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Environmental costs in the energy and transport sectors

Recommendations by the Federal Environment Agency

Für Mensch & Umwelt

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Content

1 Estimating environmental costs

A technically sound basis of information for estimating environmental costs is of great interest where environmental policy is concerned, as it helps to ensure an objective approach to the debate about the costs and benefits of environmental protection. Such estimates make it possible to quantify the economic benefits of environmental measures. This is because environmental measures reduce spending on health and the environment today and in the future.

Moreover, estimates of environmental costs provide important pointers for designing environmental protection instruments. As a matter of principle, environmental costs should not be borne by the general public, but by the parties who cause them. As long as the prices we pay do not adequately reflect the depletion of our environment, competition will be distorted at the expense of environmentally sound products and production methods, and prices will not send out any signals to consumers that they need to make more sparing use of the environment.

A large number of studies that estimate environmental costs have been conducted at national, European and international level. In some cases, however, the estimates show very wide variations – not least because of great differences in the methods used.

Serious estimates of environmental costs require

- the use of recognized valuation methods complying with the current state of scientific knowledge;
- the use of valuation yardsticks that are technically substantiated and if possible, identical for all application fields; and
- a transparent description of the assumptions and framework conditions behind the estimates.

This makes it possible to substantially reduce the range of variation of estimates in many cases.

In 2007 the Federal Environment Agency therefore drew up a "Methodological Convention for Estimating External Environmental Costs". It was intended to help determine the costs of using the environment by applying uniform and transparent criteria.

In 2009, to take account of recent research findings on the estimation of environmental costs, the Federal Environment Agency commissioned the research institute Infras, Zürich, the IER (Institut für Energiewirtschaft und rationelle Energieanwendung, Stuttgart) and the Fraunhofer Institut für System- und Innovationsforschung (ISI), Karlsruhe, to carry out the research project "Estimation of Environmental Costs and Proposals for Internalising Environmental Costs in Selected Policy Areas". The research project made it clear that the methodological principles of the Methodological Convention published by the UBA in 2007 remain valid. The updated version of the Methodological Convention can be found at http://www.umweltbundesamt.de/publikationen/oekonomische-bewertung-von-umweltschaeden-0.

Scientific advances have taken place in the estimation of environmental costs in particular, e.g. through better ways of estimating cause-effect relationships, better modelling of transport emissions, and further developments in the field of emission factors. Up-to-date best-practice cost rates have been calculated for a number of cost categories on the basis of the research project and the UBA's Methodological Convention. This background paper provides a synoptic overview of the central environmental cost rates recommended by the Federal Environment Agency on the basis of these new findings. They are concerned with greenhouse gas emissions (Chapter 2), air pollutants (Chapter 3), the environmental costs of power generation (Chapter 4), heat generation (Chapter 5) and transport (Chapter 6).

A detailed description of the recommendations on "best-practice cost rates" can be found in Annex B to the Methodological Convention. In each case the basic data and assumptions are documented in detail to give a transparent picture of how the cost rates are calculated.

2 Valuing climate impacts: Cost rate for CO_2 emissions and other greenhouse gas emissions

Climate impacts are of central importance when it comes to estimating environmental costs. They account for a large proportion of the costs when valuing energy production from fossil fuels. In some cases the damage only occurs in the distant future and on a global scale. Furthermore, the extent of the damage is uncertain and also depends on today's climate policy. In view of this, it is only possible to generate rough estimates with the aid of model calculations on the basis of what knowledge we have. In the research project the scientists made a careful evaluation of the current literature and the model results.

Based on the overview of existing damage costs and avoidance costs, and following the principle of erring on the conservative side, the Federal Environment Agency considers a best-practice cost rate of 80 €2010 / tonne CO2 to be appropriate.[1] We regard sensitivity analyses in the range €40 / t CO2 to €120 / t CO2 as meaningful. A distinction should be made between short, medium and long-term cost rates, to take account of the fact that the damage costs and also the avoidance costs increase in the course of time.

