Economic Valuation of Environmental Damage

METHODOLOGICAL CONVENTION 2.0 FOR ESTIMATES OF ENVIRONMENTAL COSTS

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Preliminary Remarks

Today, more than in the past, environmental policy has to face economic considerations. Economic valuation of environmental damage makes it possible to estimate the economic utility of environmental policy measures. This is important because environmental policy avoids environmental damage today and in the future. At present, there is no field where this fact is more evident than in climate policy. All recent publications confirm that climate protection is worthwhile, because the costs of climate protection measures are lower than those resulting from inactivity.

Economic valuation means weighing a number of options and targets against each other. Valuation requires value judgements: How does one define damage? How does one balance the relative merits of protecting different goods? How does one weigh damage occurring today against future damage? How does one deal with uncertainty about future returns and risks? These are only a few of the problems depending on value judgements that we have to face. This applies in general, and not only in economic valuation. The Methodological Convention elaborated by the Federal Environment Agency (UBA) takes up these problems. In it, we set out to explain and substantiate our value judgements and yardsticks underlying the valuation not only of environmental damage that has occurred, but also of environmental damage that has been avoided. In this way the Federal Environment Agency wishes to contribute to the transparency and consistency of decision making in environmental policy. The yardsticks have been translated into the working tools of economists: Cost categories, willingness to pay, discount rates, and risk aversion factors are only a few of the concepts considered in this context.

The first edition of the Methodological Convention, published in 2007, was the result of comprehensive discussions held both within the Federal Environment Agency, and externally with political decision makers and scientists. Scientific input was contributed by the UBA research project on "Yardsticks for the valuation of environmental externalities" *("Maßstäbe zur Schätzung umweltrelevanter externer Kosten")* conducted by the Institut für Energie-wirtschaft und Rationelle Energieanwendung (IER, institute for energy economy and efficient energy use), Stuttgart, in collaboration with a scientific advisory panel.[1]

In 2009, to take account of recent research findings on the estimation of environmental costs, the Federal Environment Agency commissioned the IER (Institut für Energiewirtschaft und rationelle Energieanwendung, Stuttgart) and the research institute Infras, Zürich, to carry out the research project "Estimation of Environmental Externalities and Proposals for Internalising Environmental Costs in Selected Policy Areas" ("Schätzung externer Umweltkosten und Vorschläge zur Kosteninternalisierung in ausgewählten Politikfeldern"). The research project

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was partly concerned with reviewing and updating the Methodological Convention in the light of the latest scientific developments. The results are documented in Appendix B, “Best-practice cost rates for air pollutants, transport, power generation and heat generation”.

The principles of valuation suggested may be used for example to substantiate cost rates for external costs of power generation. Taking them into account throws a new light on many energy-efficiency measures. This is because they not only save energy costs, but also avert damage to health and the environment. Seen from a macroeconomic perspective, therefore, their profitability is much greater than that indicated by a purely microeconomic analysis in business management terms.

1 Introduction

1.1. Economic valuation of environmental damage in the context of vision-oriented environmental policy

The term "environmental damage" refers to both damage to health and property[2], and environmental damage in a broader sense (ecological damage, e.g. harmful effects on biological diversity). Answering the question of whether environmental damage has occurred, and if so, to what extent, has to be based on both scientific knowledge and societal value judgements. Economic valuation of damage is therefore preceded by identifying its type and extent in the sense of a societal evaluation. The overall vision of sustainable development serves as a framework for valuation.

Essential conditions underlying sustainable development are that the functions of the environment as

- ➔ a human habitat and space for economic activities,
- ➔ a source of renewable and non-renewable resources, and
- ➔ a receiving medium for pollutants

are no longer put at risk. Based on the findings of the Commission of Inquiry of the German Bundestag "Protection of Humanity and the Environment"[3], this results in four principles for action, namely:

1. In the long run, the use of a resource must not exceed its regeneration rate or the rate of substitution of all its functions.
2. In the long run, the emission of substances must not exceed the absorption potential of the environmental media or their assimilative capacity.
3. Hazards and intolerable risks from human activities affecting the environment must be avoided.
4. There must be a balanced ratio between the duration of anthropogenic interference with the environment and the period of time the environment needs for a self-stabilizing reaction.

These principles for action define the limits of economic and social development pathways. The first two principles refer to the long-held but narrow view of the environment as no more than a source of materials. The last two principles imply the idea that the functionality of ecosystems must not be destroyed by the effects of economic activities[4].

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[2] In German environmental law, environmental damage was for a long time confined to these types of damage.
[3] Enquete-Kommission (1994).
[4] Cf. in this connection Geisendorf et al (1998).

Orientation to the overall vision of sustainable development requires a comprehensive consideration of the response capacity and assimilative capacity of ecological systems. Scientific findings can be taken as a basis for demonstrating impacts of today's use of the environment and proposing environmental quality targets based on the above principles for action.

To design environmental policy it is necessary to develop environmental action targets and environmental standards that are closely related to environmental quality targets. Action targets relating to protected assets or environmental media describe the extent to which environmental impacts need to be reduced in order to achieve an environmental quality target. Environmental standards are specified limits for different types of anthropogenic influences, i.e. human activities affecting humans and/or the environment, as well as of source-specific requirements. In the ideal case, environmental action targets and environmental standards therefore constitute a kind of action-oriented translation of the underlying environmental quality target.

The desired environmental quality and the environmental action targets that can be derived from it should be defined in a societal process. In Germany this has been achieved by an important step, the introduction of the German government's National Strategy on Sustainable Development and its objectives and indicators, in addition to the legal regulations that already existed in the individual fields.[5]

For the development and implementation of an environmental policy that is oriented to the overall vision of sustainable development, economic valuation is important in a number of respects:

- Exemplify economic implications of the environmental action targets: As early as the stage of formulating the environmental quality targets and environmental action targets in the preliminary stages of decision making, information on the economic implications of failure to implement environmental protection can promote the process of societal discussion and contribute to reaching a consensus[6].
- Take adequate account of environment impacts in regulatory impact assessments: Economic consequences play an important role in the valuation of environmental policy measures and instruments. Impacts arising from improvements in environmental quality or, as a consequence, from reduced health risks are often evaluated merely in qualitative terms. This may disregard the positive effects of environmental policy instruments and measures, or even impede the introduction of new policies by drawing attention to negative effects on the economy and employment[7]. Economic valuation of

[5] For the latest on the Sustainability Strategy, cf. Bundesregierung (2012).
[6] Cf. remarks made in: Rat von Sachverständigen für Umweltfragen, (Umweltgutachten 1998).
[7] Cf. for example the discussions on the reorganization of the European chemicals policy (REACH). A summary can be found in BMU Umwelt (2005).

environmental damage avoided by means of environmental policy measures and instruments has the advantage that it can be catered for adequately when assessing the costs and benefits of the instruments or measures under consideration. However, this requires that the valuation of avoided damage to health and the environment be based on an accepted valuation method.

- ➔ Identify the principal actors responsible for ecological damage and charge external costs accordingly: The economic valuation of environmental damage or polluter-specific estimation of costs of environmentally harmful activities are of particular importance for the design and assessment of environmental policy instruments intended to achieve environmental quality targets and environmental action targets. Such activities are predominantly aimed at polluter-specific internalisation of external costs. Economic valuation of environmental damage is therefore of major importance for expert substantiation of charges and subsidies based on environmental aspects. Criticisms of arbitrary or purely fiscally motivated increases in environmental charges can thus be counteracted by means of scientifically substantiated "safety thresholds" in the sense of a lower limit to the costs of damage.
- ➔ Permit a comparative environmental valuation: In addition, economic valuation helps to make it possible to compare the environmental impacts occurring in different fields and aggregate these data to arrive at a total amount of damage. Unlike valuation approaches primarily oriented to natural science, such as the life-cycle assessment method, this is possible owing to the anthropocentric basis of the economic valuation, which does not sum up the various types of environmental damage but instead, their effects on (monetary) utility. In this way economic valuation makes an important contribution to "translating" complex environmental problems in the environmental policy debate.

Economic valuation is aimed at assigning monetary values to the costs of using and damaging the environment. In economic terms, use of the environment gives rise to costs if there are competing or mutually exclusive use options, and/or if the quality of an environmental asset is impaired (to an extent beyond that regarded as tolerable). This means that the environmental asset in question is a scarce good in economic terms.[8] For example, discharging wastewater into a body of water may compete with the use of the same body of water for fish farming, drinking water abstraction, production purposes, recreation, or as a habitat for plants and animals. A habitat may be preserved as a conservation area or impaired or destroyed by the construction of a bypass. Deciding in favour of one use automatically means foregoing alternative uses.[9] Apart from these direct costs of utilization, however, there are also indirect

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[8] By contrast with scarce goods, the term "free goods" is used in economics if there are no competing uses and quality is not impaired by the use.
[9] In this case, valuation is usually based on the opportunity costs approach. This means that the calculated costs of use are at least as high as the returns from the next best alternative use.

costs to be taken into account, for example those of impaired environmental quality having a negative impact on human health, whether directly or through different impact pathways.

If the actors involved fail either wholly or partially to include the effects associated with the use of the environment in their economic decisions, the consequences are referred to as external effects. The negative effects expressed in monetary terms are referred to as external costs. It is a characteristic feature of external costs that these costs are not borne by the responsible actors but by individuals (or society as a whole) who have no direct or indirect market relationship with the responsible actors. As result, a situation will arise where the environment is exploited beyond an economically optimum level.

In literature on this subject, the terms “environmental externalities” and “environmental damage costs” are often used as synonyms. In a strict sense, however, environmental damage costs are more comprehensive than environmental externalities. Only that share of the costs which is not recovered from the polluters, i.e. not internalized, can be attributed to <u>external</u> costs. This distinction plays a role where the level of environmental costs is considered in assessing or designing environmental policy instruments, for example in order to find out the extent to which the external costs of energy production are being recovered from the responsible actors.

External costs and possible means of polluter-specific internalization

There are numerous examples of external effects: For instance, an industrial plant emitting nitrogen oxides (NOx) will cause damage to the materials of which buildings are made. This is regarded as a negative external effect unless the operator of the plant is obliged to pay for the damage caused and therefore includes it in his production decisions as (follow-up) costs. If these external costs are paid by the polluter, he will reduce NO_x *emissions to a level at which the additional costs of a further reduction in emissions will equal the environmental clean-up costs saved by the reduction measures.*

From the perspective of environmental protection, external costs should therefore be internalized, i.e. recovered from the polluter. This can be done by means of a number of instruments: A charge or tax levied on the activity detrimental to the environment (e.g. emission of pollutants), internalises external costs by means of prices. In the ideal case, the tax level is measured by the marginal damage costs (additional costs for the environment per unit of pollutant emitted). The responsible actor has an incentive to reduce emissions as long as the taxes saved as a result are higher than the costs of such reduction. In the ideal case, the incentive mechanism through taxes will therefore lead to a balance of marginal damage costs and marginal avoidance costs.

Moreover, establishing emission limit values or imposing obligations to apply the state of the art in the case of new investments will lead to internalization of external costs because the costs of avoiding/ reducing emissions have to be paid by the polluters (e.g. via higher investment costs for production plant with integrated environmental protection or additional environmental protection measures).

Internalization can also be ensured by legal provisions holding the polluter liable in the event of damage. Such a regulation makes particular sense if the damage has a low probability of occurrence and the polluter can reduce the probability of occurrence of the damage by taking risk reduction measures. In the former two cases, the avoidance costs are borne by the polluter, while in the latter, the polluter pays the costs of compensation.

1.2. Experience with estimating environmental damage costs

Estimating environmental damage costs has been an integral part of energy and environmental policy debates and extensive research programmes at both national and international levels. Since the early 1990s, increasing efforts have been made at EU level to improve the methodological principles of the assessment of environmental damage and valuation of environmental costs, and also to communicate the results of these efforts to political decision makers. Prominent examples include the extensive research programme, ExternE[10]

[10] Energy production causes external effects, e.g. due to the emission of air pollutants, which ultimately lead to health impairment, damage to materials and a decline in agricultural yields.

(Externalities of Energy) published by the European Commission[11] and the studies on the external costs of transport[12].

Activities to standardize the methods of estimation and yardsticks used in valuation are urgently needed to ensure that the resulting estimates can be used in political decision making. For illustration: Estimates of external costs of individual energy systems show variations by a factor up to 40 000. Estimates of climate change impacts also display a wide range.

What are the reasons for the large variation in estimates of environmental costs?

- ➔ The studies refer to different types of damage. Some studies include only those types of damage for which accepted calculation methods already exist, thus underestimating the level of external costs.
- ➔ Impact analysis (valuation from the viewpoint of natural science) is based on different assumptions concerning the dose-response relationships resulting in different assessments of natural damage.
- ➔ Valuation of environmental damage is performed using different methods of assessing the scale of the damage.
- ➔ In some cases, it is the damage that is assessed, in others, the costs of reducing environmental impacts (emission avoidance costs).
- ➔ The studies are based on different normative assumptions (yardsticks), e.g. on discounting of costs and benefits expected for the future.
- ➔ Valuation takes account of risks in differing ways.
- ➔ The studies use different system boundaries (e.g. spatial and temporal delimitation).

In the wake of recent research activities, a considerable number of new findings have been made and refined methods of estimation developed. It has emerged that it is now possible to state confirmed lower limits for the environmental costs of some types of damage. This applies for example to damage to materials, crop losses and environmental diseases due to the emission of air pollutants. However, this does not apply to other critical damage categories such as the valuation of damage to ecosystems, damage associated with climate impacts, and risks from nuclear power use.

The range of estimates can be reduced by disclosing the yardsticks underlying the valuation process, applying these as uniformly as possible and complying with conventions regarding the categories of damage included and the methods used.

Nevertheless, it will be impossible to completely rule out a certain degree of variation in the estimates. In many cases there is no sufficiently reliable knowledge about the material damage

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[11] European Commission (1998) and (2005). Since then there have been several follow-up projects, e.g. NEEDS, HEATCO, NewExt.
[12] UNITE (2003), INFRAS/IWW (2000) and (2004).

which may arise in the future, or about the risk of damage, which means the ranges of estimates reflect the existing uncertainties.

As a rule, it is not possible to fully quantify impacts on health and the environment. Estimates of environmental costs therefore often reflect only part of the actual damage. This should be taken into account when evaluating the results for the purposes of environmental policy. Such costs should nevertheless be taken into account, because they at least represent lower limits for the negative impacts that can actually be expected.

1.3. Objectives and structure of the Methodological Convention

A serious estimate of environmental damage costs requires a high degree of transparency with regard to the objectives, assumptions and methods of valuation in order to ensure correct interpretation and comparability of the calculated cost levels.

The present Methodological Convention is aimed at developing a standard for expert valuation of environmental costs and at improving the transparency of estimates.

