External Costs of Energy – do the Answers Match the Questions?
Looking back at ten years of ExternE

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Abstract

While the claim for 'getting prices right' is quite popular in conceptual policy papers, the implementation of appropriate internalisation strategies is still hampered by a lack of reliable external cost data. Great expectations were set into the ExternE project, a major research programme launched by the European Commission at the beginning of the 90's to provide a scientific basis for the quantification of energy related externalities and to give guidance supporting the design of internalisation measures. After more than a decade of research, the ExternE label became a well recognised standard source for external cost data. Looking back into the ExternE history, the paper pursues how emerging new scientific insights and changing background assumptions affected external cost estimates and related recommendations to policy over time. Based on ExternE results, the usefulness and inherent limitations of external cost estimates for impact categories like climate change or nuclear waste disposal is discussed. The paper also gives examples on how external costs in spite of remaining uncertainties are successfully used to support environmental policy.

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1. Introduction

In the beginning of the 1990s, the European Commission's 5th Environmental Action Programme 'Towards Sustainability' required the integration of the environmental dimension in other policy areas. Policy decisions should take into account the benefits and costs of action and non-action based on the available scientific and technical information. One of the key elements of this Programme was to 'get prices right' and to ensure that environmental externalities are accounted for in market mechanisms.

While the concept of externalities had been established for over half a century in the field of welfare economics, only few studies had considered the evaluation of externalities associated with energy, and those that had, used a very aggregated approach (e.g. Hohmeyer, 1988). To provide appropriate 'scientific and technical information', the European Commission together with the US Department of Energy launched a joint research project to assess the environmental externalities of energy use in 1991. The design of the project reflected the ambitious objectives as well as the multi-disciplinary nature of the task. A large number of researchers of different disciplines joined this attempt of integrating existing but dispersed research results in a coherent framework, including energy engineers, natural scientists, health experts, ecologists, and of course economists. The need for modelling the full 'impact pathway' of pollutants from the power plant stack through their interactions with the environment to a physical measure of impact, and where possible, a monetary valuation of resulting welfare losses forced the participating scientists to develop a common understanding and appropriate interfaces between the relevant scientific areas.

After the first phase of the project, which ran over four years, an operational accounting framework for the assessment of external costs of energy technologies – named ExternE in Europe – was delivered (European Commission, 1995). While at that time the US contribution to the joint effort was stopped, more than 50 teams from 15 countries in Europe participated in follow-up activities on the improvement, dissemination, and application of the ExternE accounting framework (European Commission, 1999). The ExternE label became a recognised 'brand', the scientific quality of the work was well accepted on the international level, national and international organisations got used to referring to ExternE numbers as a standard source for external cost data, and also industry expressed increasing interest in ExternE results (see e.g. Eurelectric, 2001).

The increasing acceptance of the ExternE methodology went along with a considerable broadening of the scope of applications of the methodological framework originally developed for the energy sector: the ExternE method for instance proved to provide useful input into cost-benefit analysis of European environmental policy measures. An attempt was made also to integrate environmental damage costs into green national accounts based on the ExternE methodology (Markandya and Tamborra, 2001), and further developments supported the application of ExternE to the transport sector (Friedrich and Bickel, 2001).

While on the one hand this looks like an impressive success story, some of the key questions which were put on the agenda a decade ago are still left unanswered in spite of continuous research efforts, which strengthened some peoples' doubts in the credibility and usefulness of external cost estimates in general. Although the author shares some of these basic concerns, they should not in general question the achievements from the research activities in the field. However, the open questions underline that care has to be taken to not take external cost estimates out of the given context, and to acknowledge the well known limitations of the concept when coming to policy oriented recommendations based on external cost data.

As there is quite some literature which critically reviews the concept of energy related externalities and the general usefulness of basic framing assumptions on a conceptual level (e.g. Stirling, 1997), the present paper explicitly does not attempt to add on this theoretical discussion. It rather takes a look at the actual numbers coming out of the ExternE work, and tries to put them into an application oriented context. The paper focuses on ExternE results derived for the electricity sector and does not cover the ExternE work on transport related externalities.

2. How robust is robust enough?

While the claim for 'getting the prices right' is quite popular in conceptual policy papers, the implementation of internalisation strategies requires a scientifically sound, robust and comprehensive quantification of external costs to ensure that adequate policy measures are taken. As reliable external cost estimates were not at hand, great expectations were set into some large research programs launched in the late 80's and early 90's in different parts of the world – among them the EC/US joint project on external costs of energy, a forerunner of the European ExternE project. It was expected that these projects provide science based guidance for the design of an environmental tax system, like the electricity tax or CO_2-emission tax discussed at that time at the European level. However, not only an adequate political environment is required to put a nice idea into practice, but science also has to prove that uncertainties are small enough to guarantee the survival of the basic message in the quarrel of different interest groups. As the ambitious task of modelling pollutants from the emission of burdens through their interaction with the environment, their mechanism of effect on ecosystems, and the subsequent economic valuation includes various sources of potentially large uncertainties, the assessment and adequate reporting of uncertainties was a key issue since the very beginning of ExternE (Rabl and Spadaro, 1999). In addition to uncertainties of scientific nature like data uncertainty and model uncertainty, which are amenable to analysis by statistical methods, the assessment of external costs is also subject of uncertainties about policy and ethical choices (e.g. the discount rate for intergenerational costs, the 'Value of Statistical Life') and a lack of knowledge about future conditions. The use of highly aggregated data that are based on such value choices is acceptable only if there is a broad societal consensus supporting basic assumptions.

