E. Bertel, P. Fraser*

Energy policy and externalities

External costs of energy have been assessed in a number of authoritative and reliable studies based upon widely accepted methodologies such as life cycle analysis (LCA). However, although those costs are recognised by most stakeholders and decision makers, results from analytical work on externalities and LCA studies are seldom used in policy making. The International Energy Agency (IEA) and the Nuclear Energy Agency (NEA) convened a joint workshop in November 2001 to offer experts and policy makers an opportunity to present state-of-the-art results from analytical work on externalities and debate issues related to the relevance of external costs and LCA for policy-making purposes. The findings from the workshop[1] highlight the need for further work in the field and the potential role of international organisations like the IEA and the NEA in this context.

Background

Getting the prices right is a prerequisite for market mechanisms to work effectively towards sustainable development in the energy sector. This requires identifying and valuing external costs, and eventually reflecting them in prices. Internalising external costs aims at providing "correct" price signals that drive consumers' choices towards an optimum, taking into account social and environmental aspects as well as direct economic costs.

Economic theory has developed approaches to assessing and internalising external costs that can be applied to the energy sector. The tools developed for addressing these issues are generally based upon a comprehensive (and exhaustive in so far as feasible) inventory of impacts and damages, followed by monetary valuation and eventually integration of the valued "external costs" in the total cost of the product, e.g. electricity.

Life cycle analysis (LCA) provides a conceptual framework for a detailed and comprehensive, comparative evaluation of potential environmental impacts of energy supply options. Traditional LCA involves a complete inventory of resource inputs and outputs in all steps of production and can incorporate indirect emissions. In a second phase, the assessment of the impacts concerning burdens on the environment and resource depletion can be carried out.

The external cost assessment methodology developed by the ExternE project[2] illustrates a bottom-up approach to estimate the impacts of different emissions from different power generation and transportation fuel options through the inventory of each emission; estimate its dispersion; examine the impact based on the dose-response relationship (impacts being measured essentially in terms of years of life lost); and provide an economic valuation of these impacts. The results are subject to a large number of uncertainties that arise not only from data limitations, but also from difficulties in quantifying certain impacts (for example those concerning the ecosystem), assumptions about future management of waste and improvements in technology, and intergenerational considerations.[3]

* *Dr. Evelyne Bertel is a member of the NEA Nuclear Development Division (e-mail: bertel@nea.fr). Mr. Peter Fraser works in the IEA Energy Diversification Division (e-mail: peter.fraser@iea.org).*

Quantifiable external costs of energy systems (in Euro-cents/kWh)

Impact	Coal	Lignite	Gas CC	Nuclear	PV	Wind	Hydro
Health effects	0.8	1.0	0.3	0.2	0.4	0.05	0.04
Crop losses	-0.03	-0.03	-0.01	0.0008	-0.003	0.0005	0.0004
Material damage	0.02	0.02	0.007	0.002	0.01	0.001	0.0007
Noise nuisance						0.006	
Acidification/ Eutrophication a)	0.2	0.8	0.04	0	0.04	0	0
Global warming b)	1.6	2	0.8	0.03	0.3	0.03	0.03
Sub-total	**2.6**	**3.8**	**1.1**	**0.2**	**0.8**	**0.09**	**0.07**

Source: A. Voss, (2000), "Sustainable Energy Provision: A Comparative Assessment of the Various Electricity Supply Options", SFEN Conference Proceedings, *What Energy for Tomorrow?*

a) Valuation based on marginal abatement costs required to achieve the EU "50% – Gap Closure" target to reduce acidification in Europe.

b) Valuation based on marginal CO_2-abatement costs required to reduce CO_2 emissions in Germany by 25% in 2010 (19 Euro/tCO_2).

The studies carried out so far show that large uncertainties remain concerning dose-effect relationships, and consequently physical damages as well as the monetary value of the damages. Differences in estimates can arise due to different methodologies, technologies, location and population densities. In addition, values given to days of life lost or loss of biodiversity depend on local economic and/or cultural conditions. These uncertainties and differences limit the applicability and relevance of external costs in policy making. However, LCA and external cost valuation may be used in many ways to improve the overall efficiency of various technologies and to measure progress towards sustainable development.

LCA and external cost assessments

Estimates of nuclear power external costs in the ExternE study, based upon the French nuclear chain,[4] show that electricity generation and fuel reprocessing are the main contributors to those costs. Results highlight that impacts take place over a very long period. The external cost is largely attributed to impacts on workers while the cost of impacts on the public are rather small (about 0.00002 € per kWh). This figure is not greatly increased by accidents, using the "large consensus" assumption that such accidents would occur at a frequency of 1 per 100 000 reactor-years and that, in such an accident, 1% of the radioactive materials would be released to the environment. Even if a risk-aversion effect is assumed, the figure for accidents would be only around 0.0001 € per kWh, still a small figure.