1. The Methodological Convention focuses on the economic valuation of environmental damage and draws attention to interfaces with other valuation methods (e.g. qualitative valuation).
2. The Convention provides a uniform framework for the methodology of estimating environmental costs. For this purpose, it provides a detailed description of the individual valuation steps.
3. The Convention contains criteria for the assessment and selection of different valuation methods and the applicability of methods depending on the problems concerned.
4. The Convention ensures transparency with regard to the assumptions and yardsticks underlying the valuation, by requiring their documentation according to a uniform pattern.
5. The yardsticks for estimating environmental costs (normative elements of valuation) are basically required to be uniform for all studies conducted by the Federal Environment Agency. Reasons must be given for any deviations from the standard procedure.
6. The Convention is intended to serve as a guideline for estimates of environmental costs and should be applied to studies commissioned by the Federal Environment Agency. The Convention also includes best-practice estimates of environmental costs.
7. In addition, the document addresses a wide circle of users of such estimates, thereby giving them an opportunity to check the yardsticks on which estimates are based. Furthermore, it offers external research groups a means of ensuring that their studies are comparable and can be linked with others.

In order to support the development of the Methodological Convention, the Federal Environment Agency commissioned the IER (Institut für Energiewirtschaft und Rationelle Energieanwendung), to carry out a research project on the estimation of external environmental costs and make proposals for internalising costs in selected policy areas. Proposals for the valuation of risks were developed by Prof. Ortwin Renn as part of a subcontract under this project. To tackle the problems relevant for valuation, the IER researchers drew up progress papers reflecting the current state of knowledge, which were discussed with a scientific advisory panel. The results obtained during the work of this project advisory panel are to a large extent reflected in the guidelines incorporated in the Methodological Convention.[13] The research project makes it clear that the methodological principles of the Methodological Convention published by the UBA in 2007 are still valid. Scientific advances have taken place in the estimation of environmental costs in particular, e.g. through better ways of estimating cause-effect relationships, better modelling of transport emissions, and further developments in the field of emission factors.

Section 0 gives a detailed description of the yardsticks established for the Methodological Convention. The application of uniform yardsticks is a precondition required for consistent expert valuations. These yardsticks must also be reflected in the cost categories to be estimated. Section 3 defines the cost categories relevant to the Methodological Convention and gives recommendations for selecting the appropriate valuation approach. Section 0 describes a standardized procedure for economic valuation by giving recommendations for a number of valuation steps to be followed. In the Methodological Convention, the main focus is on economic valuation. Section 0 contains a short summary of the most important methods of environmental valuation and provides recommendations regarding the selection of methods. Annex A to the Methodological Convention contains an extensive presentation of the most important economic valuation methods. Annex B contains best-practice cost rates for air pollutants, transport, power generation and heat generation. These cost rates represent the latest state of the art and have been derived with the aid of the valuation yardsticks in the Methodological Convention.

[13] In some respects, however, it has been impossible to reach a scientific consensus on the valuation of external costs. This applies above all to cases where it was necessary to value damage categories for which assessments differed considerably, even among experts, such as the valuation of the risks of nuclear power. Furthermore, agreement on defined (damage) values and discount rates to be applied is only possible where these values remain within plausible ranges.

2 Yardsticks for the economic valuation of external costs

2.1. What yardsticks do we need?

Environmentally relevant external effects either have a direct influence on individuals by causing a loss of utility for them (e.g. health impairment as a result of noise from heavy road traffic) or, through various impact pathways, they will result in damage to the environment which at the end of the impact chain will impair the utility for individuals (e.g. reduced soil quality will cause crop losses, pollution of waters will require higher expenditure on water treatment). Such damage may occur today or in the future; it may be reversible or irreversible; some environmental functions can be substituted in the case of damage and some cannot. In many cases, one has to face the problem that present activities affecting the environment need to be valued although no reliable information is available about the adverse effects they may cause. For all these cases, it is necessary to establish yardsticks for the valuation of such effects, for example:

- Should considerations be based on individual preferences, societal value judgements or expert assessments?
- How can irreversible damage be valued?
- Should estimates refer exclusively to costs of damage or is it also possible to include other cost categories in the estimates of environmental costs?
- How should risks and the precautionary principle of environmental policy be taken into account in valuation?
- How should damage occurring in the future be weighed against damage occurring today?

The yardsticks forming the basis of the guidelines set out in the Methodological Convention are outlined in the sections below.

2.2. Individual preferences as a yardstick for valuation

The Methodological Convention focuses on the problem of valuing environmentally relevant costs. The yardstick for valuing environmental damage is the preferences of those who are (potentially) affected by the environmental damage and who suffer loss of utility. In other words individual valuations (preferences) play a central role in the valuation of environmental damage costs.

Environmental damage costs are usually presented in terms of the source of the environmental impact (e.g. per emission unit) or the causative activity (e.g. per kilowatt hour of electricity generated). This requires knowledge of the impact chain from the source / activity to the resulting natural environmental damage. Economic valuation refers to the environmental damage or, more specifically, to the disutility for the individuals affected that will result from the environmental damage. Examples of such disutility include loss of production, a higher risk of developing respiratory disease etc.

In abstract terms, the individual valuation of the environment can be structured in terms of use-dependent and non-use-dependent values (see

Figure 1: Categories of the overall economic value of goods, after Pearce and Moran, 1998; Meyerhoff, 1997). This structure helps to interpret valuation results with regard to the completeness of the value elements included.

Figure 1: Categories of the overall economic value of goods

Overall economic value of environmental assets

Use values			Non-use values[14]		
Direct values	Indirect values	Option value	Existence value	Bequest value	Altruistic value
Economic utility, e.g. services that can be consumed directly or used for production purposes, experience value	Functional value, ecosystem services, e.g. flood control, pollutant filter	Potential future use of direct and indirect values	Utility gained from knowledge of the existence of natural goods or environ-mental protection irrespective of actual or possible utility	Utility from the knowledge of the existence of natural goods associated with the desire to preserve these to keep them available for future generations	Utility from the knowledge of the existence of natural goods associated with the desire to preserve these to keep them available for others
Economic valuation methods to identify willingness to pay					
Indirect valuation methods, analysis of market data	Indirect valuation methods, e.g. valuation based on replacement costs	Direct valuation methods, contingent valuation (surveys)	Direct valuation methods, contingent valuation (surveys)		

Source: Own diagram, after Pearce/Moran (1998) and Meyerhoff (1997).

Direct valuation methods (surveys to estimate willingness to pay) are suitable for identifying both use values and non-use values. However, it will hardly be possible to perform representative surveys of the population for each and every estimate of environmental costs. Using willingness to pay as an expression of individual preferences does not mean that only the

[14] Strictly speaking, all categories of the non-use values are altruistic motives (benefit deriving from the existence of the asset as such, for future generations, for others).

results of surveys of individuals affected are taken into account. There are several methods available that make it possible to draw conclusions about willingness to pay from the market behaviour of economic subjects (for details see Annex A). For example, the money spent by individuals on reducing damage (eliminating damage to materials) or on avoiding situations (moving to a quieter neighbourhood, fitting noise-proof windows) may help draw conclusions about the lower limit of their willingness to pay (for details see Sections 3 and 3.2).

Recommendations by the Methodological Convention:

The aim of valuing environmental costs is to describe the disutility for individuals that arises from activities affecting the environment and from the resulting environmental damage. This is why individual preferences should normally be the yardstick of valuation. Willingness to pay is an appropriate yardstick of valuation, especially where the damage to be assessed means a factual, spatial and temporal impairment of utility for the individuals affected.

2.3. Societal evaluations and expert judgements as a yardstick of valuation

Making reference to individual preferences is not always an appropriate approach. This is because, for a number of activities affecting the environment, not enough is known about the dose-response relationships, and/or the cause-effect relationships are very complex so that the resulting damage is not foreseeable or there is considerable uncertainty about the extent of the damage to be expected. If it is impossible to identify the natural damage with a certain minimum degree of accuracy, it is also impossible to estimate the costs of damage resulting from the respective impact.

One could argue that monetary valuation can be dispensed with in such cases because it is uncertain whether damage will occur, and to what extent. However, this would mean limiting the fields of application of monetary valuation to well-researched (or potentially researchable) fields of activity in environmental policy.

In some cases, the problem is that although knowledge exists about the resulting damage, no valid analyses of willingness to pay are (yet) available, or existing studies have become obsolete. Here too the question arises as to whether there is an suitable alternative to valuing individual willingness to pay, because otherwise the consequence would be to forego economic valuation.

One option consists in referring to existing environmental targets for valuation purposes, since these targets imply assumptions about damage and risk reduction measures required. Examples of such targets include emission reduction targets, air quality targets and noise abatement targets.[15] If such environmental targets refer to the exposure of the affected individual or environmental asset (concentrations, deposits, noise level), a direct relation to the environmental damage exists. In that case, the costs required to achieve the environmental quality desired (or a state that is not harmful to health) are an indicator of society's willingness to pay for reducing the damage or improving of quality of the environment. The approach consists in estimating the costs of an efficient set of measures required to achieve the target and relating these costs to the relevant unit of measurement or concentration of pollutants (e.g. costs per tonne of emission reduction). Based on the given situation, this approach can be used to calculate the marginal costs of achieving the target or the marginal costs of avoiding/reducing harmful impacts on the environment. Under certain conditions, such costs may also be used to identify society's willingness to pay (for damage reduction) and as an indicator of environmental damage costs. For an appropriate interpretation of such willingness to pay in the context of estimating environmental damage costs, the question arises as to <u>how binding</u> such targets are and how they are enshrined in the legal system or society. The Federal Environment Agency takes the view that the <u>binding</u> targets and agreements constitute a <u>legally standardized value judgement</u>.

Legally non-binding targets are found in political programmes, publications by government departments, statements by politicians in responsible government functions or in the parliamentary majority, majority opinions in surveys etc. Such valuations can largely be described as aspects of societal attitudes.

In addition to environmental targets, reference can be made to expert judgements that have not yet been included in an explicit formulation of targets (or which propose more advanced targets). Expert judgements reflect the knowledge of a population group possessing expertise that is far above average. However, such judgements are not necessarily accepted by society.

Individual preferences, societal evaluations and expert judgements do not exist as isolated elements but influence each other. The consequences of today's activities can be exemplified on the basis of scientific knowledge about the reactive and assimilative capacity of ecological systems (expert judgements). Such knowledge will influence the formation of both individual opinions and a general intention in society and politics. Therefore, present-day expert judgements are frequently used as a basis to substantiate future legal provisions.

What targets should be taken as a basis for valuing willingness to pay if no valuations of individual willingness to pay are available?

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[15] To put into concrete terms the quality target of "avoiding significant noise pollution", noise guideline values and limit values have been established by several legal provisions and standards, e.g. the Federal Immission Control Act (BImSchG), ordinances implementing the Federal Immission Control Act (BImSchV), Technical Instruction on Noise Abatement (TA Lärm), VDI 2058 (guidelines by the Association of German Engineers) on assessment of noise in the working area with regard to specific operations, DIN 4109 (German standard) Sound insulation in buildings - Requirements and testing, and VDI 4100 Noise control in housing - Criteria for planning and assessment.

We are basically of the opinion that legally substantiated targets should be used for this purpose. In many cases – climate protection targets, for example – legally substantiated targets are insufficient in the long run to avoid serious subsequent damage. We therefore take the view that it is necessary to include non-binding targets and expert judgements in the context of sensitivity calculations and in addition to the costs of achieving legally substantiated targets. In the individual case, the party making the valuation should state the environmental targets underlying the estimate and give reasons for including them.

In methodological terms, the marginal costs of achieving the targets correspond to the opportunity costs. This is because, if the target is to be achieved, emissions exceeding the target level will make it necessary to take measures elsewhere in the national economy or to forego activities causing emissions.

Recommendations by the Methodological Convention:

1) Societal evaluations and/or expert judgements should be used in the estimation of environmental costs if it is impossible or technically inadequate to perform a valuation based on individual willingness to pay for a reduction in environmental damage[16].

2) The environmental protection targets on which the societal evaluations or expert judgements are based should be presented in a transparent and differentiated way (technical description, legally binding/non-binding character, temporal horizon). In addition, reasons should be given for the choice of specific targets.

3) In principle, targets required by legislation should be taken into account since these represent the current societal and political preferences. In addition, non-binding targets and those based on expert judgements should be taken into account in the context of sensitivity calculations. The valuer should state reasons for the choice of the non-binding targets and of the specific expert judgements.

4) The costs relevant for valuation are those which have to be borne to achieve the desired environmental quality or the reduction in damage. These costs should be used as indicators of willingness to pay. In this context it has to be noted that it is not individual willingness to pay that is referred to but the society's or experts' willingness to pay.

[16] Several types of cases can be distinguished. Firstly: It may in principle be possible to determine willingness to pay in the context of surveys. However, if no valid and transferable results are available and if the expenditure required for a primary study cannot be justified, valuation of the cost of meeting the target may serve as an alternative basis. One example of this is estimating the costs of measures required to comply with noise limit values classified as safe from a health point of view. Secondly: It may be the case that a high degree of uncertainty exists with regard to the resulting material damage and the economic consequences (cf. also the example of damage to ecosystems discussed in the following section).

2.4. Valuation of irreversible damage

Environmental costs are traditionally associated with costs of damage. From the methodological angle, however, damage can only be evaluated in terms of money if something comparable exists to measure the loss of value (damage).[17] A characteristic feature of economic valuation is the assumption that goods are capable of substitution. This is because, from the perspective of individual utility perception, the substitutability of goods is a prerequisite for individuals to have the option of choosing between different goods and formulating corresponding preferences. In the framework of the neoclassical environmental economy, the valuation of environmental goods is also subjected to this substitution paradigm. The problem of substitutability (and hence also that of expression in monetary terms) arises where there is a need to value environmental damage that is irreversible and/or leads to the loss of functions of the natural balance that are classified as indispensable.

We describe environmental damage as irreversible damage if, within the planning periods relevant for humans (150 years for the purposes of this publication),

- ➔ no compensation by natural regeneration processes takes place and
- ➔ the environmental damage cannot be reversed by using anthropogenic and technical resources.

Irreversible environmental damage will lead to deficits in the well-being of present and future generations. The core problem in the valuation of irreversible damage lies in the combination of the irretrievability of the utility lost that could have been achieved without environmental impairment, and the uncertainty about the extent of this disutility.

