EXTERNAL COSTS OF ENERGY CONVERSION - IMPROVEMENT OF THE EXTERNE METHODOLOGY AND ASSESSMENT OF ENERGY-RELATED TRANSPORT EXTERNALITIES

P. Bickel, S. Schmid, W. Krewitt, R. Friedrich

IER, Germany

with contributions from

AEA Technology (‘ETSU’), United Kingdom
IVM, Netherlands
LIEE, Greece
ARMINES, France
EKONO, Finland
VITO, Belgium
DLR, Germany
University of Bath (‘BU’), United Kingdom
ITE, United Kingdom
CIEMAT, Spain
ENCO, Norway
IOM, United Kingdom
EEE, United Kingdom
DNMI, Norway
SCI, Sweden
IPTS, Spain
ECU, United Kingdom

Contract JOS3-CT97-0015

Publishable Report

01 January 1998 to 31 December 1999

Research funded in part by
THE EUROPEAN COMMISSION
in the framework of the
Non Nuclear Energy Programme
JOULE III

EXTERNAL COSTS OF ENERGY CONVERSION - IMPROVEMENT OF THE EXTERNE METHODOLOGY AND ASSESSMENT OF ENERGY-RELATED TRANSPORT EXTERNALITIES

ABSTRACT

Objectives
The supply and use of energy imposes risks and causes damage to a wide range of receptors, including human health, natural ecosystems (flora and fauna) and the built environment. Such damages are to a large extent external costs, as they are not reflected in the market price of energy. In the former stages of the ExternE Project a methodology for externality quantification for energy conversion processes was developed and applied to the sectors electricity generation and transport. Within this project the general methodology was improved and extended. With the improved methodology energy-related transport externalities were assessed.

Technical approach
The *impact pathway approach* is the methodology for externality quantification developed in the ExternE Project. Impacts due to airborne pollutants are quantified modelling emission and dispersion (including chemical transformation processes) of pollutants, leading to changes in ambient air concentrations from which impacts can be quantified using exposure-response functions. The impact pathway approach emphasises the valuation of marginal impacts rather than general perceptions of the state of the whole environment.

In the project the methodology was extended and improved in many fields: climate change models used for estimating global warming impacts have been improved, updated and extended. Knowledge and data on local, regional and global scale ozone were reviewed and provided. Monetary valuation issues were reviewed and possibilities for integrating sustainability indicators into the modelling framework were explored. Exposure-response models were reviewed, updated and extended. Work on the validation of results was undertaken. The issue of dispersion modelling on the kerbside scale was addressed. Tools and data for life cycle impact assessment were provided, and a computer tool for assessing transport-related impacts was developed.

Computer tool and improved methodology were used to extend the accounting framework of transport-related externalities, i.e. external costs were quantified for all modes, for current and future technologies and for various locations in the EU (BE, DE, ES, FI, FR, GR, NL, UK). Location-specific marginal external costs were aggregated for transport in and outside urban areas. The resulting methodology and data were applied in a number of policy case studies.

Expected achievements and exploitation
In the project major remaining issues in the ExternE methodology were addressed and the transport accounting framework and the respective tools are available so that the framework is ready for broad dissemination and application. Hence, the transport accounting framework and tools will support activities on different aggregation levels as e.g.

- assessing transport techniques in different areas (urban or regional transport),
- analysing single European transport tasks in order to compare different transport systems,
- providing a methodology for supporting the application of environmental policy instruments in the transport sector,
- "green accounting" at the national and European levels.

1. PARTNERSHIP

Contractors	Contact person
IER (Coordinator) Universität Stuttgart Heßbrühlstraße 49a D - 70565 Stuttgart	Rainer Friedrich Tel: +49 711 78061-12 Fax: +49 711 7803953 rainer.friedrich@ier.uni-stuttgart.de
AEA Technology plc. Culham, Abingdon Oxfordshire UK - OX14 3DB	Paul Watkiss Tel: +44 1 235 463948 Fax: +44 1 235 463574 paul.watkiss@aeat.co.uk
IVM Vrije Universiteit Amsterdam de Boelelaan 1115 NL - 1081 HV Amsterdam	Kees Dorland Tel: +31 20 444 9555 Fax: +31 20 444 9553 kees.dorland@ivm.vu.nl
LIEE National Technical University of Athens 9, Heroon Polytechniou, Zografou Campus GR - 157 80 Athens	Dionyssis Assimacopoulos Tel: +30 1 772 3218 Fax: +30 1 772 3155 assim@orfeas.chemeng.ntua.gr
ARMINES 60, Bd. Saint-Michel F - 75272 Paris Cedex 06	Ari Rabl Tel: +33 1 4051 9152 Fax: +33 1 4634 2491 rabl@cenerg.ensmp.fr
EKONO Energy Ltd. P.O. Box 27 FI - 00131 Helsinki	Tomas Otterstöm Tel: +358-0-4691329 Fax: +358-04691275 tomas.otterstrom@poyry.fi
VITO Boeretang 200 BE - 2400 Mol	Leo de Nocker Tel: +32-14-33 58 86 Fax: +32-14-32 11 85 denockel@vito.be
DLR, Institut für Physik der Atmosphäre Postfach 1116 D - 82234Weßling	Jutta Graf Tel: +49 815328 2522 Fax: +49 815328 1841 jutta.graf@dlr.de
University of Bath Claverton Down, Bath, BA2 7AY, UK	Anil Markandya Tel: +44-1225-323014 Fax: +44-1225 323423 hssam@bath.ac.uk
Institute of Terrestrial Ecology Merlewood, Grange-over-Sands, Cumbria UK - LA11 6JU	David Howard Tel: +44-15-395-32-264 d.c.howard@ite.ac.uk
CIEMAT Avda. Complutense, 22, Desp 102 ES - 28040 Madrid	Yolanda Lechon Tel: +34-1-346.63.06 Fax: +34-1-346.64.33 lechon@ciemat.es
IPTS Isla de la Cartuja, s/n ES - 41092 Sevilla	Peter Russ Tel: +34-95-44.88.309 Fax: +34-95-44.88.279 peter.russ@jrc.es
DNMI Niels Henrik Ables Vei 40 P.B. 43 Blindern NO - 0313 Oslo	David Simpson Tel: +46-31-460080 Fax: +46-31-482061 david.simpson@dnmi.no

2. OBJECTIVES

The supply and use of energy imposes risks and causes damage to a wide range of receptors, including human health, natural ecosystems (flora and fauna) and the built environment. Such damages are to a large extent external costs, as they are not reflected in the market price of energy. The existence of external effects in the energy and transport sectors may cause welfare losses and a non-optimal allocation of resources, as these effects, e.g. environmental damage, are not adequately considered during the decision making processes.

