



RUHR

ECONOMIC PAPERS

Manuel Frondel
Nolan Ritter
Christoph M. Schmidt
Colin Vance

Economic Impacts from the Promotion of Renewable Energy Technologies The German Experience



#156

Imprint

Ruhr Economic Papers

Published by

Ruhr-Universität Bochum (RUB), Department of Economics
Universitätsstr. 150, 44801 Bochum, Germany

Technische Universität Dortmund, Department of Economic and Social Sciences
Vogelpothsweg 87, 44227 Dortmund, Germany

Universität Duisburg-Essen, Department of Economics
Universitätsstr. 12, 45117 Essen, Germany

Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI)
Hohenzollernstr. 1-3, 45128 Essen, Germany

Editors

Prof. Dr. Thomas K. Bauer
RUB, Department of Economics, Empirical Economics
Phone: +49 (0) 234/3 22 83 41, e-mail: thomas.bauer@rub.de

Prof. Dr. Wolfgang Leininger
Technische Universität Dortmund, Department of Economic and Social Sciences
Economics – Microeconomics
Phone: +49 (0) 231/7 55-3297, email: W.Leininger@wiso.uni-dortmund.de

Prof. Dr. Volker Clausen
University of Duisburg-Essen, Department of Economics
International Economics
Phone: +49 (0) 201/1 83-3655, e-mail: vclausen@vwl.uni-due.de

Prof. Dr. Christoph M. Schmidt
RWI, Phone: +49 (0) 201/81 49-227, e-mail: christoph.schmidt@rwi-essen.de

Editorial Office

Joachim Schmidt
RWI, Phone: +49 (0) 201/81 49-292, e-mail: joachim.schmidt@rwi-essen.de

Ruhr Economic Papers #156

Responsible Editor: Christoph M. Schmidt

All rights reserved. Bochum, Dortmund, Duisburg, Essen, Germany, 2009

ISSN 1864-4872 (online) – ISBN 978-3-86788-173-9

The working papers published in the Series constitute work in progress circulated to stimulate discussion and critical comments. Views expressed represent exclusively the authors' own opinions and do not necessarily reflect those of the editors.

Ruhr Economic Papers #156

Manuel Frondel, Nolan Ritter, Christoph M. Schmidt,
and Colin Vance

Economic Impacts from the Promotion of Renewable Energy Technologies

The German Experience



Bibliografische Informationen der Deutschen Nationalbibliothek

Die Deutsche Bibliothek verzeichnet diese Publikation in der deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über: <http://dnb.ddb.de> abrufbar.

ISSN 1864-4872 (online)
ISBN 978-3-86788-173-9

Manuel Frondel, Nolan Ritter, Christoph M. Schmidt,
and Colin Vance¹

Economic Impacts from the Promotion of Renewable Energy Technologies – The German Experience

Abstract

The allure of an environmentally benign, abundant, and cost-effective energy source has led an increasing number of industrialized countries to back public financing of renewable energies. Germany's experience with renewable energy promotion is often cited as a model to be replicated elsewhere, being based on a combination of far-reaching energy and environmental laws that stretch back nearly two decades. This paper critically reviews the current centerpiece of this effort, the Renewable Energy Sources Act (EEG), focusing on its costs and the associated implications for job creation and climate protection. We argue that German renewable energy policy, and in particular the adopted feed-in tariff scheme, has failed to harness the market incentives needed to ensure a viable and cost-effective introduction of renewable energies into the country's energy portfolio. To the contrary, the government's support mechanisms have in many respects subverted these incentives, resulting in massive expenditures that show little long-term promise for stimulating the economy, protecting the environment, or increasing energy security.

JEL Classification: Q28, Q42, Q48

Keywords: Energy policy, energy security, climate, employment

November 2009

¹ Manuel Frondel, RWI; Nolan Ritter, RWI; Christoph M. Schmidt, RWI, Ruhr-Universität Bochum, CEPR London, IZA Bonn; Colin Vance, RWI, Jacobs University Bremen. – All correspondence to Manuel Frondel, RWI, Hohenzollernstr. 1-3, 45128 Essen, Germany, e-mail: frondel@rwi-essen.de.

1. Introduction

The allure of an environmentally benign, abundant, and cost-effective energy source has led an increasing number of industrialized countries to back public financing of renewable energies. For Europe, the European Commission set a target of 20% for the share of electricity from renewable sources by 2020, which is intended to foster compliance with international agreements on greenhouse gas emission reductions³ and to provide opportunities for employment and regional development (EC 2009:16). These goals are shared by the German Environment Ministry, which regards renewables as a central pillar in efforts to protect the climate, reduce import dependency, and safeguard jobs (BMU 2008:8).

