that on average the willingness to pay of the Dutch population for biodiversity by sanitation of polluted water soils – a non-use value! – would be about € 50 to € 70 per household per year, or a total of € 345 million a year[10].

However, in a pessimistic way of interpreting the results, one might assume that the non-respondents are legitimate "non-willing to payers". In tat case the average willingness to pay decreases to € 10 per household, or € 60 million per year.

[10] Annual costs are estimated at between € 25 and € 75 million per year for cleaning up water soils.

90% of the respondents (including some of those not willing to pay) state that they think that cleaning polluted water soils is important or very important, for the risks to humans and biodiversity. Most respondents (35%) that are willing to pay, state as reason to pay, that they have just enough money for it (and implicitly support biodiversity), also 35% mention reasons linked with nature protection or the health of current and future generations.

This research can be seen as a good example of asking the right questions, good information provision to respondents, right format of the questions, in order to achieve credible results.

Willingness to pay for nature protection

In 1988 in the Netherlands a study was performed on the willingness to pay of the Dutch population for nature protection. The results showed that on average the WTP of the inhabitants in the Netherlands to protect nature in 1988 was about € 71[11] per in habitant (prices 2000). For the total population (15,5 mln at that time) WTP is estimated at € 1.110 mln per year.

The willingness to pay can also be expressed per hectare, by dividing total value through the area of nature:

- Total nature area in the Netherlands is 460.300 ha;
- This leads to an annual value of the WTP per hectare of € 2.413;
- The total value per hectare can then be estimated at (over eternity, 5% discount rate) €48.270 per ha.

This number can for example be used when transferring the results from this study to for example a natural habitat in the Netherlands (to get a first indicative figure). For example, if applied to the Meinweg (see also paragraph on Compensation and preventive costs) the total value of this natural area is: 1.800 ha x €48.270 per ha = €86.884.501.

Example questions in a questionnaire for Contingent Valuation

In a Contingent Valuation survey, the key issue is to ask respondents to state their:

- knowledge of;
- experience with;
- perceptions of;
- preferences for

proposed changes in our natural environment. In addition, respondents are asked for the "Willingness to Pay for the proposed changes by means of market simulation to see if respondents are willing to support their stated revealed preferences financially.

Design of questionnaire

The design of the questionnaire is elementary in achieving reliable results. A good questionnaire at least would include:

- a description of the environmental problem to be valued and proposed changes
- general questions on respondents household;
- control questions;
- willingness to pay question.

In some cases one may choose for parallel application of different questionnaires or even different methods to survey a certain issue.

Before designing the survey, one should learn as much as possible about how people think about the good or service in question. Consider people's familiarity with the good or service, as well as the

[11] Christie et al (2004) estimate in a recent study that in Great Britain the Willingness to Pay is on average £ 50 per inhabitant per year (which is about € 75). These results are quite comparable with the study for the Netherlands.

importance of such factors as quality, quantity, accessibility, the availability of substitutes, and the reversibility of the change.

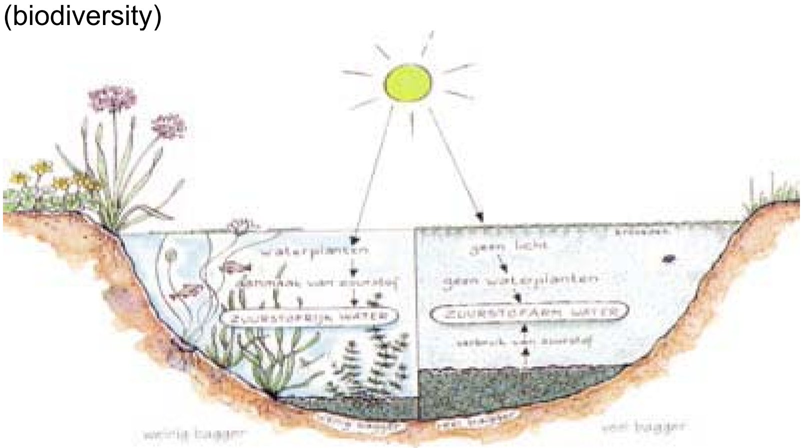
Description of the environmental good or service