“Command and Control” legislation for environmental issues have the disadvantage of being less efficient than individual strategies formed by using the market forces to pursue environmental aims. Furthermore, environmental protection is getting more and more expensive. Hence it is necessary to compare the costs of required measures to their benefits in terms of avoided environmental damages to achieve acceptance. So, to optimise welfare by

- identifying 'optimal' levels of environmental quality,
- comparing costs and benefits of measures,
- giving advice on the form and content of instruments, that use market forces to pursue environmental aims (e.g. taxes, price adders, permits, etc.),

the identification, quantification and monetisation of the external effects of the different energy conversion processes is necessary. The need for internalisation of environmental externalities of energy conversion has been addressed in different white papers of the European Commission, e.g. in the White Papers entitled "Growth, competitiveness, employment and ways forward to the 21st century", and "An energy policy for the European Union", or for the transport sector “Fair payment for infrastructure use”.

In the former stages of the ExternE Project a methodology for externality quantification was developed for energy conversion processes (including the electricity generation and the transport sector) - the *impact pathway approach*. Impacts due to airborne pollutants are quantified modelling emission and dispersion (including chemical transformation processes) of pollutants, leading to changes in ambient air concentrations from which impacts can be quantified using exposure-response functions. The impact pathway approach emphasises the valuation of marginal impacts rather than general perceptions of the state of the whole environment. However, the uncertainties in the estimation of external costs of energy conversion from both stationary plants and transport are large; furthermore some issues were not sufficiently solved and new knowledge had to be integrated into the methodology. So, further methodological improvements were necessary.

In the project “ExternE Core/Transport, the output of which is subject of this report the ExternE methodology was extended and improved. So estimates for global warming and ozone impacts were provided which are consistent with the ExternE methodology. Furthermore, new findings on monetary valuation and on dose-response relationships for impacts on human health, ecosystems and materials were incorporated. The methods for analysing the compliance with sustainability indicators (e.g. sustainable thresholds) for impacts which currently cannot be translated into external costs were further developed.

The updated methodology was implemented in a computer tool for the assessment of energy-related transport externalities. Estimates of external costs for new vehicle technologies and fuels as well as for transport modes which could not be covered in detail in the previous project *ExternE Transport* were provided. Marginal external costs were aggregated to levels required by policy instruments and the practical application of the accounting framework was demonstrated in a number of policy case studies. The computer tool allows a standardised and easier application of the methodology.

As this project was part of the JOULE Programme only energy-related effects of transport were investigated (i.e. emissions from combustion processes, but not e.g. accidents, congestion and noise).

Major remaining issues in the ExternE methodology (e.g. global warming and ozone impacts) were addressed in the project and the current scientific knowledge was incorporated. The transport accounting framework and the respective tools were developed so that the framework is ready for broad dissemination and application. Hence, the transport accounting framework and tools supports activities on different aggregation levels as e.g.

- assessing transport techniques in different areas (urban or regional transport),
- analysing single European transport tasks in order to compare different transport systems,
- providing a methodology for supporting the application of environmental policy instruments in the transport sector,
- "green accounting" at the national and European levels.

3. TECHNICAL DESCRIPTION

3.1 Introduction

The supply and use of energy imposes risks and causes damage to a wide range of receptors, including human health, natural ecosystems (flora and fauna) and the built environment. In the former stages of the ExternE Project a methodology for externality quantification for energy conversion processes was developed and applied to the sectors electricity generation and transport.

In the project described in this report, the methodology was extended and improved in many fields: climate change models used for estimating global warming impacts have been improved, updated and extended. Knowledge and data on local, regional and global scale ozone were reviewed and provided. Monetary valuation issues were reviewed and possibilities for incorporating non-monetised impacts into the decision making process were explored. Exposure-response models were reviewed, updated and extended. Work on the validation of results was undertaken. An approach for life cycle impact assessment was provided, and the existing computer tool *EcoSense* was extended for assessing transport-related impacts.

Computer tool and improved methodology were used to extend the accounting framework of transport-related externalities, i.e. external costs were quantified for all modes, for current and future technologies and for various locations in the EU (BE, DE, ES, FI, FR, GR, NL, UK). Location-specific marginal external costs were aggregated for transport in and outside urban areas. Finally, the resulting methodology and data were applied in a number of policy case studies.

3.2 Emission calculation

Comparability of case studies of externalities is an important issue in the context of European policy decision making. In this context, the use of incompatible approaches for emission calculation is an often criticised matter. Therefore it was attempted to avoid the use of national emission factor methodologies as far as possible, and to present a list of reference technologies for road transport, where the same basis was used. A major source of information was the MEET project (**M**ethodologies for **E**stimating Air Pollutant **E**missions from **T**ransport) funded by the European Commission, DG VII, where a set of methodologies for the calculation of emissions had been developed, accepted by most of the European experts. However, in some cases additional sources had to be used in order to cover all priority pollutants and all modes.

3.3 Dispersion modelling

For atmospheric dispersion modelling of non-reactive pollutants on the local scale and non-reactive pollutants and acid species on the regional scale two well established models were applied. The ROADPOL model is a Gaussian line source dispersion model predicting the annual or seasonal average concentrations of pollutants and the population exposure in a range of up to 20 km away from the emission source. Outside this local scale the Windrose Trajectory Model (WTM) is used to estimate the concentration and deposition of primary pollutants and acid species on the European ("regional") scale. The model is a receptor-orientated Lagrangian plume model employing an air parcel with a constant mixing height of 800 m moving with a representative wind speed.

