The Application of the External Costs Concept on Innovative Industrial Technologies

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Summary

The purpose of this paper is to illustrate the growing application of economic techniques in environmental decision making, drawing on analysis carried out for the EC DG Research Ecosit study. A comparison is made of the production and use of loosefills manufactured from expanded polystyrene (derived from fossil fuels) and vegetable starch (a renewable resource derived from corn). This comparison is based on the ExternE methodology, again developed with funding from DG Research of the European Commission. This methodology has been used previously to advise in the development of legislation on air quality, energy policy, waste policy, etc. Results suggest that improved environmental performance of Mater-Bi is more than enough to offset the difference in price between the two products. Results are of course subject to some level of uncertainty and this will be addressed more deeply in further work, though we believe that the overall conclusion drawn will prove to be robust. Final results from the Ecosit study will be available after November 2002, and will cover a variety of additional case studies to those presented here.

Introduction

The work presented here has been conducted as part of the Ecosit (External Costs of Innovative Technologies) project for DG Research of the European Commission. The purpose of the paper is to illustrate the growing application of economic techniques in environmental decision making, by reference to a comparison of two types of loose-fill packaging material, expanded polystyrene and a starch based alternative. A number of other case studies are currently being carried out as part of the project, which is due for completion in November 2002:

- The life cycle performance of different types of tyre
- Advanced painting facilities in a German car plant
- Total redesign of a car plant and supply operations to reduce energy demand and other environmental burdens
- Systems for optimising spraying to ensure effective pest control

In recent years a number of techniques have been developed to assist decision makers in the formulation of environmental and social policies that are both logical and reflect current understanding of the problems faced. These methods include:

- Strategic Environmental Assessment (SEA)
- Multi-criteria assessment (MCA)
- Risk analysis
- Life cycle analysis (LCA)
- Economic assessment, including cost-benefit analysis (CBA).

Each method has its own set of advantages and disadvantages, which clearly need to be considered when deciding how analysis should be done, and how results should be interpreted. The different methods should not always be seen as alternatives, as the correct approach to dealing with a problem may be to combine them, as is done in the work reported below. This starts from life cycle analysis, applies risk analysis to describe the impacts of the burdens identified in the LCA, and then economics to weight the different impacts.

One of the major advantages of the use of economics for weighting different impacts is that it permits direct comparison of the costs and environmental/social performance of alternative actions. Results are inevitably subject to some level of uncertainty, but this can be dealt with in a systematic manner through the use of statistical analysis and sensitivity/what-if analysis. [Uncertainty, of course, is not a problem confined to economic methods, but affects all approaches.]

The capacity to enable direct comparison of costs and benefits has done much to raise the popularity of economic approaches since the late 1980 following the publication of 'Blueprint for a Green Economy' by Pearce, Markandya and Barbier. The general approach has been used with increasing frequency for environmental decision making at the national government and European levels, as the following list (biased as it is to the present authors' experience and interests) demonstrates:

- ***Air quality policy***
    - Economic evaluation of air quality standards for particles, SO_2, NOx, CO, benzene, ozone, PAHs (Holland, 1999; DEFRA, 2001)
    - Assessment of national emission ceilings at the European Union and UNECE (United Nations Economic Commission for Europe) levels (Holland et al., 1998; 1999; Krewitt et al., 1999; Dame and Holland, 2000)
- ***Energy policy***
    - Comparison of the performance of different options for power generation (European Commission, 1995a)
- ***Waste policy***
    - Development of emission standards for municipal waste incinerators (Brown et al, 1997)
- ***Product policy***
    - Economic evaluation of options for disposing of PVC (Brown et al, 2000)

Over the last two years we have also started to apply these methods at a more localised level for industries in the manufacturing, food and drink, water and energy sectors, and with local authorities.