As unfortunately the actual *validation* of external cost estimates is not possible, some authors (e.g. Krupnick and Burtraw, 1996; Freeman, 1996) carried out an in depth intercomparison of different external cost studies. Such comparison exercises were very helpful to stimulate the scientific discussion, to improve the methodology, and thus to increase the reliability of the results. Rather than comparing results across studies, it is however also very instructive to have a look back into the past of the ExternE project to see how results have changed over time due to new knowledge and changing background assumptions, and what are the related implications for policy making. Some of the most important changes in ExternE assumptions over the last ten years and their implications for the final external cost estimates are summarised in Fig. 1. They are illustrated with the ExternE-based external cost calculation – excluding global warming impacts – for a South-West German coal fired power station.

- Figure 1 -

- Figure 2 -

In the very beginning of ExternE - partly justified with reference to the legal environmental impact assessment procedure - only local impacts that were expected to occur close to the power plant site were assessed, which resulted in external costs that were negligible compared to the private costs of electricity generation. These very first results quickly led to a discussion on whether external costs were relevant at all. However, it was soon obvious that the focus on local scale impacts was completely inappropriate, as a simple conservation of matter consideration shows that the transport of pollutants over long distances is likely to cause significant environmental impacts far from the power plant site. Taking effects from long range transboundary pollution into account resulted in new external cost estimates, which were still far below the generation costs, but large enough to be considered as a significant contribution to the total social costs of power generation.

Emerging evidence from epidemiological studies carried out in the US on the increased mortality risk due to long term low level exposure to fine particles (so called chronic mortality) in the early 1990s (e.g. Pope et al., 1995) was critically reviewed within the ExternE team, as the consequences for the external cost estimates were tremendous. In the first series of ExternE publications (European Commission, 1995) the effect as such was carefully discussed, but it was decided that because of the still very large uncertainties and the controversial scientific discussion the chronic mortality effect should not be included in the 'best estimate' external cost data. However, this position changed soon as the ongoing review process supported the findings from the original studies. External cost estimates jumped up to a level well above the private costs of electricity generation when chronic mortality impacts from fine particles were subsequently considered as sufficiently certain to be included in the assessment. Of course the message from these new findings to policy makers changed dramatically, and as a consequence the ExternE results were critically reviewed by various interest groups.

Within the following intense review and discussion process, the approach of valuing increased mortality risks from air pollution was identified as a potential weak point. The traditional concept of ‘Value of Statistical Life’ (VSL), although commonly used in environmental economics, was considered to be inappropriate in the context of air pollution. Most of the VSL studies rely on data from the work environment or road safety studies, which might not be directly transferable to the air pollution context, because the individual's loss of life expectancy is very different. In ExternE, the concept of ‘Value of Life Year Lost’ was introduced, which basically assigns a willingness to pay (WTP) to the risk of reducing life expectancy rather than to the risk of death (for a more detailed discussion see European Commission, 1999). A major problem is that there is a lack of empirical evidence supporting the new valuation approach, but there are ongoing studies from which we expect new insights within the next years. The new approach for the valuation of health risks brought down again the external cost estimates close to those values published some few years before. The message to the policy maker again changed drastically, leading to conclusions that partly contradicted those given only one or two years before. Some people even considered these methodological changes as a concession to industry interests.

A further reduction of the external cost estimates is explained by the adaptation of dose-response functions for chronic mortality derived from epidemiological studies in the US to the European context (Friedrich and Bickel, 2001). This downscaling was based on a comparison of findings from epidemiological studies on acute mortality impacts in Europe and the US, which in general indicated a lower slope factor in the European studies. Unfortunately, up to now there are no studies on chronic mortality from fine particles available in Europe.

The above example shows that the ExternE accounting framework has taken up rather fast new developments in different scientific areas, and has developed them further, as science further developed. It happened to be that the elements which developed fast were those which had a strong influence on the final results. As changing background assumptions were not always easy to communicate, the strive for providing most up-to-date and high level scientific quality unfortunately did not automatically increase public trust in the reliability of the external cost estimates.

It is difficult to predict to which extent, and into which direction the ongoing research might influence the external cost estimates in the future. Note also that the example given in Figure 1 does not include estimates of global warming damage costs, which would add considerably to the ups and downs. What are the conclusions to be drawn? First of all: we cannot blame the scientists, who explicitly labelled the uncertainties of the best estimates of the total external costs as 'medium confidence', which according to the ExternE nomenclature corresponds to a geometric standard deviation of 4 to 6 (approximately 1.5 orders of magnitude) (Rabl and Spadaro, 1999). The different external cost estimates calculated for the same reference power plant, resulting from a change in perspective with regard to the geographic area to be covered, from new epidemiological insights, and from a new approach towards the monetisation of health impacts, are all well within the indicated range of uncertainty. The problem is that the implications for policy seem to be quite sensitive to changes in the external cost estimates which are much smaller than the indicated level of uncertainty, a fact which suggests that external cost data have to be used very carefully.

It is however important to point out that in spite of the existing uncertainties ExternE results were quite robust with regard to the relative ranking of different electricity generation technologies. Figure 2 clearly shows that even under different background assumptions electricity generation from solid fossil fuels is consistently associated with the highest external costs, while the renewable energy sources cause the lowest externalities. The robustness of this ranking is an important finding of the ExternE study, which implies a clear message to the decision maker.

3. Are the key impacts well covered?

The above discussion points out that external costs are quite sensitive to some basic background assumptions. To further explore the robustness of current external cost estimates, we now reflect on the capability of the ExternE methodology to address the key impact categories that currently dominate the environmental and energy policy discussion:

- For fossil fuels, global climate change is the overwhelming issue which very much dominates current energy and environmental policy. On a regional level, acidification is still a significant problem. In spite of considerable achievements in Europe in cutting down SO_2 and NO_x emissions from fossil power plants, the European Commission had to adjust it's ambitious plans for completely protecting ecosystems in Europe against acidification by introducing a '50%-gap closure' interim target for 2010 (i.e. reducing the area in which critical loads are exceeded by 50%) (European Commission, 1997a). Also the availability of fossil energy sources is emerging again as a critical problem, pushed forward by the sustainability discussion, but also due to increasing concern about energy security (European Commission, 2000). Effects from air pollution on health are also addressed, but are generally not considered as the key impact in the public discussion.