Due to strong non-linearities associated with ozone formation the assessment of the effect of emission changes on ozone concentrations at the local scale is the most difficult problem within atmospheric transport modelling for ExternE. Current literature was reviewed, but no "simple" method is available to include the effects of emission control on local ozone changes into the ExternE framework. On the regional scale, a major problem of previous project phases, the lack of a regional model of ozone formation and transport applicable to the European situation, could be solved. This was possible by using the source-receptor ozone model (SROM) which allows to calculate ozone statistics. The SROM is based on source-receptor relationships from the EMEP MSC-W oxidant model for five years of meteorology.

3.4 Exposure Response Relationships

3.4.1 Impacts on human health

A set of exposure-response (E-R) functions for acute and for chronic health effects of air pollution was provided, both for the 'classical' pollutants (particulate matter, PM; ozone, SO2, NO2, CO) and for cancers. New epidemiological and other studies have illuminated not only exposure-response relationships between ambient air pollution and adverse health, but also possible mechanisms of action. The continuing information brings with it a need to keep under review not only what specific functions might be considered best, but also the strategic judgements which underlie the present quantification of impacts. This has guided the extent that we have attempted to fine-tune the values provided. As a consequence, the E-R functions for chronic mortality (Pope et al., 1995) and chronic bronchitis (Abbey et al., 1995) were scaled down by 30% and 50% compared to ExternE Transport to account for the difference between recent and historical estimates of exposure and the higher particle effects in time series studies in the USA compared to Europe.

The recommended set of E-R functions includes functions for estimating increased mortality due to primary particles, nitrates, sulphates, SO_2, ozone, benzene and diesel particles. Morbidity effects considered include endpoints such as congestive heart failure due to particles and CO, respiratory hospital admissions due to particles, SO_2 and ozone, non-fatal cancer due to benzene and diesel particles, to mention only a few. We are pleased to now have a set of E-R functions which draws heavily on European studies; and to have consolidated the use of life-table methods in estimating mortality impacts from cohort studies.

3.4.2 Impacts on building materials

New dose-response functions are available from ICP Materials, an international exposure programme, describing the degradation of a wide range of materials including metals, stone materials, paint coatings, electric contact materials, glass materials and polymeric materials.

Selected functions from the programme, valid for unsheltered positions, have been adapted and exposure-response functions suitable for inclusion into EcoSense have been derived for limestone, sandstone, zinc/galvanised steel, painted steel and painted galvanised steel. They include SO_2, temperature and relative humidity for quantification of dry deposition effects, and amount and acidity of precipitation for quantification of wet deposition effects.

A critical review of dose-response functions for soiling to materials has been performed including additional analysis on strategies for selecting maintenance intervals. The functions quantify the loss of reflectance in terms of the particulate concentration times time of exposure, i.e. the particulate dose, which means that each exposure-response function can be summarised in the form of a critical dose. No other characteristics of the environment are included in the soiling functions. Critical soiling doses in sheltered conditions have been estimated. Compared to the degradation functions from ICP Materials the uncertainties of these critical doses are high.

3.4.3 Impacts on terrestrial ecosystems

Localised, terrestrial impacts of transport on terrestrial ecosystems were considered. That is where the impacts are concentrated by the use of fixed routes such as roads, rail lines and airports. These impacts can be broadly divided into three different categories:

- Effects on the physical structure of the landscape, such as direct loss of land and habitat fragmentation, of the land used solely for transport
- Effects of management of the transport route and adjacent land, including cutting and clearing vegetation, salting and drainage
- Effects produced by use of the transport system, for example the impacts of atmospheric emissions from the transport vehicles and dispersal of organisms.

As regards the monetary estimates, the established ExternE set of exposure-response functions for crop losses was applied.

3.5 Economic valuation

In the context of economic valuation the methodology was revised as regards the use of the Value of a life year lost (VLYL), the inclusion of new morbidity estimates and endpoints, the valuation of non-marginal changes of costs and the evaluation of non-monetary environmental impacts.

3.5.1 Mortality risks

A simple approach was recommended to estimate the costs of air pollution via mortality for all cases by using VLYLs. The methodological advantages of using a VLYL measure are first that it allows greater flexibility in valuation, and second that it is one that clinicians are more comfortable in estimating in that it brings the WTP approach closer to the QALY approach. In addition, it is more amenable to valuing chronic mortality as it is easier to express chronic impacts in terms of life years lost.

Critics of the VLYL approach have argued that the VLYL approach is invalid because it assumes a constant value of a life year over the remaining lifetime, and the evidence suggests that life year values vary with age (among other factors). It is correct to say that VLYL values should not be constant and independent of age, but that does not make the method invalid. It is perfectly possible to develop values for life years that vary with age, and indeed the simple model presented gives a way of doing so. The other issue raised by critics of the VLYL approach is that it is invalid to add up life years, i.e. saving one life year for two people is not equal to saving two life years for one person. It is correct to say that the adding up of life years cannot be carried out in a simplistic fashion. The value of future years is less than that of present years on account of the discount factor and any application of the VLYL method has to take account of that. As far as adding up values across individuals, there are problems associated with such a procedure but they are no more or less than adding up VOSL (value of a statistical life) values across individuals. Hence in our opinion, the use of VLYL as a measure of risk is both valid and useful as a means of valuing changes in mortality risk.

3.5.2 Morbidity

In the time that has passed since the last Externe Task Report on Economic Valuation there have been three new European projects using the Contingent Valuation (CV) method for valuing morbidity impacts from air pollution, one in Helsinki (Finland), one in Strasbourg (France) and Kehl (Germany), and a 5-country study (Amsterdam (NL) Lisbon (P), London and surroundings(UK), Oslo (NO) and Vigo (ES)). The results of each of these three studies were reviewed. Since the 5-country study is the most comprehensive study in terms of European countries covered and is a well designed CV survey, most weight was put on the results from this study when updating the list of economic values used in ExternE. However, for those morbidity symptoms that are not covered in this study, we had to rely on the results from the other two studies.

