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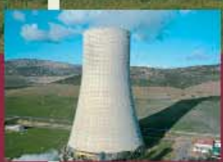
External Costs

Research results on socio-environmental damages due to electricity and transport



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Foreword

European socio-economic research plays a key role in providing policy-makers with a substantiated scientific background. In the field of energy, transport and environment, a scientific and rigorous analysis can help to assess a renewable electricity target, an energy tax, a quantified objective to reduce greenhouse gases emissions, a state aid exception for clean energies or a standard for energy efficiency.

The determination of the external costs caused by energy production and consumption, i.e. the monetary quantification of its socio-environmental damage, goes in the same direction. Indeed, external costs have to be quantified before they can be taken into account and internalised. This is precisely the goal of the ExternE (External costs of Energy) European Research Network active from the beginning of the Nineties. These multidisciplinary teams of researchers adopted a common methodology, conducted case studies throughout Europe and succeeded in presenting robust and validated conclusions.

Within this coherent framework, the ExternE results allowed different fuels and technologies for electricity and transport sectors to be compared. Policy actions could therefore be taken to tax the most damaging fuels and technologies (like oil and coal) or to encourage those with lower socio-environmental cost (such as renewables or nuclear). The internalisation of external costs will also give an impetus to the emergence of clean technologies and new sectors of activity for research-intensive and high added value enterprises.

European citizens want to live in a more sustainable world. The consideration of external costs is one way of re-balancing social and environmental dimensions with purely economic ones. The assessment of "externalities" answers a social demand and European research should help to lay down the basis for improved energy and transport policies.

Philippe Busquin
Member of the European Commission
Responsible for Research

Socio-economic research in the field of energy

Decision-making in energy and environment calls increasingly for a better evaluation of the possible impacts of any envisaged policy and measure such as a renewable electricity target, an energy tax, a quantified objective to reduce greenhouse gases emissions, a voluntary agreement between public authorities and industries, a state aid exception for clean energies, a standard for energy efficiency or an "internalisation of external costs".

Together with "technological" research which includes hundreds of projects aiming at promoting new and clean energy and environment technologies, improving quality of life, boosting growth, competitiveness and employment, "socio-economic research" in the *Energy* programme helps to provide the scientific basis for energy and environment-related policy formulation. In particular by:

- The elaboration of scenarios for energy supply and demand technologies and their interaction, and the analysis of cost effectiveness (based on full life cycle costs) and efficiency of all energy sources
- The socio-economic aspects related to energy within the perspective of sustainable development (the impact on society, the economy and employment)

The majority of energy socio-economic projects make links between energy and environment and address the issues of natural resources, economic growth and social needs. Both market competition and environmental constraints, top-down and bottom-up approaches are considered.

Three crucial issues have largely been dealt within the 5th RTD Framework Programme with the aim of providing a substantiated scientific background and evaluation tools for energy and environment policies formulation:

- The Energy-Economy-Environment *models*, which explore different scenarios and give quantified information on potential future actions: the consequences of a given CO_2 target, the cost-effectiveness of such a technology, etc.
- The *climate change* issue and particularly, beyond the purely scientific problems, the socio-economic impacts of the policies and measures taken: what are the cheapest options to achieve Kyoto, what are the effects of greenhouse gas emission trading, etc.
- The *external cost* evaluation or the measurement of socio-environmental damages provoked by energy production and consumption: what damages should be included, what methodology should be used, which comparisons could be made among technologies, etc.

Energy socio-economic activities in the 6th RTD Framework Programme (2002-2006) will give researchers the possibility of improving the assessment of external costs (emerging technologies, adaptation of the methodology, case studies in the Accession Countries, new developments in traditional technologies) and "externalities" in the broad sense (also including questions on job creation and security of energy supply).

Pablo Fernández Ruiz
Director
Research actions for energy

Definition of External Costs

The scope of the ExternE Project has been to value the external costs, i.e. the major impacts coming from the production and consumption of energy-related activities such as fuel cycles. An external cost, also known as an externality, arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group. Thus, a power station that generates emissions of SO_2, causing damage to building materials or human health, imposes an external cost. This is because the impact on the owners of the buildings or on those who suffer damage to their health is not taken into account by the generator of the electricity when deciding on the activities causing the damage. In this example, the environmental costs are "external" because, although they are real costs to these members of society, the owner of the power station is not taking them into account when making decisions.

There are several ways of taking account of the cost to the environment and health, i.e. for 'internalising' external costs. One possibility would be via eco-taxes, i.e. by taxing damaging fuels and technologies according to the external costs caused. For example, if the external cost of producing electricity from coal were to be factored into electricity bills, 2-7 eurocents per kWh would have to be added to the current price of electricity in the majority of EU Member States. Another solution would be to encourage or subsidise cleaner technologies thus avoiding socio-environmental costs. The recent Community guidelines on state aid for environmental protection explicitly foresee that EU member states may grant operating aid, calculated on the basis of the external costs avoided, to new plants producing renewable energy. Besides that, in many other widely accepted evaluation methods such as green accounting, life-cycle analysis and technology comparison, the quantitative results of external costs are an important contribution to the overall results.

Another application is the use of external-cost estimates in cost-benefit-analysis. In such an analysis the costs to establish measures to reduce a certain environmental burden are compared with the benefits, i.e. the damage avoided due to this reduction. The value of this can then be calculated with the methods described here.

Damages assessed

Seven major types of damages have been considered. The main categories are human health (fatal and non-fatal effects), effects on crops and materials. Moreover, damages caused by global warming provoked by greenhouse gases have been assessed on a global level within ExternE; however the range of uncertainty is much higher for global warming impacts than for other damages.

