The German Renewable Energy Sources Act – an investment into the future pays off already today

Wolfram Krewitt*, Joachim Nitsch

accepted for publication in Renewable Energy

*corresponding author:

Dr. Wolfram Krewitt
German Aerospace Center (DLR)
Institute of Technical Thermodynamics
System Analysis and Technology Assessment
Pfaffenwaldring 38-40
D-70569 Stuttgart
Germany
Tel.: +49-711-6862-766
Fax: +49-711-6862-783
e-Mail: wolfram.krewitt@dlr.de

co-author:

Dr. Joachim Nitsch
German Aerospace Center (DLR)
Institute of Technical Thermodynamics
System Analysis and Technology Assessment
Pfaffenwaldring 38-40
D-70569 Stuttgart
Germany

key words: external costs, environmental benefits, policy instruments

Abstract

While the success of the German Renewable Energy Sources Act in supporting the use of renewable energy sources for electricity generation is widely acknowledged, it is partly criticised for imposing unjustified extra costs on society. Based on the well established ExternE methodology for the quantification of environmental externalities the paper makes an attempt to estimate the external costs avoided in the German energy system due to the use of renewable energies for electricity generation, and to compare them against the compensation to be paid by grid operators for electricity from renewable energies according to the Renewable Energy Sources Act. In spite of existing uncertainties associated with the assessment of external costs, results clearly indicate that the reduced environmental impacts and related economic benefits do outweigh the additional costs for the compensation of electricity from renewable energies.

Introduction

Within the last ten years, the claim for ‘getting prices right’ emerged from a popular slogan to a concept with increasing implications on energy and environmental policy. Since in the early 1990s the European Commission’s 5th Environmental Action Programme explicitly required that environmental externalities should be accounted for in market mechanisms, the internalisation of external costs gained increasing attention in a large number of high level conceptual policy papers. But only in spring 2001 the European Commission’s ‘Community guidelines on State aid for environmental protection’ [1] for the first time came up with a quantitative indication of energy related external costs, with direct implications on energy market activities. Based on external costs avoided, the guidelines allow Member States to grant operating aid to new plants producing renewable energy of up to 5 €-cts./kWh.

Besides of the classical internalisation instruments like emission tax or tradable emission permits there exist a wide range of other instruments that are designed to support the market introduction of renewable energy technologies and to overcome the competitive disadvantages against traditional technologies that partly result from the existence of external costs. In Germany, the ‘Act on Granting Priority to Renewable Energy Sources’ (Renewable Energy Sources Act) came into force in April 2000 as a successor of the Act on Feeding into the Grid Electricity Generated from Renewable Energy Sources introduced 1991. According to the Renewable Energy Sources Act the grid operator is obliged to connect new installations for the generation of electricity from renewable energy sources, to purchase electricity available from these installations as a priority, and to compensate the suppliers with a minimum remuneration, which ranges from 6.65 €-cts./kWh for electricity from small hydro power plants (500 kW to 5 MW) up to 50.62 €-cts./kWh (reduced by 5 % annually for new installations) for electricity from photovoltaic. The remuneration is granted for 20 years from start of operation of an individual power plant, and is decreased by 1.5 to 5 % every year for new installations depending on the technology. While the primary target of the Renewable Energy Sources Act is to double the share of renewable energy sources on the electricity generation by 2010 (10 % as against 5 % in 2000) the price adder has been partly justified by the environmental benefits of renewable energy sources in comparison to fossil and nuclear sources [2]. The present paper makes an attempt to compare the additional costs to society resulting from the Renewable Energy Sources Act against the economic benefits resulting from avoided external costs due to electricity generation from renewable energy sources (see also [3]).

2. Calculation of external costs

Energy related external costs are the costs imposed on society and the environment that are not accounted for by the producers and consumers of energy, in other words they are damages which are not reflected in the market price. They include physical damage to the natural and built environment, impacts on human health, as well as impacts on recreation, amenity, aesthetics and other contributors to individual utility. Traditional economic assessment of energy technologies has tended to ignore these effects.

