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Environmental Impacts
Short Overview of Evaluation Approaches

Uroš Radović
Agencja Rynku Energii S.A, Warsaw, Poland
urad@are.waw.pl

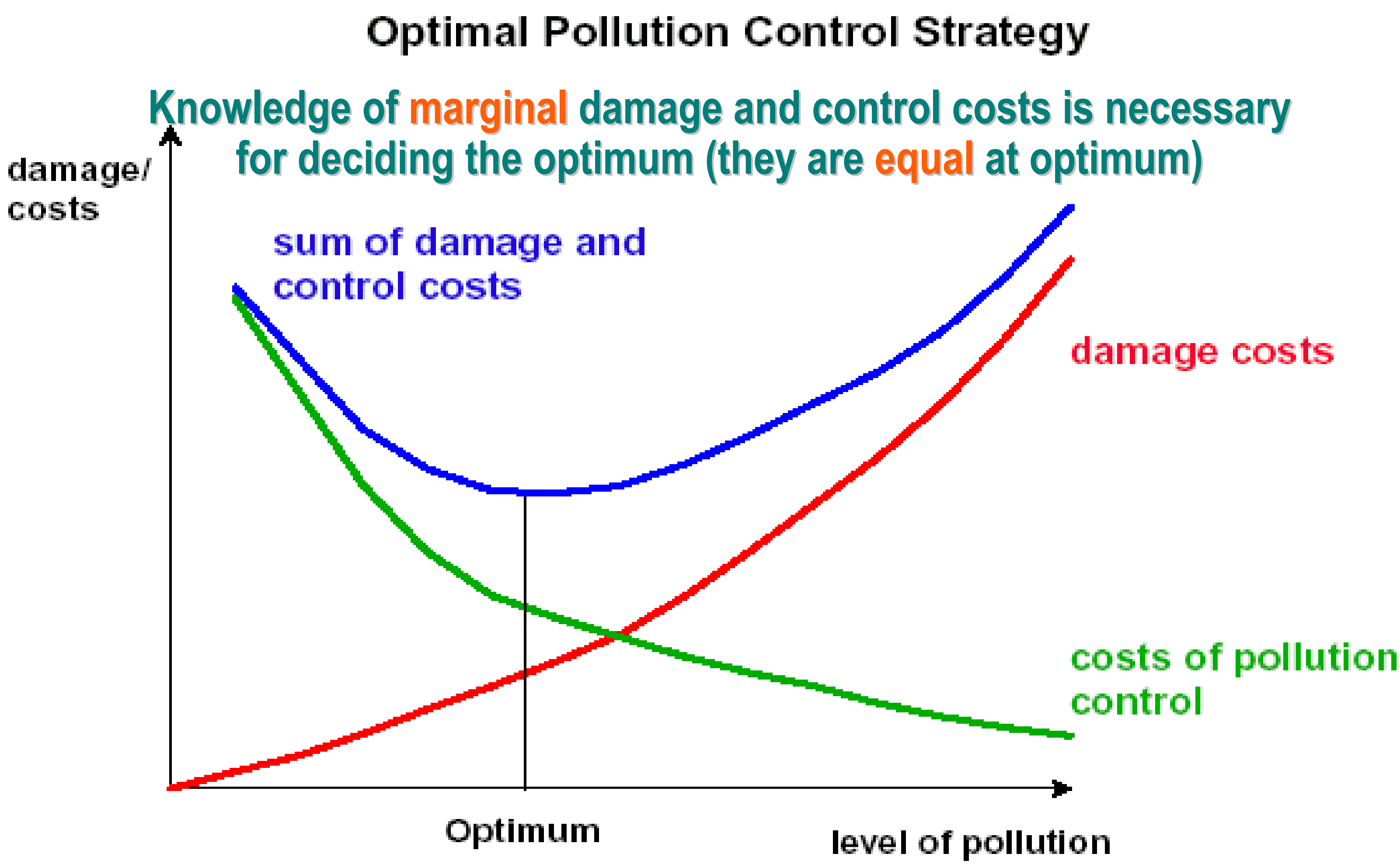
Need for environmental impacts quantification

The assessment of environmental and health impacts is needed for more informed decision-making, among others, about:

- Choices of energy systems/technologies (e.g. coal vs. nuclear)
- Environmental regulations (emission limits, polution taxes, ..)
- Cost effectiveness/ranking of abatement options, etc…
- Quantification of economic corrections to energy markets (e.g. subsidies for renewable sources of energy)

The goal is not to reduce environmental damages to zero, but achieve an ‘optimal emission level‘

Knowledge of **marginal** damage and control costs is necessary for deciding the optimum (they are **equal** at optimum)



Environmental impacts quantification

Energy production and use is a source of considerable environmental and health impacts, whose time and space scale can be very different:

Possible categories for distribution of impacts in time and space

Time→ Space↓	Short (immediate or <1 yr)	Medium (1 yr to 100 yr)	Long (> 100 yr)
Local (< 100 km)	public health environment	public health environment	radioactivity (public health)
Regional (100 to 1000 km)	public health environment	public health environment	radioactivity (public health)
Global		global warming, radioactivity (public health)	global warming, radioactivity (public health)

Boundaries between categories are approximate, and different choices can be made

Environmental impacts quantification

The methods used to estimate environmental damages must be able to:

- address these different scales
- select the most important among the large number of pollutants and damage categories for further analysis

Current models cover only a limited number of substances and possible impacts !

Approaches to Quantification of Environmental Impacts
Damage costs versus control costs

Environmental impacts may be valued either by :

(1) using costs of damages inflicted on society by pollutants, or

(2) the costs of controlling or mitigating pollution damages.

Damage costs

- The most relevant costs to be used in the assessment of externalities, as it is the damages to the society that are sought to be addressed and alleviated by incorporating environmental externality costs into utility resource selection.
- The main disadvantage in using damage costs is the difficulty of calculating them.

Approaches to Quantification of Environmental Impacts
Damage costs versus control costs

Control (abatement / avoidance) costs

Easier to estimate since data on the costs of control is more readily available.

- The method relies on the assumption that actual environmental regulations are close to optimal. In reality control costs only indicate a 'revealed preference' of regulators and have no or only minor relationship to the cost of damages imposed on society.
- If however damage costs are unavailable, use of marginal avoidance costs embeded in policy decisions, targets or costs of compliance with existing legislation can serve as a proxy (i.e. acidification, global warming). This is found to be far superior to ignoring externalities costs, and thus valuing them to zero.

Approaches to Quantification of Environmental Impacts Top-down versus Bottom-up approach

Top-down approach (Earlier externality studies)

- Calculates average costs in an aggregated way, typically for a geografical unit (country or region).
- For example, the Pace study (Ottinger et al 1991) evaluates costs associated with particular emissions (e.g. CO_2 ,SO_2 ,NO_x, particulates) based on existing literature, and then combines these with quantity estimates to obtain environmental costs associated with each fossil fuel energy source (e.g., coal, oil, natural gas).
- The method is relatively simple, however relies heavily on approximations and previous estimates.
- Clearly, the average external costs thus obtained do not account for the differences in location and conditions, nor the effects of additional or marginal impacts can be assessed.

Approaches to Quantification of Environmental Impacts
Top-down versus Bottom-up approach

