1 Executive Summary

1.1 Overview of the Methodology

The ExternE methodology provides a framework for transforming impacts that are expressed in different units into a common unit – monetary values. It has the following principal stages:

1) Definition of the activity to be assessed and the background scenario where the activity is embedded. Definition of the important impact categories and externalities.
2) Estimation of the impacts or effects of the activity (in physical units). In general, the impacts allocated to the activity are the difference between the impacts of the scenario with and the scenario without the activity.
3) Monetisation of the impacts, leading to external costs.
4) Assessment of uncertainties, sensitivity analysis.
5) Analysis of the results, drawing of conclusions.

The ExternE methodology aims to cover all relevant (i.e. not negligible) external effects. However, in the current state of knowledge, there are still gaps and uncertainties. The purpose of ongoing research is to cover more effects and thus reduce gaps and in addition refine the methodology to reduce uncertainties. Currently, the following impact categories are included in the methodology and described in detail in this report:

1) Environmental impacts:

Impacts that are caused by releasing either substances (e.g. fine particles) or energy (noise, radiation, heat) into the environmental media: air, soil and water. The methodology used here is the impact pathway approach, which is described in detail in this report.

2) Global warming impacts:

For global warming, two approaches are followed. First, the quantifiable damage is estimated. However, due to large uncertainties and possible gaps, an avoidance cost approach is used as the recommended methodology.

3) Accidents:

Accidents are rare unwanted events in contrast to normal operation. A distinction can be made between impacts to the public and occupational accident risks. Public risks can in principle be assessed by describing the possible accidents, calculating the damage and by multiplying the damage with the probability of the accidents. An issue not yet accounted for here is the valuation so-called 'Damocles' risks, for which high impacts with low probability are seen as more problematic than vice versa, even if the expected value is the same. A method for addressing this risk type has still to be developed.

1.2 The Impact Pathway Approach

The impact pathway approach (IPA) is used to quantify environmental impacts as defined above. As illustrated in Figure 1.1, the principal steps can be grouped as follows:

- Emission: specification of the relevant technologies and pollutants, e.g. kg of oxides of nitrogen (NO_x) per GWh emitted by a power plant at a specific site;
- Dispersion: calculation of increased pollutant concentrations in all affected regions, e.g. incremental concentration of ozone, using models of atmospheric dispersion and chemistry for ozone (O_3) formation due to NO_x ;
- Impact: calculation of the cumulated exposure from the increased concentration, followed by calculation of impacts (damage in physical units) from this exposure using an exposure-response function, e.g. cases of asthma due to this increase in O_3;
- Cost: valuation of these impacts in monetary terms, e.g. multiplication by the monetary value of a case of asthma.