3.5.3 Evaluating non-marginal changes

When a policy has a significant ("non-marginal") effect and prices change as a result, we must resort to the relevant supply and demand curves in order to attach an appropriate "social" valuation to the resulting changes in output or inputs. Therefore, depending on the questions to be answered by the economic analysis, an extended partial equilibrium analysis, or a full general equilibrium analysis may be required. We recommend that the way in which the welfare effects of each policy option considered by ExternE are estimated, should be determined on an individual basis since there are no hard and fast guidelines on this issue.

3.5.4 Incorporating non-monetised impacts into the decision making process

In cases where an appropriate quantification of impacts in monetary terms is not possible, ways have to be found to include such effects in decision making. Therefore, ways were considered in which the ExternE results may be combined with data on other decision factors, which are not expressed in money terms, but are equally important determinants of policy selection. It should be emphasised that the intention was not to identify a single methodology to adopt in ExternE. Rather, the intention was to reflect on the main options available to decision makers whom might wish to use the ExternE results in a multi-attribute decision making context. Some general guidance on the use of avoidance costs in the absence of willingness to pay monetary values is given and the possibilities for multi-attribute decision-making are considered.

3.6 Global warming

Marginal costs of greenhouse gases, viz. carbon dioxide, methane, and nitrous oxide, were assessed and the marginal costs of sulphur emissions (via sulphate aerosols) and nitrogen emissions from aircraft (via ozone.) were estimated. The discounting and valuation procedures for marginal cost estimation were refined. The currently recommended values of 2.4 Euro/t CO_2, 750 Euro/t N_2O, and 45 Euro/t CH_4 are lower than those of Eyre *et al.* (1998), reflecting the more optimistic tone of recent impact literature.

It should be noted that with the inclusion of new insights into the impacts of climate change, it can no longer be excluded that marginal costs are negative, particularly for methane. The sign of the costs is model and region dependent. Despite their short life-time, the marginal costs of nitrogen and sulphur emissions are relatively large, primarily because they are not much discounted.

The results presented should not be taken as final estimates. The impacts covered by the models used are only a fraction (of unknown size) of all climate change impacts. Particularly, large scale disruptions, such as a breakdown of North Atlantic Deep Water formation or a collapse of the West-Antarctic Ice Sheet, are excluded from the analysis. The methodologies to estimate climate change impacts in a different future remain weak. Adaptation is not included in its full complexity. Valuation of impacts is still troublesome, particularly for nature and health. Our knowledge of atmospheric chemistry and climate has substantial gaps. The estimates reflect our current best knowledge, and indicate a stimulating research agenda.

3.7 Treatment of up- and downstream processes

In the spirit of life cycle assessment (LCA) one should account for all the environmental consequences, from cradle to grave, of a decision about a system, process or product. For example, the replacement of conventional cars by electric ones would eliminate air pollution from cars at the expense of increased pollution from power plants; in addition there would be increased pollution from the manufacture of batteries and their eventual disposal. Electricity production, and manufacture and disposal of batteries, are processes that occur upstream or downstream of the main process, i.e. driving the car.

Unfortunately a full site-specific impact pathway analysis is far too complex to be practical for LCA, quite apart from the fact that in most cases the sites of the upstream or downstream processes are not even known. Clearly a compromise is needed for the analysis of upstream or downstream processes, a compromise that involves typical damage estimates that are approximately right for typical processes.

Two possible approaches for obtaining typical damage estimates have been explored in the current phase of ExternE. One approach is based on the multi-source version of EcoSense and the CORINAIR data base for emissions. The average damage cost per kg of a pollutant is calculated by calculating the total damage in Europe with and without emissions from the sector of interest (e.g. industry) and dividing by the total emission of that pollutant from that sector. The other approach is the "uniform world model" (UWM), a formula with five factors that follows from conservation of mass under certain simplifying assumptions. As the main processes involved in the considered up- and downstream process steps *vehicle production*, *fuel production*, and *infrastructure provision* are assumed to be located in Europe, unit damage factors per kg of pollutant, for each country calculated with EcoSense, were applied.

3.8 Uncertainty

Since the uncertainties are large, an analysis of the uncertainties is crucial for the credibility of the results. Uncertainties can be grouped 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. They are amenable to analysis by statistical methods, combining the component uncertainties over the steps of the impact pathway, to obtain formal confidence intervals around a mid estimate. For ethical choice and for uncertainty about the future a sensitivity analysis may be more appropriate, indicating how the results depend on these choices and on the scenarios for the future.

Quantifying the sources of uncertainty in this field is problematic because of a general lack of information. Usually one has to fall back on subjective judgment, preferably by the experts of the respective disciplines. That has been done, in an informal manner, for this project. We also used all the relevant information we could find in the literature.

To find the resulting uncertainty of the damage cost from the uncertainties of the components of the analysis, we followed an approach based on lognormal distributions and multiplicative confidence intervals. However, not all uncertainties are amenable to such a quantitative analysis. For the presentation of the ExternE results it is desirable to provide some indication of the full uncertainty which is larger than the uncertainties that have been quantified explicitly. This point has been addressed by estimating comprehensive uncertainties, based on our subjective judgement about reasonable upper and lower limits of the damage costs.

3.9 Marginal costs of transport

As already seen in previous ExternE projects, the quantified damages are dominated by health impacts; in particular, mortality due to primary ($PM_{2.5}$) and secondary particles (nitrates, sulphates). Compared to the project ExternE Transport, the current damage estimates are smaller, reflecting the modification of exposure-response functions for health impacts. The damages now correspond to what was given as a sensitivity in (Friedrich et al., 1998) (Table 17-5, p. 113).

Figure 3.1 illustrates the location specificity of primary pollutant emissions. The damages are determined by the population density of the area where the emission takes place. For secondary pollutants (sulphates, nitrates, ozone), which were looked at on the regional scale, the geographic position determines the size of impact.