Life cycle analyses of coal have focused on its use in both steel and electricity production as a means of identifying opportunities to improve sustainability.[5] In the power production sector, LCA shows the largest possibilities for improvement through use of more efficient technologies, use of biomass to displace coal and utilisation of fly ash in cement making. One interesting technological possibility is combining solar thermal technology with coal power generation, which improves net solar efficiency to 30-40% (compared with 13% for photo-voltaic power). Estimated additional costs for large-scale use of solar thermal in an existing coal plant are about 4 US cents per kWh.

Externalities from hydropower projects have been investigated by the IEA Implementing Agreement for Hydropower[6] that surveyed a large number of LCA studies for this purpose. The motto: "avoid (environmental externalities), mitigate (damages that can't be avoided), compensate (damages that can't be mitigated)", adopted within hydropower projects already actively contributes to reducing externalities. Emissions of greenhouse gases from hydropower dams are normally quite low, with few exceptions. The survey found that other positive benefits of hydropower dams such as irrigation or flood control are not normally taken into account by such studies. Energy security benefits are also not generally recognised, and would represent a useful extension of LCA. However, not all environmental impacts can be usefully internalised by an LCA (e.g. loss of visual amenity is not usually included in LCA), and LCA does not take into account cultural differences of the value of different amenities.

Shortfalls of the life cycle analysis approach applied to the oil[7] and gas[8] sectors may be illustrated by a number of points. Production chains often generate multiple products, some for energy use, some for other uses, and allocation of the emissions is to some degree arbitrary. Given the wide variability of oil and gas production chain characteristics, any emission estimate could be derived given the appropriate selection of wells, extraction processes, etc. More generally, it may be argued that LCA impact assessments fail to take into account unknown health and environmental impacts of new chemicals, have no objective scale, contain many assumptions and are very complex. Therefore, LCA should not be used as the basis for comparing widely different generating options or as the basis for internalising external costs. On the other hand, it is a valuable tool for systematic descriptions of resource use and environmental impact characteristics, and can be used more precisely when the production chains and technology options are all very similar, or in choosing amongst locations for the same technology option.

LCA analyses for photo-voltaic (PV) and wind power illustrate the relevance of the approach to assess changes in technology.[9] Estimates of LCA impacts for PV, originally quite high, have fallen steeply thanks to technological progress and increased efficiency. There are also further improvement possibilities. For wind, externalities are rather low, although the operation phase produces both noise and loss of visual amenity. Damage estimates for wind energy are the lowest of all the ExternE fuel cycles studied. The experience with PV shows the need to look at LCA in a dynamic way, particularly with respect to new technologies. A new international research project, ECLIPSE, will look at the life cycle inventories for future power generation technologies, focusing on PV, wind, fuel cells, biomass and combined heat and power (CHP) technologies. Sensitivity analysis will look at the impact of rapid technological improvement and differences in local conditions.

The results of LCA for power generation based on German conditions[10] show that coal (particularly lignite) power generation has the highest external costs in terms of years of life lost, followed by PV and natural gas while nuclear, wind and hydropower have lower external costs. Coal/lignite external costs are around 3 € cents per kWh; gas and PV around 1 € cent; nuclear, wind and hydropower about 0.1 € cent. If these external cost estimates are combined with direct costs, nuclear, which is already nearly competitive with coal and cheaper than natural gas, becomes the lowest-cost option for power generation. There are, however, large uncertainties remaining in terms of data and choices of discount rate, thus limiting the applicability of LCA in policy making at the national level.

The assessment of greenhouse gas in the US transportation sector shows that relying on LCA rather than on end-use comparisons generally reduces the relative advantages of alternative transportation fuels against a baseline gasoline vehicle. However, the results also show that there would be large savings from the use of ethanol (with ethanol from wood) in a conventional engine. External costs of motor vehicle use, calculated taking into account air and water pollution, noise, congestion and energy security amount to 1.2 US cents per mile travelled in a gasoline-powered vehicle.[11] The most significant externality is related to air pollution. The only other variable of significance is the impact on the economy, through the transfer of wealth outside the US (referred to as a "pecuniary externality") and the oil price shock impacts on the economy. A comparison of external costs and subsidies for different transportation modes in the US (gas or electric cars, transit bus, light rail, heavy rail) showed that making subsidies available to public transit systems greatly outweigh the benefit obtained from reduced externalities. In the comparison of social costs of transportation alternatives, differences in external cost, while not trivial, are outweighed by the differences in direct costs or in subsidies. Additional analyses on this and related subjects may be found in *Externalities and Energy Policy: The Life Cycle Analysis Approach*.[1]