A closer look at Germany's experience, however, whose history of public support for renewable electricity production stretches back nearly two decades, suggests that such emphasis is misplaced. This paper critically reviews the current centerpiece of the German promotion of renewable energy technologies, the Renewable Energy Sources Act (EEG), focusing on its cost and the associated implications for job creation and emissions reductions. The paper will show that, by and large, government policy has failed to harness the market incentives needed to ensure a viable and cost-effective introduction of renewable energies into Germany's energy portfolio. To the contrary, the government's support mechanisms have in many respects subverted these incentives, resulting in massive expenditures that show little long-term promise for stimulating the economy, protecting the environment, or increasing energy security.

The following section describes Germany's growth of electricity production from wind power, photovoltaics (PV) and biomass, the predominant renewable energy sources, together accounting for about 90% of supported renewable electricity production in 2008 (BMU 2009a). Section 3 presents cost estimates of Germany's subsidization of PV modules and wind power plants that were installed between 2000 and 2008, thereby providing for an impression of the resulting long-lasting burden on German electricity consumers. In Section 4, we assess the potential benefits of Germany's subsidization scheme for the global climate, employment, energy security, and technological innovation. The last section summarizes and concludes.

2. Germany's Promotion of Renewable Technologies

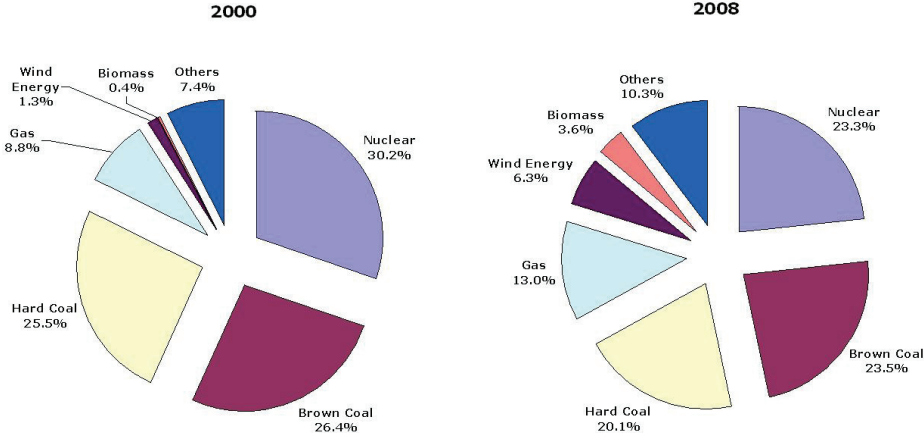
Through generous financial support, Germany has dramatically increased the electricity production from renewable technologies since the beginning of this century (IEA 2007:65). With a share of about 15% of total electricity production in 2008 (Schiffer 2009:58), Germany has more than doubled its renewable electricity production since 2000 and has already significantly exceeded its minimum target of 12.5% set for 2010.

³ The Commission has stipulated a particularly ambitious target for Germany, aiming to triple the share of renewable sources in the final energy mix from 5.8% in 2005 to 18.0% in 2020.

This increase came at the expense of conventional electricity production, whereby nuclear power experienced the largest relative loss between 2000 and 2008 (Figure 1).

Currently, wind power is the most important of the supported renewable energy technologies: In 2008, the estimated share of wind power in Germany’s electricity production amounted to 6.3% (Figure 1), followed by biomass-based electricity generation and water power, whose shares were around 3.6% and 3.1%, respectively. In contrast, the amount of electricity produced through solar photovoltaics (PV) was negligible: Its share was as low as 0.6% in 2008.

Figure 1: Gross Electricity Production in Germany in 2000 and 2008 (AGEB 2009, BMU 2009a)



The substantial contribution of renewable energy technologies to Germany’s electricity production is primarily a consequence of a subsidy policy based on feed-in tariffs that was established in 1991, when Germany’s Electricity Feed-in Law went into force. Under this law, utilities were obliged to accept and remunerate the feed-in of “green” electricity at 90 percent of the retail rate of electricity, considerably exceeding the cost of conventional electricity generation. An important consequence of this regulation was that feed-in tariffs shrank with the electricity prices in the aftermath of the liberalization of European electricity markets in 1998.