A clear description must be given of the environmental good or service that is under study. For example, if only biodiversity aspects of improving water eco systems are under survey, this should be explained and respondents should be told that user values of cleaner water excluded in the valuation. Both the ecosystem and the proposed changes need to be explained to the respondent.
In the next two textboxes, an example is given of the way biodiversity in relation to watersoil pollution was explained in a CV-study in the Netherlands, and the potential change:

YOU ARE NOW KINDLY REQUESTED TO FIRST READ THE FOLLOWING TEXT

Netherlands is situated in the delta area of the rivers Rhine, Maas and Schelde. A large part of the by these rivers transported suspended solids (named "dredging sludge") settles in our delta. Also in polders and city cannels sludge accumulates. For good water management, inland shipping, recreation and nature it is therefore necessary that rivers, cannels, lakes, ditches, etc. are regularly dredged. During the 80-toes is became clear that a large part of the on water soils accumulated sludge is polluted with heavy metals and other toxic substances. Due to the ongoing landing of sludge, the in the past accumulated polluted sludge under water has increased, as the necessity to dispose of this polluted sludge. The accumulation of polluted sludge in water-soils has negative consequences for nature. A clean water-soil is an important precondition for the existence of a variety of flora (plant-species) and fauna (animal-species), also referred to as biodiversity. Also the water-quality is influenced by polluted water-soils, as shown in the picture. One of the possible effects of polluted sludge is that it may cause water with little or no oxygen, with little or no life in it.

Figure
The effect of the accumulated sludge on water-quality and different plat- and animal species (biodiversity)



Another possible result is that the pollution will be absorbed by organisms, living in or on water-soils like worms, shell animals and plants. These organisms are eaten by fish and birds. In the end, the whole food-chain is at risk, including human beings, as presented below.

Polluted water-soils

Risk for:

Nature:	**Humans:**
Accumulation toxic substances in fish and mammals by: - direct contact with pollution - eating of soil animals - eating of plants - eating of fish	Accumulation toxic substances by: - direct contact with pollution by recreation activities in or near polluted water soils (pre higher risk for children) - eating fish

Source: Brouwer, 2004 (translation by TME)

Next an explanation is given on the possible changes that need to be compared and valuated:

> **YOU ARE NOW KINDLY REQUESTED TO FIRST READ THE FOLLOWING TEXT**
>
> In total, 85 million cubic meters (m3) of polluted sludge is accumulated in water-soils, where this is a risk for nature and environment. To compare: with this amount, 200 of the largest mammoth oil tankers on the world could be filled. If in the coming 10 years no additional dredging takes place, 90% of polluted sludge will stay in the water-soils, with as consequence that the numbers of plant- and animal-species (biodiversity) in and around water in the Netherlands remain small or even decrease further.
>
> Two situations are considered:
>
> Situation 1: In the coming 10 years no additional sludge will be dredged on places where this is a risk for nature and environment. As consequence that the numbers of plant- and animal-species (biodiversity) in and around water in the Netherlands remain small or even decrease further
>
> Situation 2: The coming 10 years all 85 million cubic meters of polluted sludge will be dredged, on places where this constitutes a risk for nature and environment. As a consequence, the number of plant- and animal species (biodiversity) in and around surface water increases.

Key descriptive statistics on the population interviewed

In the questionnaire a few questions should be added on characteristics of the population that is interviewed:

- age;
- sex;
- level of education;
- household income;
- size of household;
- ownership of dwelling.

Such information can be used in the analytical stage of the investigation to see if the sample is representative. The information can also be used (if relevant) to correct the answers of the sample. For example, if 30% of the relevant population (normally adults) is under 30 years old, and 70% over 30 years, whereas in the sample 85% of the respondents is over 30 years, the relative weight of answers of younger respondents could be increased to adapt the sample results to the entire population.

Sample and population

First one needs to decide which part of the population is relevant (all or only part of the population, for example a region or an age group). Next one has to draw a sufficient large samples out of the population(groups).

There are four ways of performing a study:

- postal survey: sending a questionnaire with (prepaid) return envelope;
- internet survey;
- telephonic interviews;
- face to face interviews.