Table 1

UBA recommendation on climate costs in $€_{2010}$ / t CO_2

	Climate costs in EUR_{2010} / t CO_2		
	Short term 2010	Medium term 2030	Long term 2050
Minimum figure	40	70	130
Average figure	80	145	260
Maximum figure	120	215	390

Source: Federal Environment Agency (UBA 2012).

The cost rates for the greenhouse gases methane (CH4) and NOx are calculated in the same way as the global warming potential, i.e. the costs for CH4 are 25 times the rate for CO2, and the costs for N2O are 298 times the rate for CO2.[2]

Greenhouse gas emissions from air transport are a special case. They are multiplied by an emission weighting factor of two. This takes account of the fact that high-altitude emissions have a greater damage potential.

3 Cost rates for air pollutant emissions

The cost rates for various air pollutants were determined during the EU project NEEDS (New Energy Externalities for Sustainability), which was completed in 2009, and are documented in Preiss et al. (2008).[3] The results represent the latest state of scientific knowledge. Table 2 shows the average environmental costs per emitted tonne of the relevant pollutant, for emissions from "unknown sources"[4] in Germany. These average figures can be used for a rough estimate of damage costs due to air pollutants if no site-specific information is available on the emission sources. The figures stated relate to emissions for the year 2010. As a rule, the lower the emission source and the higher the population density in the vicinity of the emission source, the more serious are the adverse impacts of air pollutant emissions on health and the environment. That is why the environmental costs per tonne of emissions vary as a function of these factors. This differentiation is primarily relevant for the costs of fine particulate emissions. The cost rates for other air pollutants show little variation with regard to release height and location.

For most applications it is therefore sufficient to use the average cost rates. This makes it possible, for example, to determine what emissions are avoided in Germany in a year thanks to the expansion of renewable energy, and then weight these emissions with the relevant cost rates. Calculations on this basis come to the conclusion that the expansion of renewable energy for heat and power generation avoided environmental costs of €10.1 billion in 2011.[6]

However, where it is a matter of site-specific valuations or where the particulate emissions account for a relatively large proportion of the environmental pollution to be valued, using differentiated cost rates brings a gain in information. For this reason the Methodological Convention 2.0 also includes cost rates for pollutant emissions by various types of installations (power stations, industrial facilities, small combustion plants).

Table 2

Average environmental costs of air pollution due to power generation in Germany in €$_{2010}$ / t emission

	Cost rates for emissions in Germany				
Euro$_{2010}$/t emission	Health damage	Biodiversity losses	Crop damage	Material damage	Total
Germany total					
$PM_{2.5}$	55.400	0	0	0	55.400
PM_{coarse}	2.900	0	0	0	2.900
PM_{10}	39.700	0	0	0	39.700
NO_X	12.600	2.200	500	100	15.400
SO_2	11.900	800	-100	500	13.200
NMVOC	1.600	-300	300	0	1.600
NH_3	18.200	8.700	-100	0	26.800

Source: NEEDS, http://www.needs-project.org/docs/RS3a%20D1.1.zip, own conversion from €2000 to €2010 on the basis of Eurostat/HVPI. Figures rounded.[5]

4 Environmental costs of power generation

To determine the environmental costs of power generation, it is necessary to have emission factors for the various power generation technologies. The Federal Environment Agency regularly publishes the emission factors in grams per kilowatt-hour of electricity (kWhel) for fossil and renewable power generation technologies.

In addition, the emission factors are divided into direct and indirect emissions. Direct emissions relate to the emissions that arise in the course of power generation, i.e. during the operating phase of the individual technology life cycles. Indirect emissions arise during the other phases of the life cycle (construction, maintenance, decommissioning).