- For nuclear, the potentially large consequences of a beyond design accident, and the long term impacts of radioactive waste are the main drivers that led to decisions for a moratorium or the phasing out of nuclear power in some European countries. The problem of proliferation also remains a critical issue.

- The rapid expansion of renewable energy technologies within the last decade in Europe partly resulted in an increasing opposition in parts of the affected local population because of increasing amenity impacts. Potential impacts on local ecosystem from e.g. hydro plants, offshore windparks or biomass plantations in particular raised objections from green interest groups which traditionally consider renewable technologies as a viable alternative to nuclear power.

To which extent do the external cost values actually reflect these key concerns? In the following sections we briefly review the main impact categories.

Climate change
In the first phase of ExternE, the existing literature on environmental damage costs from greenhouse gas emissions was reviewed. The cost estimates compiled from the literature span a range of several orders of magnitude, and it was concluded that '*all attempts to value these impacts require important normative judgements, and therefore the potential for synthesis or consensus is remote*' (European Commission, 1995). Because of the utter importance, and in spite of this not too encouraging conclusion, a task force for global warming was established in the follow-up ExternE phases. Two models, the Open Framework model (Downing et al., 1996) and the FUND model (Tol, 1995, 1996, 1999), were used for the assessment of marginal costs of climate change emissions. The main problems related to the quantification of climate change damage costs might be summarised as follows:

- Climate change impacts are extremely complex, with a very large number of different physical endpoints affected. The understanding of the related mechanisms of action in many cases is still very poor. The probability of extreme events is difficult to assess. As a consequence, the two models applied in ExternE only cover a time horizon up to the year 2100, which seems to be inappropriate for the assessment of external costs because of the long term nature of the expected effects.

- Following the theoretical foundations of monetisation, climate change impacts are valued at national or regional prices. This may be objectionable for ethical reasons, as – when aggregated – a life lost in Bangladesh counts less than a life lost in Europe. The economic theory of how a decision maker values impacts in other than his/her own country is underdeveloped (Tol and Downing, 2000). In ExternE, Tol and Downing (2000) offer four valuation alternatives (using regional values, world average values, EU values, and quantifying EU impacts only), which result in differences in the marginal costs up to several orders of magnitude.

- Climate change is a long term problem, so that from an economist's perspective discounting is an important issue. Tol and Downing (2000) provide results for three different discount rates (0 %, 1 %, and 3 %). Although the models cover a time horizon of 100 years only, the change in discount rate – depending on the valuation alternative – might even lead to a change in the sign of the aggregated marginal damage costs (short-term benefits might dominate the global estimate when using the 3 % discount rate).

The ongoing research on climate change damage costs certainly provides helpful guidance on potential environmental problems, but it seems that the above cited conclusion from the earlier 1995 ExternE report still holds true. Tol and Downing (2000) explicitly point out that '*the impacts covered by the models used are only a fraction (of unknown size) of all climate change impacts*'. It is thus surprising that ExternE in spite of the comprehensive discussion of the critical issues finally recommends the use of a ‘central estimate’(2.4 €/t CO_2, with a ‘minimum’ value of 0.1 €/t CO_2, and a ‘maximum’ value of 16.4 €/t CO_2; Tol and Downing, 2000). Having in mind that the impact assessment is cut off after 100 years, it seems that the recommendation of a ‘central estimate’ is at least badly misleading.

Acidification
The ExternE methodology does not provide external cost estimates for acidification impacts. The tools developed in ExternE allow the assessment of the change in ecosystem area in which critical loads for acidification are exceeded per unit emission (Krewitt et al., 2001). But as current knowledge does not allow us to quantify the physical impacts on ecosystems resulting from such an exceedance of critical loads, it is obvious that the calculation of related damage costs is not possible. Krewitt (2001) suggested to use abatement costs necessary to achieve the European Commission's target for reducing acidification in Europe, as they indicate society's willingness-to-pay for avoiding the potential, but unknown impacts of acidification. While this 'second best' solution based on the standard-price approach at least helps to make this important impact visible in summary tables, it is of course basically not compatible with the concept of externalities.

Resource depletion
There is a controversial debate on whether at all the consumption of scarce resources leads to external costs, although it is commonly considered as a key indicator in the sustainability discussion. Several studies suggest that – if at all – the externalities resulting from the use of fossil fuels are very small. ExternE made an attempt to estimate energy security externalities in the electricity supply industry. However, the methodology applied did not go far beyond a qualitative discussion. Some first estimates indicated that external costs are probably small, but uncertainties are in the range of several orders of magnitude (European Commission, 1999).

Human health effects
The assessment of health effects from air pollution was a key focus of ExternE, and certainly one of the most successful activities of the project. ExternE quite early pointed out the importance of the exposure to fine particles for human health, an effect which was not necessarily considered as a high priority impact at the project's start ten years ago, which however nowadays is a key air quality criteria covered in most policy documents. The close link of the ExternE team to leading epidemiologists facilitated an intense review and discussion process which resulted in a broad acceptance of the impact assessment methods. A recent workshop organised by the World Health Organization together with ExternE experts underlines the recognition ExternE gained in the scientific community.