First one needs to decide on the acceptable size of the sample. This should be related to the population to be surveyed (i.e. whole country or a region) and sufficient results to have reliable (significant) results. As a rule of thumb one would like to have between 500 and 2000 answers on a questionnaire (if dealing with a problem that affects large parts of population).

In order to have high response rate (the respondents in the sample that will return a useful answer), one needs to follow certain rules:

- don’t take too much time of people (10 minutes is better than 20);
- make people feel rewarded (by compensating them financially or otherwise);
- design an attractive but to the point questionnaire, with questions that leave little doubt for misunderstanding;
- make it easy to give answers and return the questionnaire (an envelope with stamp and return address).

However, getting a high response rate also may limit the possibility to get detailed answers. So always a balance needs to be sought between quality and quantity.

In case of a high non-response (to a postal survey) one might exercise a small control (telephone) interview (focussing on only a few questions) to know whether the non-respondents gradually would react the same as the respondents.

Control questions

It is always good to include control questions in the questionnaire to test the robustness of the results of a CV-survey.

Examples:

- if possible, ask people about current payments of related (environmental) services. For example, if water related issues are under investigation, one may ask respondents how much they think they are paying for water services (supply of drinking water, sewerage and wastewater treatment). Preferably, this should be an open question, but also a closed format may be used, if an open question would pose to much difficulties (for example, when not referring to private payments but to tax-increase or budget spending)
  The answers can be compared with actual recorded payments (statistical or through water companies)
- Ask if respondents their willingness to preserve nature, biodiversity, natural habitat (to check consistency with results on willingness to pay questions)
- Ask (in case of NONE willingness to pay) what reasons respondents have not to pay (for example include the following reasons):
-
  - Nature protection should be regulated by law;
  - Polluters should pay;
  - Water (Nature) already is in good shape;
  - I already pay enough taxes;
  - I do not earn enough;
  - Should be paid from general budget (rearranging priorities);
  - Etc.
- Ask (at the end of the questionnaire) if people agree with the following two propositions:
  - proposition 1: Plant- and animal species should be protected by law, not by asking people to pay for it;
  - proposition 2: Plant- and animal species have the right to be protected however much this would cost our society.

Willingness to pay questions

These form the core of the questionnaire (for analytical purposes) and can be asked in several different formats. The main choice is between:

- an open question: How much would you be willing to pay to ……..? (referring to one of the alternatives given and explained in the questionnaire) and asking people to specify a certain amount of money;
- a closed question: asking people to fill in a closed question and mark the relevant / right answers:
  - pay-card format: about 10-30 different amounts can be mentioned and respondents should specify which amount he would be willing to pay (one answer only);
  - digotomous choice format: for about 10 amounts respondents are asked if they are willing to pay or not for the mentioned amount (note that in each questionnaire only one amount is mentioned, on which respondents should answer yes or no on the willingness to pay question). This means that 10 different kind of questionnaires are diffused (with 10 different “yes or no” questions on a varying amount of money);
  - in both cases the designer of the questionnaire should have some idea of the range of willingness to pay of the surveyed population. Such information can be obtained from earlier investigations, or from a quick rough sample with the open question (for example street interviews).

Also a combination of formats is possible. For example the following question could be asked, combing the "open" and "closed" format:

"How much would you be willing to pay for improved air quality to EU standards in the inner city of ………." (assuming that some background information is given on air quality, the causes and the morbidity and mortality due to air pollution):

- € 2 per year (for the household I am living in)	YES NO, please specify amount which you would be willing to pay less than € 10
- € 5 per year,	YES
- € 10 per year,	YES
- € 20 per year, ,	YES, NO, if more specify what you would be willing to pay.

Things that should be specified in relation to the willingness to pay question are (based on King and Mazzota):

- If the household is the unit of analysis, the reference income should be the household's, rather than the respondent's income;
- The mechanism by which the payment will be made, for example through increased taxes or private contribution;
- Respondents should be reminded to consider budget constraints;
- Respondents should understand the frequency of payments required, for example monthly or annually, and whether or not the payments will be required over a long period of time in order to maintain the quantity or quality change. They should also understand who would have access to the good and who else will pay for it, if it is provided;
- In the case of collectively held goods, respondents should understand that they are currently paying for a given level of supply. The scenario should clearly indicate whether the levels being valued are improvements over the status quo, or potential declines in the absence of sufficient payments.