External costs, LCA and policy making

In spite of the many limitations and uncertainties underlying life cycle analysis and the valuation of external costs, the methodology has a wide range of possible applications. It can provide valuable support to decision makers with regard to technology evaluation, comparison of future energy supply options, cost-benefit analysis of policy measures and extension of green-accounting frameworks, for example. LCA is also a useful tool for technology designers, providing indicators of technology-specific sustainability and pointing to priority areas for the reduction of environmental impacts.

LCA analysis can provide a useful set of indicators on the sustainability of different energy technologies and, by extension, the electric power and transport sectors. Such an assessment could help national energy policy making by:

- Providing indicators of the sustainability not only of the power generation sector, but of the other steps in the "fuel cycle" of different energy alternatives. Such indicators might include greenhouse gas emissions, energy diversification and resource depletion.
- Pointing to opportunities to improve the sustainability of full fuel cycle operations (for example by improving the sustainability of mining practices).
- Helping to assess the impacts of different economic instruments (such as carbon taxes or a cap and trade system) on international energy trade (e.g. the international trade of natural gas).
- Providing input to political debate on improving the sustainability of energy systems.

As liberalised electricity markets are becoming the norm in OECD countries, decision making on investments in generating capacity is more commonly made by privately owned companies seeking the most profitable option. They will be influenced not by theoretical considerations of external costs but by government policies that attempt to internalise these costs. In that case, LCA can help governments determine where to apply policy pressure, and companies assess the cost and net environmental impacts of these policies. For example, governments could use LCA to evaluate where in the electricity chain the environmental impacts lie, and how to focus policy intervention to alleviate these impacts. Conversely, companies could use LCA to help assess the potential financial impacts of government policies (such as carbon taxes) on different generating technologies.

While the usual academic conclusion that more research is needed typically frustrates policy makers, it should be recognised that we do need to improve LCA methodology and data. Issues that need to be addressed in order to enhance the applicability of LCA in policy making include: consistency between LCA and economic theory generally; uncertainties with respect to health-related externalities; uncertainties and relevance of discounting costs in relation to global warming; and the empirical underpinnings for "disaster aversion" in externality estimates.[12] Possible areas for future research include: better assessment of externalities such as security and diversity of supply, as well as loss of forest cover; further investigations in the field of discount rates applicable in the very long term and the value of statistical life; incorporation of technology progress in LCA; evaluation of energy policy measures with LCA; further effort to reduce uncertainties in external cost estimates; and establishment of a database containing information on externality assessment and the way it is being used, possibly under NEA/IEA auspices. ■

References

1. IEA/NEA (2002), *Externalities and Energy Policy: The Life Cycle Analysis Approach, Workshop Proceedings, 15-16 November 2001*, OECD, Paris; also available on the two agencies' websites.
2. European Commission (1995), *Externalities of Energy, Vol. 2 Methodology*, European Commission, Brussels-Luxembourg.

Presentations from the workshop "Externalities and Energy Policy: The Life Cycle Analysis Approach", 15-16 November 2001, Paris:

3. A. Rabl and J.V. Spadaro, "The ExternE Project: Methodology, Objectives and Limitations".
4. C. Schieber and T. Schneider, "The External Cost of the Nuclear Fuel Cycle".
5. L. Wibberley, "A Life Cycle Perspective of Coal Use".
6. F.H. Koch, "Hydropower – Internalised Costs and Externalised Benefits".
7. J. Cadu, "Well-to-wheel Energy Analysis Study".
8. E. Furuholt, "Life Cycle Analysis as a Basis for Evaluating Environmental Impacts of Energy Production" and M. Darras "From Life Cycle Analysis Approach to Monetarisation of the Impacts: An Evaluation in Terms of Decision Process".
9. P. Frankl, "Life Cycle Assessment of Renewables: Present Issues, Future Outlook and Implications for the Calculation of External Costs".
10. A. Voss, "LCA/External Costs in Comparative Assessment of Electricity Chains. Decision Support for Sustainable Electricity Provision?".
11. M.A. Delucchi, "Life Cycle Analysis and External Costs in Transportation".
12. D. Pearce, "Energy Policy and Externalities: An Overview".