Using emission factors and the above-mentioned environmental costs per tonne of pollutant emitted, it is possible to calculate environmental damage avoided and environmental costs for various power generation technologies.[7]

Power generation using lignite gives rise to the highest environmental costs, at 10.75 €-cent/kWhel, followed by the fossil fuels coal and oil. The environmental costs of power generation from natural gas are considerably lower, and the most environmentally friendly solution is power generation from renewable energy sources. Weighting renewable energy sources on the basis of their shares of power generation, the environmental costs of renewable energy sources, in terms of their shares of power generation in 2010, average only around 1.8 €-cent pro kWhel. By contrast, the environmental costs of fossil fuels are around 7 to 9 €-cents per kWhel higher.

This shows that the promotion of renewable energy sources avoids substantial follow-on costs for health and the environment. Thus the environmental damage avoided by using renewable energy sources for power generation amounted to:[8]

- 2007: € 5.6 billion
- 2008: € 5.9 billion
- 2009: € 5.7 billion
- 2010: € 5.8 billion
- 2011: € 8.0 billion

It often makes sense to value the environmental costs of the average electricity mix, for example to quantify the scale of the environmental damage avoided as a result of energy savings. The average costs per kWh are calculated by weighting the share of power generation with the relevant cost rates.

For the year 2010 the results are as follows:

- Electricity mix Germany (with nuclear energy):[9] 7.8 €-Cent / kWh_{el}
- Electricity mix Germany (without nuclear energy): 7.0 €-Cent / kWh_{el}
- Electricity mix, renewable energy, Germany: 1.8 €-Cent / kWh_{el}
- Electricity mix, railway: 7.0 €-Cent / kWh_{el}

These cost rates can also be used to value the economic benefits of investments in saving electricity. This is because not only the electricity costs saved, but also the environmental costs saved can be expressed in euro. Such estimates underline the fact that measures to reduce electricity consumption frequently offer greater benefits than building new power stations.

Table 3

Environmental costs of power generation in Germany in €-cent$_{2010}$ / kWh$_{ele}$

Electricity generation from	Air pollutants	Greenhouse gases	Total environmental costs
Lignite	2.07	8.68	10.75
Coal	1.55	7.38	8.94
Natural gas	1.02	3.90	4.91
Oil	2.41	5.65	8.06
Renewable energy sources			
Hydrodynamic power	0.14	0.04	0.18
Wind energy	0.17	0.09	0.26
Photovoltaic systems	0.62	0.56	1.18
Biomass*	1.07	2.78	3.84

* Average weighted by production shares for solid, liquid and gaseous biomass (households and industry), range from 0.3 to 7.2 €-cent / kWh

Source: Breitschopf (2012) and BMU (2012).

5 Environmental costs of heat generation

Table 4 shows the environmental costs of heat generation for the year 2010. Heating with coal and electricity causes the highest environmental costs by far. They are followed after a sizeable gap by district heating and heating with natural gas and oil. The environmental costs of renewable energy sources for heat generation are considerably lower still. This shows that the expansion of renewable energy on the heating market substantially reduces the resulting environmental costs.

Table 4

Environmental costs of heat energy generation for households in Germany in €-cent$_{2010}$ / kWh$_{final\ energy}$

Heat generation using	Air pollutants	Greenhouse gases	Total environmental costs
Heating oil	0.80	2.52	3.32
Natural gas	0.26	2.02	2.28
Lignite (briquettes)	2.74	3.43	6.17
District heating with grid losses	0.88	2.60	3.48
Electric heating with grid losses	1.14	5.15	6.29
Renewable energy sources			
Solar thermal	0.54	0.55	1.10
Shallow geothermal energy	0.39	1.75	2.13
Biomass*	0.25	1.63	1.88

* Average figure, weighted by production shares, for gaseous, liquid and solid biomass (household and industry), range from 0.56 – 3.2 €-cent/kWh.

Source: Breitschopf, B. (2012) and BMU (2012).

6 Environmental costs of transport

To determine the cost rates for road transport in Germany, the first step is to find out the emissions resulting from operating the various types of vehicles. They arise from fuel combustion and from tyre abrasion and suspended dust thrown up by traffic. Then the emissions from the other life-cycle phases are estimated, e.g. construction, maintenance and waste management, and fuel supply logistics.