Statistical analysis

Before making any claims on the "willingness to pay", the results of the investigation should be analysed making use of statistical techniques to test the statistical significance of the results.

Benefit transfer

Benefit transfer is a method that aims at using results of earlier studies to put a value on environmental resources and nature. The outcomes of the studies that can be used in benefit transfer can be of any type of the here above described methods.

The main reason for the application of benefit transfer is that fundamental research is in most cases quite costly, whereas in certain cases benefit transfer can produce reliable results at much lower costs.

To apply benefit transfer successfully the following three criteria apply (Boyle and Bergstrom (1992)):

Similarity of the environmental good or service to be valued;

Similar demographic, geographic, economic and social characteristics, or the ability to adjust for these kinds of parameters statistically (King & Mazzotta, 2004). EFTEC/RIVM mention the following potential adjustments (p. 127):

- average income;
- population size and characteristics;
- background conditions;
- level of impacts (i.e. concentrations), and
- other determinants;

Evidence of sound economic and statistical methodology applied in the preliminary study or studies.

A fourth criterion can be added:

Use if possible more than one reference study to have an idea of credibility and reliability. Nowadays a large amount of benefit assessments is available for any kind of environmental problem.

The advantage of benefit transfer compared to more fundamental research method is the saving of time (quick results) and costs. The disadvantage is the potential lack of credibility (especially when using results from EU or US and transfer them to other countries in very different stages of development) and the lack of “local evidence” (benefits assessments based on local interviews/assessments).

Application

The benefit transfer methodology is especially useful in cases where an assessment of a wide range of environmental damages needs to be made. In such case the assessment of different damages require various different approaches/methodologies. It then will be very costly and time consuming to apply various original valuation techniques like Contingent Valuation (“Willingness to Pay”), Hedonic pricing, Travel Time costs, etc.

Applying Benefit Transfer, requires adjustments of some of the parameters used in the original study. For example, when using damage estimates of air pollution of a reference case and applying it to a new case, one needs to consider:

- concentrations of the pollutants in question;
- exposure (how many people are exposed to certain concentrations);
- the dose-response function: if it is a general one (like presented in the paragraph on dose-response functions), one needs to consider whether the exposed population has the same characteristics as in the reference case. This of course does not have to be the case: a relative young population will be less sensitive than a population with more aged people;
- the value of life (this may differ largely between countries depending on purchase power parity comparisons: see box). In general the value of life needs to be adapted to the local circumstances. For example, if the value of life in the original study was € 1 million (let’s assume the Netherlands) and the correction factor for the case-study area is 14%, the value of life to be used in the benefit transfer is € 140.000 per capita.

Purchase Power Parity

A common way to make international economic comparisons between countries is to use so called purchase power parity (PPP) figures instead of using the official exchange rate. By using PPP attention is given to lower real prices in some countries than others(for example agricultural and other local products). PPP-indicators are frequently published by the OECD (and can also be found in the CIA factbook, which gives standardised profiles of nations around the world)).

The following table gives a few comparisons of GDP and GDP per capita expressed in PPP (2012)

GDP and GDP per capita in selected countries. purchase power parity in US$ 2005

	GDP mln US$ (ppp'12)	GDP/cap US$ (ppp'12)	GDP/cap as % of GDP/cap Netherlands
Netherlands	$718.600	$42.900	100,0%
Georgia	$27.110	$6.000	14,0%
Armenia	$19.970	$5.900	13,8%
Azerbaijan	$98.360	$10.700	24,9%
Russia	$2.555.000	$18.000	42,0%
Turkey	$1.142.000	$15.200	35,4%
Kosovo	$13.590	$7.400	17,2%
Serbia	$80.020	$10.600	24,7%
Greece	$281.400	$24.900	58,0%

CIA, 2013

Compared to surrounding countries, GDP per capita in Georgia/Armenia in 2012 is about 30 – 70% lower. Compared to the Netherlands, Georgian/Armenian GDP per capita is 14% in 2012.

An illustrative example of how these corrections can be made is given below.