However, in spite of the large achievements, also in the field of health impact assessment there are still open questions which should not be ignored when interpreting external cost data. While current results suggest that mortality impacts from exposure to fine particles are a dominating source of external costs, the actual mechanism of impact is not yet well understood. Although epidemiological studies more or less consistently observe a statistical relationship between the mass concentration of fine particles and health effects, we still do not know whether it is the number of particles, their mass concentration, or their chemical composition which is the driving force. For some technologies like gas fired power plants or biomass the largest fraction of external costs result from the emissions of NO_x and the subsequent formation of nitrate aerosols. Although nitrate aerosols are partly soluble and neutral, for impact assessment they are treated like the potentially more harmful particles from other sources. A better understanding of the influence of the particle composition might have a strong influence on the external costs, and thus on the relative ranking of these technologies.

Figure 1 points out also the sensitivity of external costs towards monetary valuation approaches. The discussion on the valuation of mortality risks is quite controversial, offering different alternative ways to go:

- The actual expenditures of public authorities for reducing mortality risks in some European countries are considerably lower than the willingness-to-pay (WTP) suggested by Contingent Valuation studies. A valuation based on such revealed preferences would lead to lower external costs.
- The most recent phase of ExternE (NewExt) performs empirical valuation studies in three European countries, which are expected to support the current ExternE approach which assumes a strong relationship between individuals' WTP for risk reduction and the respective change in life expectancy.
- A study by Rowlatt et al. (1998) for the UK Department of Environment, Transport and the Regions and the Department of Trade and Industry suggests to use a context specific Value of Statistical Life (i.e. different Values of Statistical Life for e.g. road safety and the air pollution context) rather than a Value of Life Year for the valuation of mortality risks from air pollution. Rowlatt et al. (1998) argue that people’s WTP to reduce mortality risks depends upon a great deal more than life span. The length of expected future life span is undoubtedly one factor for determining people’s WTP to reduce the risk of premature death. It appears however to be only one of many factors, and one which over much of people’s life is far from the dominant factor in determining how their WTP to reduce this risk changes with age. Rowlatt et al. (1998) suggest that the WTP for avoiding mortality risks from air pollution is higher than for road accident risks.

We see that the different options offer everything between going up and down. However, in contrast to the climate change problem, even the extreme alternatives provide a fairly reasonable range of uncertainty, which at least provides a good hint on the order of magnitude of health related damage costs from air pollution.

Nuclear: beyond design accidents, and disposal of radioactive waste

The instruments for the assessment of consequences from beyond design accidents in a nuclear power plant are well established, and the message from the use of such models is rather clear and non-ambiguous: the impacts from a single event can be very large, resulting in up to several ten-thousand cases of fatal cancers, and in monetary terms they could amount to billions of Euro. Normalised to the probability of the event, and to the electricity generation over the power plant's lifetime, the expected value of risk (i.e. probability times consequences) is low, a fact which is even robust against uncertainties in the accident probability.

The assessment of impacts from radioactive waste disposal is more difficult. While an actual facility for the disposal of high level radioactive waste does not yet exist, detailed modelling results are available from the assessment of potential disposal sites. Results suggest that the exposure of the public resulting from high level waste disposal is probably very low, but persists over a very long period of time. The validity of this type of assessment for the calculation of external costs has been questioned in ExternE for various reasons (European Commission, 1995a). The maximum possible dose rates resulting from high level waste disposal are expected to occur after several hundred-thousand years. The conditions that exist today will most probably change during this time period in an unknown way, both with respect to parameters determining the collective dose, but also with regard to valuation based on individuals' preferences, so that '*results of the evaluation may be meaningless*' (European Commission, 1995a). In addition, the probability of an 'altered evolution scenario' due to e.g. a change in the hydrogeological regime at the disposal site, or due to direct human intrusion, leading to the corrosion of containers, and leaching of the glass-waste matrix, is unknown.

The application of methods developed in the field of risk assessment and welfare economics suggests relatively low external costs both for beyond design accidents and radioactive waste disposal. However, the applicability of such tools is at least questionable when putting monetary values on effects that occur at a time horizon which is large compared to the short time from Neanderthal man to modern times. It is difficult to bring the external cost estimates in line with some of the key sustainability guidelines. The reversibility of an impact is a strong sustainability criteria which is not necessarily well addressed in the concept of externalities. The disposal of high level radioactive waste certainly ranks bad on the reversibility criteria because of the very long time span to be considered. From the perspective of welfare economics, the use of an even small, but positive discount rate 'awards' the irreversibility of the effect by bringing the monetary value of long term effects practically down to zero.

It is also widely accepted that it is not only the expected value of risk (i.e. probability times consequence) that is important for the valuation of major accidents. The potential consequences from a single incident are also recognised as an important key criteria on it’s own (see e.g. WBGU, 1999). While the approach of explicitly suggesting acceptable risk levels is partly established in environmental policy, ExternE up to now failed to consistently integrate the level of potential consequences as an individual parameter into the valuation framework.

After the publication of the first series of ExternE results in 1995, the fact that the external costs from a badly sited wind turbine (located close to a population centre, thus high externalities due to noise impacts; see European Commission, 1995b) were similar to those from the nuclear fuel chain attracted a great deal of attention and was controversially discussed. This case shows that the aggregated numbers as such do not tell the whole story: even if the external costs happen to be the same, the very different spatial and temporal characteristics of the respective mechanism of impact leads to a quite different valuation when assessed against key sustainability criteria. Noise effects from a wind turbine are very local, with no significant impact outside the immediate locality. And the very day the operation of a wind turbine is stopped, the noise impact is zero, which is different for the long lasting remains of the nuclear fuel chain, with which people have to deal over thousands of years after the shut-down of the power plant.