In addition to the damage cost estimates, for impacts on ecosystems and global warming, where damage cost estimates show large uncertainty ranges, marginal and total avoidance costs to reach agreed environmental aims are calculated as an alternative second best approach. The costs for ecosystems are based on the political aim of reducing the area in the EU where critical loads are exceeded by 50%. For global warming, a shadow price (i.e. like a virtual taxation) for reaching the Kyoto reduction targets is used.

The following table gives an overview of the health and environmental effects currently included in the analysis (current research aims at constantly enlarging this list).

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External costs of energy and transport: Impact pathways of health and environmental effects included in the analysis

Impact Category	Pollutant / Burden	Effects
Human Health – mortality	PM_{10} [a], SO_2 NOx, O_3	Reduction in life expectancy
	Benzene, Benzo-[a]-pyrene 1,3-butadiene Diesel particles	Cancers
	Noise	Loss of amenity, impact on health
	Accident risk	Fatality risk from traffic and workplace accidents
Human Health – morbidity	PM_{10}, O_3, SO_2	Respiratory hospital admissions
	PM_{10}, O_3	Restricted activity days
	PM_{10}, CO	Congestive heart failure
	Benzene, Benzo-[a]-pyrene 1,3-butadiene Diesel particles	Cancer risk (non-fatal)
	PM_{10}	Cerebro-vascular hospital admissions Cases of chronic bronchitis Cases of chronic cough in children Cough in asthmatics Lower respiratory symptoms
	O_3	Asthma attacks Symptom days
	Noise	Myocardial infarction Angina pectoris Hypertension Sleep disturbance
	Accident risk	Risk of injuries from traffic and workplace accidents
Building Material	SO_2 Acid deposition	Ageing of galvanised steel, limestone, mortar, sand-stone, paint, rendering, and zinc for utilitarian buildings
	Combustion particles	Soiling of buildings
Crops	NO_x, SO_2	Yield change for wheat, barley, rye, oats, potato, sugar beet
	O_3	Yield change for wheat, barley, rye, oats, potato, rice, tobacco, sunflower seed
	Acid deposition	Increased need for liming
Global Warming	CO_2, CH_4, N_2O, N, S	World-wide effects on mortality, morbidity, coastal impacts, agriculture, energy demand, and economic impacts due to temperature change and sea level rise
Amenity losses	Noise	Amenity losses due to noise exposure
Ecosystems	Acid deposition, nitrogen deposition	Acidity and eutrophication (avoidance costs for reducing areas where critical loads are exceeded)

[a] *particles with an aerodynamic diameter < 10 µm, including secondary particles (sulphate and nitrate aerosols)*

ExternE methodology

The impact pathway approach - and coming along with this approach, the EcoSense model, an integrated software tool for environmental impact pathway assessment - was developed within the ExternE project series and represents its core. Impact pathway assessment is a bottom-up-approach in which environmental benefits and costs are estimated by following the pathway from source emissions via quality changes of air, soil and water to physical impacts, before being expressed in monetary benefits and costs. The use of such a detailed bottom-up methodology – in contrast to earlier top-down approaches – is necessary, as external costs are highly site-dependent (cf. local effects of pollutants) and as marginal (and not average) costs have to be calculated. An illustration of the main steps of the impact pathway methodology applied to the consequences of pollutant emissions is shown in the following diagram.

Two emission scenarios are needed for each calculation, one reference scenario and one case scenario. The background concentration of pollutants in the reference scenario is a significant factor for pollutants with non-linear chemistry or non-linear dose-response functions. The estimated difference in the simulated air quality situation between the case and the reference situation is combined with exposure response functions to derive differences in physical impacts on public health, crops and building material. It is important to note, that not only local damages have to be considered – air pollutants are transformed and transported and cause considerable damage hundreds of kilometres away form the source. So local and European wide modelling is required.

Regarding dispersion, with NewExt, not only atmospheric pollution is analysed, but also pollution in water and soil. Human exposure to heavy metals and some important organic substances (e.g. dioxins), which accumulate in water and soil compartments and lead to a significant exposure via the food chain, is represented in further models.