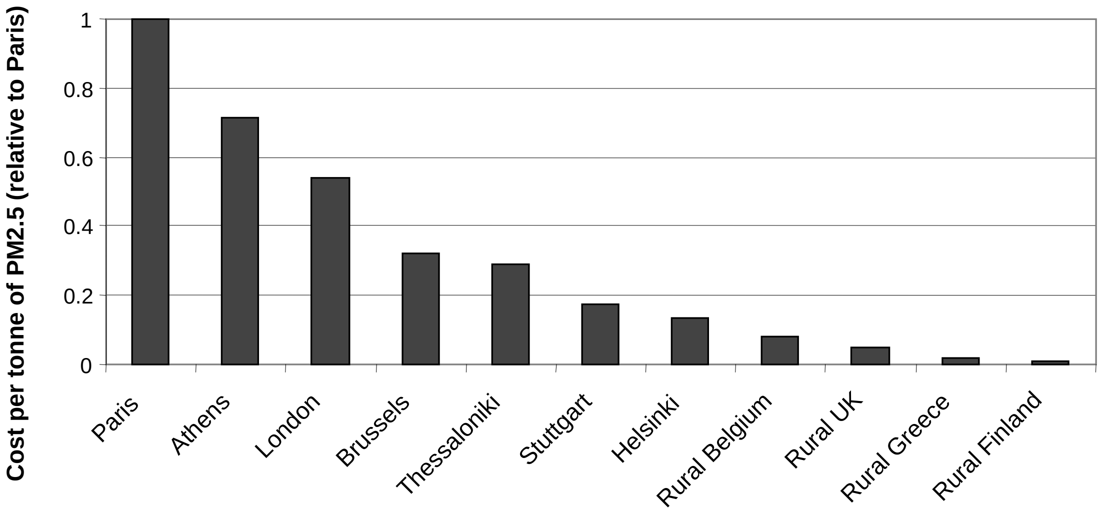

Figure 3.1 Relative damage per tonne of $PM_{2.5}$ in different urban and rural locations

A comparison of damage costs for different car technologies shows that diesel cars cause much higher damages than petrol cars due to their high primary particle emissions. This is illustrated in Figure 3.2 for the case of Athens, but the picture is similar for other locations. The introduction of EURO1, EURO2, and EURO3 emission standards reduces the damage costs per vehicle kilometre by 65%, 75% and 90% respectively compared to an uncontrolled diesel car This is almost only due to the reduction of particle emissions. The reduction of damage costs caused by petrol cars by 65% is considerable from ECE 15/04 to EURO1. The reductions due to the introduction of EURO2 and EURO3 are much smaller, because particle emissions are only reduced marginally, but dominate the damages in the urban environment.

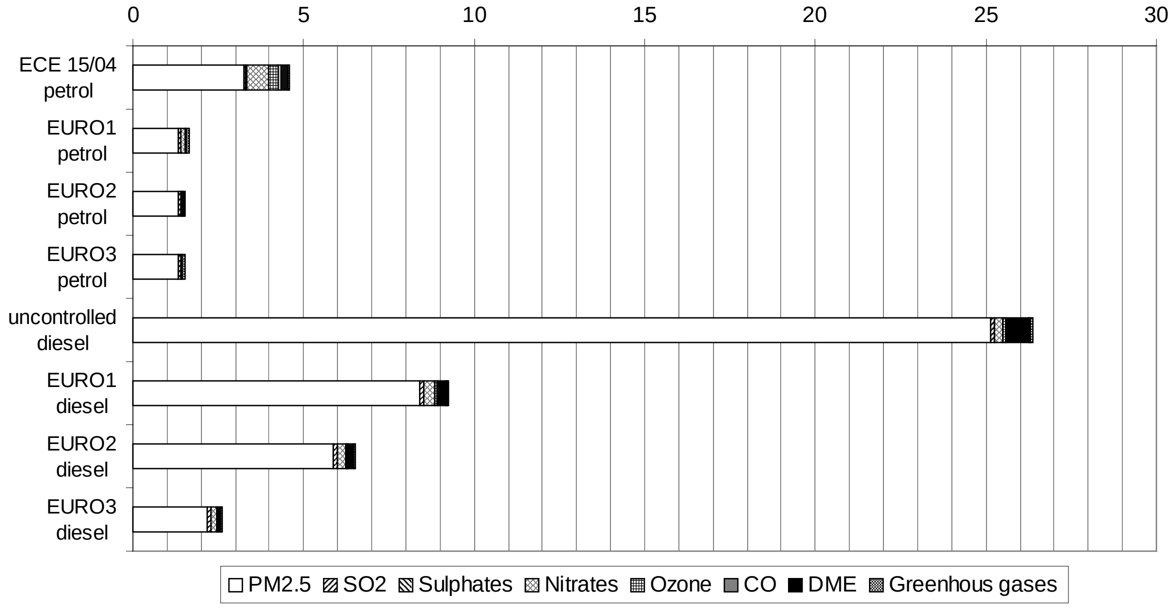

Figure 3.2 Damage costs in Euro per 100 vkm for different car technologies in Athens

For comparisons between vehicle types and modes it is important to include up- and downstream processes. This is done in Figure 3.3, where costs due to passenger transport in the city centre of Stuttgart are presented. In Stuttgart, rail vehicles for passenger transport are operated electrically only, that means there are no direct emissions from vehicle use. Of the remaining processes, fuel (electricity) production causes the highest share of costs. For vehicles with internal combustion engine, vehicle operation plays a very important role in the urban environment. The only exception is the petrol car complying with EURO2, where infrastructure use causes the highest cost per passenger kilometre (pkm). Costs per pkm due to vehicle production, fuel production and infrastructure use are much lower for busses and coaches than for cars. When looking at the total costs per pkm, the electric rail vehicles by far cause the smallest damage costs due to air pollution. They are followed by the coaches, but this is mainly due to the high load factor, which usually cannot be reached for inner-urban trips. So the ranking in terms of increasing damage costs for modern road passenger vehicles is modern urban bus, EURO2 petrol car and EURO2 diesel car.