Impacts on local ecosystems from renewable energy sources

Results from the National Implementation phase of ExternE (European Commission, 1999a), which analysed a broad range of different renewable energy sources at various sites throughout Europe, suggest that external costs from most of the renewable energy technologies are dominated by impacts from life cycle emissions, mainly from energy conversion in upstream processes like component manufacturing or transportation. Although mainly based on engineering science and not biased by valuation problems, even this information needs careful interpretation. In such a case the external costs basically characterise the environmental performance of the underlying energy system and the resource efficiency of the national economy rather than the performance of a specific technology. External costs for the same photovoltaic (PV) application are thus very different when the production of the PV plant is assumed to take place in Germany (with a high share of fossil fuels for electricity generation) or in Switzerland (electricity production mainly from hydro power and nuclear). This strong context dependency in general is not acknowledged when reporting 'technology specific' external costs. In particular when external cost estimates are used to evaluate the role of new technologies in future energy scenarios, the use of life cycle data representing the fuel mix of the current energy system might be misleading. The same is of course true for all future technologies.

However, in most cases the life cycle emissions from the PV, hydro and wind fuel chains are anyway lower than those from the fossil fuel chains, so that air pollution is not the primary concern. Most often the potentially large impacts on local ecosystems (e.g. from small scale run-of-river hydro plants or from offshore windparks in a sensitive marine environment) are much more important than the relative small externalities resulting from airborne emissions. The very site dependent impacts on local ecosystems are difficult to quantify, and monetary valuation might be even more problematic. Navrud et al. (in European Commission, 1995b) showed that the approach of monetisation is nevertheless viable. Using the results from an extensive Environmental Impact Assessment of a specific hydro project in Norway, they carried out a contingent valuation survey to derive monetary values for the expected impacts on local ecosystems. This approach is of course quite resource intensive and in most cases not transferable to other sites.

Assuming good siting practice, the legal requirements as well as the involvement of both public authorities and local interest groups in the siting process are expected to as far as possible avoid significant impacts to the local environment, thus leading to low external costs. However, the low external costs calculated for a specific reference facility as such do not convey the information that potential sites with such relatively low environmental costs might be limited (e.g. suitable areas for offshore windparks in the North Sea).

4. External cost estimates in the policy context

One of the main objectives of ExternE was to quantify the various social costs associated with the production and consumption of electricity from different fuel sources to give science based recommendations on the height of electricity price adders that are required to internalise external effects. Taking into account the points discussed above, this original objective appears to be at least too ambitious. Without cutting down the large achievements that very much improved our understanding of energy related environmental impacts, one can say that ExternE somehow failed to come up with a set of comprehensive and precise external cost data that are sufficiently robust for satisfying the original purpose. However, it is interesting to see how the external cost estimates all the same made their way into European environmental policy.

One of the policy measures which probably comes closest to the original idea are the recent 'Community guidelines on State aid for environmental protection' of the European Commission. The guidelines allow Member States to '*grant operating aid to new plants producing renewable energy that will be calculated on the basis of external costs avoided*' (European Commission, 2001). Member states providing state aid have to provide an assessment of competing energy providers' external costs in order to demonstrate that the aid does genuinely compensate for external costs not covered. The aid granted to a renewable energy producer is however limited to a maximum of 5 €-cent/kWh. On which basis avoided external costs will be quantified remains open, the guidelines require '*a method of calculation that is internationally recognised and has been communicated to the Commission*' (European Commission, 2001).

Taking into account the uncertainties and limitations inherent in the assessment of external costs, the way of dealing with externalities suggested by the European Commission seems to be a pragmatic, but reasonably science-based compromise between the pure theory and the need for policy action under uncertainty. While changing background assumptions resulted in significant changes of the absolute level of external cost estimates, the relative ranking of energy technologies was much more robust, indicating lower external costs for electricity generation from hydro, wind, and in many cases from photovoltaics compared to fossil fuels. Based on the current 'best estimates' from ExternE, the maximum allowance of 5 €-cent/kWh for the renewable energy sources seems to be quite generous. However, due to the limitations discussed above the ExternE estimates for global warming damage costs should be considered as a lower boundary rather than a best estimate, so that it should be questioned whether the 5 €-cent/kWh ceiling is justified at all.

A very successful field of application which was not intended in the beginning of ExternE is the use of the ExternE methodology in the context of cost-benefit analysis of environmental policy measures. The big advantage here is that – in contrast to the calculation of electricity price adders – cost-benefit studies do not necessarily require a comprehensive quantification of *all* external costs. Past experience shows that in many cases the consideration of impact categories like crop losses, material damage or non-fatal health effects is sufficient to show that the benefits from avoided environmental damage compensate the costs for achieving them. The impact assessment methods for these impact categories largely rely on experimental work, and valuation is based on market values, so that uncertainties are much lower than for effects like mortality risks or climate change. ExternE team members have applied the ExternE tools in several policy oriented cost-benefit studies, including e.g. the economic evaluation of the European Commission's draft Incineration Directive (European Commission, 1997), the Large Combustion Plant Directive (Krewitt et al., 1999), the EU strategy to combat acidification (Holland and Krewitt, 1996; Krewitt et al., 1999a), and air quality standards under the EU Air Quality Directive (Olsthoorn et al., 1999). In most cases the ExternE methodology could help to point out the advantages of investments in environmental friendly technologies also from the economic point of view even without considering the more uncertain impact categories.