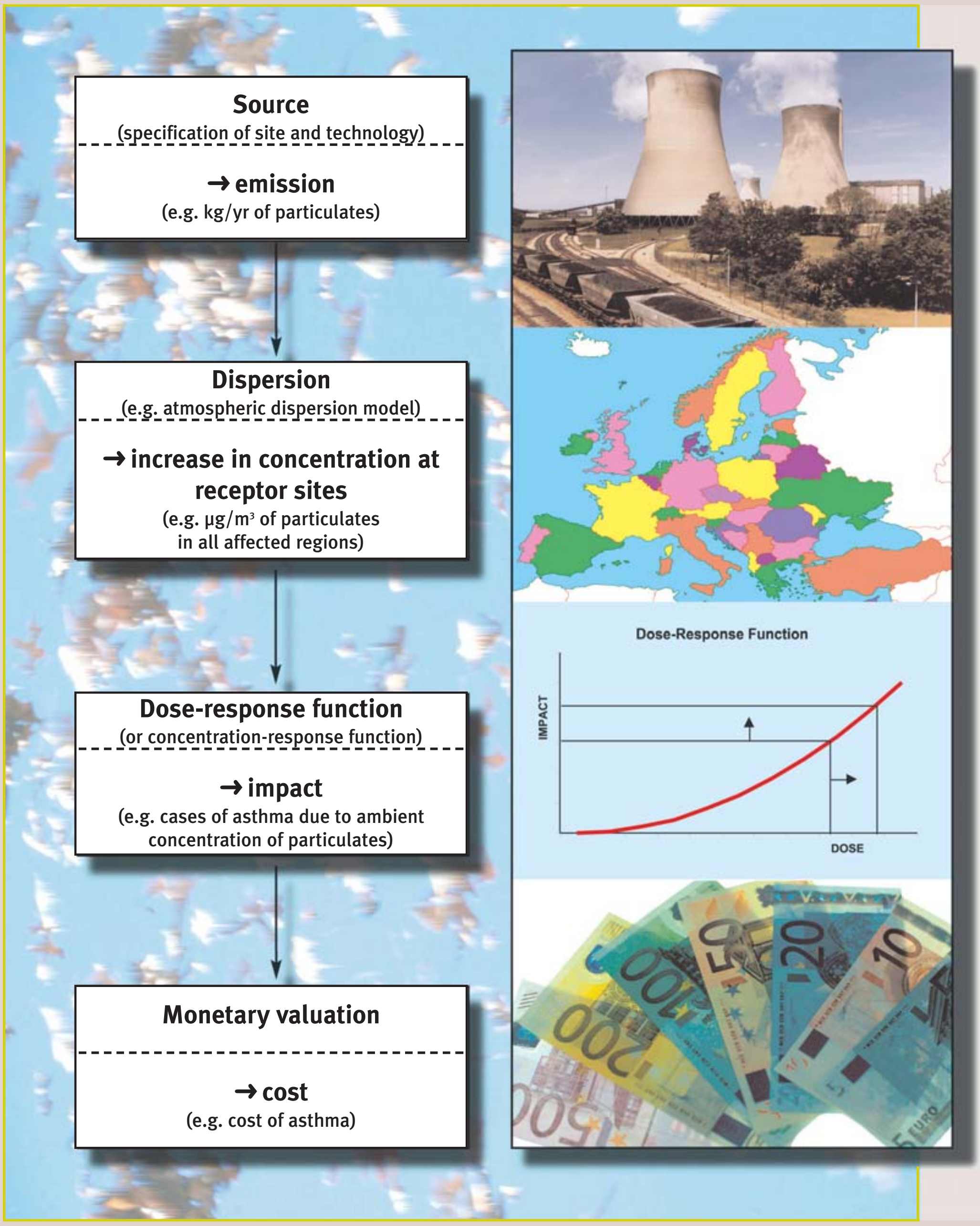
As a next step within the pathway approach, exposure-response models are used to derive physical impacts on the basis of these receptor data and concentration levels of air pollutants. The exposure-response models have been compiled and critically reviewed in ExternE by expert groups.

In the last step of the pathway approach, the physical impacts are evaluated in monetary terms. According to welfare theory, damages represent welfare losses for individuals. For some of the impacts (crops and materials), market prices can be used to evaluate the damages. However, for non-market goods (especially damages to human health), evaluation is only possible on the basis of the willingness-to-pay or willingness-to-accept approach that is based on individual preferences. The monetary values recommended in ExternE by the economic expert group have been derived on the basis of informal meta-analysis (in the case of mortality values) and most recent robust estimates.

In some cases where uncertainty is still large, avoidance costs can be calculated, e.g. for ecosystem damages resulting from acidification or for global warming damages. To complete the external costs accounting framework for environmental themes (acidification and eutrophication) that have not yet been properly addressed but are the main driving force for current environmental policy, a complementary approach for the valuation of such impacts based on the standard-price approach is developed and improved. This procedure deviates from the pure welfare economic paradigm followed in ExternE, but it allows to estimate damage figures for ecological impacts complementary to the existing data on impacts from the same pollutants on public health, materials and crops (based on damage function approach and welfare based valuation studies). The integration of this methodology and data into the existing external costs framework is an important extension as it also covers impact categories that could otherwise not be addressed properly in ExternE. This will again improve the quality and acceptance of the accounting framework.

To perform the calculations, a software package called EcoSense is used. EcoSense provides harmonised air quality and impact assessment models together with a database containing the relevant input data for the whole of Europe.

In general, dependent on the question to be answered, the analysis is not only made for the operation of the technology to be assessed as such, but also including other stages of the life cycle (e.g. construction, dismantling, transport of materials and fuels, fuel life cycle).



Applications

The ExternE methodology has been applied for a large number of European and national studies to give advice for environmental, energy and transport policies.
One of the first objectives of the ExternE programme was to make a comparative evaluation of different technologies and fuel cycles for electricity generation. A decade of research has resulted in detailed set of data for impacts from a wide range of fuels, technologies and locations. They include:

- **Fossil fuels**: coal and oil technologies with varying degrees of flue gas cleaning, natural gas, centralised systems and CHP, orimulsion
- **Nuclear**: PWR, open and closed systems for fuel provision
- **Renewable**: onshore and offshore wind, hydro, a wide range of biomass fuels (waste wood, short rotice, crops) and technologies

The application on transport externalities (road, rail, aircraft and navigation) focused on the specific requirements of emission and dispersion modelling and the extension and update of dose-response functions. In addition to air pollution impacts, those from noise and accidents have been analysed. Besides the estimation of marginal costs of transport, aggregated costs can be calculated, e.g. those which refer to the entire transport sector of European countries. Moreover, several policy case studies and scenarios have been examined in different countries of the European Union, e.g. the use of alternative fuels in city buses or the introduction of electric or CNG-fuelled vehicles.

Besides the different phases of the ExternE project itself, the methodology developed within this project has been used to support a large number of policy decisions and legislative proposals, e.g. of Directorate-General for Environment, such as to perform economic evaluations of the:

- Draft directive on non-hazardous waste incineration
- Large combustion plant directive
- EU strategy to combat acidification
- Costs and benefits of the UN-ECE Multi-pollutant, Multi-effect protocol and of proposals under this protocol (e.g. NO_x and VOC control)
- Costs and benefits for the emission ceilings directive
- Air quality limits for PAHs
- Diversion of PVC from incineration to landfill and recycling
- Benefits of compliance with the EU environmental acquis: quantification of the benefits of air quality improvements
- Costs and benefits of acidification and ground level ozone
- Regulatory appraisal of the SO_2, NO_2 and PM_{10} air quality objectives for UK Department of the Environment, Transport and the Regions
- Air quality guidelines on CO and benzene
- Environmental costs of lorries (a study to incorporate environmental costs in vehicle excise duty rates in UK)
- Second NO_x Protocol (for the UNECE Task Force on economic aspects of abatement strategies)

Moreover, EcoSense has been adapted to other territories in the world, especially for China, Russia, Brazil and Mexico.