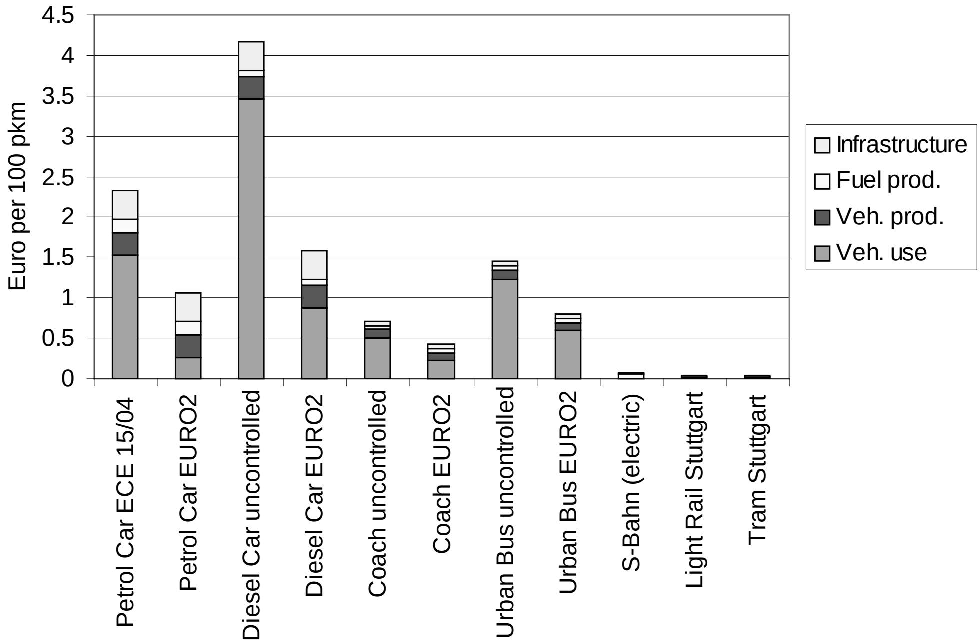

Figure 3.3 Comparison of air pollution costs due to urban passenger transport in Stuttgart (pkm = passenger kilometre)

The goods transport vehicles presented in Figure 3.4 are run by diesel fuel or electricity. The highest costs per tonne kilometre (tkm) are caused by light duty vehicles (LDV) due to their comparably small load. The heavy duty vehicles (HDV) considered have a total maximum weight of 32 to 40 tonnes and a maximum load of about 25 tonnes (compared to 1 to 2 tonnes for LDVs). As they are used for long-distance transport, the average capacity use is higher than for LDVs. For this reason the cost per tkm is comparably small. The same is true for the goods trains considered. The costs of the electric train are hardly visible on the given scale.

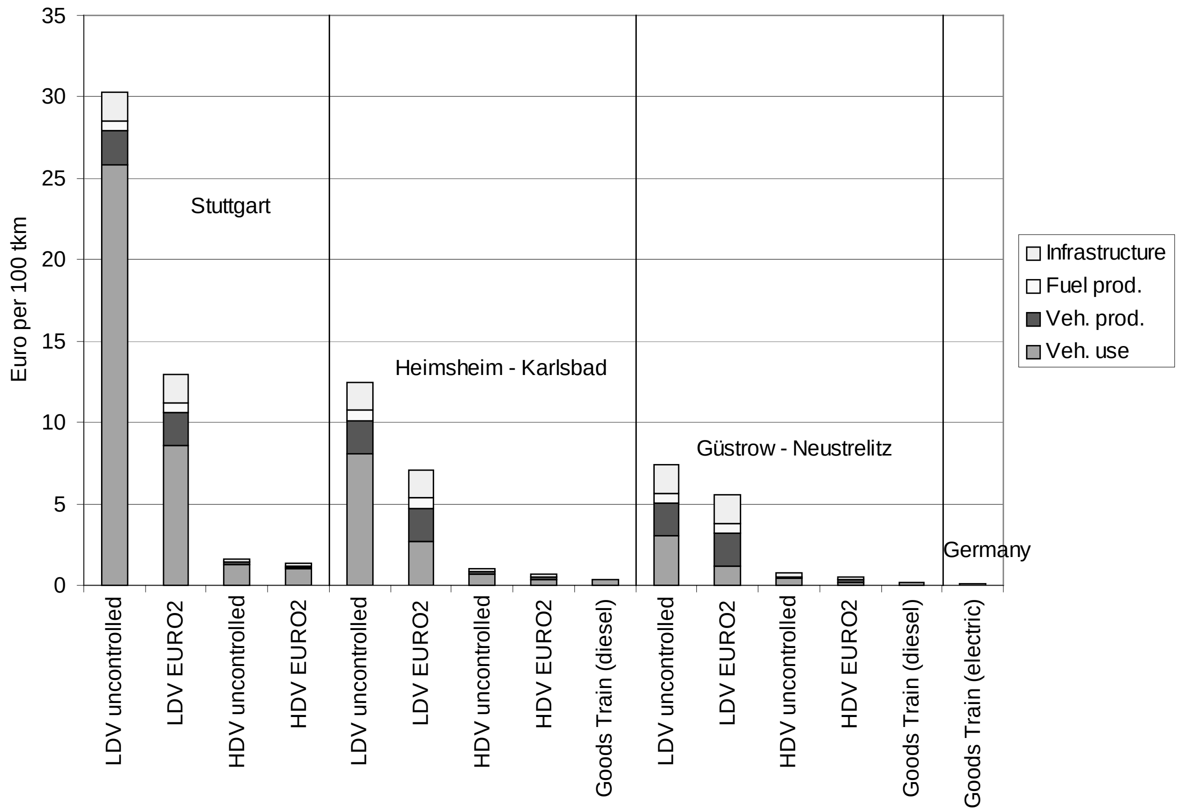

Figure 3.4 Comparison of air pollution costs due to goods transport in Germany (tkm = tonne kilometre)

3.10 Aggregated costs

New issues arise when extending the process of estimating marginal costs to aggregating externality data to levels required by policy instruments and for the analysis of energy balances. The issue of geographical transferability becomes extremely important for transport, because of the importance of local impacts on damages. It is discussed how these issues can be addressed and the updated debate concerning the issue of economic valuation in aggregation including the discussion how these should be dealt with is presented. Finally, the issue of data compatibility (by location) between countries for national level aggregation is raised as an issue warranting further research. This is particularly important for producing consistent European wide results for future policy analysis.