While ExternE in the beginning aimed at calculating external costs per kWh for different energy conversion technologies, later on there was growing awareness of the fact that specific damage costs per unit of pollutant emitted sometimes are more useful in a policy analysis context, as they do not depend on a specific technology, and thus can be transferred more easily to a broader context. Figures 3 to 5 compare the environmental damage costs quantified for a tonne of SO_2, NO_x and CO_2 against emission taxes that are in place in some of the European countries (European Commission, 2001a). Figures 3 and 4 show that only in

Sweden - because of relatively high taxes imposed on SO_2- and NO_x-emissions on the one hand, and the low specific damage costs on the other hand - the emission taxes do cover the expected environmental damage costs caused by these emissions. The picture is different for CO_2: existing CO_2-taxes are several times higher than the 'central estimate' global warming damage costs reported by ExternE. Just to give an idea of the order of magnitude, Figure 5 also indicates the marginal CO_2-abatement costs for achieving the current European CO_2-reduction targets, which of course very much depend on the energy policy context and vary considerably between countries. It is obvious that there is a huge gap between the ExternE based damage costs and the marginal abatement costs for achieving current reduction targets. The ExternE 'central estimate' of marginal CO_2-damage costs suggests that current CO_2-reduction targets are much too stringent. We want to emphasise again that the ExternE cost estimates cover a time horizon of 100 years only, and are most likely to underestimate the actual damage.

- Figure 3; Figure 4; Figure 5 -

5. Outlook

Do the answers match the questions? Yes, they do – but they are 'only' partial answers, which however is a lot, taking into account the enormous complexity of our environment. The ExternE methodology and related results have been very successfully used in different fields of environmental and energy policy. And even if the uncertainties remain large in some areas, the process of trying to quantify damage costs has led to a far better understanding of environmental impacts. ExternE for instance very much helped to identify and communicate the importance of fine particles emissions for public health.

On the other hand many people have the expectations that external costs are as simple to understand as price tags in a store. It is important to acknowledge both the inherent limitations of the concept of externalities, and the partial character of the information conveyed in the highly aggregated external cost estimates in order to use external costs in environmental policy decisions in an appropriate way. Uncertainties in external cost data are particularly large for key impact categories like global warming or acidification which require immediate countermeasures. Policy decisions need to be taken to react on current environmental pressure without being able to identify a cost-optimal level of intervention. In such a situation decisions should be guided by the precautionary principle rather than waiting for scientific evidence that can prove a cost-optimal strategy. Besides of further improving impact assessment and valuation methods, future work on a theoretical level might help to better understand the partial incongruence between the intended use of external costs and their reality. We might also strive for better linking the large amount of information available at the various stages of the ExternE 'impact pathway' to the multi-dimensional character of actual policy decisions.

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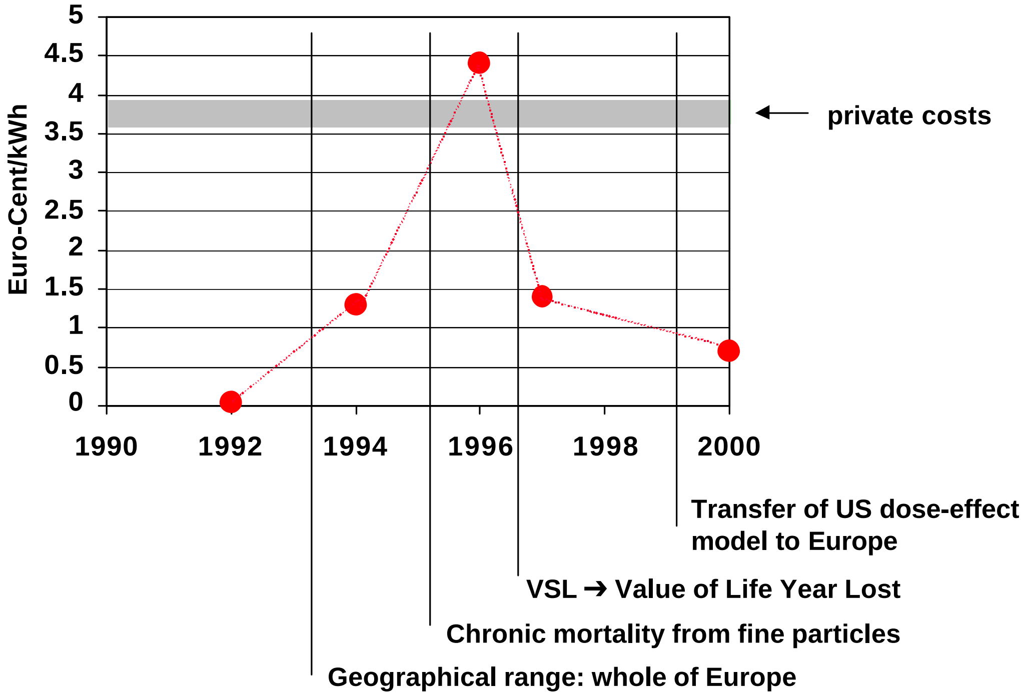

Figure 1: Estimates of external costs (excluding global warming impacts) from a coal fired power plant in Germany under changing methodological assumptions (the technical characteristics of the power plant remain constant)