To derive guidelines for valuation, a distinction must be made between different cases:

1. The environmental damage to be assessed is a <u>loss of a function that can be replaced by produced goods:</u> In this case, valuation is based on the disutility expected in the present and in the future. The indicator of this disutility is the cost required to replace the functions affected (replacement cost approach). Economic valuation can be applied because although the <u>environmental damage</u> is irreversible, the <u>loss of function</u> caused by it can be compensated by specific measures.
2. These are cases of irreversible damage where <u>nothing can yet be said</u> about <u>the consequences</u> (e.g. loss of a species): Economic valuation of the damage is only possible if analyses exist which describe the possible damage scenarios and consequences for alternative assumptions. Such consequences can be evaluated in monetary terms and described in their variation range according to the scenarios available. In this case, a large variation range will indicate considerable uncertainties

[17] In many cases this comparison will be made with the aid of monetary units as a yardstick (numeraire good).

with regard to the actual effects. In the absence of analyses of scenarios suitable for evaluation, the only possibility left is a qualitative description of the risks (also cf. Section 2.5.5). In the latter case, estimation of the environmental costs is impossible.

3. Finally, there are types of irreversible damage where ethical reservations exist about expressing these in monetary terms (e.g. deaths, years of life lost): Economic valuation approaches to death risks are often rejected based on the argument that the value of a life or the damage due to disease cannot be measured in terms of money. In this context it must be stressed that all estimates of environmental costs available so far do not assess the "value" of a human life but the (marginal) variation in the expected mortality and morbidity levels and/or the resulting costs (e.g. costs of medical treatment). Such marginal changes are capable of monetary valuation and are very important as a category for estimating environmental costs.[18] These estimates must therefore be included as a component of environmental costs.

Recommendations by the Methodological Convention:

In cases of irreversible damage where the loss of function can be tolerated and/or can be replaced by produced goods, valuation is to be based on the replacement costs. If the consequences of irreversible damage cannot yet be established exactly, estimates of the variation ranges of possible damage should be stated, if available. If such estimates are not available, the risks should be described in qualitative terms.

The valuation of environmental costs should include the willingness to pay that refers to (marginal) changes in expected mortality or morbidity.

2.5. Taking account of uncertainty and risk aversion in the valuation of environmental costs

2.5.1. Valuation in cases of risk neutrality

The central criteria of classical risk assessment are the *extent of damage* and the *probability of occurrence*.

- Generally, damage is understood as the sum of negatively rated consequences of human activities (examples of environmental and health damage: climate change, ozone hole, core melt in a nuclear power station, car accidents, cancer from smoking) or natural events (e.g. earthquakes, flood disasters, avalanches, volcanic eruptions).

[18] By contrast, risks with a high probability of occurrence for the individuals affected, for example if the probability of developing an incurable disease or of dying approaches the value of one, hardly play a role in the practical estimation of environmental costs and are therefore omitted in the framework of this Convention.

- The probability of occurrence is calculated from data observed in the past (extrapolation), logical linking (plausibility), fault analyses (fault tree or event tree) or assumptions about the relative frequency of an event over a specific period of time (stochastics).

Conventional economic valuation is based on the assumption that the effects of the alternative actions that have to be assessed are sufficiently well known for the resulting damage to be specified with regard to both its extent and its relative frequency of occurrence (or the distribution of the probabilities of occurrence).

Multiplying the extent of damage by the probability of occurrence will result in the expected value of the damage. By using expected values, it becomes possible to compare different risks and weigh them against each other, provided they can be converted to a uniform yardstick (e.g. costs). In this case, the risk concerned may also be referred to as a “calculable risk“.

Calculation involving expected values is a method commonly used in economic valuations. It ensures that consistent decisions about risk reduction measures are made at the macro-economic level on the basis of weighing costs against utility. This kind of approach is based on the assumption of risk neutrality. Risk neutrality means that the valuation of the risk depends only on the expected value, i.e. the product of the probability of occurrence and the extent of damage, and not on whether a low probability is associated with a high extent of damage or a high probability with a low extent of damage. In the case of risk aversion, risks associated with an identical expected value are rated worse if the extent of damage is higher (also cf. Section 2.5.2).

Recommendations by the Methodological Convention:

In principle, the expected value of the damage should be used for the valuation of environmental costs. If the estimate of probability is based on a probability distribution, the standard deviation of the estimate should also be established and the resulting ranges of expected values stated.

However, there are cases where valuation of risks based on expected values is insufficient.

Firstly, this applies to risks for which risk aversion exists among the population (Section 2.5.2). This means that people are prepared to invest more resources to avoid the risk than is reflected in the level of the expected value of damage. Risk aversion is particularly pronounced in the assessment of catastrophic risks (Section 2.5.3). Catastrophic risks are characterized by the assumption that their probability of occurrence is low, but when they do occur they cause very great damage (e.g. extreme floods, chemical accidents, nuclear accidents).

Secondly, this includes risks whose probability and/or potential damage is characterized by a considerable or even deep uncertainty[19] (e.g. hitherto unknown effects of introduction of certain substances into the environment, Section 2.5.5). A research project commissioned by the Federal Environment Agency entitled "Berücksichtigung des Vorsorgeprinzips und qualitativer Risikomerkmale bei der Ermittlung umweltrelevanter externer Kosten" (The precautionary principle and qualitative characteristics of risks in the valuation of external environmental costs)[20] has shown a number of possibilities for the valuation of such risks and discussed their inclusion in an economic valuation method. The following sections give a summary of the conclusions drawn for the Methodological Convention. In addition, reference is made to experience with the implemetation of disaster risk valuation in Switzerland.

2.5.2. Valuation in cases of risk aversion

If there is reason to suspect that potential damage has not been completely identified, a risk increment (or uncertainty increment) is often included in the utility valuation.

For the translation of risk aversion into an economic valuation method, the following options may be considered:

- ➔ Presentation of the expected values plus supplementary verbal description of the risk using additional arguments;
- ➔ Determination of a risk aversion factor and use of the expected value modified by this factor as a basis for valuation.

This immediately gives rise to the question of which aversion factors to use and how to determine these factors, if required. The majority of experts prefer risk aversion factors to be determined in a *well-structured* discursive process. By contrast, individual interviews are assumed to be less successful, mainly due to the wide variation in individual estimates.

In Switzerland, experience exists with regard to such discourses and the systematic inclusion of aversion factors. All risks having the potential to cause disasters and emergencies have been subjected to systematic description, analysis and uniform valuation. The fundamentals have been published in "KATARISK – Katastrophen und Notlagen in der Schweiz – eine Risikobeurteilung aus der Sicht des Bevölkerungsschutzes" (Disasters and emergencies in Switzerland - Risk assessment from a civil protection perspective) (2002). More than 20 panels of experts made contributions to this document developed from the results of workshops, discussions and statements.

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[19] Uncertainty can be expressed in the form of probabilities (or probability functions). The term "deep uncertainty" is used to indicate that no statements on probabilities of occurrence of damage (or probability distributions) can be made on the basis of current knowledge. The transition from uncertainty to deep uncertainty is continuous, i.e. once a certain degree of uncertainty (large variance of estimates) is reached, the term deep uncertainty may be used.

[20] Renn/Pfenning (2004).

In the publication, events are classified by different risk classes, and aversion factors from 1 to 100 are assigned to them. The risks expressed in monetary terms and their aversion serve as a basis for decision making in disaster and emergency aid in Switzerland. Summary 2 provides an overview of the defined risk classes and risk aversion factors used.

In Switzerland, the application of these aversion factors arises from a comprehensive discussion involving relevant decision makers, something that has yet to take place in Germany. For this reason the results are not directly applicable to German conditions. However, they form a good basis for substantiating factors for sensitivity calculations.

Recommendations by the Methodological Convention:

In the presence of risk aversion[21] the expected value of the damage should be included in the valuation as a lower limit. It has to be noted here that the expected value does not take account of the probable risk aversion. The risk and the reasons in favour of risk aversion existing among the population should be described in qualitative terms.

In addition, sensitivity calculations should be performed to take account of one or more risk aversion factors. Multiplication of the expected value by the aversion factor (>1) will result in a value corrected by the risk aversion. Until studies for Germany become available, the Swiss recommendations may serve to substantiate the risk aversion factor chosen.

The ranges of variation of the corrected expected values obtained by this method should be shown in the results.

[21] For the special case of catastrophic risks, see the following section.

Figure 2: Risk classes and aversion factors used in Switzerland

Event class (EC)	Probability of occurrence in Switzerland	Aversion factor
EC 1: Everyday event Events where damage can normally be managed by means of local response resources.	Several times a day.	1
EC 2: Local disaster / emergency Events where damage management typically exceeds the capacities of local response resources. Assistance by neighbouring authorities is required.	A few times a year to once in 10 years: expected in Switzerland several times in the next 25 years.	3
EC 3: Regional disaster / emergency Events where damage management typically exceeds the capacities of regional response resources. Assistance by neighbouring authorities is hardly possible. Supra-regional assistance is required.	A few times a year to once in 10 years: expected in Switzerland only a few times in the next 25 years.	10
EC 4: Supra-regional disaster / emergency Events where damage management typically exceeds the capacities of supra-regional response resources. Inter-cantonal or federal assistance is required.	A few times in 100 years to once in 1 000 years: expected in Switzerland at least once in the next 25 years with a probability of 25%.	30
EC 5: National disaster / emergency Events where damage typically exceeds the capacities of national response resources. International assistance is required.	A few times in 1 000 years up to once in 100 000 years: Expected to occur in Switzerland at least once in the next 25 years with a probability of 2%.	100

Source: KATARISK (2002), table compiled by the authors of the present document.

2.5.3. Valuation of Damocles-type risks (catastrophic risks)

In its Annual Report 1998, the German Advisory Council on Global Change (WBGU: Wissenschaftlicher Beirat der Bundesregierung "Globale Umweltveränderungen")

- identified a *taxonomy of globally relevant risks* and highlighted the particularly relevant classes of risk;
- assigned to these risk classes both established and innovative strategies and corresponding instruments in order to define *priorities* for environmental policy.

In this analysis, the WBGU identified six different classes of risks and illustrated these by characters from Greek mythology. These six classes are referred to as: Damocles, Cyclops, Pythia, Cassandra, Pandora and Medusa. In the context of the Methodological Convention, the Damocles and Pythia classes are of particular importance (for a description of Pythia-type risks see Section 2.5.5).

Damocles risks
Greek mythology reports that Damocles was once invited to a banquet given by his king. However, he had to eat his meal under a razor-sharp sword suspended above him on a fine thread. Thus, the "Sword of Damocles" has become a symbol of a danger overshadowing a happy situation. However, the myth does not relate that the thread was broken with fatal consequences. The danger was thus characterized more by the possibility that the event that would have been deadly for Damocles could have occurred at any point in time, albeit with an extremely low probability.[22]

Accordingly, Damocles-type risks are characterized by combining a high damage potential with a very low probability of occurrence (catastrophic risks). Such "high consequence – low probability" risks constitute a social risk-utility dilemma if the damage is considered as catastrophic and intolerable and the low probability of occurrence cannot be interpreted as an indication that the event is improbable, but rather that the danger is random ("could just as well happen tomorrow"). Due to the high catastrophic potential, risk aversion should be expected to exist among the population. Typical examples include technological risk potentials such as those posed by nuclear energy facilities, large-scale chemical facilities, dams and liquid-gas tanks. In addition to technological risks, natural disasters such as meteorite impacts also fall into this risk class.

The assessment of catastrophic risks will, as a rule, depend on the context. This means that qualitative characteristics, such as the type of catastrophic event (nuclear power accident, chemical accident, airplane crash) and assessments of the reliability of information sources play an important role.

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[22] Cf. WBGU (1999).

The methodological problems of monetary valuation of catastrophic risks are not due solely to the fact that risk aversion exists in view of the high damage potential, since such risk aversion could be included in valuation through corrected expected values, as described in the foregoing section. Much greater relevance is attributed to the fact that estimates of the reliability of risk identification vary considerably both within the population and among experts. Due to the extreme rareness of such events, no empirically confirmed source of data is available. As a consequence, the range of variation of expected values will be very large even in the absence of aversion factors. Thus such variation does not primarily result from differences in the extent of risk aversion, but is rather an indication of uncertainties associated with assessing the probability of occurrence and the extent of damage. Where expected values differ very widely (in the case of valuation of the risks from nuclear energy the factor is about 30 000), it is of course possible to state variation ranges, but as a rule these will not provide a basis for taking decisions as to what risks are tolerable under what circumstances.

This suggests that although monetary valuation of catastrophic risks is possible, the variation ranges of estimates are usually too large to provide an adequate basis for decision about the management of such risks. It is therefore necessary to identify society's risk tolerance in a societal discourse and on this basis, to initiate measures that make the most cost-effective contribution possible to risk reduction.

The Methodological Convention lays down the following procedure for the assessment of catastrophic risks:

It is necessary to state the variation ranges of the probabilities of occurrence and of the extent of damage, as well as the expected values derived from these. The reasons for the different estimates must be described verbally. In the case of catastrophic risks, the existence of risk aversion among the population has to be taken for granted. Therefore, sensitivity calculations should be carried out taking into account risk aversion. As long as no studies are available for Germany on the levels of aversion factors, the authors suggest applying an aversion factor of 100, based on the results obtained in Switzerland.

2.5.4. Valuation of nuclear power risks

The variation range resulting from different valuations of catastrophic risks becomes impressively obvious from a comparison of different results on the external costs of nuclear power. While in the current ExternE study, the external costs estimated for nuclear power amount to 0.2 cent per kWh, the majority of the Study Commission on Sustainable Energy Supplies (Enquete-Kommission Nachhaltige Energieversorgung (2002)) estimated that external costs reached up to 200 cents per kWh.

The variation of the estimates is due to differing assumptions (e.g. on discounting) and different qualitative estimates of the damage and risks. For illustration: Estimates of damage arising from a core meltdown accident in Germany vary between €500 billion[23] and €5 trillion[24]; the estimated probabilities of occurrence range from 1:33 000[25] to 1:10 000 000[26].

Although the variation range of the estimated damage costs can be presented, this does not provide a sufficient basis to substantiate decisions, according to the current state of knowledge. Decisions on the management of such catastrophic risks may ultimately have to be made as the result of a societal and political discourse.

External costs of power generation: How to deal with the large variation range?

The average environmental costs of power generation are an important item of information for environmental policy, because they can be used to quantify the additional economic utility of energy savings. However, as long as nuclear power still accounts for a substantial proportion of power generation in Germany, the wide range of variation in the environmental costs of nuclear power will also result in corresponding bandwidths in the environmental costs of average power generation. If opinions differ on the extent and probability of damage (and such discrepancies cannot be resolved by scientific means), a large variation of environmental costs is inevitable and cannot be reduced even by methodological conventions. If the aim is nevertheless to suggest pragmatic cost rates, the only practical possibility consists in defining a cost rate and explicitly disclosing and presenting the underlying assumptions in a transparent way. One option, for instance, might be to calculate the external costs of the energy production mix without including nuclear power[27]. Another option would be to use the environmental costs of the "next worst" energy source used for energy production after the phasing out of nuclear energy. This value, i.e. the environmental costs of the next worst energy source, may then serve as an alternative, for example when it is necessary to value external costs of energy production in the present decision-making situation. However, this does not by any means imply that we are suggesting a value for the damage costs of nuclear power. The examples are only intended to point out possible options for dealing, in a pragmatic way, with the prevailing uncertainties and lack of knowledge with regard to valuation by disclosing all underlying assumptions.