The approaches proposed were applied in a number of aggregation studies at a national/regional level showing the potential usefulness of the numbers in policy and strategy studies.

The national level results are particularly interesting. Although the national aggregation assessments use different methods (and so some care must be taken in directly comparing results), they have all used a higher dis-aggregation for local impacts as recommended in the methodological part. The results show that the aggregated costs for the road transport sector are significant. The externalities of exhaust emissions from the road sector are estimated at 4.2 billion Euro (1.8% of GDP) for Belgium and 8.7 billion Euro (1% of GDP) for the UK. These values are interesting as they are higher than many estimates in the literature (which are of the order of 0.5% of GDP). This is to be expected, as these are the first national aggregation studies to take local impacts into account properly when estimating the external costs of the road transport sector (i.e. specifically taking into account the higher external costs in urban locations). All studies show that passenger cars are the dominant source of road transport sector damages, though heavy goods vehicles give rise to a dis-proportionately large share of damages relative to their share of vehicle kilometres.

The analysis of the entire transport sector in the Netherlands shows that road transport is also the dominant source of damages from all transport and mobile sources, responsible for around 82% of the total transport externalities of 3.9 billion (1.1% of GDP). Finally, the results show that life-cycle emissions are important: the aggregation studies in Belgium and the Netherlands show emissions from fuel production, vehicle manufacture and infrastructure are 23% (Belgium) and 40% (Netherlands) of total road sector externalities.

The regional analysis for Germany presents an elaborated approach to increase the resolution of local scale impact analysis. The central feature is the use of cost factors which were derived per exposed receptor. With these factors, aggregated costs can be calculated using a GIS (Geographic Information System) up to national or the European level. Thus, together with the multi-source EcoSense tool this approach allows to calculate damage costs on the national level for all European countries.

3.11 Policy case studies

The policy case studies undertaken have set out to demonstrate the practical application of the ExternE accounting framework for policy and decision making. They include a wide range of examples covering different types of issues, at different aggregation levels – showing the application of the numbers from local to national levels.

The case studies in Belgium were at a national level, looking at general transport sector trends and policies. The first study looked at the externalities of the Belgian road sector over time. The analysis showed that road sector externalities have shown modest benefits over recent years, despite the introduction of tightening legislation on emission standards for road vehicles. This contrasts with the same analysis over the same period in the UK (chapter 14) which did show significant reductions in road sector externalities. Further analysis shows that there are specific reasons for this difference: both countries have seen rising annual mileage and numbers of vehicles but in Belgium there has been a greater uptake of diesel cars and a greater increase in goods vehicles. This shows how national level policies to influence vehicle technology uptake can have an important effect on transport related externalities and indicates current excise levels for certain vehicle types (e.g. diesel passenger cars, heavy duty vehicles) are sending the wrong signals with respect to the environment and transport.

The second study for Belgium looked at the external costs of air pollution and assessed them in relation to the current levels of duty (tax) on fuel. Interestingly the study shows that the externalities from air pollution are higher than level of duty on fuel tax for diesel in Belgium, but lower for gasoline – potentially justifying a raising of diesel duty and a lowering of gasoline duty. This issue is especially important as the shift from petrol to diesel cars in Belgium is one of the reasons why the total impacts from passenger cars have not dropped over recent years, even with the introduction of stricter environmental standards for new cars.

The Finnish policy case study looked at the introduction of alternative fuel buses in Helsinki, relative to the existing diesel fleet. The results show significant benefits from the use of natural gas in terms of the reduction in environmental costs. The study showed the change from diesel to gas buses would lead to slightly higher overall costs (operating and environmental), though it is stressed that the benefits gained with the gas buses might be greater than quantified in this study due to a number of additional benefits. The study also provided a good example on prioritising measures – an analysis of Helsinki showed that the natural gas buses had the greatest benefit on the central city routes – thus policies to introduce CNG buses into these areas should be a priority. The study also provides a good example of the use of the ExternE approach in cost-benefit assessments.

The French policy case study has looked at the potential for electric battery vehicles (EVs) in Paris. The study calculated the external cost of air pollution for electric vehicles and for conventional cars fuelled by gasoline or by diesel. The study showed that the air pollution related costs from cars in Paris are large, even for cars that meet the rather strict emission limits of the latest regulations. The damage cost amounts to approximately 4% of the private life cycle cost for new gasoline cars, and 70% for new diesel cars. If these costs were internalised, EV's would be competitive at current prices against diesel cars but not against gasoline. In terms of total social cost the EV is at least 50% more expensive than the gasoline cars, both <97 and new, but about 20 to 40% less expensive than diesel cars. Interestingly, the study indicates that if the cost of air pollution are not enough to give the EV a clear advantage against conventional cars in Paris (a very large metropolitan area where the external costs of electricity are small) then the potential for introduction may be low. It concludes that it may be more cost-effective to curb pollution by technologies other than the EV (e.g. hybrid or fuel cell vehicles) or by policies such as scrapping older highly polluting cars.

The German policy case study looked at alternative fuels for road transport in the federal state of Baden-Württemberg. The study looked at the introduction of CNG vehicles, over the time scale from 1995 to 2020 and assessed the levels of environmental benefits from potential levels of CNG introduction into different vehicle fleets. The study showed that in terms of the external costs, the introduction of CNG would have significant environmental benefits – with the potential reductions of more than 50 million Euro in the year 2010.

The policy case study in Greece looked at the use of the ExternE methodology in cost-benefit analysis for local transport decision making. The study assessed the externalities of the bus network of Athens, which is characterised by the existence of old buses with significant environmental burdens to the local environment. The assessment of the externalities resulting from the operation of the bus network, using different bus technologies, revealed a great potential for the substitution of the old buses with new technology or with alternative fuelled vehicles. A cost-benefit analysis was conducted for various scenarios of substitution of old vehicles with CNG buses. The analysis showed that such an investment would have positive results, if the resulting social benefits are included, and that the optimal number of CNG vehicles varies between 300 and 450 vehicles depending on the time preference rate.