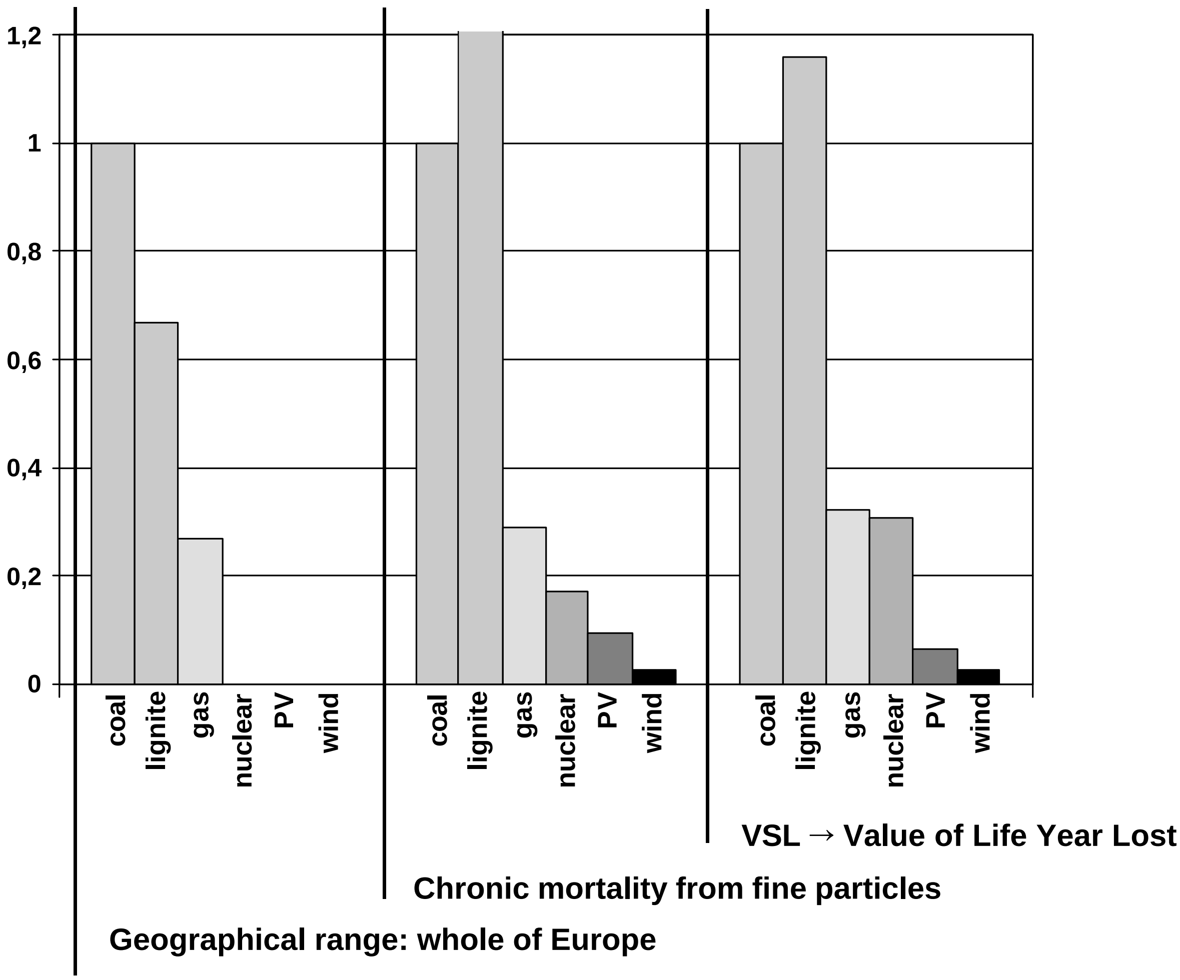

Figure 2: Relative ranking of external cost estimates (excluding global warming impacts) for different electricity generation technologies under changing background assumptions. External costs are normalised to the external costs from the coal fuel cycle (For consistency reasons, only data from the German ExternE case study are used. Not all the technologies were analysed in the first phase of the German ExternE study.)

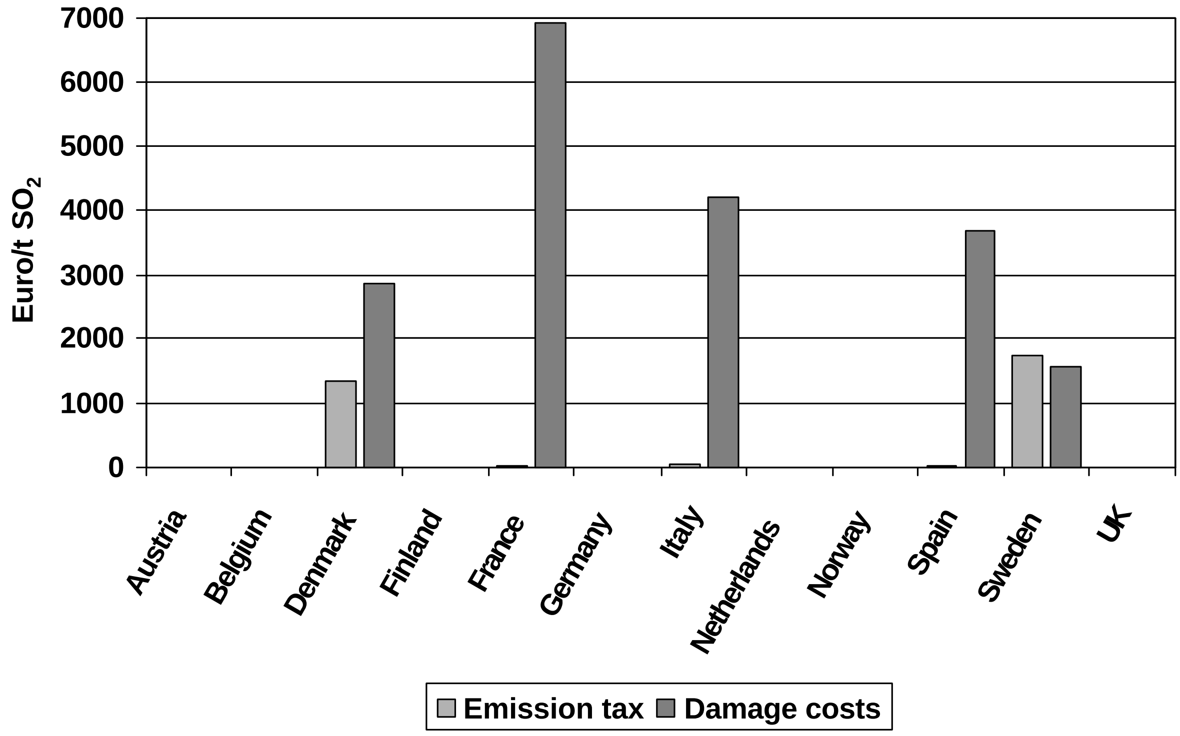

Figure 3: Comparison of ExternE based country specific damage costs from SO_2-emissions and SO_2-emission taxes in European countries