Within the EU funded ExternE-Project (External Costs of Energy), a methodology for the quantification and valuation of environmental impacts from various electricity generation technologies has been developed over the last ten years. The ExternE accounting framework for the assessment of external costs became a widely recognised standard methodology for the calculation of energy related externalities which is used now by various national and international organisations. The ExternE approach aims at modelling the 'impact pathway' of an environmental burden from the release of pollutants through their interactions with the environment to a physical measure of impact. To allow an aggregation and comparison of impacts across impact categories, the welfare losses resulting from health and environmental effects are translated as far as possible into monetary values. Based on the concepts of welfare economics, monetary valuation follows the approach of 'willingness-to-pay' for improved environmental quality. If no dose-effect models are available to quantify a physical impact, thresholds like e.g. critical loads for acid deposition on ecosystems can be used to identify the level of emission reduction required to protect the environment. The ExternE methodology has been described in detail in [4], [5].

While ExternE had a strong focus on the calculation of marginal external costs for specific power plants at specific sites, in the present context we are more interested in the costs and benefits resulting from changes in the overall German electricity system. We have thus applied the ExternE methodology to calculate average damage costs per unit pollutant emitted from the German power sector (see [6] for a description of the methodology, results are updated according to the most recent ExternE developments). By using pollutant specific abatement costs it is straightforward to calculate changes in the total external costs from the German power sector resulting from changes in the total emission load. For the assessment of external costs we consider only those impact categories that proved to dominate energy related externalities in a large number of ExternE case studies (see e.g. [7]). The main assumptions underlying the quantification of external costs for these impact categories are briefly summarised in the following sections:

Human Health Effects

A large number of well conducted epidemiological studies is now available that link air pollution with health effects ranging from a slight impairment of the respiratory system to increased mortality, and there is a growing tendency to treat the associations as causal (see e.g. [8], [9]). Fine particles – either directly emitted from the stack or as aerosols subsequently formed in the air from gaseous SO_2 and NO_x emissions – are of particular importance for the energy sector, as a long term exposure of the population is expected to lead to increased mortality rates even at low concentrations. The economic valuation of health effects is based on empirical studies which measure individuals' *willingness-to-pay* for avoiding specific health risks (see e.g. [10]).

Climate change

In recent years several studies made an attempt to estimate environmental damage costs resulting from global climate change. A modelling exercise in ExternE [11], which covered a time horizon until the year 2100, suggests marginal damage costs of only 2.4 € per tonne of CO_2. However, the authors of the study explicitly state that because of the limited time period covered '*the impacts covered by the models used are only a fraction (of unknown size) of all climate change impacts*' [11].

Because of the large uncertainties associated with the quantification and valuation of climate change impacts, it has been proposed also to use abatement costs required to achieve specific reduction targets as an indication of society's willingness-to-pay for avoiding the potential, but unknown climate change impacts. Although basically not compatible with the concept of externalities, this 'second best' solution based on the standard-price approach at least helps to get an indication of the order of magnitude of potential costs. We here use CO_2 average abatement costs of 30 € per tonne of CO_2 for the German power sector that were calculated for a 40% CO_2-reduction until 2020 in Germany [12]. Of course CO_2-abatement costs heavily depend on general energy-policy conditions.

Acidification and Eutrofication of Ecosystems

Our still limited understanding of the complex mechanism leading to acidification and eutrofication of ecosystems does not yet allow us to apply impact models for the quantification of ecosystem damage. A basic requirement for avoiding future adverse effects on ecosystems is that critical loads and critical levels as defined by the UN ECE [13] shall not be exceeded. Similar to greenhouse gas emissions we can use abatement costs required to achieve reduction targets agreed on by society to put a monetary value on emissions contributing to acidification and eutrofication. The European Commission aims at a ‘50% gap closure’ to protect ecosystems in Europe, which means that the area in which critical loads are exceeded should be reduced by 50% in 2010 [14]. Corresponding abatement costs can be derived from a IIASA study [15] which has quantified the SO_2 and NO_x reductions necessary to achieve the 50% gap closure target.

Material damage and agricultural losses

The effects of air pollution on building materials and agricultural crops have been studied in a large number of experiments, so that reliable dose-effect models are available that can be used for the quantification of impacts. The monetisation of physical impacts is not very problematic neither as market values can be used. However, costs from material damage and yield loss in most cases are low and contribute only a minor fraction to the overall externalities. At low background concentration, an additional exposure to SO_2 might even lead to an increase in crop yield and thus to negative external costs because of a fertilising effect.