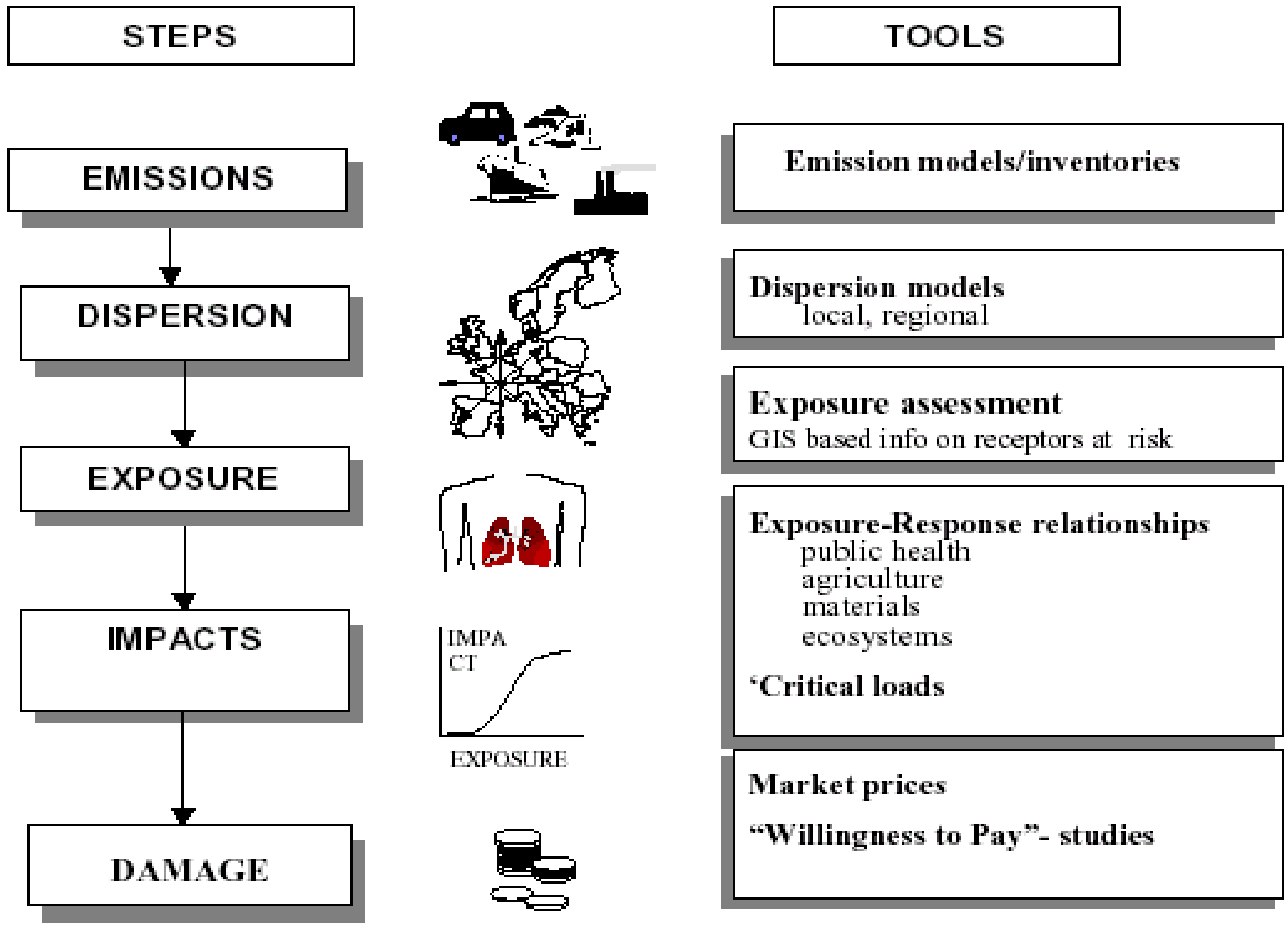
Bottom-up approach (Recent externality studies)

The bottom-up (also called Impact pathway or Damage function) approach, is a step by step procedure linking a burden to an impact, and subsequently assessing physical measure of impact and, where possible, its monetary value.

The calculation process is site dependant for two principal reasons:

- the data and/or model used at each stage may be dependent on the location;
- the aggregate impact is determined by the geographical distribution of receptors.

The Impact Pathway Approach is now widely recognised as the most reliable tool for environmental impact assessment



There are large uncertainties in cost assessments of environmental impacts, i.e. results consist of a range rather then a single value

Emissions → Dispersion (concentration) → Impact on receptors → **Costs**

Emissions	Dispersion (concentration)	Impact on receptors	**Costs**
• uncertainties in data itself	• uncertainties associated with dispersion models	• uncertainties in the dose response functions and receptors	• uncertainties in cost of illnes, value of of human life etc.

- The final results of environmental cost studies cannot be validated, in the sense of being able to compare them with some objective reality / measurement of actual phenomena (produced final results can be compared only with results of other similar studies).

- The impacts of the assumptions and monetary values implicit in different estimates is large enough that isolated quantitative estimates of environmental costs are meaningless unless they are given in the context of a study's assumptions and the environmental effects that are included.