For the transport sector, this methodology developed in ExternE is applied in a broader context within the European projects UNITE and RECORDIT.

Fair and efficient pricing of transport infrastructure use is a fundamental aspect of developing a sustainable transport policy that takes account of the full social costs and benefits of transport. The project UNITE (Unification of accounts and marginal costs for transport efficiency) supply policymakers with the framework and state-of-the-art cost estimates to progress this policy. This framework integrates pilot transport accounts for all modes and marginal costs, consistent with public finance economics and the role of transport charging in the European economy.

In RECORDIT (Real cost reduction of door-to-door intermodal transport) a comprehensive methodology is designed and validated for the calculation of real (internal and external) costs of intermodal freight transport and for the understanding of cost formation mechanisms. For selected corridors external costs from direct emissions as well as lifecycle emissions are calculated.

A project called ECOSIT applies the same methodology to the evaluation of several innovative industrial technologies outside the energy and transport sector. The GARP II project and the GREENSENSE project incorporate the methodology into the systems of national accounting.

Comparison of damage costs per kWh for coal, gas, nuclear and wind electricity

A comparative evaluation of fossil, nuclear and renewable fuel cycles reveals a wide range of impacts from a wide range of power generation technologies. Data illustrate that the external costs of electricity generation differ greatly, depending on fuel choice, technology and location. A short overview of some results is shown in order to give an idea of the range of results, the underlying parameters that influence the impacts and the assumptions to take into account for their interpretation.

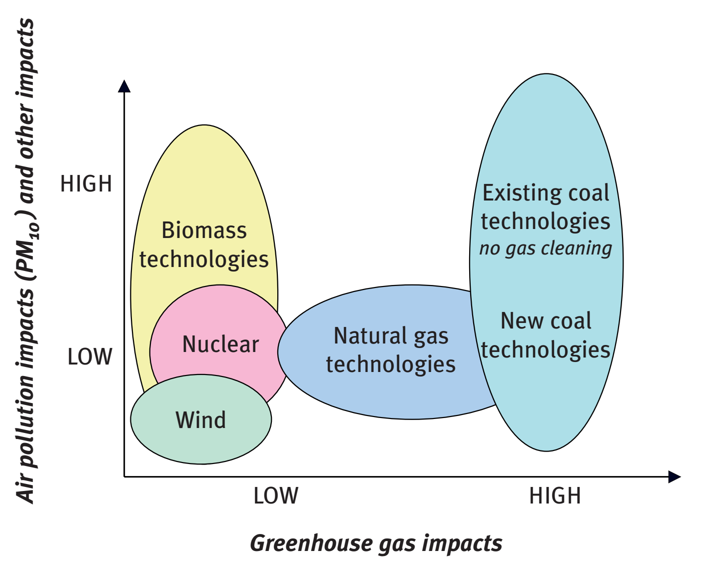
Although the data have been generated with a common methodology, it may be misleading to simply compare the final results because:

- Results are by nature location and technology specific, therefore no simple generalisations are possible
- Only subtotals are available, as not all impacts have been assessed completely
- Assumptions and parameters included in the analysis may be specific for the fuel cycle, technology or location
- Assumptions and parameters have changed over time, reflecting the state of the art at that time

The comparison of results can be described as follows: ExternE methodology has been applied to a wide range of fuels, different technologies and locations. The overall result is somewhat summarised in the picture, though generalisation is not what ExternE is aiming at (in contrast, the site and technology-specificity is one of the most innovating aspects of ExternE). In general, wind technologies are very environmental friendly with respect to emissions of "classical" pollutants (SO_2, NO_X, dust particles) and with respect to greenhouse gas emissions. Wind gets a favourable rating for both impact categories. Not every location is equally suited for wind generation, and hence the variability in external costs due to noise or other amenity impacts. Nuclear power in general generates low external costs, although the very low probability of accidents with very high consequences and the fuel cycle impacts are included. It is also a technology with very low greenhouse gas emissions. There are dozens of different biomass technologies, and depending on the care given on gas cleaning technologies, the biomass options can range from low to high external costs. They generate very low greenhouse gas emissions in their life cycle. Photovoltaics is a very clean technology at the use stage, but has considerable life cycle impacts.

Gas-fired technologies are quite clean, with respect to classical pollutants, but their impact on climate change depends strongly on the efficiency of the technology. Newer combined-cycle technologies can also be categorised as generating average to low greenhouse gas impacts. Coal technologies carry the burden of their very high CO_2 emissions, even for new, more efficient technologies, and in addition cause quite high impacts due to the primary-secondary aerosols. Old coal-fired power plants are also very high emitters of classical pollutants, making them overall the worst available technology. For nuclear, results are presented for a discount rate of 0%. Results for an (alternative) discount rate of 3% are even lower.

For wind energy (one of the more promising renewable technologies to be implemented in some European countries) it should be emphasised that impacts from upstream processes and amenity impacts become important, since no pollutants are emitted during electricity produc-



External cost figures for electricity production in the EU for existing technologies[1] (in € cent per kWh*)

Country	Coal & lignite	Peat	Oil	Gas	Nuclear	Biomass	Hydro	PV	Wind
AT				1-3		2-3	0.1		
BE	4-15			1-2	0.5				
DE	3-6		5-8	1-2	0.2	3		0.6	0.05
DK	4-7			2-3		1			0.1
ES	5-8			1-2		3-5**			0.2
FI	2-4	2-5				1			
FR	7-10		8-11	2-4	0.3	1	1		
GR	5-8		3-5	1		0-0.8	1		0.25
IE	6-8	3-4							
IT			3-6	2-3			0.3		
NL	3-4			1-2	0.7	0.5			
NO				1-2		0.2	0.2		0-0.25
PT	4-7			1-2		1-2	0.03		
SE	2-4					0.3	0-0.7		
UK	4-7		3-5	1-2	0.25	1			0.15

* *sub-total of quantifiable externalities (such as global warming, public health, occupational health, material damage)*
** *biomass co-fired with lignites*

tion by wind turbines. These impacts and costs are calculated using emission databases for steel and concrete production - materials used to build a wind turbine and tower. Impacts from noise are quite low. Impacts from visual intrusion are difficult to value. Both impacts can be minimised through planning and consultation. Impacts on birds and animals are negligible when quantified. Human accidents during construction, or due to collisions on sea, are also very small, but can become relatively important when emissions from the production of materials decrease further.