Pollutant specific external costs (average costs for Germany) quantified according to the ExternE methodology are summarised in Table 1 for the main impact categories discussed above.

3. External costs avoided due to the use of renewable energy sources

3.1 Electricity generation from renewable energy sources

For the assessment of external costs avoided due to the use of renewable energy sources for electricity generation we assume that the renewable energies will primarily substitute electricity from fossil fuel fired power plants operated by public utilities. As Germany decided to phase out nuclear power, we do not consider nuclear as a competitor to renewable energy sources.

Table 2 shows that there was an impressive increase of electricity generation from renewable energies in Germany between 1999 and 2000, which are the two base years of our analysis. In particular electricity generation from wind and photovoltaic are characterised by high growth rates, with photovoltaics however still contributing only a minor share of the total electricity production. As far as electricity from hydro plants is concerned, only the electricity generated from power plants with a capacity of less than 5 MW that is compensated according to the Renewable Energy Sources Act is considered for the assessment of external costs avoided.

3.2 Emission reductions resulting from the use of renewable energy sources

The assessment of external costs avoided in a first step requires the calculation of emission reductions resulting from the use of renewable energy sources for electricity generation. Avoided emissions are estimated by multiplying the amount of electricity produced from renewable energies as given in Table 2 with the average emission factors of the fossil fired power plants operated by public utilities in Germany (Table 3). As electricity generation from biomass leads to partly significant emissions of SO_2, NO_x and particles, for the sake of simplicity biomass here gets a credit only for a reduction of CO_2 emissions. Table 4 summarises the emissions avoided due to electricity generation from renewables in Germany.

3.3 External costs avoided

The external costs avoided due to the use of renewable energy sources for electricity generation are calculated by multiplying the pollutant-specific damage and abatement costs given in Table 1 with the avoided emissions shown in Table 4. The integration of renewable energies into the German electricity mix resulted in a reduction of energy related externalities of 311 Million € in 1999, in 2000 the external costs avoided already amount to 518 Million €. These benefits from reduced environmental impacts go along with the additional costs for the compensation of electricity from renewables according to the Act on Feeding into the Grid Electricity Generated from Renewable Energy Sources respectively the Renewable Energy Sources Act of 260 Million € in 1999 [16] and 490 Million € in 2000 [17].

4. Costs and benefits – can we compare them?

If in spite of still significant uncertainties associated with the quantification of external costs we dare to directly compare the costs and benefits associated with the German Renewable Energy Sources Act, Figure 1 shows that both costs and benefits are in the same order of magnitude, with the external costs avoided due to electricity generation from renewables higher than the costs required for compensation. The external costs avoided are largely determined by the impact categories acidification and eutrofication, human health effects, and climate change, while impacts on crops as well as material damage are negligible. As discussed above, from a methodological point of view summing up damage costs (health effects, crop losses, material damage) and abatement costs (climate change, acidification and eutrofication) is problematic, but widely accepted as a second best option to at least come up with an indication of potential external costs for the important impact categories climate change and acidification.

Experience from the assessment of environmental externalities tells us that unfortunately those impact categories which potentially lead to high external costs are associated with particular large uncertainties, so that changing background assumptions might have a strong influence on final results. If we would use the marginal damage costs of 2.4 €/t of CO_2 as suggested by the ExternE study for the valuation of climate change impacts, the external costs avoided due to renewable energies would be much lower than indicated in Figure 1. However, ExternE explicitly points out that the reported damage costs are expected to represent only a fraction of the total unknown damage costs because of the limited time horizon covered. If on the other hand we use the *marginal* abatement costs instead of the average abatement costs for CO_2-reduction, i.e. the costs of the most expensive CO_2-reduction measure that is required to achieve the CO_2-reduction target as an indication of society's willingness-to-pay to avoid climate change impacts, the external costs would be much high than shown in Figure 1. Taking into account the existing large uncertainties in this field, we consider the assumptions underlying the present analysis as a pragmatic but sound approach that provides a robust indication of external costs. For a more detailed discussion of uncertainties related to the quantification of energy related externalities see [19] and [20].