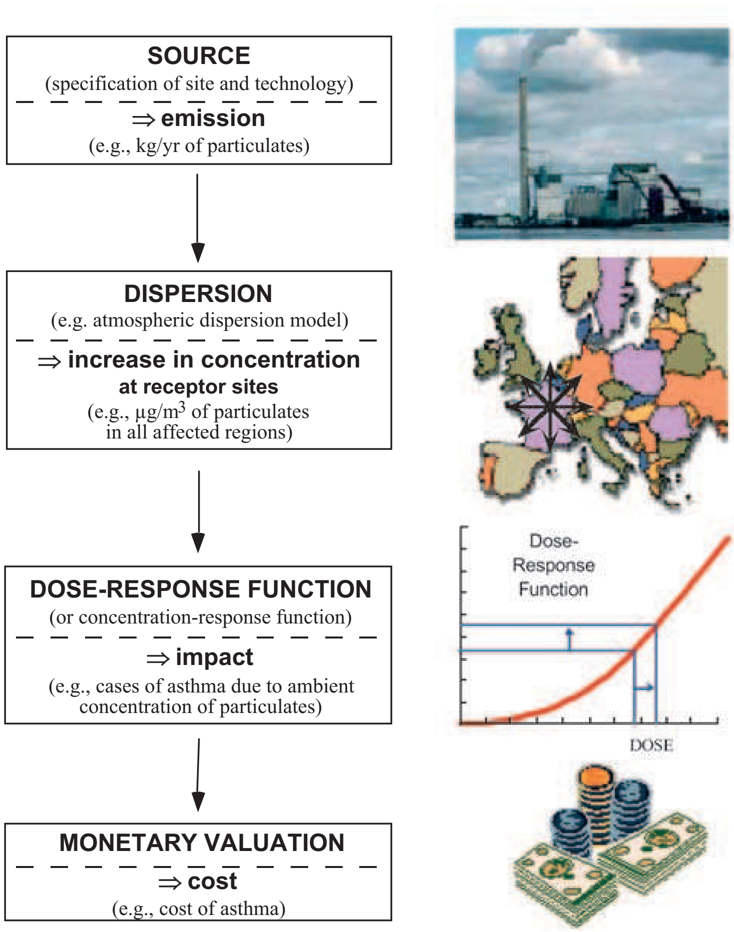

Figure 1.1 The principal steps of an impact pathway analysis, for the example of air pollution.

Whereas only the inhalation dose matters for the classical air pollutants (PM_{10}, NO_x, SO_2 and O_3), toxic metals and persistent organic pollutants also affect us through food and drink. For these a much more complex IPA is required to calculate ingestion doses. Two models were developed for the assessment of external costs due to the emission of the most toxic metals (As, Cd, Cr, Hg, Ni and Pb), as well as certain organic pollutants, in particular dioxins.

Table 1.1 Air pollutants and their effects on health.

Primary Pollutants	Secondary Pollutants	Impacts
Particles (PM_{10}, $PM_{2.5}$, black smoke)		mortality cardio-pulmonary morbidity (cerebrovascular hospital admissions, congestive heart failure, chronic bronchitis, chronic cough in children, lower respiratory symptoms, cough in asthmatics)
SO_2		mortality cardio-pulmonary morbidity (hospitalisation, consultation of doctor, asthma, sick leave, restricted activity)
SO_2	Sulphates	like particles?
NO_x		morbidity?
NO_x	Nitrates	like particles?
NO_x+VOC	Ozone	mortality morbidity (respiratory hospital admissions, restricted activity days, asthma attacks, symptom days)
CO		mortality (congestive heart failure) morbidity (cardio-vascular)
PAH diesel soot, benzene, 1,3-butadiene, dioxins		cancers
As, Cd, Cr-VI, Ni		cancers other morbidity
Hg, Pb		morbidity (neurotoxic)

In terms of costs, health impacts contribute the largest part of the damage estimates of ExternE. A consensus has been emerging among public health experts that air pollution, even at current ambient levels, aggravates morbidity (especially respiratory and cardiovascular diseases) and leads to premature mortality (see Table 1.1). There is less certainty about specific causes, but most recent studies have identified fine particles as a prime culprit; ozone has also been implicated directly. The most important cost comes from chronic mortality due to particles (this term, chosen by analogy with acute and chronic morbidity impacts, indicates that the total or long-term effects of pollution on mortality have been included, in contrast to acute mortality impacts, which are observed within a few days of exposure to pollution).

1.3 Methods for Monetary Valuation

The impact pathway requires an estimation of the impacts in physical terms and then a valuation of these impacts based on the preferences of the individuals affected. This approach has been successfully applied to human health impacts, for example, but in other areas it cannot be fully applied because data on valuation is missing (e.g. acidification and eutrophication of ecosystems) or because estimation of all physical impacts is limited (e.g. global warming).

For these cases, a second best approach is better than having no data. Therefore the use of approaches that elicit implicit values in policy decisions to monetise the impacts of acidification and eutrophication and of global warming has been explored. Table 1.2 gives a general overview of the methods for quantifying and valuing impacts.

Table 1.2 Overview of methods used in ExternE to quantify and value impacts.