With the introduction of the Renewable Energy Sources Act (EEG), the support regime was amended in 2000 to guarantee stable feed-in tariffs for up to twenty years, thereby providing for favourable conditions for investments in “green” electricity production over the long term. Given the premature over-compliance with the target for 2010, it is not surprising that Germany’s EEG is widely considered to be very successful in terms of increasing green electricity shares, and has thus been adopted by numerous other countries, including France, Italy, Spain and the Czech Republic (Voosen 2009).

Under the EEG regime, utilities are obliged to accept the delivery of power from independent producers of renewable electricity into their own grid, thereby paying

technology-specific feed-in tariffs far above their production cost of 2 to 7 Cents per kilowatt hour (kWh). With a feed-in tariff of 43 Cents per kWh in 2009, solar electricity is guaranteed by far the largest financial support among all renewable energy technologies (Table 1). Currently, the feed-in tariff for PV is more than eight times higher than the electricity price at the power exchange (Table A1) and more than four times the feed-in tariff paid for electricity produced by on-shore wind turbines (Table 1).

This high support for solar electricity is necessary for establishing a market foothold, with the still low technical efficiencies of PV modules and the unfavorable geographical location of Germany being among a multitude of reasons for solar electricity's grave lack of competitiveness. With the exception of electricity production from large water power stations, other sources of green electricity are also heavily dependent on the economic support stipulated by the EEG. Even on-shore wind, widely regarded as a mature technology, requires feed-in tariffs that exceed the per kWh cost of conventional electricity by up to 300% to remain competitive.

Table 1: Technology-Specific Feed-in Tariffs in Euro Cents per kWh

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Wind on-shore	9.10	9.10	9.00	8.90	8.70	8.53	8.36	8.19	8.03	9.20
Wind off-shore	9.10	9.10	9.00	8.90	9.10	9.10	9.10	9.10	8.92	15.00
Photovoltaics	50.62	50.62	48.09	45.69	50.58	54.53	51.80	49.21	46.75	43.01
Biomass	10.23	10.23	10.13	10.03	14.00	13.77	13.54	13.32	13.10	14.70
Mean Tariff	8.50	8.69	8.91	9.16	9.29	10.00	10.88	11.36	12.25	--

Sources: BDEW (2001 through 2009), EEG (2000, 2004, 2009)

While utilities are legally obliged to accept and remunerate the feed-in of green electricity, it is ultimately the industrial and private consumers who have to bear the cost through increased electricity prices. In 2008, the price mark-up due to the subsidization of green electricity was about 1.5 Cent per kWh, that is, roughly 7.5% of the average household electricity prices of about 20 Cents per kWh. This price mark-up results from dividing the overall amount of feed-in tariffs of about 9 Bn € (US \$12.7 Bn) reported in Table 2 by the overall electricity consumption of 617 Bn kWh (AGEB 2009:22).

Although PV accounted for only 6.2% of renewable electricity production, it is the most privileged technology in terms of highest support per kWh, appropriating 24.6% of the overall feed-in tariffs in 2008 (Table 2). In contrast, the share of hydro power in renewable energy production is 7.0%, but it received only 4.2% of total feed-in tariffs in 2008. Overall, the level of feed-in tariffs increased nearly six-fold between 2001 and 2008, from almost 1.6 to about 9 Bn €.

Some sense for the sheer magnitude of this figure can be gleaned from a comparison with the government's investment in R&D for renewable energies, which we

will later argue to be a considerably more cost-effective means of fostering efficiency improvements. In 2007, this investment amounted to 211.1 Mio. € (BMW 2009), an inconsequential 3% of the total feed-in tariffs of 7.59 Bn € in the same year.

Table 2: Share of Feed-in Tariff Expenditures Allocated to Major Technologies

	2001	2002	2003	2004	2005	2006	2007	2008
Wind Power	-	64.5%	65.1%	63.7%	54.3%	47.1%	44.5%	39.5%
Biomass	-	10.4%	12.5%	14.1%	17.7%	23.0%	27.4%	29.9%
Photovoltaics	-	3.7%	5.9%	7.8%	15.1%	20.3%	20.2%	24.6%
Total in Bn €	1.58	2.23	2.61	3.61	4.40	5.61	7.59	9.02

Sources: BDEW (2001 through 2009) and own calculations.