The simplifying focus on direct emissions from energy conversion might be criticised, as we know that electricity generation from wind or photovoltaic is not a zero emission technology. Material production and the manufacturing of components lead to environmental impacts from downstream processes. However, fossil fuel chains are associated with significant indirect emissions, too. Various life cycle assessment studies showed that indirect emissions in particular from the wind and hydro life cycles are much lower than those from fossil fuel chains (see e.g. [21]). This is not yet the case for PV systems produced under today's conditions, but the contribution of PV electricity to the total electricity generation is still very small. The overall emission reduction resulting from the use of renewables for electricity generation is underestimated here because of the focus on direct emissions only.

5. Environmental benefits do outweigh the costs

Results discussed above show that – based on our current understanding of environmental externalities – the environmental benefits due to electricity generation from renewable energy sources do outweigh the extra costs resulting from the support of renewables according to the German Renewable Energy Sources Act. Independently of other objectives followed by the Renewable Energy Sources Act, the support of renewable energy sources can be justified just on the basis of avoided environmental impacts and the related economic benefits. This does not necessarily mean that the Renewable Energy Sources Act should be considered as an optimal measure for the internalisation of environmental externalities. The compensation of electricity with 50.62 €-cts./kWh for photovoltaic cannot be justified based on avoided external costs alone. It should be mentioned that the Renewable Energy Sources Act was not designed as an internalisation instrument, but follows a range of different targets within the broad context of various energy and environmental policy measures. The present results however underline that the Renewable Energy Sources Act has been designed in a way that ensures that the total costs imposed to society are well compensated by the social benefits due to avoided environmental damage.

Of course there are also instruments in place besides of the Renewable Energy Sources Act that support the market introduction of renewable energy in Germany. Similar to the Renewable Energy Sources Act, these programmes follow a variety of different targets related to energy, environmental and technology policy. Present results show that at least the direct compensation for electricity from renewables as laid out in the Renewable Energy Sources Act is compensated by avoided environmental externalities. But in addition to the impact categories which have been quantified above we should also take into account aspects like the protection of resources, the security of supply, the tolerance towards technological risks and the fair distribution of environmental property rights, which are of essential importance for a sustainable energy supply but not covered by current external cost estimates. With respect to these aspects, electricity generation from renewable energy sources facilitates a valuable contribution to sustainable development of energy supply which is beyond a monetary cost-benefit assessment.

Acknowledgement
The authors would like to thank Ole Langniß (DLR/Lund University) for helpful comments which helped to improve the paper.

References

[1] European Commission (2001) 'Community guidelines on State aid for environmental protection' Official Journal C 037, 03/02/2001, P. 0003-0015 http://europa.eu.int/eur-lex/en/lif/dat/2001/en_301Y0203_02.html

[2] Entwurf eines Gesetzes zur Förderung der Stromerzeugung aus erneuerbaren Energien (Erneuerbare-Energien-Gesetz – EEG) sowie zur Änderung des Mineralölsteuergesetzes. Beschlussempfehlung und Bericht des Ausschusses für Wirtschaft und Technologie (9.Ausschuss) zu dem Gesetzesentwurf der Fraktionen SPD und BÜNDNIS 90/DIE GRÜNEN. Bundestagsdrucksache 14/2776.

[3] Krewitt W, Nitsch J. Das EEG – eine Investition in die Zukunft zahlt sich schon heute aus. Accepted for publication in Energiewirtschaftliche Tagesfragen.

[4] European Commission. Externalities of Fuel Cycles. European Commission, DG XII, Science, Research and Development, JOULE. ExternE Externalities of Energy. Volume 2: Methodology. Published by the European Commission, EUR 16521, 1995.

[5] European Commission. Externalities of Fuel Cycles. European Commission, DG XII, Science, Research and Development, JOULE. ExternE – Externalities of Energy. Volume 7: Methodology 1998 update. Published by the European Commission, EUR 19083, 1999.