An important feature of the ExternE results is that they are site-specific. This is expressed in the following table. Note that not all fuel cycles are typically applied in all European countries that took part in the National Implementation phases of ExternE, so several cells are left empty. The spectrum of results for each fuel cycle technology consists both of technological differences and of the different location structure of the receptors affected in the local and regional surroundings of the plant.

The following table points out - exemplified for different selected types of power plants in Germany - the different damage categories that contribute to external costs. In this table, in addition to the damage cost estimates, avoidance costs are given for impacts on ecosystems (acidification and eutrophication) and global warming, where damage cost estimates show large uncertainty ranges. The costs for ecosystems are based on the political aim (as stated in European Commission 1997) of reducing the area in the EU where critical loads are exceeded by 50%. For global warming a shadow price for reaching the Kyoto reduction targets is used. Besides global warming, health impacts is the most important damage category; here especially the reduction of life expectancy due to long term exposure with primary and secondary particles causes the highest damage.

Quantified marginal external costs of electricity production in Germany[2] (in € cent per kWh)

	Coal	Lignite	Gas	Nuclear	PV	Wind	Hydro
Damage costs							
Noise	0	0	0	0	0	0.005	0
Health	0.73	0.99	0.34	0.17	0.45	0.072	0.051
Material	0.015	0.020	0.007	0.002	0.012	0.002	0.001
Crops	0	0	0	0.0008	0	0.0007	0.0002
Total	0.75	1.01	0.35	0.17	0.46	0.08	0.05
Avoidance costs							
Ecosystems	0.20	0.78	0.04	0.05	0.04	0.04	0.03
Global Warming	1.60	2.00	0.73	0.03	0.33	0.04	0.03

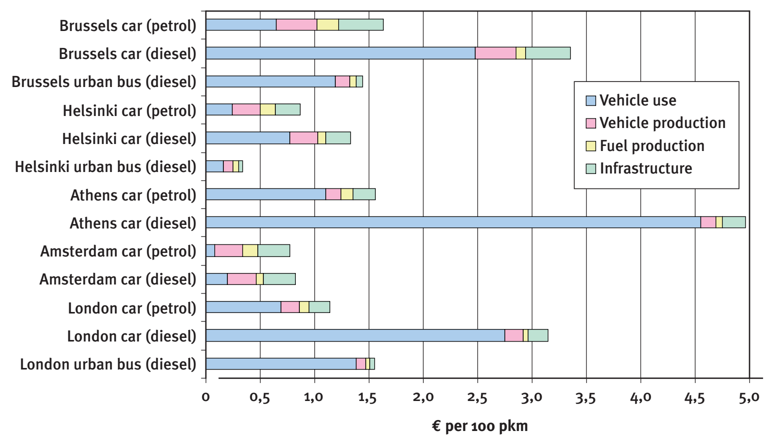
[1] *Global warming is valued with a range of damage cost estimates from € 18-46 per ton of CO_2*

[2] *Median estimates; current technologies; CO_2 emissions are valued with avoidance costs of € 19 per ton of CO_2*

Comparison of damage costs between transport modes

This section presents a comparison of costs for road and rail transport[1]. For this purpose, costs due to vehicle use, vehicle production, fuel production and infrastructure use are included. The costs are related to the load of a vehicle to facilitate comparison between modes. Of course the load factors used are very important for the results.

Air pollution costs due to urban passenger transport [2]



The following figures refer to marginal costs, except the last one, which presents total costs. All marginal costs presented refer to specific locations, illustrating the range of costs in different countries locations. They are not to be interpreted as "typical" values for the respective countries.

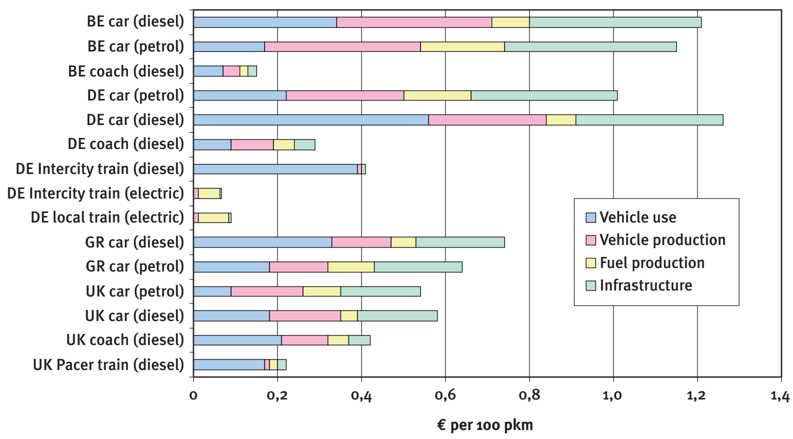
The first figure illustrates the damage costs due to road passenger vehicles in urban areas, which comply with the EUROII emission standard. It is obvious that the costs due to vehicle use dominate the cost and vary considerably between cities. This is mainly caused by different numbers of persons affected by airborne pollutants in the vicinity of the road. Besides the population density the local climate has an important influence on the population exposure, as illustrated by the peak values for Athens.