[23] Friedrich (1993), a similar order of magnitude is found in the study by Krewitt (1997).
[24] Ewers, Rennings (1992).
[25] Ewers, Rennings (1992). The basis for this probability is the German Reactor Safety Study Phase B (GRS-B), severe accidents in power plant of the Biblis type. Manual accident management measures can reduce the risk to 1:270 000, according to GRS-B. This risk is taken as a basis e.g. for the study by Friedrich (1993).
[26] Krewitt (1997). This is based on the most modern type of plant operated in Germany at present (Konvoi reactor). However, this type is represented by only three out of the 20 nuclear power plants operated.
[27] If the value calculated by this method is taken for the external costs of energy production, this implicitly amounts to applying the average external costs of the other energy sources to nuclear energy production.

Recommendations by the Methodological Convention:

For the purpose of determining the overall environmental costs of power generation, the Federal Environment Agency recommends using the cost rate for lignite. In view of the uncertainties involved in determining the environmental costs of nuclear power, the Federal Environment Agency regards this as the best solution. This is based on the view that the costs due to nuclear power must be rated at least as high as the next worst energy source used.

2.5.5. Catering for the precautionary principle: Valuation of Pythia-type risks

Pythia risks

In cases of doubt or uncertainty, the ancient Greeks consulted one of their oracles. The most famous of these was undoubtedly the Delphic Oracle with its blind prophetess Pythia. Pythia exposed her senses to gases in order to be able to make her oracular revelations and give advice for the future. However, Pythia's prophecies always remained ambiguous.[28] Examples of the application of this risk class include the assessment of effects of low radiation doses, food additives and chemical plant protection products.

It is a characteristic of Pythia-type risks[29] that both the probability of occurrence and the scale of possible damage are uncertain. For precautionary reasons, however, it is justifiable to take measures that reduce the risk of such damage occurring.

In the case of Pythia risks, estimating costs is even more problematic than for Damocles risks. This is because the question of risk tolerance depends to an even greater extent on context variables than in the case of Damocles risks. The estimated extent of damage and that of utility play only a minor role as variables in the valuation. The decisive variables are the perception and assessment of the existing uncertainty.

Auxiliary indicators: Ubiquity, persistence and irreversibility

Practical applications fall back on adding safety increments for risks involving a high degree of uncertainty (or even deep uncertainty). The level of such increments is, however, not derived from individual preferences but from an estimate of the follow-up costs likely to be incurred in the worst case[30], based on the replacement cost approach used in cost-benefit analysis (Geisendorf et al. 1998) In the context of this approach, the WBGU has suggested basing the valuation of follow-up costs on the following criteria (WBGU 1999):

- ➔ Ubiquity (area/space affected);

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[28] Cf. WBGU (1999).
[29] Cf. WBGU (1999).
[30] This approach corresponds to the maximin Rule described in Section 2.5.7.

➔ Persistence (period of time involved);

➔ Irreversibility (degree of impossibility of restoring the condition that existed before the damage occurred).

The above three criteria are suitable for delimiting the approximate follow-up costs of a worst case.[31]

However, great problems arise when one tries to use these criteria to derive an equivalent relationship for the establishment of environmental costs. These criteria are based on the assumption that every substance which is ubiquitous and persistent and for which the cost of avoiding environment inputs is high, will always prove to be potentially harmful to the environment in the course of time. Due to the great uncertainty, however, the extent to which the relevant damage will actually occur remains unclear. The less marked the three criteria are, the lower the assumed follow-up costs will be, other things being equal. However, cardinal quantification of such “the more - the less” relationships is impossible because this would amount to elimination of the uncertainties. The extent of the potential damage remains unknown. This can only be resolved if the decision makers or participating bodies establish defined measures of risk reduction.

If it is desired to establish a monetary equivalence relation in spite of these problems, conclusion by analogy seems to offer the most conclusive results. One option would consist in characterizing the uncertain risks in terms of the attributes of ubiquity, persistence and irreversibility, then referring to known risks with similar characteristics and choosing the resulting variation range of damage (or the costs of avoiding the damage) to serve as an indicator of the consequences of the expected damage. This method would at least make it possible to identify roughly the potential damage expected from the risks under consideration.

Recommendations by the Methodological Convention:

It is methodologically impossible to undertake a monetary valuation of damage arising from risks for which no estimates of probabilities or extent of damage are available. The damage potential from such risks should be characterized by the attributes of ubiquity, persistence and irreversibility and described in qualitative terms. Where risk reduction targets exist, the costs of achieving these targets should be included (cf. also remarks in Section 2.3).

[31] The precision of these three variables has been confirmed by another project (Renn et al. 2003). In this EU-financed project, the three criteria were applied to persistent organic chemicals and transferred to a mathematical forecast model, which in fact resulted in an almost perfect correspondence between the acceptability established by the model and the international legislation actually in force (banned vs. non-banned substances). It is thus possible to use auxiliary indicators to make a comprehensible and consistent assessment of the acceptance of certain risks. For the example of POPs (persistent organic pollutants) this method has been described in detail in Annex 1 to Renn (2004).

2.5.6. The role of societal discourses in risk valuation

When describing the yardsticks for risk assessment, it has been mentioned several times that decisions on what risks are tolerable can only be made in the context of a societal discourse. The purpose of discursive methods is to include everyday experience and societal interests and values in the processes of balancing interests. In addition, local knowledge, collective preferences and habits play an important role, as do demands made by individuals concerning the design of their own lifestyle and environment.

However, discourse does not mean agreement at the level of the – mostly trivial – least common denominator. Rather, the parties involved should tackle the conflict with all clarity and also, if necessary, with all severity, and explain their different values and interests. More often than not, such discourses will not result in an agreement but instead, in agreement to disagree. In such cases, all participants are aware why one party is in favour of an argument and the other against it. But in the course of the discussion, the relative strengths and weaknesses of the individual arguments will have been reviewed and scrutinized. The remaining differences will no longer be based on apparent conflicts or erroneous convictions but instead, on clearly defined differences in the valuation of the consequences of decisions.[32] A discourse will not necessarily result in an agreement but in more clarity.

Even if a discourse ends in disagreement, such a result will be as important for decision making and for the establishment of weighting factors for environmental costs as a consensus approved by all parties involved. In either case, the legal decision makers will be able to make balanced decisions which are rational in the classical sense.

This will be less painful in cases of consensual proposals, while in the event of disagreement, the decision makers will have to give preference to one solution or the other, making reference to overarching values or to their own programmatic approach.

A decision has to be made one way or the other. However, being in a position to make such decisions on the basis of a discursive argument will not only improve the results of the decision but also the chances of better acceptance, even among those who were unable to implement their own preferences[33].

2.5.7. Strategies for dealing with deep uncertainty

The development of strategies for dealing with deep uncertainty is an element of decision theory[34]. The different strategies also reflect different attitudes and yardsticks for assessments, e.g. a pessimistic or optimistic basic position, and may also be applied to environmentally relevant valuation. Strategies for dealing with uncertainty are an alternative to monetary

[32] Cf. Schimank (1992).
[33] Dryzek (1990).
[34] Cf. for example Bamberg/Coenenberg (2006).

valuation (or to the life-cycle assessment method) if it is necessary to choose an alternative from a number of options or to establish a ranking of options.

As a rule, the decision problem is described as follows: A choice has to be made between a number of alternative actions ($a_1,...a_m$) to which a number of environmental situations have been assigned ($z_1,...z_m$). The environmental situations are described by means of indicators. The decision maker knows the environmental situations that may arise but not the probability of their occurrence.

Figure 3: Example of a decision matrix

Possible environmental situations/alternatives	z_1	z_2	z_3
a_1	20	42	12
a_2	25	20	28
a_3	15	21	36

Common decision rules include:

The maximin rule

When applying the maximin rule, success in the most unfavourable case is decisive. Therefore, the action with the highest minimum (a_2) is chosen. This rule reflects a very cautious value judgement.

The maximax rule

A choice is made in favour of the alternative that can provide the chance of the greatest success, i.e. the alternative with the highest maximum (a_1). This approach corresponds to a very optimistic value judgement.

The Hurwicz principle or the weighted optimism-pessimism rule

A weighted compromise is chosen between the maximin and maximax rules[35], i.e. for each action, a weighted average of the minimum and the maximum success is established. Depending on whether more emphasis is put on the maximum or on the minimum, the tendency is towards optimism (maximax rule) or pessimism (maximin rule).

The Savage-Niehans rule

The alternative involving the "least regret" is chosen. The extent of the regret is defined as the difference between the payoff of the selected alternative and the highest payoff in this situation. The maximum of these "regret values" is determined for each row (this is the greatest

[35] For this purpose, an optimism parameter (between 0 and 1) is defined. No details of the exact derivation are provided here.

regret that this decision can cause). Then the alternative with the lowest of these values is chosen. In the present case this is the alternative a_3.

Laplace rule

An equal distribution of situations is assumed to exist and therefore, the choice is made in favour of the action with the highest sum of possible utility (a_1).

2.6. Discounting of future costs and benefits

In economic analyses, a major role is attributed to the time when the costs and benefits (or returns) of today's decisions become reality. In microeconomic analyses, future costs and returns are discounted at a market rate (or a discount rate) at the present time, because for investors, the market rate represents the opportunity cost of the capital. An investment will be profitable if the capitalized value, i.e. the difference between the discounted returns and costs, is positive. In such cases the return on an investment is at least as high as that of investing the capital at the market rate.

In macroeconomic valuations, all experts agree that the discount rate applied must be lower than the market rate. As a rule, the real money market interest rate for low-risk bonds is used in this case. This money market interest rate can be used for short-term and medium-term periods of up to 20 years. Retrospectively, it has been found that apart from short-term variations, the real market rate has repeatedly returned to levels of between 2.5 and 3 percent over the last 150 years.

For the Methodological Convention we have set a discount rate of 3 percent for valuations relating to periods of up to 20 years.

Discounting for cross-generational effects

Frequently, the valuation of external costs and environmental damage refers to damage extending far into the future: This is because depending on the type of effects considered (health damage with a latency period, climate change, radiation from permanent repositories for the disposal of radioactive waste), the resulting damage may reach far, e.g. hundreds of years, into the future. It is impossible to empirically establish a market rate for such long periods of time. However, the farther the damage to be assessed extends into the future, the greater the influence of the discount rate level on the result will be. For example, the cash value of annual damage amounting to €100 and occurring over 200 years totals €20 000 at a discount rate of 0%, €8 633 at a discount rate of 1%, €3 324 at a discount rate of 3%, and as little as €2 000 Euro at a discount rate of 5%[36].

The level of the discount rate used to evaluate cross-generational aspects cannot be substantiated scientifically because choosing a discount rate implies value judgements. In order to understand the influence of value judgements on the level of the discount rate, it is helpful to interpret the discount rate as the result of an inter-temporal utility calculation.

The social discount rate can be described by the following formula:

i = z + n*g

i = social discount rate

z = pure (social) time preference rate

n = absolute value of percentage reduction in additional benefit for a 1 percent increase in consumption (marginal social elasticity of consumption)

g = consumption growth rate

The social discount rate (i) will grow with an increase in the pure time preference rate (z), in the marginal utility elasticity of consumption (n), and in the growth rate of consumption (g).

Setting a level for the discount rate firstly requires an assumption about the essence of preferences of future generations. Secondly, there is a need to establish how to weigh the costs and benefits for future generations against those for the present generation (this determines the pure time preference rate). Thirdly, assumptions have also to be made about the other variables which are decisive for the social discount rate (growth rate of consumption, marginal utility of consumption).

[36] The cash or present value P_c of a time series of costs c_t, arising at times $t = 0,1,2,\ldots,T$ is calculated as the total amount of the costs of each period weighted with a discount factor r:

$$P_c = c_0 + c_1 \frac{1}{1+r} + c_2 \frac{1}{(1+r)^2} + \ldots + c_T \frac{1}{(1+r)^T} = \sum_{t=0}^{T} \left(c_t \frac{1}{(1+r)^t} \right)$$

For the three aspects mentioned above, the Methodological Convention has set the following yardsticks:

1.) The valuation of cross-generational effects is based on the preferences of the present generation.

This is because the cross-generational development of preferences relating to different needs (such as food, housing, mobility) takes the form of a very slow evolution, so that the essence of preferences of the generation living today represents the most appropriate estimate for those of future generations (for a period of at least 150 years).

2.) The benefits for generations living today and for generations living in the future are attributed equal importance.

This means that in cross-generational valuations, the pure time preference rate is set to zero[37]. This is based on the assumption that the facts to be evaluated have the same importance for future generations as for those living today (if the event were to occur today).[38]

Explanation: In principle, a distinction has to be made between individual and intergenerational discounting of benefits. From an individual perspective, discounting future costs and benefits and thus attributing a lower value to them at present is a convincing approach: This is because if an amount of €100 will be needed in one year's time, the amount to be invested at present would be less than € 100 (approx. €97.09), based on an interest rate of 3%. However, intergenerational utility discounting is concerned with comparing the benefits for the generation living today with those for future generations. Therefore, the benefits under consideration are not those experienced by a defined individual from a certain event either today or in the future. Rather, the question to be answered is whether the individuals living today rate a certain event in a similar way to those living in the future. In the opinion of the Federal Environment Agency, discounting benefits cannot be ethically justified in cross-generational considerations since it would conflict with the cross-generational perspective of sustainable development. Therefore both the benefits for people living today and the benefits for future generations should be assigned the same importance.

3.) For the standard case, it is assumed that the marginal utility elasticity of consumption[39] equals a value of one, and growth is 1.5%. These values correspond to the common assumptions underlying economic analyses.

The result obtained from summarizing these three assumptions is as follows:

The social discount rate to be applied as a standard value in cross-generational valuations is set at 1.5 percent.

[37] A positive time preference rate would imply that the benefits for future generations were of lesser importance in the valuation.
[38] The case $z = 0$ corresponds to the "prescriptive approach" in Arrow et al. (1995). The case $z > 0$ is described by Arrow et al as the "descriptive approach".
[39] The marginal utility elasticity of consumption designates the percentage change in additional utility if consumption increases by 1 percent.

This standard case reflects an optimistic value judgement since it is associated with the assumption that economic growth and/or growth in efficiency as a consequence of technological progress will continue in the future and later generations will fare better in material terms[40]. If there are any reasons suggesting a different growth rate or utility elasticity, the social discount rate will change accordingly.