	Air pollution			Global warming
	Public health	Agriculture, building materials	Ecosystems	
ExternE, "Classical" impact pathway approach				
Quantification of impacts	Yes	Yes	Yes, critical loads	Yes, partial
Valuation	Willingness to pay (WTP)	market prices		Yes, WTP & market prices
Extension: Valuation based on preferences revealed in				
Political negotiations			UN-ECE; NEC	Implementing Kyoto, EU
Public referenda				Swiss Referenda

Under certain assumptions the costs of achieving the well-specified targets for acidification, eutrophication and global warming can be used to develop shadow prices for pollutants or specific impacts from pollutants. These shadow prices can be used to reflect these effects for comparison of technologies and fuel cycles.

For global warming damage cost estimates of ca. €9/tCO_2 were derived for a medium discount rate. However, this figure is conservative in the sense that only damage that can be estimated with a reasonable certainty is included; for instance impacts such as extended floods and more frequent hurricanes with higher energy density are not taken into account, as there is not enough information about the possible relationship between global warming and these impacts.

Thus, to account for the precautionary principle, we propose to use an avoidance costs approach for the central value. The avoidance costs for reaching the broadly accepted Kyoto target is roughly between €5 and €20 per t of CO_2. In addition it is now possible to analyse the prices of the tradeable CO_2 permits, which increased from end of July 2005 to the beginning of October 2005 from about €18/tCO_2 to about €24/tCO_2. This confirms the use of €19/t CO_2 as a central value. The lower bound is determined by the damage cost approach to about €9/t CO_2.

More stringent reduction targets, e.g. the EU target of limiting global warming to 2°C above pre-industrial temperatures may lead to marginal abatement costs as high as $350/tC = ca. €95/t CO_2. However it is still an open question whether such an ambitious goal with such high costs will be accepted by the general population. Thus, as an intermediate target, the Dutch value of ca. €50/t CO_2 could be used as an upper bound for sensitivity analysis.

In the context of acidification and eutrophication the study shows that a simple analysis may not be correct, i.e. abatement costs for SO_2 and NO_X need to be corrected for other impacts. By analysing the decisions of policy makers in detail, shadow prices for exceedance of critical loads for eutrophication and acidification (ca. €100 per hectare of exceeded area and year with a range of €60 - 350/ha year) have been derived.

1.4 Uncertainties

Damage cost estimates are notorious for their large uncertainties and many people have questioned the usefulness of damage costs. The first reply to this critique is that even an uncertainty by a factor of three is better than infinite uncertainty. Second, in many cases the benefits are either so much larger or so much smaller than the costs that the implication for a decision is clear even in the face of uncertainty. Third, if policy decisions are made without a significant bias in favour of either costs or benefits, some of the resulting decisions will err on the side of costs, others on the side of benefits. Analyses of the consequences of such unbiased errors found a very reassuring result: the extra social cost incurred because of uncertain damage costs (compared to the minimal social cost that one would incur with perfect knowledge) is remarkably small, less than 10 to 20% in most cases even if the damage costs are in error by a factor three. However, without any knowledge of the damage costs, the extra social cost could be very large.

One possibility to explore the uncertainties in the context of specific decisions is to carry out sensitivity analyses and to check whether the decision (e.g. implementation of technology A instead of technology B) changes for different assumptions (e.g. discount rate, costs per tonne of CO_2, valuation of life expectancy loss). It is remarkable that certain conclusions or choices are robust, i.e. do not change over the whole range of possible values of external costs. Furthermore, it can be shown that the ranking of electricity production technologies, for example, with respect to external costs does not change if assumptions are varied. A further option is to explore how much key values have to be modified before conclusions change. It can then be discussed whether the values triggering the change in decision can be considered realistic or probable.

A considerable share of uncertainties is not of a scientific nature (data and model uncertainty) but results from ethical choices (e.g. valuation of lost life years in different regions of the world) and uncertainty about the future. One approach to reduce the range of results arising from different assumptions on discount rates, valuation of mortality, etc. is to reach agreement on (ranges of) key values. Such "conventions for evaluating external costs", resulting from discussion of the underlying issues with relevant social groups or policy makers, help in narrowing the range of costs obtained in sensitivity analyses. This would help to make decision making in concrete situations easier and to focus on the remaining key issues to be solved in a specific situation.