Petrol cars cause lower costs per passenger kilometre compared to diesel cars, as they emit much less fine particles, leading to lower health impacts. On a passenger kilometre basis urban buses perform better than diesel cars due to their higher number of occupants. But for instance in London, petrol cars cause less specific costs than urban busses.

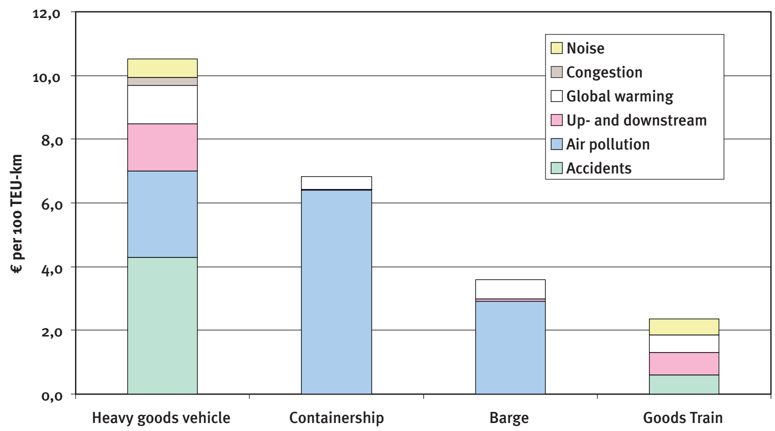
The next figure shows costs due to transport in extra-urban areas. Due to a lower number of people affected close to the road or rail track, the impact of tail pipe emissions is reduced, leading to a lower total per passenger kilometre. As a consequence, emissions from the up- and downstream processes (vehicle and fuel production and infrastructure provision) gain in relative importance. Vehicles of the public transport, i.e. coaches and trains, cause lower costs per passenger kilometre due to the higher number of occupants. Trains with electric traction have no direct emissions; for them, the dominating process is the electricity production. They cause by far the smallest costs; the second best vehicle category is the coach due to its high capacity use.

The range of transport externalities assessed has been extended to impacts due to noise, accidents and congestion. A methodology consistent with the approach for airborne pollutants has been developed. The following figure compares the costs of goods transport between modes exemplarily. Costs are expressed per TEU (Twenty feet equivalent unit) kilometre for a heavy goods vehicle on a motorway in Germany, a containership from Rotterdam to Felixstowe, a barge on the river Rhine from Basle to the Dutch border, and for an electric goods train

Air pollution costs due to extra-urban passenger transport [2]



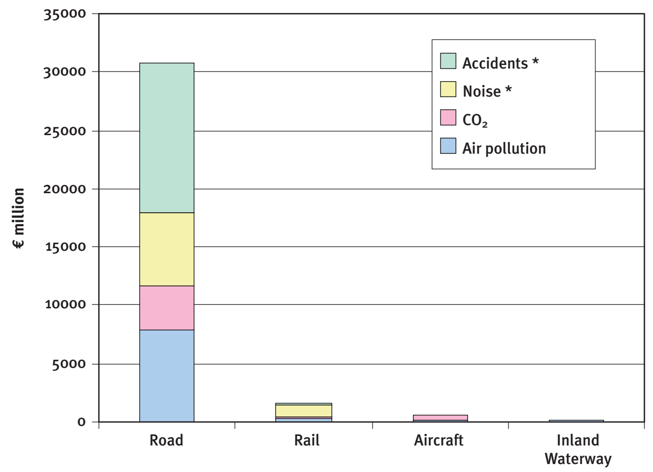
External costs due to goods transport[3]



in Germany. The highest cost per TEU-km is caused by the heavy goods vehicle, mainly due to accident and air pollution costs. The high air pollution costs for the containership are mainly due to the high NO_x emissions. Accident risk and noise impacts are very low for the containtership as well as for the barge. So air pollution and global warming are the dominating cost categories. The goods train considered causes comparably low costs due to airborne pollutants (which are included in the category "up- and downstream"). The total costs split almost equally between the cost categories "accidents", "up- and downstream", "global warming" and "noise". Please note that the costs reflect the specific technologies actually used for the transport task described. Other technologies may cause higher or lower costs.

The method can also be used to generate aggregated values that reflect the damage caused by different transport modes or techniques in a larger area, e.g. a whole country. In the following figure, damage costs due to air pollutants, global warming, accident risks, and noise caused by all transport modes in Germany have been estimated. Quantifiable total costs for the year 1998 amount to ca. €33 billion for the transport sector. This corresponds to 1.7% of that year's gross domestic product. Road transport takes the lion's share; rail, aircraft and inland waterway transport cause much lower costs. In the road transport sector external accident costs are the most important category, followed by air pollution, noise, and global warming. Rail transport shows a good environmental performance except for noise costs, which dominate the result for rail transport.

Quantifiable externalities due to transport in Germany



* accidents and noise only available for road and rail; airborne emissions include direct emissions and emission due to fuel and electricity production; air pollution aircraft: emissions at cruising height not included

1 *Results for airborne pollutants see: Friedrich, R. and Bickel, P. (Eds.): Environmental External Costs of Transport. Springer, Berlin/Heidelberg, 2001*

2 *Road vehicles comply with EUROII standard; pkm = passenger kilometre, BE = Belgium, DE = Germany, GR = Greece, UK = United Kingdom*

3 *Locations see text; TEU = Twenty feet equivalent unit*

Uncertainties and Reliability

The methodology is sometimes criticised by pointing at the – large – uncertainties involved. But before discussing these, one has to distinguish these uncertainties from deviations of current results compared to earlier results as well as from ExternE itself and from other publications. Firstly there has been a substantial methodological development in the last ten years, e.g. from a top-down to a site-dependent bottom-up approach or with regard to the monetary valuation of health effects. Therefore, comparisons should include an analysis of whether the chosen methods are appropriate and state of the art, and whether the studies are complete. Secondly, new knowledge, e.g. about health impacts, of course changes the results. For example, the emerging knowledge that fine particles can cause chronic diseases resulting in a reduction of life expectancy changed the results considerably. An assessment always reflects current knowledge. That an assessment changes with new knowledge – and also may change due to a change in people's preferences – is natural and not a methodological problem.