Let's assume the following:

- SO_2 emissions have a unit cost of €4 per kg in the Netherlands (the "reference study country");
- SO_2 emissions per square km in the Netherlands are 3 tonne per year, in the case study 1 tonne;
- The population density in the case study is 30% of the Netherlands;
- The income level (GDP per capita, PPP) in the case study is 15%.

The unit costs (UCc) in the case study can be assessed as follows:

UCc = UCref * PDc/PDref * EKMc/EKMref * GDPc/GDPref

In which UCref is the unit costs in the reference country (€4 per kg), PDc and PDref the population densities in case study and reference country and EKMc and EKMref the Emission per suare kilometre in case study and reference country and GDPc and GDPref the respective per capita incomes.

UCc = €4 * 30% * 1/3 * 15% = €0,06 per kg

This example shows the importance of corrections of the unit costs found in reference studies. In this example the damage costs in the case study are reduced to just 1.5% of the original value!

Further corrections may be necessary for (i) inflation (inflating the original value with adequate index for price- and or income inflation) an or (ii) different currencies (applying historical exchange rates).

Practise

Examples of studies in which the benefit transfer methodology has been used successfully are:

European Environmental Priorities: an Environmental and Economic Assessment

The European Commission DG Environment study "European Environmental Priorities: an Environmental and Economic Assessment" (RIVM et al 2001a). This study estimates at EU level the economic costs to prevent and benefits to environment for various scenarios and over ten policy priorities. The methodology is based on a logical stepwise progression through emission, change in exposure, quantification of impacts using exposure-response functions, to valuation based on willingness-to-pay. For acidification and ozone the benefits are calculated by using monetary unit damage estimates for four pollutants (expressed as € per tonne SO_x, NO_x NH_3 and VOC), which were derived from a AEA-Technology study (RIVM, 2001b, p. 63, 73). Benefits of reducing particle matter (PM_{10}) in air are based on mortality and morbidity costs and dose (emissions and concentrations) – response functions (RIVM et al, 2000a, p. 68-71). For climate change unit damage values (in € per tonne CO_2, CH_4 and N_2O) are used to asses benefits (RIVM, 2000b, p. 62). For water quality unit benefits were estimated based on Willingness to Pay studies for improved water quality and unit damage costs (expressed in € per tonne N and P) were derived from various Baltic Sea studies on nutrient reduction (RIVM et al., 2000c, p.34). Waste related benefits were also estimated using unit damage values for various disposal routes (expressed as € per tonne waste incinerated, landfilled, recycled and composted) (RIVM, 2000d).

The Benefits of Compliance with the Environmental Acquis for the Candidate Countries

The European Commission DG Environment study "The Benefits of Compliance with the Environmental Acquis for the Candidate Countries" (Ecotec et al. 2001). In this study, air quality benefits are estimated making use of the Ecosense model which was developed for the EU ExternE project. In Ecosense emissions and concentrations, dose-response functions for health damages, crops and monuments are modelled and linked by monetary unit values (for human life, etc.) to assess damages. For water damages were assessed by using Willingness to Pay studies from UK and USA for improved water quality (using € per inhabitant per year estimates). Waste damages are mostly assessed indirectly through impact-pathway analyses combined with Life Cycle Analyses of waste, estimating emissions of air pollutants (CO_2, CH_4, NO_x, etc.) and applying unit values (expressed as € per tonne CO_2, CH_4, NO_x, etc.).

Valuing the Benefits of Environmental Policy: The Netherlands

The study for the Netherlands Ministry of Economic Affairs "Valuing the Benefits of Environmental Policy: The Netherlands" (EFTEC/RIVM 2000), London, 30 June 2000. This study largely follows the European Commission DG Environment study "European Environmental Priorities: an Environmental and Economic Assessment" (RIVM et al 2001a). Additionally damages for noise and soil have been estimated. For noise benefit transfer (% decrease in value of property related to increase in noise levels, based on "hedonic pricing" studies) has been applied to assess benefits of the policy.