[6] Krewitt W, Heck T, Trukenmüller A, Friedrich R. Environmental Damage Costs from Fossil Electricity Generation in Germany and Europe. Energy Policy 1999; 27: 173-183

[7] European Commission. Externalities of Fuel Cycles. European Commission, DG XII, Science, Research and Development, JOULE. ExternE – Externalities of Energy. Volume 10: National Implementation. Published by the European Commission, EUR 18523, 1999.

[8] Schwartz J. Air Pollution and Daily Mortality in Birmingham, Alabama. American Journal of Epidemiology 1993; 137: 1136-1147.

[9] Pope CA, Thun MJ, Namboodr MM, Dockery DW, Evans JS, Speizer FE, Heath CW. Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of US Adults. Am. J. Resp. Critical Care Med 1995; 151: 669-674.

[10] Rowlatt P, Spackman M, Jones S, Jones-Lee M, Loomes G. Valuation of Deaths from Air Pollution. A report for the Department of Environment, Transport and the Regions and the Department of Trade and Industry. Published by National Economic Research Associates, 1998 London.

[11] Tol R, Downing T E. The marginal costs of climate changing emissions. D-00/08. Institute for Environmental Studies, Vrije Universiteit, Amsterdam, 2000.

[12] Prognos. Energiepolitische und gesamtwirtschaftliche Bewertung eines 40%-Reduktionsszenarios. Endbericht im Auftrag des Bundesministeriums für Wirtschaft und Technologie, 561-5459. Basel, 2001.

[13] Posch M, de Smet P A M, Hettelingh J-P, Downing R J (Eds.). Calculation and Mapping of Critical Thresholds in Europe: Status Report 1995. RIVM Report No. 259101004, RIVM, Bilthoven, 1995.

[14] Commission of the European Communities. Communication to the Council and the European Parliament on a Community Strategy to Combat Acidification. COM(97) 88 final. Brussels, 12.03.1997.

[15] Amann M, Bertok I, Cofala J, Gyarfas F, Heyes C, Klimont Z, Makowski M, Schöpp, W, Syris. Emission Reduction Scenarios to Control Acidification, Eutrophication and Ground-level Ozone in Europe. Report prepared for the 22nd Meeting of the UN/ECE Task-Force on Integrated Assessment Modelling. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria, 1998.

[16] Staiß F. Jahrbuch Erneuerbare Energien 2000. Hrsg.: Stiftung Energieforschung Baden-Württemberg. Bieberstein-Verlag, Radebeul, 2000.

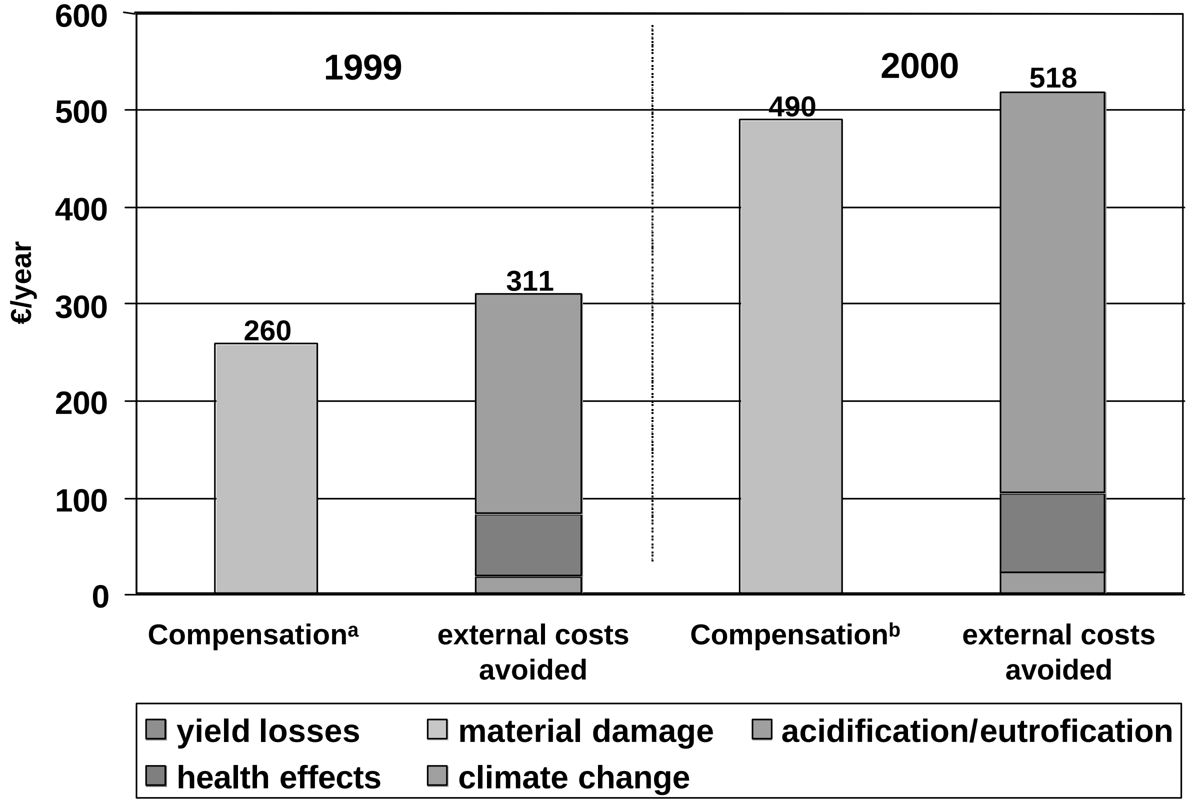
[17] Staiß F. Jahrbuch Erneuerbare Energien 2001. Hrsg.: Stiftung Energieforschung Baden-Württemberg. Bieberstein-Verlag, Radebeul, 2001.