However, the use of economic approaches is far less frequent at other levels, partly because of concern that an economic assessment does not sit well with policy to protect the environment, and partly because of a view that it is unethical to place values on human health, ecosystems, etc. In our opinion these objections do not, however, stand up to close inspection. On the first point, it is important that a system is established for prioritisation of issues and of solutions to problems, given that there is never enough money to pay for everything that we would like to see funded, whether it concerns the environment, health, social concerns or whatever. Without such a system there is a strong danger that priorities will be established more or less solely on the basis of who is able to lobby most effectively for their own favoured issue. On the second point, of the ethics of monetisation, thinking that life, biodiversity, etc., is sacred or so fundamental to existence that it is beyond valuation, ignores the fact that someone has to take decisions made on the value of these things everyday, in setting budgets on health, environmental protection, overseas aid, etc, and in deciding exactly how those budgets are spent. The advantage of the methods used here is that they make the valuation process explicit, which must make for a more transparent system than at present.

There may of course be disagreement over the level at which a particular valuation is set, but having declared values, it is a relatively easy matter to see whether overall conclusions would be affected by the use of an alternative valuation. Decision makers are not tied to the results of the analysis as, for example, other factors that cannot be quantified may sway them to alternative courses of action, but they should be able to provide a justification for adopting a different strategy to that suggested.

The Mater-Bi loose-fill case study

The objectives of the Ecosit Project are to quantify the external costs[1] of environmentally innovative industrial technologies and to compare them against competing processes and products. These 'innovative' technologies include those that minimise resource use during production or application, promote sustainability through the use of renewable resources, or improve recycling. The project applies the ExternE methodology (European Commission, 1995, 1999) to the results of existing life cycle analyses to quantify impacts, and (where possible) to value them in monetary terms. Monetisation permits direct comparison of the performance of these innovative technologies with traditional alternatives and allows consideration of methods to encourage their adoption in the market place.

The objectives of this specific case study are:

- **To demonstrate the application of the ExternE[2] approach** to a production process,
- **To assess the environmental performance of Mater Bi** as a material for loose-fills and compare its environmental performance with expanded polystrene, and;
- **To discuss the merits and problems of the methods used here** against methods already in common use in LCA.

Methods

The analysis is in three parts:

1. Life cycle analysis to quantify the environmental burdens of Mater-Bi and expanded polystyrene
2. Quantification of impacts and monetisation, using the ExternE Methodology
3. Review of results against the costs of the different product streams.

Given that the study is focussed on the development of economic methods, it was decided to take the results of an existing LCA study, carried out for Novamont S.p.A. in Italy. The Life Cycle Analysis compared Mater Bi loose-fill with polystyrene loose-fill, accounting for emissions of pollutants such as CO_2, NOx, NH_3, SO_x, N_2O metals (Ni, Cd) and hydrocarbons (Estermann et al., 2000). The system boundaries are defined in Figure 1. The life cycle analysis (Estermann et al., 2000) includes raw material acquisition, production, processing, disposal of loose fills as well as transport. The unit processes of packaging, distribution, use and collection of organic waste were not considered due to the dependency of these processes on the respective bulk buyers and retailers.

The ExternE methodology is based around the 'impact pathway approach' (see Figure 2). This is a bottom-up-approach in which environmental benefits and costs are estimated by tracking the pathway from emissions to impacts through the chain shown in the following diagram: Impacts are quantified using exposure-response and other data taken from the environmental, health, and social science literature. Monetisation is based on the concept of willingness to pay, which seeks to reflect society's views on value.

A major advantage of the ExternE method is that it permits account to be taken of the specificity of burdens (e.g. air pollutants) with respect to the location in which they are released. Analysis for the European Commission has demonstrated that the damage to health for example, from the release of one unit of a given pollutant may easily vary by more than an order of magnitude depending on local population density, distance to other large centres of population, prevailing winds, etc.

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[1] Externalities (or external costs) are the costs imposed on society and the environment that are not accounted for by the producers and consumers of industrial products, i.e. that are not included in the market price.