The policy case study in the Netherlands looked at the private and external costs of different scenarios for tyres. These included a base case, the introduction of an eco-tyre (improving fuel consumption), correct tyre pressure inflation and increased tyre lifetime. The study showed that the best measure was to improve, monitor and manage tyre pressures, followed by the use of eco-tyres.

The Spanish Policy Case Study assessed the environmental benefits from the introduction of biofuels for transport in a region of Spain. The study showed that some benefits could be achieved in the vehicle use stage from the introduction of bioethanol, though the study highlighted that by optimising upstream stages of fuel production much greater overall environmental benefits could be achieved.

The UK policy case study looked at the current level of environmental costs from heavy goods vehicles in the UK using the ExternE methodology and compared these costs against the current levels of fuel duty and vehicle tax. The results suggest that greater fiscal incentives should be introduced to switch goods moved from road to rail, in addition to any measures considered for reducing those of road freight alone, for example through use of larger vehicles with lower environmental costs per tonne.

Overall the policy case studies provide examples of the use of the ExternE methodology for decision making at a local, regional and national level. At the local level, the numbers have been demonstrated with examples as diverse as local scheme appraisal (the environmental benefits of different options and cost benefit analysis). At a regional level the examples show how the numbers can provide information on which fuels and technologies should be encouraged to reduce environmental impacts of the transport sector and also how they can be used to quantify the benefits of regional plans. At the national level the examples show how current policies can impact on road sector externalities and can indicate which vehicles or technologies should be targeted in order to reduce environmental impacts. They also show how the externality numbers could be used (through internalisation) with fiscal and regulatory policy instruments (such as fuel duty or vehicle taxation) to stimulate the greater use of cleaner and more efficient vehicles.

3.12 Outlook

In the project major remaining issues in the ExternE methodology were addressed. The transport accounting framework and the respective tools are available for broad dissemination and application. Marginal cost estimates were provided for all regions of Europe. A methodology for quantifying damage estimates on all aggregation levels was developed and applied. The practical application of the ExternE accounting framework for policy and decision making was demonstrated in a great variety of policy case studies, covering decision making on the local, regional and national level. Hence, the transport accounting framework and tools are ready to support activities such as

- assessing transport techniques in different areas (urban or regional transport),
- analysing single European transport tasks in order to compare different transport systems,
- application of environmental policy instruments in the transport sector,
- "green accounting" at the national and European levels.

4. RESULTS AND CONCLUSIONS

Major remaining issues in the ExternE methodology (e.g. global warming and ozone impacts) were addressed in the project and the current scientific knowledge was incorporated. The transport accounting framework and the respective tools were developed so that the framework is ready for broad dissemination and application. Hence, the transport accounting framework and tools supports activities on different aggregation levels as e.g.

- assessing transport techniques in different areas (urban or regional transport),
- analysing single European transport tasks in order to compare different transport systems,
- providing a methodology for supporting the application of environmental policy instruments in the transport sector,
- "green accounting" at the national and European levels.

5. EXPLOITATION PLANS AND ANTICIPATED BENEFITS

The main deliverables of the project are

- an improved methodology for assessing external costs of energy conversion,
- external cost estimates for a large number of different transport technologies.

The output of this project is a rich and consistent source of information which can be used to provide support to inform a variety of policy issues. In particular, the improved ExternE methodology and the database of monetary valuation of environmental impacts will be critical for implementation of modified economic indicators and cost benefit analyses required by the Fifth Environmental Action Programme.

According to DGVII's (now DG TREN) objectives expressed in the white paper "Fair payment for infrastructure use" prices of transport should reflect marginal costs. A prerequisite for that is the knowledge of marginal costs as calculated in this project.

The methodology and results of *ExternE Transport* were presented to and considered by the *High Level Group on Infrastructure Charging*. It was also presented and discussed in *CAPRI* (Concerted Action on Transport Pricing Research Integration) and at the European Investment Bank in Luxemburg. Within the Fifth Framework Programme, the methodology to assess impacts from transport systems will be applied in the projects UNITE (Unification of Accounts and Marginal Costs for Transport Efficiency) and RECORDIT (Real Cost Reduction of Door-to-Door Intermodal Transport).

Results of this project have been successfully used in the projects QUITS, PETS, TRENEN (all DGVII), the UIC study 'External Cost of Transport', and many others.

For further dissemination, the great amount of information from the project research has been documented by publications in journals and participation in international conferences. Final results are going to be published in a technical report, providing detailed information on the methodological approach and results.

In addition, as part of the exploitation plan there has been interaction with the potential users of the ExternE results. As with previous phases, the application of the ExternE results to different problems was demonstrated in a set of case studies. Most of the policy case studies involved potential users of the results (such as national authorities and the industrial and transport sectors). Therefore, the results directly reach such groups of decision makers, who in many cases act as co-funders. Of course, the results are disseminated in a suitable format for presentation and discussion to other potential users than the co-funders as well.

The project partners, who have close links to governmental organisations and industry in their individual countries, are exploiting the results by actively offering their expertise in calculating external costs to industry, national authorities and the European Commission. This way of exploitation has proved to be efficient in previous phases of ExternE. For example the German team used the ExternE methodology for work with German utility companies, several German government authorities and DG XI.

In consequence, the ExternE methodology has been widely accepted and applied, e.g. by DG XI in cost-benefit analyses in the context of defining air quality guidelines (e.g. air quality targets for CO and Benzene; cost-effective control of acidification and ground-level ozone). Furthermore, the methodology and results feed into UTOPIA, where a large number of industrial partners is involved.

Possible further applications comprise:

- Use of the results in the development of the UK air quality strategy
- Presentation of the results to the UN/ECE Committee looking at the NO_x protocol.
- estimation of external costs of transport for the Belgian Sustainable Mobility program

Within the consortium contacts have been established with car manufacturers (e.g. BMW, Mercedes-Benz), railway companies (Deutsche Bahn), airlines (Lufthansa, British Airways), as well as the International Organisation of Motor Vehicle Manufacturers (OICA), the International Union of Railways (UIC) and the MWV (association of oil companies). Several presentations on ExternE have been made to representatives of government and industry (Ministère de l'Environnement de la France, EdF, Italcementi (cement industry)).