In the case of cross-generational valuations, we basically recommend performing a sensitivity analysis, using a discount rate of zero. This case reflects a value judgement characterized by risk aversion and precautionary orientation.

In summary, the following convention results for the choice of the social discount rate:

For short-term periods (up to approx. 20 years), a discount rate of 3 percent should be applied.

For damage extending further into the future, the discount rate is set to a standard value of 1.5 percent. Furthermore, for cross-generational considerations, a sensitivity calculation should be performed using a discount rate of 0 percent.

In each case, these discount rates should apply over the entire period of time considered (constant discount rates).[41]

The values chosen for the Methodological Convention are within the commonly accepted scientific limits.

2.7. Summary of yardsticks

Economic valuation of environmental effects needs the assistance of a number of tools, for a variety of reasons:

- ➔ There are no market prices which directly reflect the value of the environment.
- ➔ Environmental impacts are frequently uncertain, and the impacts of today's activities on the environment are not yet fully known.
- ➔ Valuation is also required for irreversible environmental damage.
- ➔ Decisions sometimes have to be made today on the valuation of damage that will occur in a distant future.

Given the problems mentioned, other valuation methods also come up against their limits, since the problem of valuation is an inherent one and does not depend on the economic method applied. In many cases, the relevant decisions have to be taken today in spite of existing uncertainties about possible long-term effects. In such cases, economic valuation has the advantage of exemplifying at least partial aspects that are accessible to economic valuation

[40] This implies for example that the utilization of resources will improve owing to technological progress, and future generations will therefore need relatively fewer resources to satisfy their needs than the generations living today.
[41] Some authors recommend discount rates diminishing over time. Cf. for example Weitzmann (1994).

and revealing valuations that are otherwise only implied. Frequently, the cost of damage (or opportunity cost) determined in this way is sufficient to substantiate decisions on the protection of the environment.

Of course, the yardsticks that should be applied to economic valuation cannot be substantiated on a scientific basis. Nevertheless, these yardsticks should be consistent with individual and societal preferences, targets and framework conditions.

In the following, a summary is given of the yardsticks for economic valuation of environmental effects derived in the foregoing sections (for details please refer to the respective sections).

Individual willingness to pay as a yardstick

Valuation of environmental costs sets out to describe economic consequences of environmental damage and of the resulting disutility (loss of benefits). This is why the principle of individual market valuation is chosen as a general basis. This means that individual willingness to pay is applied as a yardstick for estimates of environmental costs. Willingness to pay is an appropriate yardstick for valuation, particularly if the damage to be assessed means a factual, spatial and temporal impairment of benefits for the individuals interviewed. There are, however, cases where one has to deviate from this yardstick for certain reasons. One case of great importance for environmental valuation is the valuation of cross-generational damage. For this case, we explicitly suggest referring to certain ethical value judgements (cf. statements made in Section 2.6).

Societal evaluations and expert judgements

Societal evaluations and/or expert judgements should be used as yardsticks in cases where it is impossible or inappropriate to make a valuation based on individual preferences. Reasons for having recourse to expert judgements and societal evaluations may include e.g. cross-generational effects, a high degree of uncertainty, or valuation of damage not directly perceptible by individuals. Such valuations will, as a rule, not represent willingness to pay for reductions in environmental damage but rather, they will consist in recommendations (or also, depending on how binding they are, limit values) that have to be complied with in order to avoid intolerable damage. On the basis of these targets it is possible to calculate the costs that society has to pay to achieve these targets.

Environmental protection targets as a framework for valuation

Environmental protection targets serve as a framework for valuation so long as the costs of achieving the targets can be interpreted as societal willingness to pay (or as opportunity costs). The selection of relevant targets must be presented in a transparent way. The criteria for the selection of relevant targets described in Section 2.3 must be taken into account.

Valuation of irreversible damage

In cases of irreversible damage where the loss of function can be tolerated and/or can be replaced by produced goods, valuation is to be based on the replacement costs. If the consequences of irreversible damage cannot be determined exactly, estimates of the variation range of possible damage should be stated, if available. If no information is available about the latter, a qualitative description of the risks is needed.

Valuation of deaths and illnesses

Valuation of deaths and illnesses is frequently rejected for ethical reasons. In this respect, it has to be pointed out that it is not the "value" of a human life but instead, the (marginal) change in expected mortality rates that is determined in economic analyses. Risks and money are also weighed against each other in everyday life. Estimates of environmental costs should therefore include willingness to pay relating to modifications of mortality or morbidity rates.

Discounting of future costs and benefits

The standard discount rate to be applied for temporal horizons of up to 20 years is 3 percent, and that for longer periods of time (intergeneration aspects) is 1.5 percent. For intergeneration analyses, a sensitivity calculation should be performed using a discount rate of 0 percent.

Valuation in cases of uncertainty and risk

In principle, the expected value of the damage should be used for the valuation of environmental costs. In the presence of risk aversion, the expected value of the damage represents the lower limit of costs. The risk and the arguments in favour of risk aversion on the part of the population should be described in qualitative terms, and sensitivity calculations should be performed, taking into account a risk aversion factor.

Valuation of catastrophic risks (Damocles risks)

It is necessary to state the variation ranges of the probabilities of occurrence and of the extent of damage, as well as the expected values derived from these. In the case of catastrophic risks, the existence of risk aversion among the population has to be expected. Sensitivity calculations taking account of risk aversion should therefore be carried out. As long as no studies on aversion factor levels are available for Germany, the authors suggest applying an aversion factor of 100, based on the results obtained in Switzerland.

Valuation in cases of deep uncertainty (Pythia-type risks)

It is methodologically impossible to perform monetary valuation of damage arising from risks characterized by a very high degree of uncertainty about their effects and by a lack of estimates of their probability and extent of damage. The damage potential of such risks should be characterized by the auxiliary indicators of ubiquity, persistence and irreversibility and described in qualitative terms.

3 Cost categories for valuation of environmental costs

3.1. Damage costs as a yardstick for willingness to pay

Economic valuation of different types of damage (e.g. environmental diseases, damage to materials) is made by estimating certain cost categories that can be interpreted as indicators of the disutility (loss of benefits) experienced. The yardsticks derived in Section 2 for economic valuation should also be reflected in the cost categories.

In order to interpret the results and avoid duplication it is of decisive importance to define the different cost categories and clearly distinguish between them. Figure 4 provides an overview of the definitions established for the purposes of the Methodological Convention.

Environmental damage costs consist of damage reduction costs and the costs of unavoided environmental and health damage.

Damage reduction costs correspond to the willingness of affected individuals to pay for an improvement in environmental quality. The costs of remediation measures taken (or planned) and the adjustment costs and costs of evading environmental impacts should be interpreted as the lower limit of willingness to pay because individuals or society will pay such costs only if the resulting gain in utility is higher than the costs of the measure. In this context, the term “revealed preferences” is used.

Damage reduction costs can be subdivided into

a) Direct costs

These include costs of measures directly affecting the remediation or mitigation of the damage that has occurred, such as costs required for the cleaning of facades, costs of water treatment, soil restoration costs, costs of medical treatment, etc.

b) Indirect costs

These include, for example, costs arising from a change in behaviour or adjustments in response to the impairment, for example costs of evading environmental impacts by installing noise-proof windows, or of switching to more distant recreation areas. Such changes in behaviour do not result in any material improvement in the environmental situation. However, they reduce or compensate the effects on the individuals affected.

c) Costs of prevention

These include costs of measures taken in advance (before damage occurs) to reduce the probability of the damage occurring or to limit the extent of damage, such as flood protection measures.

The second category (costs of unavoided environmental damage) includes all costs or loss of benefits due to environmental damage that are not limited by means of remediation, control or alternative measures.

It is possible to distinguish two cases here: 2a) attributes a special role to the costs of possible measures for damage reduction, which for a variety of reasons have not (yet) been implemented. Such costs can be taken into account if they can be based on societal and/or expert judgements, i.e. an intention to carry out these measures. The recommendations explained in Section 2.3 should therefore be observed. 2b) cites the remaining utility losses, which – for various reasons – are not (or cannot be) further reduced or curbed. Valuation of these types of damage would require an estimate of the willingness of affected individuals to pay for a further reduction in the damage (for the relevant methods, see Annex A).

They include, for example:

- ➔ Impairment of recreational benefit or quality of life;
- ➔ Loss of yields due to changes in productivity;
- ➔ Chronic health damage.

When performing this analysis it is necessary to investigate carefully whether there is any double counting that needs to be eliminated.

Figure 4: Cost categories for estimating environmental costs

	Cost categories	Starting point for valuation	Relevance / validity of valuation
1	Damage reduction costs		
1a	Direct costs, e.g. restoration costs, clean-up costs, repair costs, after-care costs	Measures implemented or planned to limit or eliminate material damage and health damage	Element of external costs (revealed preferences)
1b	Indirect costs, e.g. adjustment costs, costs of averting environmental impacts	Adjustment responses in the shape of measures implemented and planned by affected individuals to reduce environmental impairment	Element of external costs (revealed preferences)
1c	Costs of prevention	Measures to reduce the probability or extent of damage	Costs which may already have been internalized, e.g. through environmental liability
2	Costs of unavoided damage to health and the environment		
2a	Costs of other measures to reduce damage	Possible measures to reduce damage, based on societal and political targets and/or expert judgements about the impairment to be avoided[42]	Element of external costs if underlying target is accepted (e.g. costs to comply with noise abatement targets)
2b	Costs of unavoided or unavoidable environmental damage, e.g. yield losses in farming, reduction in recreational utility, reduction in quality of life, chronic health damage	Loss of benefits for affected individuals that is not reduced by other averting measures Measures to compensate for environmental damage	Element of external costs, partial risk of duplication, strict distinction from cost categories 1b and 2a required

Source: Own compilation.

3.2. Avoidance costs as an auxiliary indicator for the valuation of environmental costs

A fundamental distinction should be made between the damage costs and the costs referred to as avoidance costs which are not directly related to the environmental damage. The latter

[42] Other measures which could be taken but which are not linked to a socially established environmental target should not be included in the valuation of external costs. This would involve a risk of overestimating external costs.

describe the costs associated with avoiding or reducing the activity causing the environmental damage (e.g. emission avoidance costs).

Avoidance costs are the costs arising from measures to avoid a specific environmental impact[43] (e.g. reduction in pollutant emissions). Avoidance costs are always directly related to the relevant activity detrimental to the environment (e.g. emission avoidance costs). They should therefore not be confused with damage costs.

A number of studies rely on avoidance costs as an indicator for valuation of environmental damage in cases of insufficient knowledge about environmental impacts. In the authors' opinion, this kind of approach is meaningful if the politically justified rating of the expected damage is implicitly higher than the costs of avoiding the source of the environmental impact. As explained in Section 2.3, explicit reference should in this case be made to environmental protection targets accepted by society. As a consequence, avoidance costs can be interpreted as a lower limit of the (assumed) damage costs.

However, in methodological terms, this is not a valuation of environmental damage because the valuation refers to the costs that would have to be paid for reducing adverse environmental impacts. Therefore, the problem of valuation cannot be solved by making reference to avoidance costs.

This is why avoidance costs are not an indicator of damage costs. They should be interpreted as opportunity costs and therefore presented separately, because emissions exceeding the target level will require measures to be taken elsewhere in the national economy and/or make it necessary to forego activities causing emissions.

3.3. Total external costs, average costs and marginal costs of environmental damage

When estimating environmental costs it is possible, depending on the subject investigated and the data situation, to determine total costs, average costs or marginal costs. These terms are explained with the aid of examples.

3.3.1. Total costs

Total costs correspond to the total amount of all environmental costs in relation to certain system boundaries (e.g. temporal and spatial delimitation). Estimates of total costs may be helpful to illustrate the order of magnitude of environmental damage caused by a specific sector, for example. In addition to this actor-oriented approach, the valuation of total costs broken down by certain types of damage or environmental media may also be of interest, e.g. the costs of environment-related damage to health or of water pollution, which in turn may be

[43] Sources of environmental impacts can be seen in the totality of all activities relating to the subject in view, such as utilization of resources, land use, airborne emissions, noise etc., cf. also definitions in the Manual “Leitfaden Betriebliche Umweltauswirkungen“ (Guidelines of Operational Environmental Impacts), Umweltbundesamt (1999).

disaggregated in terms of groups of responsible actors. Furthermore, estimates of total costs may help to substantiate a need for environmental policy action or to establish priorities.

The estimate of total costs is usually based on a top-down approach. This implies that based on the total pollution load (e.g. air pollutant emissions), shares of this load are attributed to the activities under consideration (e.g. transport), and these activities are further subdivided into certain types of transport (e.g. passenger transport, freight transport). In cases of site-related environmental pollution, additional information will be needed, e.g. by weighting the sources of environmental impacts (activities affecting the environment) as a function of regional conditions.

Example: An estimate of the environmental costs of transport comprises the sum of all external costs that can be determined for the current traffic situation (point in time) in a certain spatial dimension (e.g. Germany). These costs can be estimated for different traffic situations or modes of transport in order to exemplify for instance the cost saving that would result from a reduced traffic volume or a different modal split. The estimated costs can also be compared with the costs of other sectors in order to substantiate priorities of environmental policy.

Figure 5: Example: Environmental costs of transport

Arising from transport activities	Environmental effects/environmental costs
Accidents	Accident risk for non-drivers, accident costs not covered by the insurance of the responsible party
Air pollution	Costs of disease caused by air pollution, costs due to non-availability of resources, damage to materials of buildings, forest damage, crop losses in agriculture and forestry
Greenhouse gas emissions	Contribution to climate change, economic consequences
Noise problems	Noise-induced diseases, costs of treatment, loss of income, impairment of the quality of life
Fragmentation effects of transport routes	Loss of benefits in the tourism sector, in agriculture and forestry, ecological impairment and resulting disutility
Land take	Consumption for traffic infrastructure
Consequences of transport activities	Follow-on costs of infrastructure use

Source: Own diagram.

3.3.2. Average costs

The term average external costs describes the ratio between total costs and a defined reference unit.

The types of average costs calculated will depend on the problem under consideration. Thus, the total costs of road freight transport can be related for example to tonne-kilometres, to kilometres driven or to litres of fuel used. In the field of energy supply, one kilowatt hour of electrical energy generated is a common reference unit. In this way it is possible, for example, to establish whether existing instruments such as the electricity tax recover the environmental costs of power generation per kilowatt-hour.

3.3.3. Marginal costs

The term marginal costs describes the additional costs caused by an expansion of the environmentally harmful activity (e.g. emissions in tonnes, traffic volume in kilometres, energy production in kilowatt hours) by one unit.