[18] VDEW. Emissionsentwicklung bei EVU-Kraftwerken. VDEW Materialien, M-03/2001. Frankfurt, 2001.

[19] Rabl A, Spadaro J V. Damages and costs of air pollution: an analysis of uncertainties. Environment International 1999 Vol. 25, No. 1, pp. 29-46

[20] Krewitt W. External costs of energy – do the answers match the questions? Accepted for publication in Energy Policy.

[21] Marheineke T, Krewitt W, Friedrich R. Lebenszyklusanalyse verschiedener Stromerzeugungstechnologien. Energiewirtschaftliche Tagesfragen, 2001, 51. Jg., Heft 5, pp. 274-279.



[a] Compensation according to the Act on Feeding into the Grid Electricity Generated from Renewable Energy Sources
[b] Compensation according to the Renewable Energy Sources Act

Figure 1: External costs avoided compared with costs resulting from the compensation of electricity generation from renewable energies in Germany

Table 1: Environmental damage costs and abatement costs per unit pollutant emitted (average costs for Germany; in € per tonne of pollutant)

	SO_2	NO_x	PM_{10} [a]	CO_2
Damage costs				
human health effects	5200	5910	10890	
yield losses	- 2	10		
material damage	130	80		
Abatement costs				
climate change				30
acidification and eutrofication	1480	1530		
Total [b]	6808	7530	10890	30

[a] PM_{10}: particulate matter with an aerodynamic diameter < 10 µm
[b] in a strict sense the use of different valuation methods does not allow summing up across different impact categories

Table 2: Electricity generation from renewable energy sources in Germany [16], [17] in GWh/a

	1999	2000
Wind	5390	9200
Biomass	846	1300
Photovoltaic	15	50
Hydro [a]	1660	3500
Total	7911	14050

[a] only the amount of electricity that was compensated according to the Act on Feeding into the Grid Electricity Generated from Renewable Energy Sources (1999) or the Renewable Energy Sources Act (2000)

Table 3: Average emissions from fossil fired power plants operated by public utilities in Germany [18]

	1999	2000
specific CO_2-emissions in g/kWh	960	980
specific SO_2-emissions in mg/kWh	940	470
specific NO_x-emissions in mg/kWh	670	620
specific particle emissions in mg/kWh	30	30

Table 4: Avoided emissions due to electricity generation from hydro power (< 5 MW), wind, photovoltaic, and biomass (only reduction of CO_2-emissions) in Germany in 10^3 t

	1999	2000
CO_2	7594.6	13769.0
SO_2	6.6	6.0
NO_x	4.7	7.9
Particle	0.2	0.4