In addition to air pollutant emissions and greenhouse gas emissions, traffic also causes noise and adverse impacts on nature and landscape. Cost estimates exist for these aspects as well, and must be added to the emission-related costs. The approach and the resulting transport-related cost rates are described below.

Emission-induced adverse impacts on environment and health are greater in cities than in rural areas. In order to estimate transport-related cost rates (e.g. costs per vehicle kilometre), it is therefore necessary to determine the relevant emissions (e.g. per vehicle kilometre) and the breakdown of mileage between urban and rural areas.[10] The differences are considerable: For example, an average of some 72 percent of local buses operate in urban areas, whereas the figure for trains is only 20 percent.

Table 5 shows the environmental costs per vehicle kilometre for various vehicle types in Germany, in each case based on the average for the vehicles of that type on the road. It makes it clear that, on average, diesel cars give rise to higher environmental costs than petrol-engined cars.

To obtain information about the relative environmental impacts of the various vehicle types, it is necessary to convert the costs shown per vehicle kilometre into cost rates per passenger-kilometre (pkm) and tonne-kilometre (tkm).

Table 5

Environmental costs of transport: €-cent$_{2010}$ / vehicle km

Data for fleet mix 2010

Vehicle category		Urban	Rural	Motorway	All routes (average)
Cars	Diesel	7.7	4.3	5.0	5.8
	Petrol	5.9	3.3	4.0	4.5
Delivery vans	Diesel	18.6	6.7	8.3	12.9
	Petrol	14.9	4.4	5.0	9.7
HGVs	Diesel	44.6	18.3	18.3	25.1
Bus	Diesel	54.4	25.9	23.4	37.3
Motorcycles	4-stroke	6.2	2.1	3.1	3.6
	2-stroke	6.3	2.2	3.0	3.7
Passenger train	Diesel	371.8	228.6	-	257.2
	Electric	160.2	106.5	-	117.2
Freight train	Diesel	1’034.1	628.0	-	709.2
	Electric	282.0	166.7	-	189.8

Underlying data: Federal Environment Agency (UBA 2012).

Table 6 shows the average environmental costs calculated in this way (for all routes) per passenger kilometre or per tonne kilometre.

The cost estimates show that shifting freight traffic from road to rail can make a substantial contribution to avoiding environmental costs. Whereas on average a heavy goods vehicle causes environmental costs of around 2,4 €-cent / tkm, the figure for an electric freight train is only 0,3 €-cent / tkm. This corresponds to a drop of around 90 percent in environmental costs per tonne-kilometre.

The table also demonstrates the benefits of expanding public transport. While cars give rise to environmental costs averaging 3.1 €-cent per passenger-kilometre (petrol) or 4 €-cent per passenger-kilometre (diesel), the figure for electric trains is only 0,8 €-cent / pkm and for buses only 2,2 €-cent / pkm.

Table 6

Environmental costs for various vehicle types in Germany in €-cent$_{2010}$ / passenger km or tonne-kilometre

Vehicle type		Total environmental costs
Cars	Diesel	4.0 €-cent / pkm
	Petrol	3.1 €-cent / pkm
Commercial vehicles	Light commercial vehicles (diesel)	16.2 €-cent / tkm
	Light commercial vehicles (petrol)	12.1 €-cent / tkm
	Heavy goods vehicles (diesel)	2.4 €-cent / tkm
Bus	Diesel	2.2 €-cent / pkm
Motorcycles	Petrol (4-stroke)	3.2 €-cent / pkm
	Petrol (2-stroke)	3.3 €-cent / pkm
Passenger train	Diesel	8.1 €-cent / pkm
	Electric	0.8 €-cent / pkm
Freight train	Diesel	3.2 €-cent / tkm
	Electric	0.3 €-cent / tkm

Source: Federal Environment Agency (UBA 2012).

