



Fraunhofer  
Institut  
System- und  
Innovationsforschung

## **External costs of electricity generation from renewable energies compared to electricity generation from fossil energy sources**

**- Executive Summary -**

**Wolfram Krewitt**

German Aerospace Centre (DLR), Institute for Technical Thermodynamics  
Dept. of Systems Analysis & Technology Assessment  
Stuttgart

**Barbara Schlomann**

Fraunhofer Institute for System and Innovation Research (ISI),  
Dept. of Energy Policy and Energy Systems  
Karlsruhe

14 March 2006

## Background

The concept of external costs is firmly anchored in economic theory. Various instruments of energy and environmental policy aim to internalise external effects in the energy sector. In spite of considerable research over the past 15 years, quantifying external costs still involves uncertainties. Moreover, new findings in recent years have at times led to a re-assessment of the external costs of electricity generation. Against this background, the BMU commissioned the DLR (Stuttgart) and the FhG-ISI (Karlsruhe) to draw up an expert opinion summarising the current status of knowledge on external costs of electricity generation and elaborating recommendations for using the available data on external costs in the context of energy policy.

## Quantifying external effects

The activities connected with electricity provision lead to various possible external effects. The impacts of greenhouse gas emissions and the health damage caused by air pollutants are especially relevant for quantifying external costs:

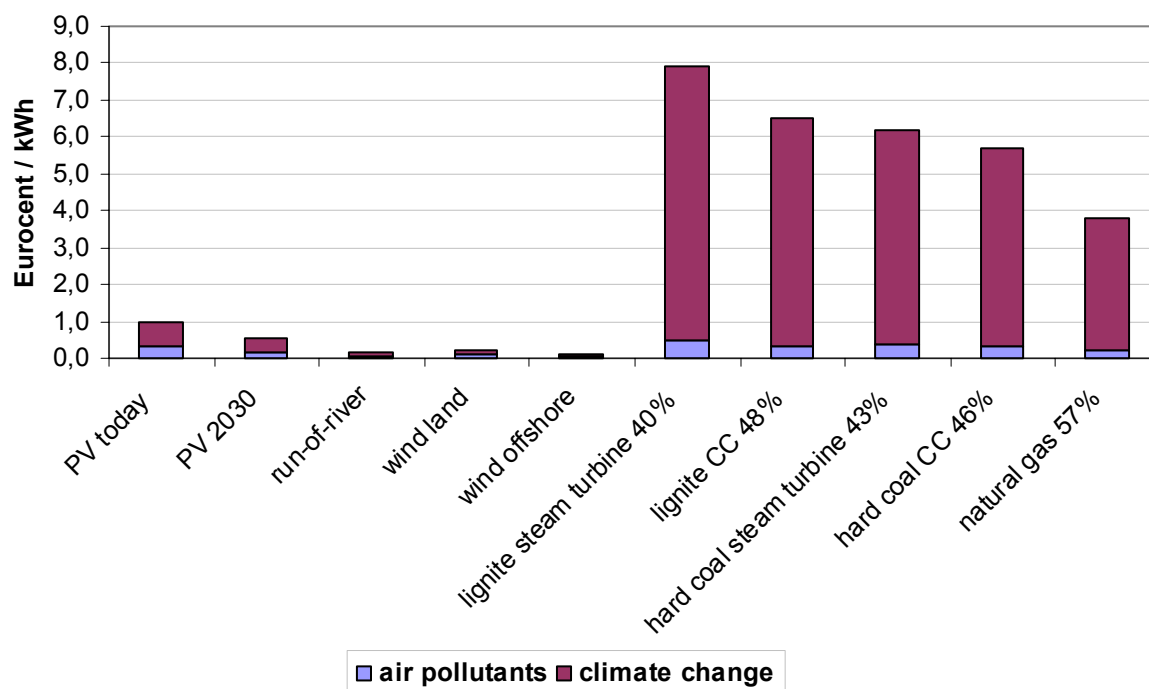
*Climate change:* the impacts of global climate change are diverse and possibly immense. The interactions between the global climate system, the ecosystem and the socio-economic system are very complex. Intensive research over the past years has increased our understanding of the various areas and led to continual improvement in the corresponding models. A recent report by the UK Department for Environment, Food and Rural Affairs (Defra) concludes that the costs of climate change damages are very likely higher than 15 €/t<sub>CO2</sub>. The report's model calculations, based on the Integrated Assessment Model FUND and using plausible estimates of input parameters, indicate damage costs of up to 300 €/t<sub>CO2</sub>. Following an evaluation of the available literature and taking particular account of the findings of the Defra report, damage costs from CO<sub>2</sub> emissions of 70 €/t<sub>CO2</sub> are recommended as a "best guess" for calculating external costs (lower limit value: 15 €/t<sub>CO2</sub>; high estimate: 280 €/t<sub>CO2</sub>). This estimate of climate change damage costs corresponds well to the marginal avoidance costs for stabilising global CO<sub>2</sub> concentrations below 450 ppm as calculated in various scenarios by the German Advisory Council on Global Change (WBGU).