[2] The ExternE approach has been developed by an international team of experts in 15 European countries since 1991, funded by European Commission DG Research. The methods developed have been used in modelling work to inform policy makers in air quality policy, waste policy and energy policy. Ecosit represents the first project to apply the method systematically to a series of different production processes.

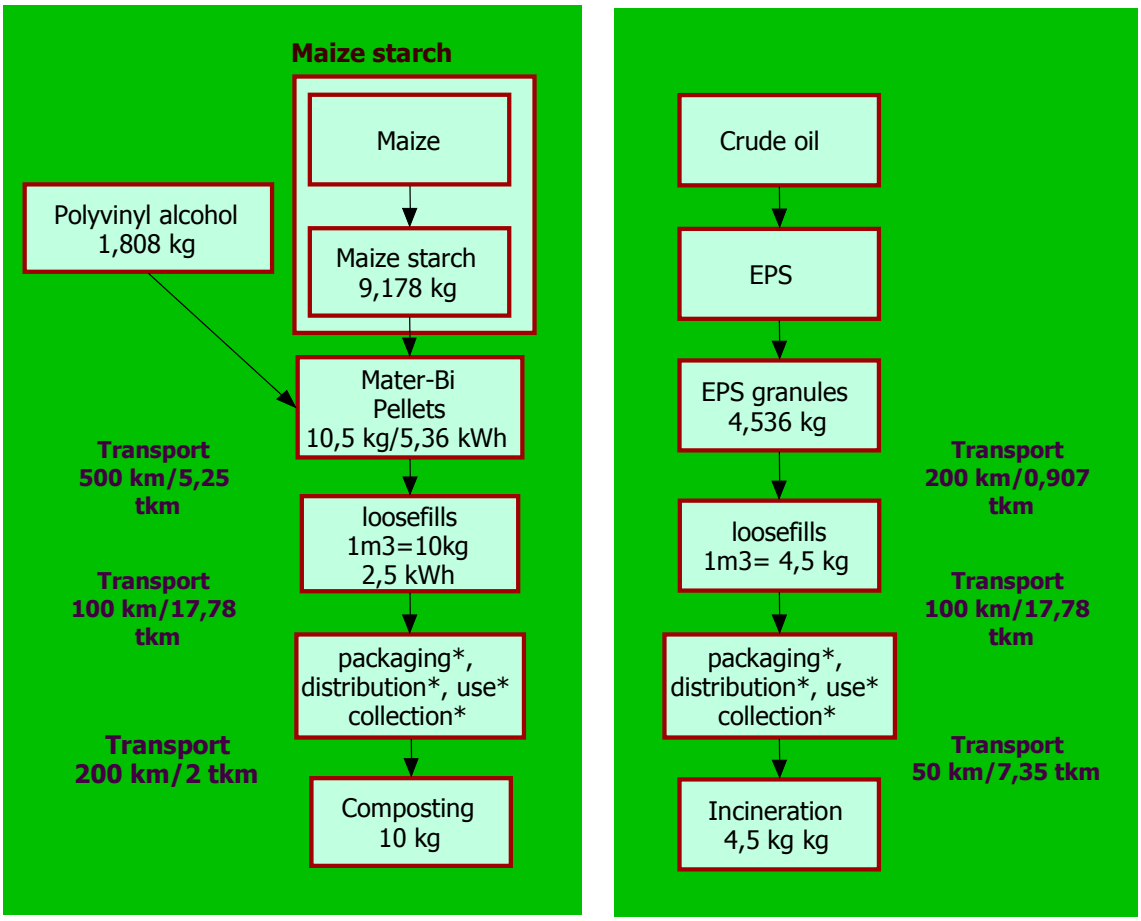

Figure 1: Broad definition of system boundaries for the LCA of Mater BI and EPS.