Individual sources of uncertainty then have to be identified and quantified. It is appropriate to group them into different categories, even though there may be some overlap:

- Data uncertainty, e.g. slope of a dose-response function, cost of a day of restricted activity, and deposition velocity of a pollutant

- Model uncertainty, e.g. assumptions about causal links between a pollutant and a health impact, assumptions about form of a dose-response function (e.g. with or without threshold), and choice of models for atmospheric dispersion and chemistry

- Uncertainty about policy and ethical choices, e.g. discount rate for intergenerational costs, and value of statistical life

- Uncertainty about the future, e.g. the potential for reducing crop losses by the development of more resistant species

- Idiosyncrasies of the analyst, e.g. interpretation of ambiguous or incomplete information

The first two categories (data and model uncertainties) are of a scientific nature and can be analysed by using statistical methods. Results show a geometric standard deviation of ca. 2 to 4 which means that the true value could be 2 to 4 times smaller or larger than the median estimate. The largest uncertainties lie in the exposure-response function for health impacts and the value of a life year lost – current research is directed towards reducing these uncertainties which reflect our limited knowledge.

Furthermore, certain basic assumptions have to be made, e.g. such as the discount rate, the valuation of damage in different parts of the world, the treatment of risks with large impacts or the treatment of gaps in data or scientific knowledge. Here, a sensitivity analysis should be and is carried out demonstrating the impact of different choices on the results. Decisions then would sometimes necessitate a choice of the decision-maker about the assumption to be used for the decision. This would still lead to a decision process that is transparent and, if the same assumptions were used throughout different decisions, these would be consistent with each other. If uncertainties are too large, as currently still is the case for global warming impacts, shadow values could be used as a second best option. Shadow values are inferred from reduction targets or constraints for emissions and estimate the opportunity costs of environmentally harmful activities assuming that a specified reduction target is socially desired.

Despite these uncertainties, the use of the methods described here is seen to be useful, as

- The knowledge of a possible range of the external costs is obviously a better aid for policy decisions than the alternative – having no quantitative information at all

- The relative importance of different impact pathways is identified (e.g. has benzene in street canyons a higher impact on human health as fine particles?)

- The important parameters or key drivers, that cause high external costs, are identified

- The decision making process will become more transparent and comprehensible; a rational discussion of the underlying assumptions and political aims is facilitated

- Areas for priority research will be identified

It is however remarkable that despite these uncertainties certain conclusions or choices are robust, i.e. do not change over the whole range of possible external costs values. Furthermore, it can be shown that the ranking of e.g. electricity production technologies with respect to external costs does not change if assumptions are varied. Thus, the effect of the uncertainty of externalities depends on the application. The key question is: what is the increase in total life cycle cost to society if one makes the wrong choice? A detailed analysis of this question in a specific situation involves the probability distribution of the total social cost for each of the options under consideration, to estimate the expectation value of the social cost or the probability of making the wrong choice.

It should also be noted that gaps can be closed and uncertainties reduced by performing further research, e.g. further contingent valuation studies and epidemiological studies.

Frequently Asked Questions

Can I use the numbers that I have found in ExternE reports for further calculations?

Yes you can, provided you make a clear reference to the source and you are aware of the assumptions made and the uncertainties involved. It is also recommended to check with the author or somebody from the ExternE network whether these are the best and latest data. It has to be noted that there are a lot of other studies that use and build further on the ExternE data (see also the National Implementation Report).

Is external cost information only understandable for economists?

No, external costs are based on a multi-disciplinary approach involving a lot of different scientific disciplines to quantify impacts from emissions and burdens from energy use. These impacts are weighted using monetary values - based on the willingness to pay concept - to reflect the importance of these impacts for society. This information can also be completed with other indicators and used in e.g. a multi-criteria analysis.

Why are the ExternE numbers different from some other scientific sources?

Some numbers may be based on avoidance costs, which is a very different methodology. Most other studies use a top-down approach analysis, which does not fully reflect the marginal cost approach referring to an additional plant or produced unit of electricity at a specific site. Other studies are also based on a kind of impact pathway approach, but may have used other models, assumptions or inputs. Thus a detailed comparison would be required.

Can I compare numbers of the most recent studies with those from older reports?

One has to be prudent in comparing the numbers, because in some areas scientific understanding is changing fast and significantly, and this scientific development is reflected into the ExternE numbers. As a rule of thumb, the most important changes relate to the quantification of public health impacts from pollutants and the quantification of global warming impacts.

Although for some case studies numbers have been upgraded, this is not a general rule, and there is no systematic upgrade of the numbers of older reports. A first short-cut attempt can be made by using new numbers per ton of emissions for the specific sector and country, and emission factors.

Why are ranges of numbers often displayed?

There are two main reasons: to reflect variability in nature, technology, etc. and to reflect uncertainty in our knowledge. However, the ranges do not reflect changes of the results over time due to growing scientific understanding.

Can the numbers be used for policy preparation, even if you only give subtotals and uncertainties are large?

Yes - although not as figures that have the same quality of accuracy as data gathered from the official national accounts. However, external cost data gained from ExternE are useful for a quantitative comparison of magnitude with each other as well as with other data expressed in monetary values, e.g. gross or net domestic products (which is done in “Green Accounting”). Such a comparison represents a trade-off ratio between marketed and non-marketed goods that is based on a consistent (and widely accepted in economic theory) approach of individual preferences and willingness-to-pay.