The valuation of marginal costs is based on the bottom-up method. Pollutants are ascertained at source, and damage to health and the environment, for example, can be estimated by means of assumptions about dose-response relationships and dispersion calculations.

In practice, marginal external costs are determined by considering the differences between two scenarios. The situation including the activity considered (e.g. additional power station, additional traffic) is compared with a situation without this activity. Because this does not mean a marginal analysis (this would be the case if the effect of only one unit of additional emissions were considered), the costs determined are also referred to as quasi-marginal costs. Marginal costs and (variable) average costs are identical if linear dose-response relationships are used to study environmental effects.

An estimate of marginal costs is a meaningful reference parameter particularly in the case of proposals for designing economic incentive instruments in the environmental sector. Environmental charges aimed at internalising external costs[44] should be based on the marginal costs of the environmental pollution. The rational course for the polluter is then to keep reducing the environmental pollution as long as the additional costs of such measures (e.g. investments in energy saving) remain lower than the environmental charges saved via the instrument (e.g. electricity tax saved, expenditure saved on emission allowances). In the optimum case, the marginal damage costs are then equal to the marginal avoidance costs[45].

Increased utilization of the environment will, as a rule, be associated with increasing marginal costs (i.e. the higher the initial pollution, the more relevant are the negative effects). In this case, the additional costs due to an increase in traffic volume or the construction of another power station are higher than the costs already produced on average by the existing traffic volume or the existing number of power stations. However, there are also sources of environmental impacts that are characterized by decreasing marginal costs, depending on the type of environmental pollution involved. For example, the additional noise level on already busy roads will be less relevant than the average noise level caused by the existing traffic. In this case, it is not economically meaningful to refer to the marginal costs of the additional

[44] In a strict sense this serves the objective of “achieving a macroeconomic optimum”.
[45] A detailed description of the objectives of internalization and the resulting requirements for the instruments is given in van Essen/Maibach (2007).

pollution load as a measure of internalization because the incentive to reduce noise would be insufficient. Instead, it would be necessary to charge the average environmental damage costs.

3.4. Approaches to estimating environmental damage costs

Depending on the framework of the investigation and the objectives, it is possible to use different estimation methods: the impact pathway approach, the standard price approach and the top-down approach. These approaches are described below and criteria are formulated for choosing the appropriate analytical approach.

3.4.1. The impact pathway approach

The impact pathway approach is an approach which permits an estimate of the marginal costs of the environmental pollution. It has been developed and applied in the context of the EU research programme, ExternE. There is consensus among the scientific community that this approach should be followed provided that sufficient data and information are available.

This valuation approach is based on the following principles for the valuation of environmental costs:

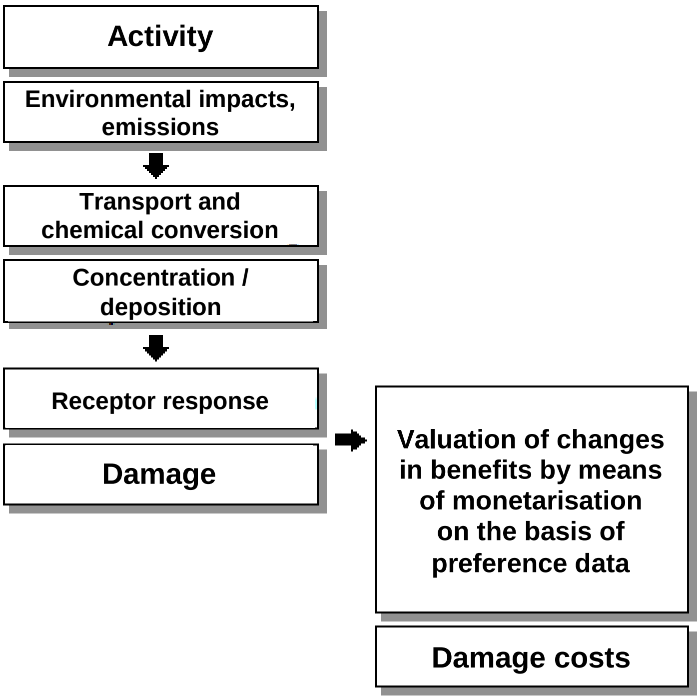
- ➔ Valuation is based on a bottom-up model;
- ➔ The measure of valuation is represented by the individual preferences of the individuals affected, which are identified by means of conclusions drawn from behaviour or by way of surveys;
- ➔ The valuation refers to damage (e.g. respiratory disease) and risks (e.g. increased accident risk), and not to the sources of environmental impacts (e.g. greenhouse gas emissions).

The term bottom-up means that the impact chain is ascertained from the activity affecting the environment, via transport and possible chemical transformation processes (e.g. the formation of ozone and photochemical smog), through to the effects on different receptors (e.g. humans, plants), before the physical damage and risks quantified in this way are evaluated in monetary terms. It is important that the valuation refers to the end points (damage, risks) and not the sources of environmental impacts.

The monetary values determined reflect the negative effects on well-being and health, and restrictions on use of the environment, which correspond to the loss of benefits for the individuals affected.

The approach described makes it possible to identify marginal or quasi-marginal costs (e.g. those produced by construction and operation of an additional power plant at a specific site). In this context, quasi-marginal means that the estimate refers to damage caused by an additional measurable environmental pollution load, such as the damage due to the construction of an additional power plant.[46] For the above example, the damage determined in this way is related to the additional kilowatt hours produced by that power plant. Therefore, the additional costs per kilowatt hour are calculated from the additional costs of the power plant.

Figure 6: The impact pathway approach to identifying environmental costs



Source: IER diagram.

In many cases, information is required on the costs arising at a higher aggregation level (e.g. for the total number of power plant sites in one federal Land or for a category of vehicles consisting of different vehicle types). These costs are determined by combining individual site-specific results (e.g. weighted averages). The dependence on the site is methodologically integrated by means of a site classification (e.g. rural, urban and metropolitan areas). For estimates of environmental costs for a certain region or a federal Land, the shares of the different types of sites in the region have to be determined and the results weighted accordingly. Thus it is also possible to calculate the average marginal costs for a federal Land. This is a common method of estimating the environmental costs of power generation.

Figure 7 provides an overview of the environmental costs that can currently be determined using the impact pathway approach for the airborne pathway. Details of the impact analysis

[46] Unless otherwise specified, the term marginal costs is used below to mean quasi-marginal costs.

have been published in the methodological report on ExternE.[47] This list will grow as the knowledge available continues to develop.

The impact pathway method can also be applied to valuing damage arising from transport of the pollutants through soil, ground water and surface water, and also to valuing accident risks such as the risk of injury or death due to traffic, workplace or industrial accidents. At the international level, this approach is currently the preferred one for the valuation of environmental costs. This approach has been operationalized (dispersion and impact models are available, as are monetary values) for many impact pathways (air pollutants, noise, media subdivisions for soil and water), and is suitable for direct application.[48]

Figure 7: Environmental costs that can be determined by means of impact pathway analysis (airborne pathway)

Impact category	Pollutant / Load	Effects
Health damage	Primary and secondary particles, SO_2, O_3, benzene, PAH / benzo[a]pyrene, 1,3-butadiene, arsenic, cadmium, chromium, lead, nickel, radioactive substances, other carcinogenic substances Cadmium, lead Noise	**Inhalation:** Reduced life expectancy due to short-term and long-term exposure, other health effects (e.g. respiratory disease, heart disease, cancer) **Ingestion** Reduced life expectancy due to long-term exposure, other health effects
Damage to materials	SO_2, acid deposition Primary particles	Corrosion of building materials Soiling of buildings
Changes in agricultural yield	SO_2, O_3 Acid deposition Nitrogen input	Changes in crop yields Additional lime required by soils Reduced fertilizer requirements
Nuisance	Noise	Nuisance effect due to noise

Source: IER diagram.

3.4.2. Standard price approach

For a number of important damage categories, knowledge about the dose-response relationship and/or the monetary values of damage is (still) insufficient to allow damage costs to be calculated with sufficient certainty. In a number of these cases, the standard price approach – as the second-best solution – can and should be used to express environmental impairment in terms of costs. This approach presupposes an existing environmental protection target which has been defined in the context of a decision process, if possible involving the actors affected, and which is accepted and desired by society. It is assumed that the

47 Cf. ExternE Volume 7, Methodology 1998, www.externe.info, and European Commission (2005).
48 For human exposure via the media water and soil and for noise nuisance, cf. Schmid, S. A. (2005) and Bachmann, T. M. (2006), for example.

environmental protection target was defined in the light of the knowledge available about costs and avoided damage, even if such findings may have been available as qualitative knowledge only. This is therefore a method intended to include societal assessments and/or expert judgements in the valuation. The restrictions explained in Section 2.3 should be taken into account.

This approach thus serves to calculate the cost of reducing environmental impairment to a defined target level / standard (costs of achieving the target). These costs of achieving the target can be interpreted as society's willingness to pay (for the reduction of damage) or opportunity costs (cf. remarks in Section 2.3). It is however important to point out that these are not damage costs in the strict sense. Since these costs implicitly result from the agreed objectives, they cannot themselves be used to justify the agreed objectives. However, costs of achieving a target or opportunity costs are at least suitable for giving an idea of the magnitude of the assumed, but not measurable, damage.

The individual steps are as follows:

1.) Selection and substantiation of the environmental protection targets: The target selected should refer to the exposure of a protected asset (human health or environmental media), i.e. to concentrations, deposits, or noise levels.

2.) Identification of efficient packages of measures: It is necessary to examine how the defined environmental target can be achieved in an efficient way (i.e. at the lowest possible cost). The marginal costs of efficient achievement of the objective correspond to the cost of achieving the objective. The monetary values may differ in place (e.g. by federal Länder) and in time.

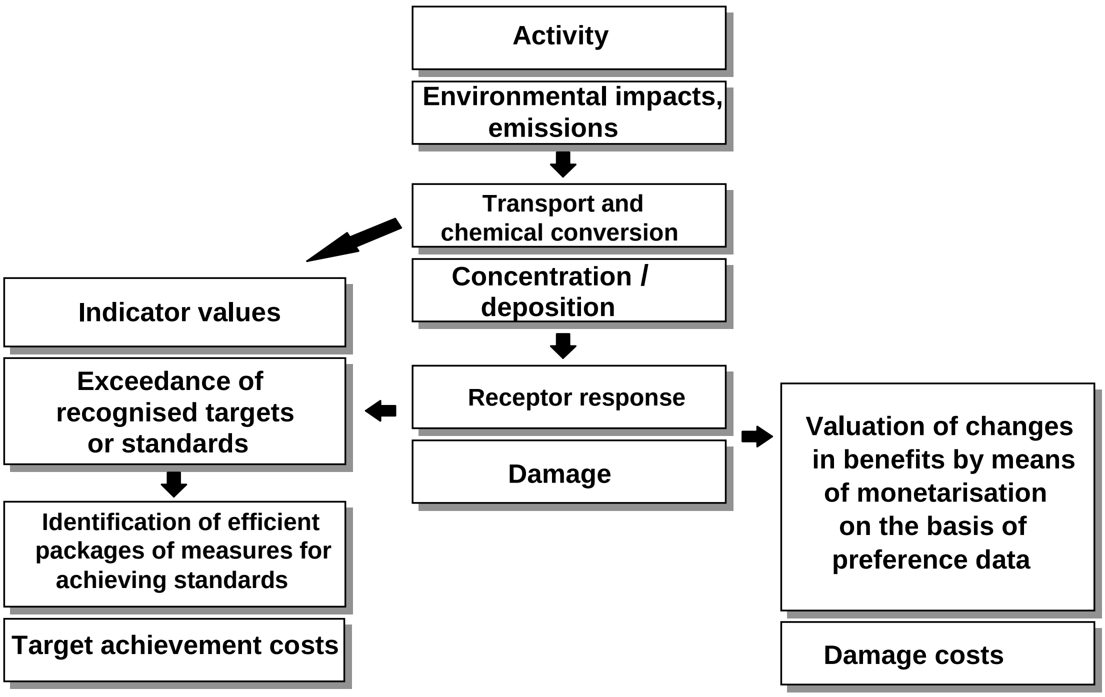
The costs determined using the standard price approach are designed to ensure that the respective environmental target would be just achieved by recovery of these costs. In the context of sensitivity calculations it is of course possible to examine the possible effects of other, e.g. more stringent, environmental quality or environmental action targets on the results obtained.

Currently, fields of application of the standard price approach include valuing the consequences of climate change due to greenhouse gas emissions (above all estimates about compliance with long-term climate protection objectives) and the effects of emissions of substances resulting in acidification and eutrophication of ecosystems.

3.4.3. Extended impact pathway approach: Combination of impact pathway approach and standard price approach

As can be seen from the above explanations, the majority of valuation problems require a combination of the impact pathway approach and the standard price approach. This means that not only damage costs and damage reduction costs, but also the costs of achieving the target are included in the estimate of environmental costs. In the relevant literature, this combination is referred to as the extended impact pathway approach.

Figure 8: The extended impact pathway approach for calculation of environmental costs



Source: IER diagram.

In this approach, the impact pathway from the activity affecting the environment to the damage evaluated in monetary terms (right branch in Figure 8) is followed as far as possible. If not enough is known about the relationship between the activity and the physical damage, aversion costs are calculated according to the standard price approach, as described above (cf. left branch in Figure 8).

3.4.4. Top-down approach for the valuation of health risks

Monetary estimates of environmental damage based on the top-down approach refer to the modelling of macroeconomic relationships between economic activity and environmental pollution.

The approach can be illustrated by taking the example of estimating the environmental costs of power generation from fossil fuels.

Step 1: Establish an inventory of emissions;

Step 2: Identify the share of total emissions that is due to power generation from fossil fuels;

Step 3: Weight emissions using toxicity factors and describe the impacts on the categories to be considered (e.g. flora, fauna, human health, materials, climate);

Step 4: Review the literature or make own estimate for monetary valuation of the damage considered;

Step 5: Estimate the damage costs per kWh for each damage category considered, based on the results of Steps 3 and 4.

Owing to the link between economic activities and emissions, these studies will make it possible to draw conclusions about environmentally relevant changes in pollution loads depending on the level and sources of economic development.

The top-down approach can be used to establish total and average costs, but it is not suitable for determining marginal costs.

3.4.5. Recommendations made by the Methodological Convention for the choice of valuation approach

We recommend giving preference to the impact pathway approach for estimating the marginal costs of use of the environment, provided that sufficient data are available or can be obtained with reasonable effort. For the damage fields of health risks, damage to materials and crop losses caused by air pollutants, accepted calculation methods are available that were developed in the framework of the ExternE project series and have already been applied in a considerable number of valuation studies. These studies have also been used by the World Health Organisation (WHO) as a basis for the valuation of environmental health risks. In the framework of the European research programme, ExternE, the impact pathway approach is undergoing onward development and refining so that results are available that reflect the current state of scientific knowledge.