Valuing the Meinweg (1 800 ha natural habitat)

Another example of benefit transfer, related to nature is the study on the value of the Meinweg (in the Netherlands).
For the Meinweg different approaches were applied to assess the value of this natural habitat of 1,800 ha (see also paragraphs on willingness to pay, compensation costs and prevention costs). This leads to the following estimates making use of benefit transfer:

Original method	Value per hectare (€)	Total value Meinweg
Willingness to pay	€ 48,270	€ 86.8 mln
Compensation costs	€ 45,000	€ 81 mln
Prevention Costs	€ 63,000	€ 115 mln

Source: TME, 1999.

Valuing the Kolketi wetlands

For the Kolketi wetlands, an overview was made of the standardised results of various studies on wetland valuation. This results in the following overview of values (per hectare)

Derived annual unit values for wetlands (in € of 2005 per ha) from various studies, Georgian price level and purchase power parity

Study	Unit value € per hectare	Comments
"Nature study" (Constanza, 1997)	1,554	Specific for wetlands, PPP correction Results of study later heavily criticised (overestimation)
"Baseline Resource valuation study" (Neiland et al, 2002)	1,110	Specific for Georgia, direct use value (total value divided by area)
"Meta study on wetlands valuation"(Brouwer et al, 1997)	401	Specific for wetlands, based on WTP per household, PPP, Georgian population
Worldbank Cost Benefit study (Arin, 2001)	315 - 325	Specific for Georgia, mainly direct use value (total value divided by area)
TME (2002)	304	For nature conservation in general, PPP correction
"Meta study on wetlands valuation"(Brander et al, 2004)	40 (large range)	Specific for wetlands in the CCRU database on global wetlands, based on value per ha

Source: TME, based on various studies reviewed

The table shows that before applying benefit transfer, one must make difficult choices: which studies are most representative for the "transfer" case. This often means that the original studies must be carefully examined, as to assess what comes closest to the "transfer" case.

Unit Damage costs of selected environmental pollutants

In case the damages of environmental pollution have to be evaluated (and thus the potential benefits of environmental policy), a relative simple benefit transfer methodology can be applied. In this kind of benefit transfer unit values for a variety of pollutants have been established, reviewing relevant available literature (of which many sponsored by the EU).

Two sets of unit costs have been used:

- unit costs based on a "supply" approach;
- unit costs based on a "demand" approach.

In general, the supply approach leads to lower estimates than the demand approach. The unit damage costs presented in this section, are typically calculated for the Netherlands. If this approach is applied in other countries, the unit costs need to be adapted as explained at the begin of the section on benefit transfer.

"Supply approach"

The supply approach for the estimation of unit costs of pollutants is based on the principle that for each pollutant it is possible to derive a marginal abatement function. This was for example done for the first Environmental Outlook ("Concern for Tomorrow", RIVM, 1988) and the consequent first National Environmental Policy Plan of the Netherlands (VROM, 1989). These cost function were based on the underlying calculations of environmental costs (or better said abatement costs) to arrive at the targeted reduction of emissions (Jantzen, 1989), thus enabling an estimate of the marginal costs to achieve the targeted emission(reduction)s.

The unit costs derived from this study are presented in the following table.

Table A
Unit costs for various main pollutants based on the marginal cost approach to achieve (National) environmental targets (price level 2010)

full name	abbreviation	unit costs
		€ per tonne
Carbon dioxide	CO_2	68
Sulphur dioxide	SO_2	3.693
Nitrogen oxides	NO_x	3.545
Volatile organic compounds	VOC	863
Ammonia	NH_3	12.409
Fine particles	PM_{10}	28.364
Heavy metals		295.455
Water use		1.35
Chemical oxygen demand	COD	1.477
Phosphorous compounds	P-TOT	5.909
Nitrogen compounds	N-TOT	11.818
Heavy metals		295.455
Oil/organ comp		1.477
Non-hazardous waste		52
Hazardous waste		414

source: Jantzen (1989) and TME (2001).

“Demand approach”

In this case the unit values are derived from studies in which both emissions (or emission reductions) and total damages (or reduction or total damage) have been assessed. The total damage can be assessed by an “impact pathway” analyses, “willingness to pay/to accept”, etc.

“Value of Life”

In many of the studies reviewed the “value of life” plays an important role in the assessment of damages. For example, in the study on benefits of environmental policy in the Netherlands (EFTEC/RIVM, 2000), damages related to air pollution have been assessed by:

- assessing emissions;
- assessing concentrations of pollutants in the air;
- assessing the relation between concentration of pollutants in the air and the resulting health damages (mortality and morbidity);
- assessing the value of life (for persons under and above 65).