Numbers have indeed already been used in several policy areas, such as economic evaluations of the draft directive on non-hazardous waste incineration, the Large Combustion Plant Directive, the EU strategy to combat acidification, the National Air Quality Strategy, the Emission Ceilings Directive, proposals under the UNECE multi-pollutant, multi-effect protocol and many more policies, green accounting research projects, and air quality objectives.

Future Research Topics

Extending and Improving the Methodology

Epidemiology

The dose-response functions of ExternE must be updated to take into account the enormous amount of research on air pollution epidemiology in recent years. The assumptions of ExternE about the health effects of the different types of primary and secondary particulate matter should be re-examined.

Atmospheric dispersion

The ExternE models for atmospheric dispersion and chemistry could be improved.

Sound propagation

The models for sound propagation could be validated and improved.

Monetary valuation

New contingent valuation studies are needed to improve the monetary valuation of the dominant contribution to the external costs (loss of life expectancy and chronic bronchitis). For several potentially significant impacts ExternE has not yet been able to calculate reliable damage costs, in particular for acidification and eutrophication, other ecosystem impacts, damage to cultural values, reduced visibility, and impacts of transmission lines.
The difficulties lie not only in the monetary valuation. For ecosystems, the estimation of physical impacts is problematic because the slope of the dose-response functions is needed, whereas so far only thresholds are known. In reality, there are usually no sharp thresholds but a gradual increase of damage with burden. To circumvent these difficulties one can try valuation by experts who would be asked to compare these impacts with the health damage costs that have been quantified.

Validation of the methodology by experts

Experts of the various disciplines involved in an impact pathway analysis could be asked by means of questionnaires to assess the validity of the various assumptions and calculations in their respective field of expertise.

Security of energy supply

The growth of energy demand in recent years, coupled with the current political situation, raises the spectre of new energy shortages. The security of supply implications of different energy technologies should be examined. Other positive externalities like "jobs creation" could also be studied.

Data on traffic accident risks

Costs due to accident risks make a considerable share of the total cost of transport externalities. But available empirical evidence is still comparably poor for some key factors such as the marginal risk caused by an additional vehicle kilometre. These key factors should be further examined to reduce uncertainties in the estimates.

New Applications

New energy technologies

Energy technologies are evolving, and their externalities should be reassessed periodically. Of particular interest would be a life cycle externalities analysis of fuel cells, including the impacts of hydrogen production. A new life cycle externalities analysis is also appropriate for renewables, because the technologies have been improving and their use is expected to increase.

New technologies in the transport sector

Vehicle propulsion technologies are evolving, internal combustion engines are being improved and new systems such as fuel cells and hybrid systems are approaching market maturity. For this reason the externalities should be reassessed. In addition, new transport technologies, e.g. airship-based logistics services, are being developed which should be assessed.

Further economic, especially industrial activities

Several other industrial processes outside of the energy sector cause significant external effects as well, and the potential of new and innovative technologies replacing conventional processes is not only able to reduce factor inputs and thus internal costs, but also external costs. In addition to the singular pilot case studies examined in the ECOSIT project that show the principal application of the ExternE results to further industrial processes, there is a growing need for these companies to have at hand a standardised decision-supporting instrument of its own for all strategic product and process decisions affecting health and environment. Such an instrument is helpful to meet environmental regulations and obligations, but becomes even more inevitable as companies of nearly all branches, e.g. car producers, nowadays are increasingly confronted with a strong awareness of their customers and shareholders regarding political correctness and environmental friendliness of the company and their products.

Transfer of results to policy

External costs can be internalised in a variety of ways, in particular environmental regulations (e.g. limit values for emission of pollutants), taxation or tradable permits. To help policy makers to use the results of ExternE, the implications for the economy should be studied, including distributional effects and taking into account the uncertainties.

Dissemination

Internet tool

The EcoSense software can be made available on the Internet to enable others to carry out their own analysis of externalities.

Stakeholder involvement

Stakeholders (utility industries, policy makers, environmental organisations, consumer groups, etc) will be asked to react to the results of ExternE. Stakeholder involvement will be solicited by workshops and, more efficiently, by electronic communication (Internet site and e-mail).

More information

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Moreover, there is a large network of European and world-wide institutions that apply the methodology of ExternE for national and international policy support.

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Web Pages

http://www.externe.info/
http://externe.jrc.es/ (past phases of ExternE)
http://www.ier.uni-stuttgart.de/newext/ (current phase: NewExt)
http://www.isis-it.com/doc/progetto.asp?id=46 (ECOSIT project)
http://www.its.leeds.ac.uk/projects/unite/index.html (UNITE project)
http://www.recordit.org (RECORDIT project)

Publications

ExternE volumes available on e-mail request:
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- Volume 1: Summary
- Volume 2: Methodology
- Volume 3: Coal and Lignite
- Volume 4: Oil and Gas
- Volume 5: Nuclear
- Volume 6: Wind and Hydro
- Volume 7: Methodology 1998 update
- Volume 8: Global Warming Damages
- Volume 9: Fuel Cycles for Emerging and End-Use Technologies, Transport and Waste
- Volume 10: National Implementation

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From the Earth Summit (Rio, 1992) to the Johannesburg conference (2002), a large step has been taken towards the implementation of sustainable development. In Europe, especially from the Göteborg Council, a strategy has been launched and the internalisation of external costs is becoming one common sustainable point.
The ten years ExternE ("External costs of Energy") socio-economic energy research project (€10 millions of Community funding through the RTD Framework Programmes) has certainly played an important role in the assessment of the health and environmental effects coming from the production and use of energy.
ExternE has not only been useful in terms of "European awareness" about the possibility to quantify - and therefore to internalise - external costs, but particularly to provide a coherent and complete accounting framework for European Union external costs for electricity and, partially, for transport sectors.
The multidisciplinary team of researchers has furnished a common scientifically agreed methodology and made enough case studies to launch a concrete debate on the internalisation of external costs in Europe.

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