Selected studies published since 1998

Study	Methodology	Key attributes
Hohmeyer 1998	Top-down	Germany. First attempt to assess social costs of energy
Pace (Ottinger et al.) 1991	Top-down	USA. Eight fuel chains. Most of major impacts. Global warming by abatement cost
Pierce at al 1992 and 1995	Top-down	UK and EU. Thirteen fuel chains/technologies. Most of major impacts.
ORNL/RFF 1994	Bottom-up	American part of ExternE study. 2 sites SE and SW of USA. Seven fuel chains. Local and regional impacts.
Rowe et al 1995	Bottom-up	2 sites in New York State, USA. Six fuel chains. Local and regional impacts.
ExternE 1995	Bottom-up	EU, 3 sites (UK and Germany). Seven fuel chains. Local and regional impacts. Literature survay for global warming.
ExternE 1997	Bottom-up	15 countries of EU, most with several sites. Large number of technologies. Local, regional and global impacts

Differences among studies make a meaningful comparison of results difficult. Taken together these studies point rather more toward the diversity of approaches than toward common conclusions.

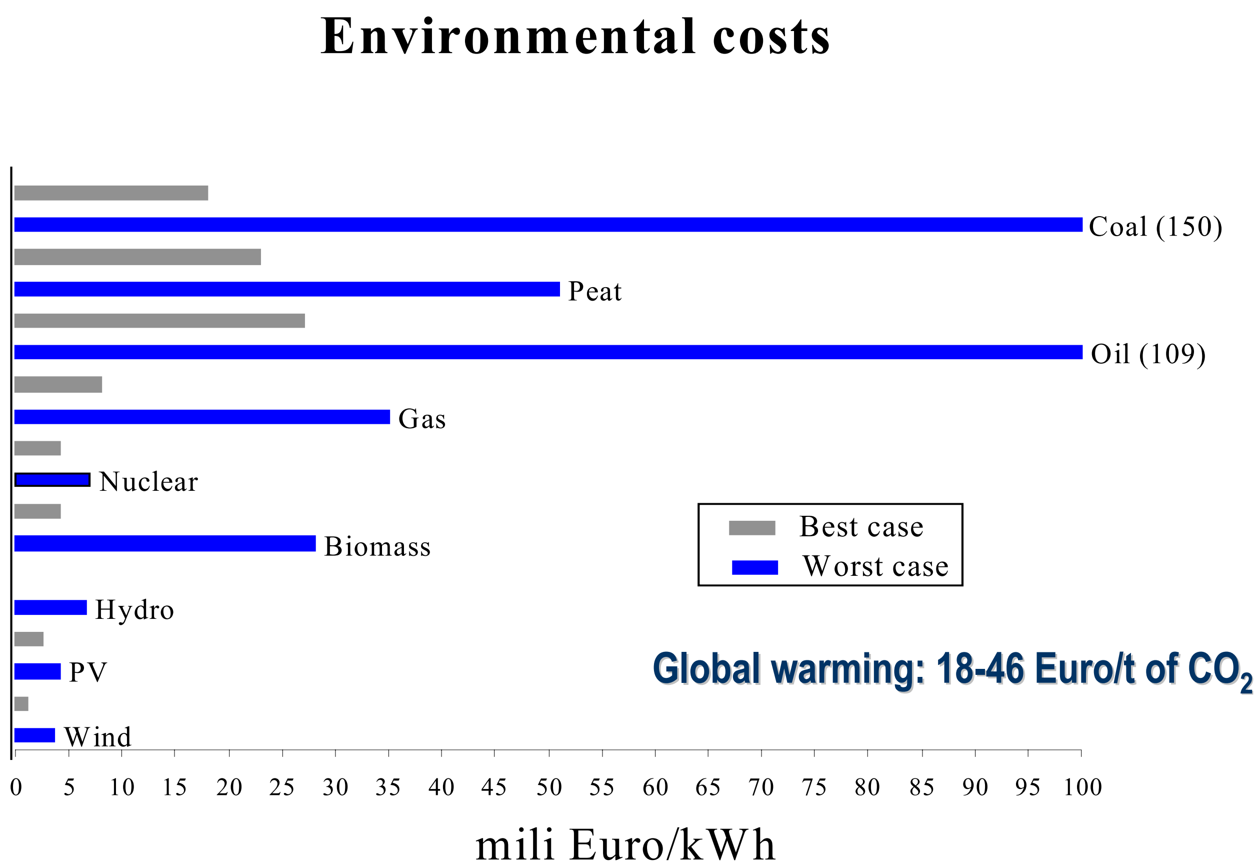
Damage costs in [Euro cents/kWh] for coal and nuclear chains for selected studies