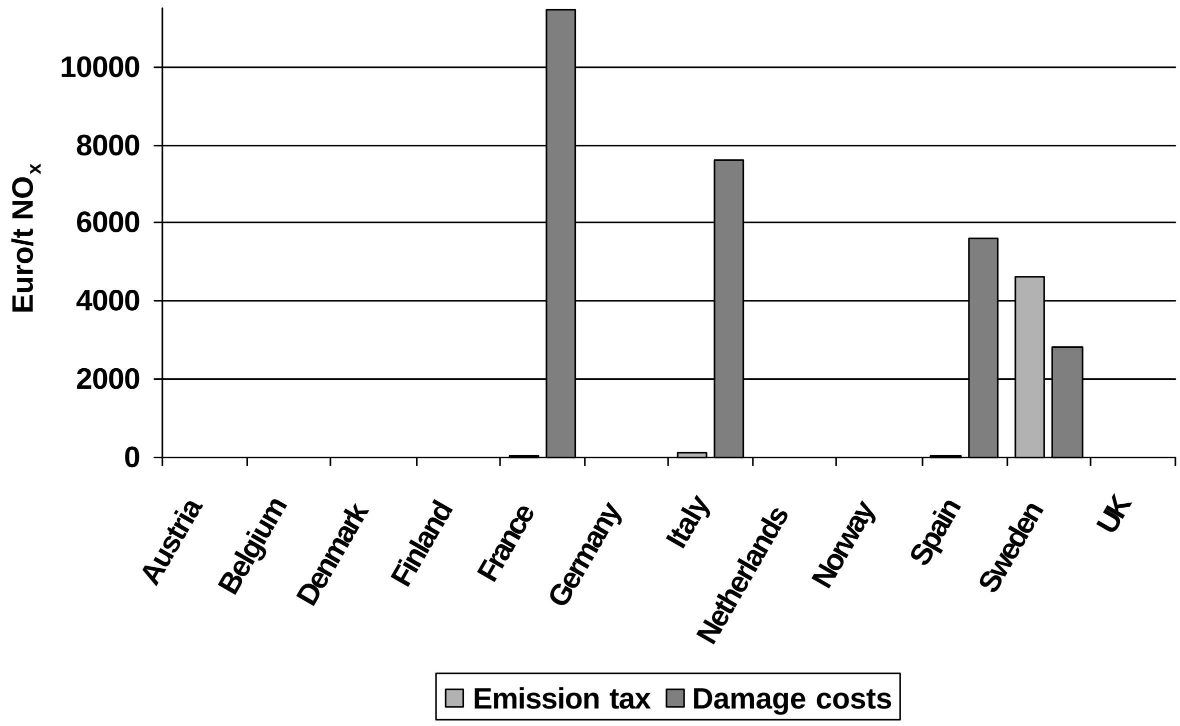

Figure 4: Comparison of ExternE based country specific damage costs from NO_x-emissions and NO_x-emission taxes in European countries

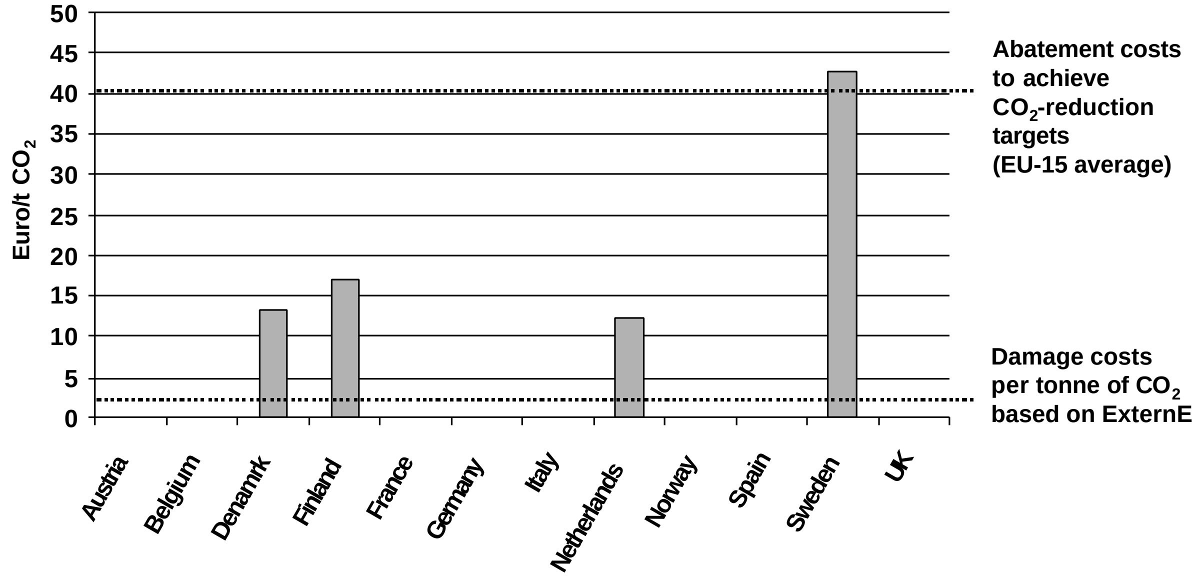

Figure 5: Comparison of ExternE based damage costs for CO_2-emissions, abatement costs for achieving European CO_2-emission targets, and CO_2-taxes in European countries