The central value of life used in the assessment (for the Netherlands) is € 3,47 million per premature dead. For people aged over 65 a value of 70% has been taken: € 2,4 million.

Dioxins and PAC’s

Koehler et al (2004) made an assessment of health related damages (cancers) due to substances defined in the Toxic Releases Inventory (TRI) of the US EPA.

The emissions were divided in:

- dioxins;
- PAC’s (polycyclic aromatic compounds);
- other PAH’s.

The total annual damage in the US, based on cancers, is estimated at US$ 1,1 billion or US$ 702 million if a latency period is assumed of 10 years, at a 5% discount rate. This is based on a value of life

(VOL) of US $ 4,4 million per human being and 260 fatal cases per year due to dioxin, PAC's and other releases of substances in the TRI. Making a correction for both exchange rate, inflation (= 1) the total damage would be assessed at between €1,1 billion and € 702 million.
As noted before, the unit damage value (VOL) in the Netherlands has been estimated at €3,47 million, which is 79% of €4,4 mln. Making a correction for this lower VOL the total (lower estimate of) damage can be assessed at €554 million per year.

About 76% of this damage is related to dioxins and 20% to PAC's, whereas other substances in the TRI's count for 4% of total damage.

Combining this figure with annual emissions of dioxins and PAC's an assessment can be made of the damage caused by the emissions of one unit of dioxins or PAC's.

Total annual emissions in the United States are estimated at:
- dioxins: 5,218 kg;
- PAC's: 650.000 kg;
- total Toxic Releases studied: 54.456.471 kg.

Combining annual damages and emissions results in the following unit damage values (US 1998 values):
- dioxin: between US$ 81.000.000 and US$ 160.000.000 per kilogram;
- PAC's: between US$ 170 and US$ 338 per kilogram;
- other PAH's: between US$ 0,41 and US$ 0,81 per kilogram.

PM_{10} fine particles

EFTEC&RIVM have carried out a study on the Benefits of environmental policy in the Netherlands. Part of this study has addressed air quality problems related to PM_{10}.

The unit damage value has been derived fm the 1990 emissions and the estimated economic damage (mainly mortality and morbidity).

The emissions of PM_{10} in 1990 were 27.400 tonnes. The total economic damage is estimated at €2,383 billion in 1990 (related to a mortality of 931 persons). This leads to unit damage costs per tonne PM_{10} emitted are estimated at € 86,9 per tonne.

Heavy metals

Little knowledge exists on the damage caused by heavy metals. Only a few studies have addressed this problem and the outcomes are sometime at least "strange". The following table gives an overview of some figures found in literature.

Table B
Unit damage values for heavy metals discharged to water or soil

substance	unit damage costs
Cu (copper)	€ 5.657 per tonne
Ni (nickel)	€ 13.577 per tonne
Cr (chromium)	€ 19.799.644 per tonne
Zn (Zinc)	€ 1.131 per tonne
Cd (Cadmium)	€ 703.736 per tonne
As (Arsenic)	€ 348.474 per tonne
Hg (Mercury)	€ 1.022.000 per tonne

source: ECON

The ECON study based the damages on control costs (for only one heavy metal) and adapted values for other heavy metals by applying toxicity factors.

Lead (Pb)

For lead (Pb) unit costs have been derived as follows:

- the costs to reduce lead emissions are estimated at between 1 and 2 US$ cent per litre gasoline (price-level 1985) (Lovei, 1999);
- adapted for inflation this is (2,5 % per year, 20 years) 1,64 and 3,28 US$ cents per litre;
- assuming an exchange rate of 1 € per 1 US$;
- lead contents in leaded gasoline is about 0,4 gram per litre;
- costs to reduce 1 kg of lead emissions are then estimated at € 27,3 to € 54,6 per kilogram;
- the actual benefits of reducing lead are estimated to be 10 times higher than the costs (US EPA, cited in Lovei (1999));
- so the unit damage costs for lead are estimated at between € 273.000 and € 546.000 per tonne.

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