* **Not included in the Life Cycle Profiles.**

The implementation of the analysis shown in Figure 2 has been simplified through the development of the EcoSense Model (European Commission, 1999) which was designed by the ExternE Project team to provide a tool for quantification of the effects of regional air pollutants on health, buildings, agriculture and ecosystems. The model inputs are level of emission and the precise location of those emissions. It then proceeds to model the fate of those emissions, resulting population exposures, impacts (assessed using exposure-response functions) and values. The model has been developed to account for both local and European wide impacts around any source or set of sources, reflecting the extreme distances (>1000 km) required to account for air pollution impacts.

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 (ozone, and it relationship with its precursors, NOx and VOCs provides an excellent example) 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. EcoSense accounts for emissions of particles, heavy metals, a variety of organic carcinogens, VOCs, SO_2, NOx, and NH_3. Greenhouse gas emissions are not included in the model, as the site of emission is of very little relevance to impact. They are instead valued at €20/tonne CO_2, a figure derived by the European Commission, reflecting the marginal costs of meeting the requirements of the Kyoto Protocol, and being representative of figures derived in economic assessments of climate change impacts.

Health impacts of air pollution dominated the Mater-Bi / EPS analysis. Exposure-response data have been taken from the international literature, and have been subject to extensive peer review. Valuation data have likewise being subject to extensive peer review.

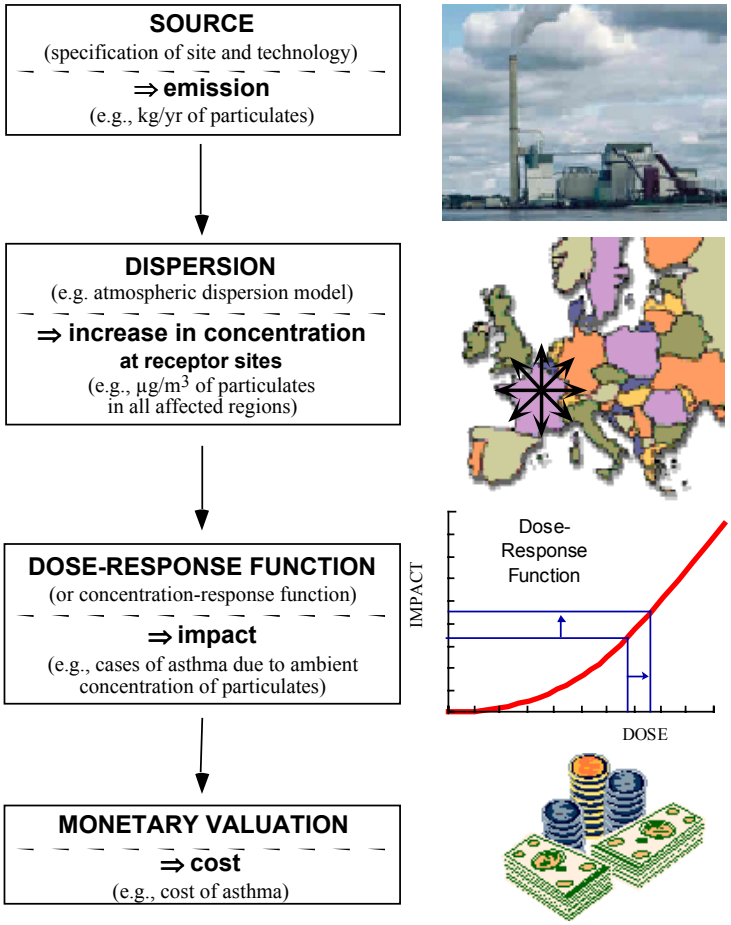

Figure 2: The impact pathway approach.

Results

Results from the LCA, comparing Mater BI and EPS are show in Figure 3. Mater BI performs best in all categories except salification and deposited waste. A problem in interpretation of the findings of the LCA relates to determining which option is 'best' where the overall answer is not clear cut, as here. The ExternE methodology provides a means of investigating this further (even if data are unavailable for quantifying a particular impact, the overall framework of the impact pathway approach is useful), and also of assessing the relevance of external costs to any price differential between alternative products.