Application of the standard price approach is recommended as the second-best solution for damage categories for which knowledge about the dose-response relationships and/or monetary values of damage is not (yet) sufficient to calculate external damage costs with a sufficient degree of certainty. This approach requires an environmental protection target (see statements made in Section 2.3). However, the environmental costs calculated using this approach cannot be used to substantiate the selected targets, but only to describe current societal willingness to pay for a reduction in the risk of damage. In the absence of other values, this alternative is still better than not taking account of any costs at all.

We recommend the top-down approach if the analysis concentrates on estimating the environmental costs of an entire sector (e.g. environmental costs of transport, external costs of agriculture).

4 Standardized procedure for economic valuation of environmental damage

The economic valuation of environmental damage is based on knowledge about cause-effect relationships and the description of the detrimental (economic) consequences, in the sense of an impairment of utility that results from the relevant activities. Economic valuation constitutes the last step in the analysis to express the wide range of environmental effects on a uniform basis, i.e. monetary units, thus making them comparable.

Figure 9: Procedure for analysis and valuation of environmental costs

	Valuation steps	
1	Describe the target	
2	Specify the subject of analysis and define system boundaries with regard to ➢ Responsible actors / activities ➢ Sources of environmental impacts ➢ Types of damage to be analysed, environmental impact on protected assets ➢ Regional, temporal, project-related system boundaries etc..	
	Physical impact pathway	Monetary valuation
3	Describe relevant environmental impacts	
4	Describe cause-effect relationships (impact assessment)	
5	Assign to economic utility and cost categories	
6		Perform economic valuation of the resulting changes in utility for humans
7	Describe and interpret results in the context of the target	

Source: Own diagram.

The following sections give a detailed description of the steps in valuation.[49]

[49] Valuation steps 3 to 6 are also contained in the valuation approaches described in Chapter 3. In the impact path approaches used within ExternE the valuation steps are elaborated with the aid of models. This section describes the general procedure, i.e. irrespective of the availability of models.

4.1. Step 1: Describe the target

Explicit description of the target is an important step in the valuation, because the target will dominate the level of detail required for the analysis, the sectors of responsible actors to be selected, the fields of damage and the system boundaries to be chosen.

For the purpose of economic valuation, the focus is on the following targets:

1) Environmental valuation:

The target is to identify all environmentally relevant costs of the options for action to be analysed, in order to measure the environmental impacts of these options in monetary units and make them comparable.
Example: External costs of different power generation systems per kWh.

2) Ecologically extended cost-benefit analysis:

The valuation of environmental damage is one component in the framework of a comprehensive cost-benefit assessment. In the sense of an ecologically extended cost-benefit analysis, an option for action (e.g. an energy-saving investment) is to be classified as favourable if the cost-benefit difference discounted for a certain point in time is positive (taking account of external benefits and costs).

Example: Valuation of environmental effects in the context of the German National Transport Infrastructure Plan

3) Technical substantiation of the design of economic incentive instruments in environmental protection, e.g.:

- Recovery of external costs from responsible actors (environmental taxes, special charges related to environmental protection);
- Rewarding of eco-friendly behaviour shown by responsible actors (environmental subsidies);
- Incentives to reduce the risk of environmental damage in the framework of environmental liability legislation (regulations on liability for environmental damage caused).

4) Substantiation of the need for environmental policy action:

Based on the status quo, an investigation is made of the environmental damage that would occur in the future if no appropriate environmental protection measures were taken today. These costs of inactivity can be used as an argument in favour of measures to improve environmental quality.

Example: Valuation of the cost of disease caused by air pollution in order to justify more stringent limit values.

5) Description of the environmental costs of certain economic activities:

Estimates of activity-specific environmental costs can be used to substantiate action targets for certain sectors. This could for example focus on the share of selected sectors in defined environmental problems over the course of time or on the total environmental damage caused by the respective sector.

Example: Environmental costs of transport, environmental costs of agriculture

A clear description should be given of the target and the resulting priorities of the analysis.

4.2. Step 2: Specify the subject of analysis and define system boundaries

In the second step, the subject of analysis is to be specified in accordance with the target. This is done by selecting the responsible actors and/or activities, the relevant sources of environmental impacts and the relevant protected assets or types of damage that are to be subjected to analysis.

In addition, it is necessary to define system boundaries that serve as a cut-off criterion for identifying responsible actors and activities, sources of environmental impacts, environmental impacts and the environmental damage considered.

Important system boundaries to be defined, with regard to both the sources of environmental impacts and the environmental impacts themselves, include:

- Spatial system boundaries
  The boundaries may follow from the target, e.g. if a valuation has to be made of the environmental costs of energy production in Europe, and/or they may be used as a cut-off criterion.
- System boundaries related to a project, a process or a measure
  In such cases, it is important to state the extent to which upstream and downstream operations are included in the calculation.
- Temporal system boundaries
  These refer to the responsible activity and the damaging effect (e.g. emissions during a calendar year, effects over a period of 100 years).
- System boundaries related to the information available
  Boundaries of an analysis will depend on the availability of data and of knowledge about cause-effect relationships.
- Methodological system boundaries
  This will above all refer to the question of whether damaging effects cannot be included because no appropriate valuation is (yet) available.

When it comes to global and long-term effects, the selection of system boundaries may determine the result of the valuation. One example: In studies performed to establish climate impacts, the periods for which damage is included vary from about 100 to 1000 years. When valuing damage occurring in different countries, some studies use average values while others refer to specific national criteria. Valuations based on specific national criteria may vary considerably, above all between highly developed industrial countries and developing countries. For example, one important question here is whether crop or production losses are evaluated at national prices or at world market prices. Another important question is whether the valuation of reduced life expectancy and increased mortality is the same for all countries or whether specific regional indicators are used.

The definition of system boundaries and the associated assumptions are important information for correct interpretation of the valuation results. Such information should therefore be presented in transparent form.

4.3. Step 3: Describe the relevant environmental impacts

The third step in the framework of valuation of environmental damage is concerned with describing the relevant sources of environmental impacts (e.g. emissions, land use, input of substances into watercourses) and, if applicable, aggregating this information to arrive at environmental pressure indicators (e.g. CO_2 equivalents).

Depending on the subject of the analysis and the target, the sources of environmental impacts are assigned to the responsible actors or activities.

In economic analyses, two types of approach are basically used to assign sources of environmental impacts to responsible actors. These are referred to as the top-down method and the bottom-up method.

The top-down method is based on the modelling of macroeconomic relationships between economic activity and environmental pollution. For this approach, the responsible actors are aggregated into groups (e.g. economic sectors based on the input-output system). Then environmental pressure indicators, e.g. emissions, are assigned to the responsible actors. Thanks to the link between economic activities and emissions, conclusions can be drawn about environmentally relevant changes in environmental pollution loads[50] depending on the level and structure of economic development.

The bottom-up method, on which the impact pathway analysis is also based, tracks the environmental pollution along its physical impact pathway from the source to the receptor and

[50] Initially, the relationship exists only between the sources of environmental impacts and the responsible actors. To be able to make statements about changes in pollution loads in top-down models as well, information is required about the relationship between the source of environmental impacts and the environmental pollution load.

draws conclusions about the changes in utility for humans[51]. This makes the bottom-up method suitable for problems requiring a site-specific valuation of environmental damage.

Figure 10: Examples of industrial sources of environmental impacts

Direct sources of environmental impacts

- Use of renewable resources (e.g. water abstraction)
- Use of non-renewable resources
- Land use (e.g. industrial infrastructure, transport infrastructure areas)
- Direct discharge of sewage into receiving waters
- Noise emissions and impacts
- Emission of air pollutants, odour emissions
- Other emissions (soil)
- Potential risks from storage of substances dangerous to water or posing a fire hazard
- Radiation

Indirect sources of environmental impacts

Upstream and downstream supply and disposal

- Energy supply
    - Emission of air pollutants
    - Use of resources (fossil fuels)
- Water supply
    - Use of renewable resources
- Wastewater management:
    - Discharge of sewage into water bodies
    - Land use for sewage sludge deposits
    - Emission of air pollutants from incineration of sewage sludge
- Waste management:
    - Land use (disposal site / landfill)
    - Emission of air pollutants (incineration)

Upstream and downstream production operations

- Activities of upstream and downstream production operations in accordance with the system boundaries selected

Source: Based on Leitfaden Betriebliche Umweltauswirkungen, UBA (1999), p. 30.

4.4. Step 4: Describe cause-effect relationships (impact assessment)

Impact assessment is the basis of any environmental valuation. Sources of environmental impacts (activities affecting the environment) are described with regard to their impact

[51] The bottom-up method has been methodologically refined in the course of a major EU research project on the external costs of power generation (ExternE). It has also been empirically tested in the context of determining site-related external costs of energy production, including case studies from several EU Member States.

potentials and the adverse effects to be expected. As a rule, both regional and temporal differentiation is meaningful (cf. Figure 11).

Figure 11: Examples of environmental problems and corresponding relevant sources of environmental impacts

Environmental problem	Possible relevant sources
Local level	
Noise problems	Noise emissions
Odour nuisance	Emissions of air pollutants
Soil surface heating	Soil sealing
Fire hazard	Storage of substances posing a fire hazard
Groundwater contamination potential	Storage of substances hazardous to water
Regional level	
Photochemical smog	Emission of volatile organic compounds
Soil acidification	Emission of acidifying air pollutants
Water acidification	Emission of acidifying air pollutants
Eutrophication of soil	Emission of air pollutants causing eutrophication
Eutrophication of water	Inputs of nutrients and oxygen-depleting substances into waters
Toxicity to humans / respiration and food chain	Emission of air pollutants potentially toxic to humans and of pollutants potentially accumulating in the food chain
Terrestrial ecotoxicity	Emission of potentially ecotoxic air pollutants
Aquatic ecotoxicity	Introduction of potentially ecotoxic pollutants into water bodies
Loss of natural habitats	Land take
Supra-regional /global level	
Greenhouse effect	Emission of climate gases
Resource depletion	Utilization of renewable and non-renewable resources
Stratospheric ozone depletion	Emission of ozone-depleting substances
Nuisance due to traffic noise	Traffic volume
Landscape fragmentation	Land use (industrial areas, transport)

Source: Based on Leitfaden Betriebliche Umweltauswirkungen, UBA (1999), p. 30.

This Methodological Convention does not deal with assessment and technical description of the cause-effect relationships from the point of view of the natural sciences. The assumptions or models used should be disclosed in order to permit an appropriate interpretation of the valuation results.

4.5. Step 5: Assign to economic utility and cost categories

All effects whose impact chain influences the benefits for economic subjects have to be assigned to economic value categories.

This step constitutes an important link between scientific assessment and economic valuation.

In this process, the following categories may serve as a guide. The groups of subjects affected should be listed as additional subcategories.

(1) Direct impairment of individual benefits, e.g.

- Loss of recreational utility of cultural landscapes or bathing waters;
- Health-damaging effects, e.g. acute cardiovascular disease;
- Impairment of the quality of life, e.g. by noise;
- Damage to private goods, e.g. damage to facades of buildings due to air pollution or damage caused by floods.

(2) Impairment of the production of goods and services, e.g.

- Loss in agricultural yields due to reduced soil productivity;
- Loss in fishery yields due to increased water pollution;
- Loss in forestry yields;
- Increase in production costs due to treatment costs (e.g. cost of water treatment for industrial use);
- Reduced labour productivity due to environment-related illnesses.

(3) Impairments which are not directly allocatable but nevertheless give rise to costs for the entire national economy, e.g.

- Reduction in groundwater recharge rate;
- Reduction in the self-purifying capacity of natural waters;
- Damage to materials of public buildings or monuments;
- Costs of research, development, planning, control and implementation of environmental quality targets and standards.

Depending on the subject to be analysed, non-use values should also be included. This applies above all to the bequest value, which indicates that an intact environment is worth preserving for future generations as well, in the sense of the vision of sustainable development. It is important not to neglect these value categories, especially in the case of environmental damage that is caused today but will result in impairment in a distant future (cf. also Figure 1).

4.6. Step 6: Perform economic valuation

In the sixth step, the disutility resulting from the impairment of the environment is estimated in monetary terms. To this end, the following individual steps should be followed:

1. The impairment of use values resulting from the preceding analytical step has to be assigned to the economic cost or utility categories presented in Figure 4.
2. Depending on the subject investigated, it may be important for economic valuation purposes to know whether quantified environmental quality targets, environmental action targets or environmental standards exist with regard to the sources of environmental impacts considered and/or the environmental impacts themselves. If these targets are used as a yardstick for valuation, they should be described.
3. Appropriate economic valuation methods should be chosen for the cost and benefit categories that are to be estimated. A decision in favour of a particular valuation method should be substantiated by means of specific criteria (cf. Annex A).
4. There are some types of damage that can only be estimated by combining two or more methods. This involves the risk of double counting (overestimation). It is therefore important to check carefully and ensure that the methods applied refer to the valuation of different cost categories[52].
5. The normative assumptions underlying the economic valuation (discounting, handling of risks etc.) should be described and substantiated. For this purpose, the yardsticks described in Section 0 should be applied.
6. We recommend performing sensitivity calculations in order to point out the dependency of the results on the assumptions. The decision as to which specific sensitivities it makes sense to examine can only be made in the context of the analysis (e.g. different discount rates in cases of long-term damage, different risk aversion factors, or different targets where the standard price approach is applied).
7. Depending on the subject of the analysis and the applicability of economic valuation methods, it is also important to point out which types of environmental damage cannot be subjected to economic valuation. The extent of such effects should be described in qualitative terms.

[52] For example, a reduction in soil productivity will result in crop losses in agriculture. The reduction in soil productivity will also be reflected in a loss of value of the arable land. An economic valuation can be performed either by using the added value approach (estimate of the crop loss) or by analysing the development of land prices as a function of soil productivity (hedonic method). However, an aggregation of the two values would result in duplicate counting.

4.7. Step 7: Present and interpret the results

The final step serves to make the estimates transparent. To this end, the results should be presented separately by types of damage, and the different valuation methods underlying the estimates should be explicitly described. In addition, it must be made clear whether the estimates refer to damage reduction costs, costs of unavoided environmental damage or avoidance / opportunity costs. The results should be interpreted in the context of the valuation target.

When interpreting the results, the following aspects should be taken into account:

- Interpretation of results for the purposes of the problem considered;
- Disaggregated presentation of results (by types of damage, groups of responsible actors etc.);
- Assessment of how complete the types of damage covered are in the context of the target;
- Description and qualitative presentation of the effects not subjected to economic valuation;
- Presentation of the yardsticks applied (targets included as a framework for valuation) and of the valuation approach;
- Influence of the assumptions on the result (results of sensitivity analyses, e.g. for different discount rates, for different targets if the standard price approach is applied);
- Description of the variation ranges of estimates, stating confirmed lower limits.