Study	COAL		NUCLEAR	
	Total cost	Global warming	Total cost	Major accident
Hohmeyer 1998	0.74 – 4.0		0.78 – 7.8	0.6 – 6.0
Ottinger et al 1991	2.2-5.5		2.3	1.85
Pierce at al 1992	0.014	0.004	0.0007 – 0.0017	0.0002 – 0.0006
Pierce at al 1995	0.011		0.0007 – 0.0017	0.0002 – 0.0006
ORNL/RFF 1994	0.07 – 0.14	nq	0.009 – 0.01	0.00477 - 0.0083
Rowe et al 1995	0.3 – 0.5	nq	0.009	0 – 0.008
ExternE 1995	0.6 – 1.6 w/o glob. warming	1.0 – 1.8	0.26	0.00014 – 0.00235
ExternE 1997	2.0 – 10.0	1.0 – 5.0	0.25	0.00005 – 0.0023

Nq – not quantified

Source: Rabl, 1998 and other sources

Current Assessment of Fuel Chains – ExternE 1997
EcoSense Model



Source: Eurostat 1998

EcoSense – An integrated computer tool for IPA assessment developed within the ExternE project

*See http://externe.jrc.es

EcoSense : Comparison between continents – Years of Life Lost (YOLL) resulting from the emisson of one kilo-tonne of pollutant (Base year 1990)

	YOLL / kt_ SO_2 direct exposure	YOLL / kt_ SO_2 sulfate aerosols	YOLL / kt_ NO_x nitrate aerosols	YOLL/kt _PM_{10} direct exposure
EU-15 average	**1.7**	**27.0**	**28.5**	**56.7**
Germany	2.2	31.6	27.9	68.6
France	2.3	40.0	51.4	62.9
Sweden	0.4	9.6	11.5	7.3
Finland	0.3	7.0	7.8	6.0
Asia average	**2.5**	**55.2**	**56.9**	**130.8**
China	4.6	104.7	145.2	131.7
Japan	2.5	36.1	39.7	84.6
South Corea	3.5	50.3	47.6	101.0
South America av.	**0.34**	**4.9**	**6.8**	**16.3**
Brazil	1.2	13.3	10.9	16.4
State of Sao Paulo	3.9	38.5	52.5	39.9
Columbia	0.33	3.6	6.0	5.5