First, the impact groupings were prioritised for consideration. Effects of air pollutants (greenhouse gases, ozone precursors, acid gases and air toxics) were prioritised. Nutrification of water bodies was regarded as of minor importance because of measures, such as the Urban Waste Water Treatment Directive and the Nitrates Directive that are being introduced to stop eutrophication in sensitive waters in Europe. 'Energy' was also discounted largely because its major environmental impacts are reflected in emissions of pollutants covered elsewhere in the LCA inventory. Water toxicity was omitted from the analysis for the time being because methods for its detailed assessment are still under development.

This leaves the two impact categories for which the LCA reports that Mater-Bi performs less well than EPS, salification and deposited waste. No quantification of either impact category was possible beyond the results of the LCA. At issue is the relative impact of growing maize compared to other crops – does maize production lead to a greater or lesser degree of salification than other crops? If it leads to a lower level of salification it would be appropriate to conclude that promoting the growth of maize had environmental advantages that are not reflected in the results of the LCA. In the event that maize is either as salifying or worse than other crops, planting could preferentially be carried out in less sensitive areas.

Clarificaiton is needed of the types of waste materials generated by the two processes. It may or may not be that EPS production leads to a more hazardous waste than Mater-Bi production, which could clearly alter the interpretation of the results of the LCA. It may also be that, given modern techniques for waste management, neither generates a problematic waste. If this is the case, the impact category of 'deposited waste' would seem to be of little environmental significance.