In the interests of transparency, we suggest using standardized forms (Figure 12 and Figure 13).

Figure 12: Form 1: General study data

Title of the study	
Authors, institutions involved	
Published / commissioned by	
Target of the study	
Subject of valuation	
System limits	
Time horizon considered	
Discount rate	
Data sources	
Treatment of risks and uncertainty	
Types of damage assessed in monetary terms	
Types of damage assessed in qualitative terms	
Types of damage not taken into account	
Sensitivity analyses included	
Special characteristics of the study	
Miscellaneous	

Figure 13: Form 2: Damage categories[53]

Damage category	
Valuation approach (impact pathway approach (bottom-up), standard price approach, top-down approach)	
Environmental quality targets, environmental action targets included in the valuation as yardsticks	
System limits	
Sources of environmental impacts	
Assumptions about cause-effect relationships (environmental impacts) / sources of data	
Information about the quantity structure used	
Description of the population affected and of the values taken into account (use values, option benefit etc.)	
Cost categories included in valuation (cf. Figure 4)	
Cost categories not included	
Valuation methods applied (e.g. added value method, valuation of restoration costs, contingent valuation)	
Time horizon	
Discount rate	
Risk aversion included	
Sensitivity analyses performed	
Benefit transfer (transfer of results from other studies) (cf. Annex A)	
Quality testing of the methods applied	
Validity, assessment of completeness of the valuation	
Assumptions about the transfer of results in benefit transfer (cf. Annex A)	
Special characteristics of the study	
Miscellaneous	

[53] If more than one valuation approach is applied, a separate form should be filled in for each approach.

5 Guidelines for selecting methods

5.1. Overview of the main valuation methods

A large number of different valuation methods are available[54] for the valuation of environmental damage.

Valuation by means of market prices may be used for valuing a change in added value (e.g. yield losses in agriculture) and for valuing types of damage that can be wholly or partially reversed by means of appropriate restoration measures. In the latter case, the restoration costs represent only an estimate of the lower limit of the damage.[55] A special case consists in the valuation of compensation and substitution costs. This estimates the costs of market goods which could compensate the damage or serve as a substitute for the function of impaired environmental assets.

Indirect valuation methods calculate the value (or loss in value) of a public good (environmental quality) based on observable market behaviour. In this context the term "indirect" indicates that estimates of the value of non-traded environmental goods are derived from the demand behaviour for goods traded in the market. For example, expenditure on visits to recreational areas makes it possible to draw conclusions for estimating the recreational value.

By contrast, direct valuation methods use special interview techniques to find out direct from the economic subjects their willingness to pay, or their claims for payment of compensation. As a rule, surveys require considerable expenditure in terms of time and money. In most cases, therefore, direct methods are applied only if it is impossible to derive economic valuations indirectly from the market behaviour observed (e.g. option benefit for the preservation of cultural landscapes). By contrast with indirect valuation methods, direct interviews may reveal existence values (e.g. improvement of living conditions for species which will most probably not be experienced by the interviewed persons themselves) and option values (i.e. the preservation of the potential option to experience natural landscapes). Direct valuation methods may therefore serve to estimate both use and non-use values.

The overview below summarises the fields of application of the different valuation methods.

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[54] The methods are described in detail in Annex A.
[55] Cf. Section 3.1.

Figure 14: Fields of application of valuation methods

Valuation method	Main applications
Valuation based on market prices	
Added value methods	Yield losses in agriculture and forestry; Increase in production costs due to impaired environmental quality (increase in water treatment costs, increase in cost of maintaining soil quality).
Estimating costs of reducing damage	Material damage to facades; Noise (costs of noise abatement measures); Costs of medical treatment and loss of income due to environmental diseases.
Costs of compensating for environmental damage	Estimate of costs of market goods as a functional substitute for environmental goods, e.g. costs of technological waste water treatment for the value of the cleansing performance of a reed zone; Compensation of damage to ecological goods in the context of environmental liability; Compensation measures under nature conservation law as an indicator of disutility.
Indirect valuation methods	
Hedonic valuation method	Assessment of the influence of environmental quality on the housing environment.
Expenditure and travel expenses methods	Recreational value of natural landscapes, cost-intensive uses.
Direct valuation methods	
Contingent valuation	Most comprehensive approach for determining willingness to pay for changes in environmental quality, applicable on principle to all cost and utility categories, such as noise (willingness to pay for noise abatement measures); individual disutility due to health risks, reduced life expectancy; Willingness to pay for the preservation of biodiversity, for the conservation of virgin nature.
Conjoint analysis approaches	Fields of application as for contingent analysis, but method is more complicated.

Participatory valuation methods	Applicable to those categories where reference to individual preferences does not serve interest of the target (e.g. because there are large variations in individual willingness to pay, because lack of information plays an important role, or the risks that need valuation can only be decided on by societal consensus).
Valuation by means of avoidance costs and costs of achieving the target	
Avoidance cost approach	Second-best approach to include categories for which knowledge about effects is insufficient, adverse effects are very complex or no confirmed estimates exist yet of the assumed damage (damage to ecosystems, acidification, eutrophication).

5.2. Guidelines for selecting methods

Economic valuation of environmental damage is only of use to environmental policy if the methods of estimation are accepted. From the scientific perspective, there are many arguments in favour of using direct valuation methods (analyses of willingness to pay), the more so since methods have now become available that prevent strategic response behaviour, and quality criteria have been developed for the design of such surveys. However, so far it has been impossible to dispel reservations about the results of such estimates. This aspect is taken into account in the guidelines for selecting methods.

1) As a rule, economic valuation methods quantify only part of the damage. Therefore, economic valuation is aimed at defining confirmed lower limits for the extent of the environmental damage and expressing in monetary terms the resulting economic disutility and subsequent damage.

2) The first thing to be examined in the valuation process is whether it is possible to use methods that are based on (adjusted) market prices: firstly, such methods are less expensive and secondly, their results can be communicated more easily in environmental and economic policy debates. Added value methods, valuations based on damage reduction costs, compensation and substitution methods can be applied in many cases. These methods are valid in cases where damage to market goods has to be evaluated and/or damage can be remedied or compensated by appropriate measures.

3) Methods based on analysing real property prices (hedonic methods) are valid only if a significant relationship exists between the real property prices and environmental quality. For other indirect methods (travelling expenses methods, expenditure methods), it must be

possible to assign the expenses to the value to be estimated. If this is the case, valid lower limits of willingness to pay can be estimated with the aid of these methods.

4) Direct valuation methods can be used for estimates of all cost and benefit categories. For a comprehensive valuation of environmental damage, a combination with market price methods and, if applicable, with indirect methods is often recommended.

5) In economic valuations, climate impacts and health risks often account for the largest share of quantifiable damage. According to the latest findings, these categories account for more than 95 percent of the damage costs relating to power generation.[56] Uniform application of these cost rates can considerably limit the range of variation of estimates, especially when estimating the environmental costs of power generation. The Federal Environment Agency therefore makes recommendations on the application of uniform cost rates (Annex B).

6 Summary

Serious valuation of environmental costs requires

- the use of recognized valuation methods complying with the current state of scientific knowledge;
- the use of valuation yardsticks that are technically substantiated and if possible, identical for all application fields; and
- a transparent description of the assumptions and framework conditions behind the estimates.

In many cases this makes it possible to considerably reduce the range of variation of estimates. In those cases where uncertainty about the extent of damage is very great, the sensitivity of results in relation to the assumptions can be described. These are important prerequisites for using the estimates for political purposes. The Federal Environment Agency's Methodological Convention is intended to make a contribution to achieving this aim.

The essential yardsticks and rules defined in the Convention are summarised below.

Individual preferences as a yardstick for valuation

The Methodological Convention focuses on the valuation of environmentally relevant damage costs. Therefore, individual valuations (preferences) play the central role in the valuation of damage costs. This is why the UBA basically recommends using the individual preferences as a yardstick for the valuation of environmental damage. This is subject to the restriction that the effect to be assessed must influence the benefits for the individuals at the factual, spatial and temporal levels.

[56] Cf. the project series NewExt (http://www.ier.uni-stuttgart.de/forschung/projektwebsites/newext/) and ExternEPol for the EU Commission.

Societal and political evaluations and expert judgements

Societal evaluations (e.g. sustainability objectives) or expert judgements should be used as yardsticks in cases where it is impossible or inappropriate to perform valuation on the basis of individual preferences. Reasons for falling back on expert judgements and societal evaluations may include e.g. inter-generational effects, a high degree of uncertainty or evaluation of damage not directly perceptible by individuals. It is a prerequisite for making a cost estimate that environmental targets exist which serve as a basis for estimating willingness to pay for the reduction in environmental damage. These could be legally enshrined targets (e.g. emission reduction targets in climate protection) or expert judgements. This means that in the event of non-compliance with the targets, the costs of achieving them would serve as a yardstick (societal willingness to pay) for the environmental damage to be valued.

Individual preferences, societal evaluations and expert judgements do not exist as isolated elements but influence each other. The consequences of today's activities can be made clear on the basis of scientific knowledge about the reactive and assimilative capacity of ecological systems. Such knowledge (expert judgements) will influence both the formation of opinions by individuals and the process of intent formation in society and politics. The valuer should assess the targets and yardsticks to be used and substantiate their choice in the context of the objective. In the UBA's opinion, it is of paramount importance to disclose and explain the reasons why certain targets were chosen for the valuation. It is only on this basis that the estimate of external costs can be appropriately interpreted.

Valuation of irreversible damage

For the valuation of irreversible damage, various valuation approaches are suggested by the UBA, depending on the type of damage. If the damage is irreversible but can be compensated for (the loss of function is replaceable), the replacement cost approach should be applied. In economic valuation, this is the standard case. If the consequences of a damage are unknown or knowledge is very uncertain (e.g. loss of a species), the ranges of possible damage should be described and evaluated in monetary terms (analyses of scenarios). If no analyses of possible damage are available, the potential consequences can be described in qualitative terms only.

Valuation in cases of uncertainty and risk

We basically recommend using the expected value of the damage for the valuation of external costs. In the presence of risk aversion among the population, the expected value of the damage represents the lower limit of costs. The risk as well as the arguments indicating risk aversion among the population should be described in qualitative terms and sensitivity calculations performed, taking into account a risk aversion factor.

Valuation of catastrophic risks (Damocles risks)

Catastrophic risks are characterized by the fact that they combine a high damage potential with a very low probability of occurrence. Typical examples include technological risk potentials such as nuclear power plants, large-scale chemical plants, dams and liquid gas tanks. It is necessary to state the variation ranges of the probabilities of occurrence and of the extent of damage, as well as the expected values derived from these. In the case of catastrophic risks, risk aversion among the population has to be taken for granted. Therefore, sensitivity calculations should be carried out taking into account risk aversion. As long as no studies are available for Germany on the levels of aversion factors, the authors suggest applying an aversion factor of 100, based on the results obtained in Switzerland.

Valuation in cases of deep uncertainty (Pythia-type risks)

It is a characteristic of Pythia-type risks that both the probability of occurrence and the dimension of possible damage are deeply uncertain. For precautionary reasons, however, it is justifiable to take measures that reduce the risk of such damage occurring.

It is methodologically impossible to make a monetary valuation of damage arising from risks characterized by a <u>very high degree of uncertainty</u> about their effects and by a lack of estimates of their probability of occurrence and extent of damage. The damage potential associated with such risks should be characterized by the markers of ubiquity, persistence and irreversibility and described in qualitative terms.

Discounting future costs and benefits

For long-term environmental damage, the discount rate selected has a decisive influence on the result: The higher the discount rate, the lower the values of future utility and costs included in the valuation will be.

The Methodological Convention recommends using a standard discount rate of 3 percent for time horizons of up to 20 years, 1.5 percent for longer periods, and performing a sensitivity calculation on the basis of 0 percent.

Recommended valuation approaches

The yardsticks used for valuation are also reflected in the valuation approaches.

In principle we recommend using the <u>impact pathway approach</u> for valuation of environmental costs. This bottom-up approach comprises the impact chain from the activity affecting the environment to the effects on different receptors (humans, animals). A monetary valuation is made for <u>damage</u> and <u>risks</u>. For the damage categories of health risks, damage to materials, and crop losses caused by air pollutants, best practice estimates are available for use.

The standard price approach should be applied as the second-best solution in the case of damage categories for which available knowledge about the dose-response relationships or monetary values of damage is not (yet) sufficient to calculate external damage costs with a sufficient degree of certainty. This approach presupposes an existing environmental protection target which has been defined in the context of a decision process, if possible involving the actors affected, and which is accepted and desired by society. The costs of achieving the target or the avoidance costs must be determined.

Standardised procedure for estimating environmental costs

The procedure for estimation of environmental costs comprises seven valuation steps. These steps should be recorded in detail and the important underlying assumptions explained in a transparent way.

Figure 15: The seven steps in valuation

	Valuation steps	
1	Describe the target	
2	Specify the subject of analysis and system boundaries with regard to ➢ Responsible actors / activities ➢ Sources of environmental impacts ➢ Types of damage to be analysed, environmental impact on subjects of protection ➢ Regional, temporal, project-related system boundaries etc.	
	Physical impact pathway	Monetary valuation
3	Describe relevant environmental impacts	
4	Describe cause-effect relationships (impact assessment)	
5	Assign to economic utility and cost categories	
6		Perform economic valuation of the resulting changes in benefits for humans
7	Describe and interpret results in the context of the target	

Source: Own diagram.

Guidelines for selecting methods

We recommend giving priority to cost estimation methods that are based on (adjusted) market prices because firstly, such methods are less expensive than other instruments and secondly, their results are easier to communicate in environmental and economic policy debates. Added value methods and valuations based on damage reduction costs can be applied in many cases. These methods are valid in cases where damage occurs to market goods and the costs of remedying such damage can be estimated.

Best-practice estimates

The recommendations of the Methodological Convention provide a basis in particular for determining best-practice estimates for energy-related and transport-related environmental costs.[57] We suggest reviewing the recommended values regularly (every three years if possible).

Ensuring transparency

In the opinion of the Federal Environmental Agency, ensuring the transparency of the assumptions underlying the valuation is a central prerequisite for improving the usability of estimates. To this end, the Methodological Convention offers a form that can be used as a standard for all valuation studies. This form shows at a glance the yardsticks incorporated in the valuation and the types of damage included.

Binding nature of the Convention

The Convention is to be used for all future studies performed or commissioned by the Federal Environment Agency. In addition, the suggestions made should also be considered in studies conducted by other government departments.

[57] Cf. Annex B.

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