*Health damage from air pollutants:* the ExternE study by the European Commission shows that especially the increased mortality risk arising from chronic exposure to particulate matter (PM<sub>10</sub> or PM<sub>2.5</sub>) leads to substantial external costs. The current approaches of the ExternE study (ExternE Methodology update 2005) are used to quantify external costs arising from health damage.

*Other external effects:* External effects arising from agricultural yield loss and material damage are quantified according to the ExternE method, but these are very small. Up to now there has been no satisfactory means of expressing in monetary terms the impacts on biodiversity and ecosystems of SO<sub>2</sub> and NO<sub>x</sub> emissions due to acidification and eutrophication. Neither is there an approved method to express in monetary terms non-environmental external effects such as impairment of supply security or geopolitical effects. Therefore, the effects quantified here should always be seen as a subtotal of the external costs related to electricity supply.

## External costs of electricity generation

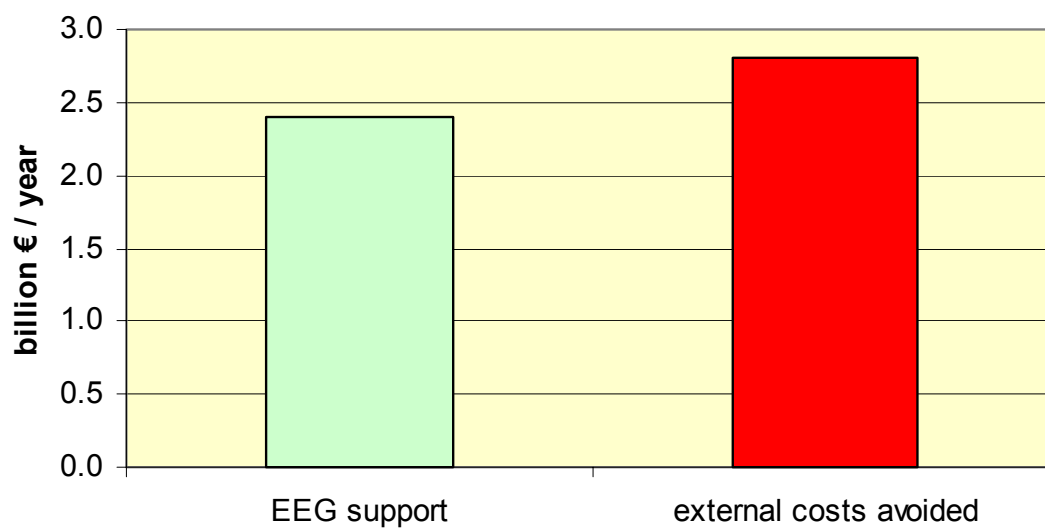
Figure 1 shows the external costs of electricity generation for various generation options, calculated according to the methods described above. The external costs are clearly dominated by the climate change damage costs. For electricity generation from fossil energy sources, external costs are of the same magnitude as the (internal) electricity generation costs. On the other hand, for electricity generation from renewables the external costs are significantly below 1ct/kWh (with the exception of current PV installations, which nevertheless have a great potential for further reductions in external costs).



**Figure 1** external costs of electricity generation for different electricity generation options

## External costs avoided through support of renewable energies

The expansion of renewable energies initiated by the support provided under the Renewable Energy Sources Act (EEG) leads to electricity from conventional power plants being substituted by electricity from renewables and hence to avoidance of environmental damage and its resulting external costs. In 2005, the electricity from renewable energy paid for under the EEG resulted in avoided emissions of 38 million t CO<sub>2</sub>, 13 kt SO<sub>2</sub>, 27 kt NO<sub>x</sub> and 3 kt particulate matter in Germany. Using the above methods for monetary evaluation this corresponds to avoided external costs of around €2.8 billion. This is set against fees of €4.3 billion paid according to the EEG; taking an assessable electricity price of 4.2 ct/kWh, this corresponds to support of €2.4 billion due to the EEG. It can therefore be concluded that the avoided external costs fully compensate the EEG expenditures for supporting renewables. Thus, irrespective of the various other objectives of the EEG, supporting renewable energies "pays off" due to the avoided environmental damage and consequent economic benefit alone.



**Figure 2** Comparison of the costs for supporting renewable energies with the EEG and the external costs avoided in 2005 through EEG electricity.