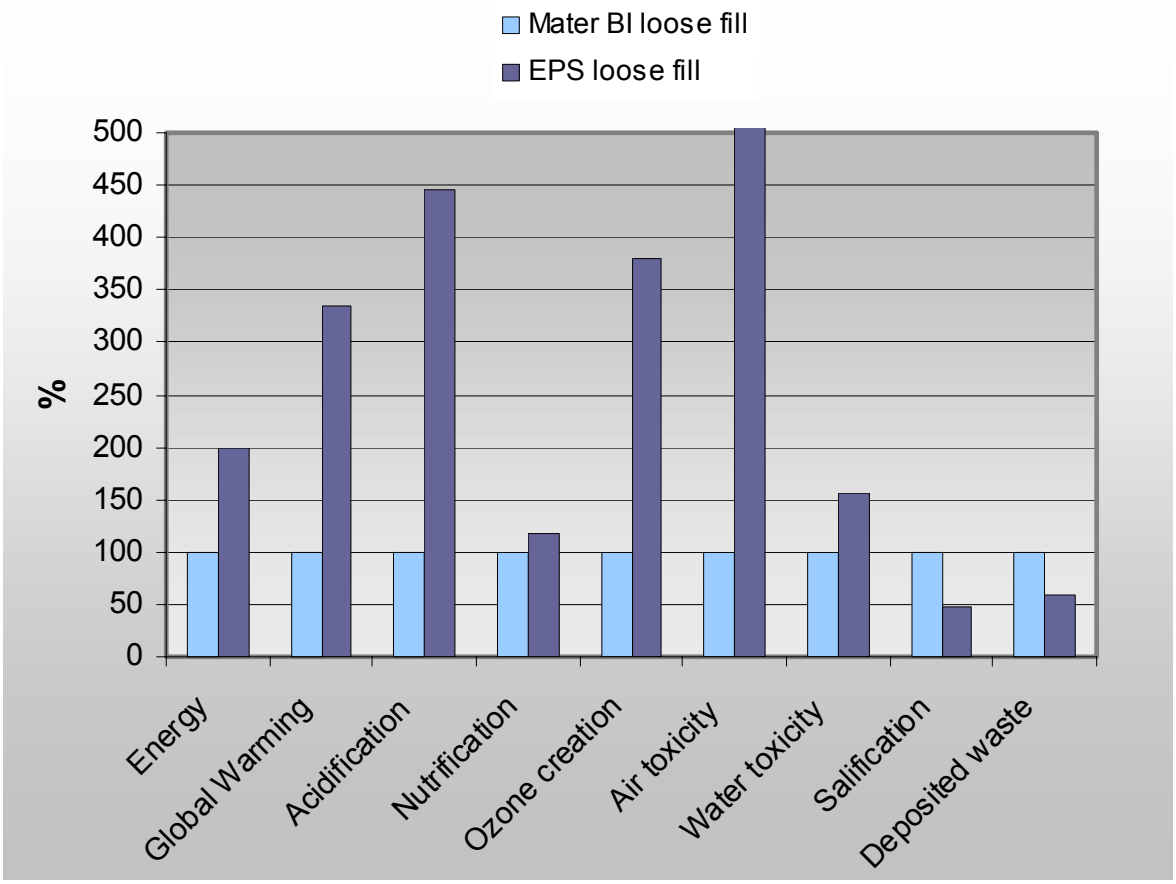

Figure 3: Comparison of the relative performance of EPS (for which values are set to 1) against Mater BI. Mater BI performs best in all categories except salification and deposited waste.

Emissions data from the LCA have been fed into the EcoSense model to quantify impacts and associated external costs. Mater-Bi production is distributed in several Italian sites :

- Raw material process in Veneto
- Pellet production in Terni
- -Loosefill production in Lombardy

Consequently the external cost calculation, including the burdens provided by the transportation of the raw material from Veneto to Terni and of pellets material from Terni to Lombardy, has been assessed considering the localization of the processes.

The LCA expresses emissions in grams, relative to production of the functional unit of 1 cubic meter of Mater BI or EPS. This has had to be scaled up in the externalities assessment as the input for EcoSense has to be in ktonnes per year. However, given the scale of total emissions of the pollutants in question across Europe, results can reasonably be scaled linearly to reflect actual emissions, once outputs have been generated by EcoSense. Hence, it was assumed that in both cases loose-fills for five million package units are produced. For example, 200 g NO_x for the production of one package unit's worth of loose fills would lead to emissions of one kilo tonne of NO_x per year if loose-fills for five million package units are produced. The result of the calculations with EcoSense are summarised in Table 1. Estimated global warming impacts are shown in Table 2.

Table 1: External costs of loose fill production for 5 million package units, in million euro per year, for regional air pollution impacts

	EPS	Mater Bi
Building material	1.25	0.19
Crops	3.15	0.32
Human Health	42.77	6.98
Total	47.17	7.48

Table 2: External costs of loose fill production for 5 million package units, in million euro per year for global warming impacts

	EPS	Mater Bi
Global Warming	5.5	2.13

The results from Tables 1 and 2 are plotted in Figure 4, demonstrating the clearly better performance of Mater BI compared to EPS, for those impact categories that have been included in the analysis.