7 Conclusions

In recent years there have been steady advances in scientific findings about estimating environmental costs. In the Methodological Convention the Federal Environment Agency summarises the latest knowledge in this field, puts forward specific suggestions for best-practice cost rates, and gives a transparent picture of the assumptions and value judgements behind the proposed cost rates. The Methodological Convention thus creates a valid basis for estimating environmental costs and makes it easier to use them in practice.

Environmental costs are of great importance for the economy as a whole. Emissions of greenhouse gases, air pollutants and noise, land take and the depletion of scarce resources cause substantial follow-on costs for health and the environment. If these costs are not charged to the parties responsible, competition is distorted to the disadvantage of environmentally sound products and production processes. This also hinders the development and market diffusion of environmentally sound technologies and products. Especially in highly environment-intensive fields such as the energy and transport sectors it is therefore important to ensure that the resulting environmental costs are charged.

Estimates of environmental costs can be used in many ways. They show the adverse effects of failure to protect the environment, thereby underlining the need to pursue ambitious environmental policy objectives. When assessing the impacts of legislation they can be used to express in monetary terms the economically quantifiable benefits of legislation or its adverse effects on health and the environment. Estimating environmental costs is also important for decisions on infrastructure expansion. For example, investment in sustainable energy systems (e.g. for renewable energy expansion) or transport systems (e.g. public transport, new drive systems) would be placed at a systematic disadvantage if investment decisions were based entirely on company-oriented cost calculations.

Environmental costs are also important for assessing measures and instruments. When assessing the Renewable Energy Sources Act, for example, it is important to consider not only the additional costs due to renewable energy expansion, but also the environmental costs saved as a result. This also applies to measures designed to promote energy efficiency. Their benefit lies not only in the direct energy costs they save, but also in the environmental and health damage they avoid. The environmental cost rates per unit of energy which are published in the Methodological Convention 2.0 can be used directly to express these avoided costs in monetary terms. In this way the costs of transforming the energy system can be compared with their benefits for the economy.

Local authorities, businesses and private households can also make use of environmental cost estimates – especially for environmentally relevant investment decisions. Examples include decisions on energy-saving refurbishment of buildings, investment in new industrial facilities or the purchase of electrical equipment.

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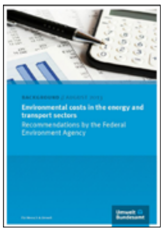
Notes

1 Basic requirements of the Methodological Convention relate to the discount rate (1 percent) and the weighting of damage by income (equity weighting), cf. details in Annex B to the Methodological Convention, UBA (2012).
2 Cf. IPCC (2007) and Blasing (2012).
3 The documentation of the cost rates recommended in NEEDS can be found in http://www.needs-project.org/docs/RS3a%20 D1.1.zip (all figures in €2000).
4 Unknown sources (unknown height of release) means that no details are available on the location of the installation (e.g. inside or outside built-up areas) or the height of the chimney. The figures are therefore averages. Emissions from low sources and in densely populated areas give rise to higher costs; emissions from high sources and/or in thinly populated areas result in correspondingly lower costs.
5 To a small extent, individual areas may give rise to negative external costs, i.e. positive returns. Compared with the overall impacts, however, the individual effects are small.
6 See the detailed account in Breitschopf (2012), and BMU (2012).
7 See the detailed account in Breitschopf (2012), and BMU (2012).
8 Cf. Breitschopf et al. (2010), Breitschopf et al. (2011) and Breitschopf (2012).
9 The rule from the Methodological Convention (UBA, 2012) is used here to assess the environmental costs of nuclear power. In view of the wide range of estimates of the environmental costs of nuclear energy, the emissions are assessed by applying the emission factors of the technology with the highest environmental costs that can be estimated precisely, which in this case is lignite. For a more detailed explanation, cf. UBA (2012).
10 The figures for mileage in urban and rural areas are taken from IFEU (2010) and the authors‘ own estimates. The calculations relate to fine particulate emissions and permit a breakdown into urban and rural areas and motorways.



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