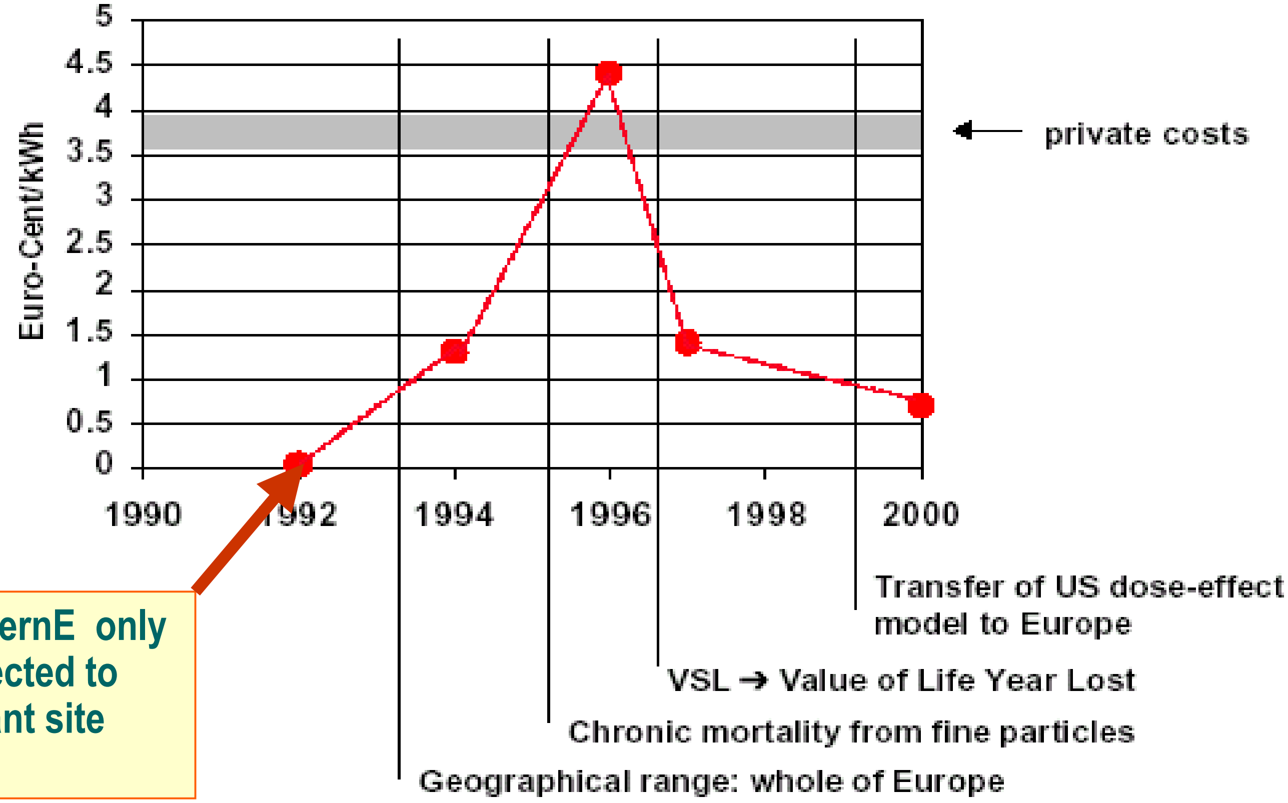
Source: Krewitt at al. (2001);, Int. J. of Life CycleAssessment 6 (4), pp. 199-210

EcoSense : Comparison between continents – Years of Life Lost (YOLL) resulting from the emisson of one kilo-tonne of pollutant (Base year 1990)

- Differences between average damages for kontinents are smaller then the differences between individual countries of a continent
- On the continental average, one of the main parameters determining health related damage factors is the population density
- However, other factors like meteorology (wind speed and direction) and the location of main urban centers also have a significant influence.

Source: Krewitt at al. (2001);, Int. J. of Life CycleAssessment 6 (4), pp. 199-210

Evolution of ExternE results over time due to new knowledge and changing background assumptions (Global warming impacts excluded)



In the very beginning of ExternE only local impacts that were expected to occur close to the power plant site were assessed.

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

Source: Krewitt , External Costs of Energy – do the Answers match the Questions?, Energy Policy (to be pub.)

Evolution of ExternE results over time : Inclusion of estimates of global warming would add considerably to the ups and downs

	Global warming cost	Remarks
ExternE 1995	Results cluster around : 14 Euro/t of CO_2	Based on review of available literature [Cline 1992, Frankhauser 1993, Toll 1995]
ExternE 1997	Intervals of values: - conservative 95% conf. interval: 3.8 to 139 Euro/t of CO_2 - illustrative restricted range : 18 to 46 Euro/t of CO_2	Based on reports of IPCC [1995]
ExternE 2000	Interval of values: 0.1 to 16.4 Euro/t of CO_2 Central estimate: 2.4 Euro/t of CO_2	[Toll and Downing 2000]. Estimates (world averages for impacts up to 2100) described as 'only a fraction, of unknown size', of all climate change impacts'.

Final note

Four parameters have shown to be very important when comparing external costs estimated in different studies, although the studies may be based on the same approach:

- Difference in impacts considered
- Difference in dose-response functions
- Difference in background concentrations of pollutants and population densities for the regions involved
- Diference in monetary values used

It is therefore of outmost importance when using externalities in assessment of different fuel chains that, beside using the same methodology, the damage estimates are based on the same background assumptions. Although the uncertainties remain, the differences will then be mainly due to each fuel chain.