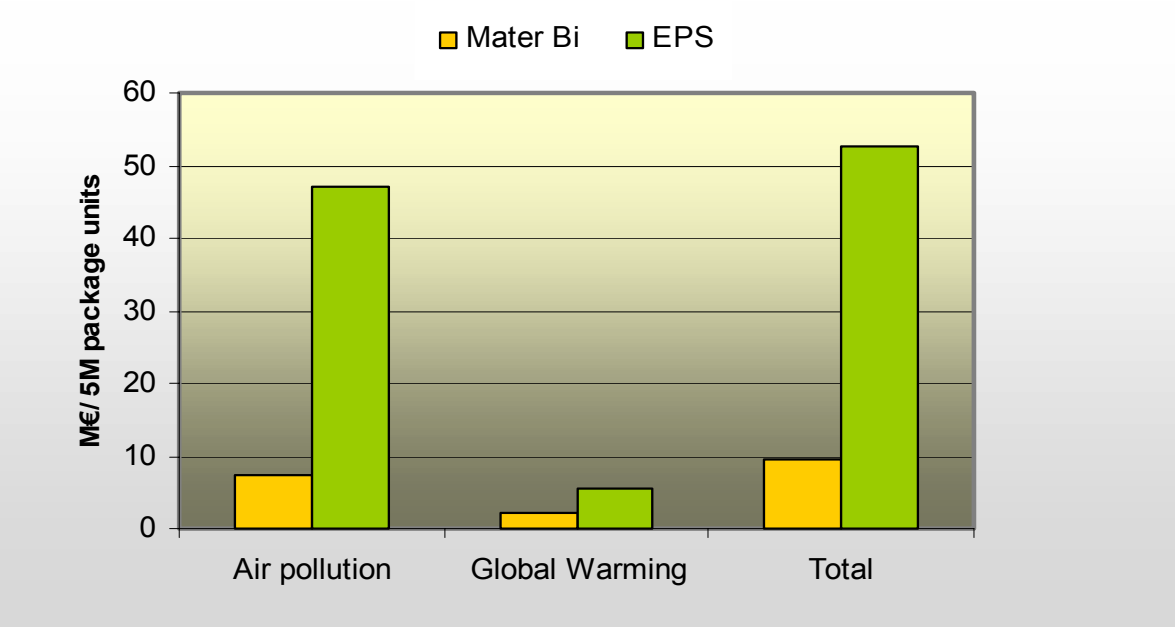

Figure 4 Comparison of the external costs caused by Mater BI and EPS production (5 million packages), including regional and global air pollution impacts.

Total damages attributable to EPS are therefore more than 5 times higher than those for Mater-Bi, at 100 million euro against 17 million euro for production of 5 million packaging units, or 20 euro against 3.4 euro for production of one packaging unit (a volume of 1 m^3).

Conclusions regarding Mater BI and EPS

Using the EcoSense software to calculate the external costs of the two different loose fills it was shown that production of Mater BI, generates lower external costs than the conventional production method of EPS. The analysis presented here suggests that there is a difference of about 16 euro per 1 m^3 packaging unit in external costs, easily exceeding the difference in price between the two products: EPS loosefills typically cost between 15 and 20 euro per m^3, whilst Mater-Bi costs between 20 and 25 euro per m^3. [Exact prices will of course vary with location, volumes purchased and other factors.]

Against this must be set the worse performance of Mater-Bi reported in the LCA regarding salification and waste production. These issues need to be looked at in more detail in the final stages of the study. From consideration of the issues (see above) the authors conclude that these issues are far less serious than the factors that have been quantified, and believe that the conclusion, that Mater-Bi is environmentally preferable to EPS, is robust.

Questions remain as to what should be done to promote environmentally safer products that cost more than those that are cause greater burdens on the environment. Several options exist, for example, use of the tax system to promote the environmentally preferable option (as was successfully done in the UK to promote lead-free petrol), though this would clearly require legislation, which seems inappropriate for dealing with loosefills specifically. At the other extreme smaller organizations may consider the results of studies such as this as a good guide for prioritizing future environmental expenditures.

A number of comments are necessary in relation to the current state of the ExternE methodology. The analysis is currently biased in its scope to those impacts that are most prominent for the energy sector – air pollution, noise (e.g. from wind turbines), amenity, occupational health and so on. The major omission at the present time is probably water pollution which is currently covered in depth only for radionuclide emissions. This is currently being investigated in studies funded by the European Commission that have followed from ExternE – for example, GreenSense and NewExt. The development of methods from these and other studies will be strengthened by the experience gained in Ecosit which will help to focus attention on those issues where clarification of the link from burden to impacts is most needed.

Conclusions on the advantages and disadvantages of the ExternE methodology

A number of approaches have been developed in LCA methodologies to go beyond normalisation of environmental burdens within categories to compare the overall burdens arising from alternative products. The ExternE approach adopted in the Ecosit project seeks to go beyond these approaches in a number of important ways, including the following:

1. By taking account of the location of emissions (etc.) which is a fundamental determinant of the magnitude of damages.
2. By taking account of the location of receptors. So far as ozone is concerned the highest levels tend to occur towards the centre of Europe, surrounded as it is by sources of NOx and VOCs on all sides. Areas around the European fringes experience lower levels.
3. By taking account of thresholds for impacts where they exist, the acidification issue being a good example. This facility is particularly useful for analysing scenarios of the future, where it is anticipated that emissions will be at a lower level than they are now, providing that existing legislation is put fully into force. Alternative scenarios can account for the situation where it is not fully applied.
4. By expressing the end result in monetary terms, a common measure that is universally understood.

5. The use of monetisation also permits direct comparison of the costs and benefits of environmental protection measures. Given that monetary resources are finite, it provides, amongst other things, a mechanism for prioritising actions.

The main disadvantages of the ExternE approach are:

1. The existence of problems in valuation of some 'goods' such as ecosystems, whose functions are sometimes difficult to convey, especially when considering very long term issues. There are methods for resolving this problem (e.g. integration of multi-criteria decision analysis with monetisation), but none give the ideal solution in the sense of one that is fully compatible with the impact pathway framework. It is often better to leave some impacts quantified to a stage prior to economic valuation, and to factor them into deliberations once the balance of costs against those impacts that can be quantified is known.
2. The fact that results are subject to uncertainty. However, uncertainty has to be reduced by carrying out an analysis that reflects current scientific opinion. Methods have been developed to take account of the uncertainties that are present (see for example, Holland *et al*, 1999). Problems can still arise when uncertainty analysis is carried out in a way that provides misleading results. However, provided that results and underlying data are expressed openly, thorough inspection of the data should permit any such problems to be identified.

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References

Brown et al: (1997) Cost-benefit analysis of the draft directive on the incineration of non-hazardous waste. Contract report for DGXI of the European Commission.

Brown, K.A., Jones, H. and Holland, M.R. (2000) Economic Evaluation of PVC Waste Management. Contract report for European Commission DG Environment, Brussels, Belgium.

Dame, E. and Holland, M. (2000) Cost-Benefit Analysis for the Goteborg-Protocol. Submitted to Water, Air and Soil Pollution.

DEFRA (2001) Second report of the Interdepartmental Group on Costs and Benefits (IGCB). DEFRA (Department for Environment, Food and Rural Affairs), in partnership with the Scottish Executive, The National Assembly for Wales and The Department of the Environment for Northern Ireland.

Estermann R, Schwarzwalder B, Gysin N, Life cycle assessment of Mater-Bi and EPS Loose Fills. Internal document of Novamont spa, 2000.

European Commission (1995) DGXII (JOULE Programme) Externalities of Energy, ExternE Project, Report Number 2, Methodology. Prepared by ETSU and others.

European Commission (1995a) DGXII (JOULE Programme) Externalities of Energy, ExternE Project, Report Number 1, Summary. Prepared by ETSU and others.

European Commission (1999) DGXII (JOULE Programme) Externalities of Energy, ExternE Project, Report Number 7, Methodology: Update 1998. Holland, M.R. and Forster, D. (eds.).

Holland, M. R., Forster, D., King, K., Haworth, A. and Watkiss, P. (1999) Economic Evaluation of Proposals for Emission Ceilings for Atmospheric Pollutants. Contract Report for European Commission DGXI.

Holland, M.R. (1999) Economic evaluation of air quality limits for CO and benzene. Contract report for European Commission DG XI.

Holland, M.R. and King, K. (1998) Economic evaluation of air quality targets for tropospheric ozone. Part C: Economic benefit assessment. Contract report for European Commission DG XI.

Holland, M.R., Jones, H., Visschedijk, A. and Berdowski, J. (2001) Economic Evaluation of Air Quality Targets for PAHs. Report for European Commission DG Environment.

Krewitt, W., Holland, M., Trukenmuller, A., Heck, T. and Friedrich, R. (1999) Comparing Costs and Environmental Benefits of Strategies to Combat Acidification in Europe. Journal of Environmental Economics and Policy Studies, 2, 249-266.

Pearce, D., Markandya, A. and Barbier, E. (1988) Blueprint for a Green Economy. Earthscan Publishing, London.