Along with the significant increase in total tariffs, there was an enormous growth in renewable energy production capacities over the past decade, particularly of wind power (Figure 2). Apart from the U.S., Germany has the largest wind power capacities globally, being almost 24,000 Megawatt (MW) in 2008 (Figure 3). This is one sixth of the overall power capacity of about 150,000 MW in Germany. With respect to PV, Germany's capacity outstrips that of any other country, followed by Spain in second position. In fact, the annual installation of PV capacities almost tripled in the last five years. With 1,500 MW of new installations in 2008, the German market accounted for 42% of the global PV business (REN21 2009:24).

Given the tremendous growth illustrated by Figure 2 and Table 3, it is no wonder that Germany's support scheme based on feed-in tariffs is globally regarded as a great success and that similar promoting instruments for renewable technologies have been implemented elsewhere. The critical issue that will be assessed in the subsequent sections is, however, whether Germany's renewable support scheme is also cost-effective.

Figure 2: Installed Capacities of Wind Power, PV, and Biomass in Germany (BMU 2009a:21)

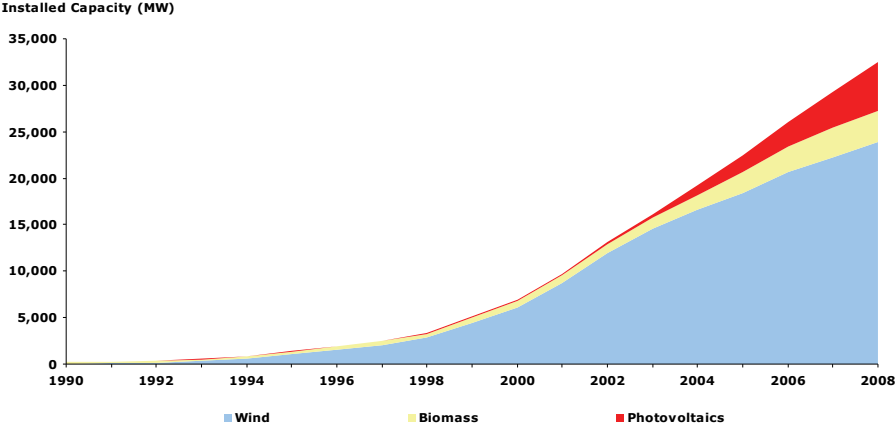
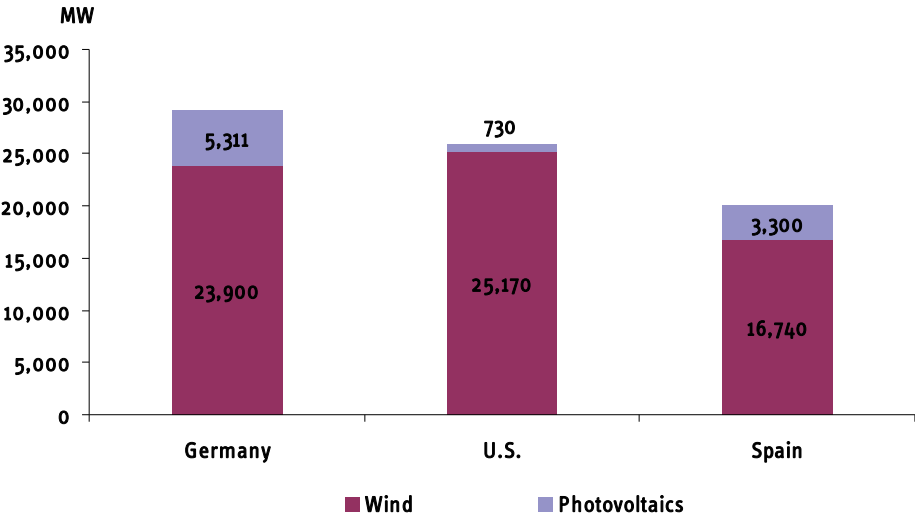


Table 3: Solar Electricity Capacities and Production in Germany

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Capacity Installed, MW	100	178	258	408	1,018	1,881	2,711	3,811	5,311
Annual Increase, MW	-	78	80	150	610	863	830	1,100	1,500
Annual Solar Cell Production in Germany	16	33	54	98	187	319	530	842	1,450

Sources: Production: BMU (2009a), Capacity Installed: BMU (2009a), German Cell Production: BSW (2009).

Figure 3: Installed Capacities of Wind Power and PV in 2008 (REN21)

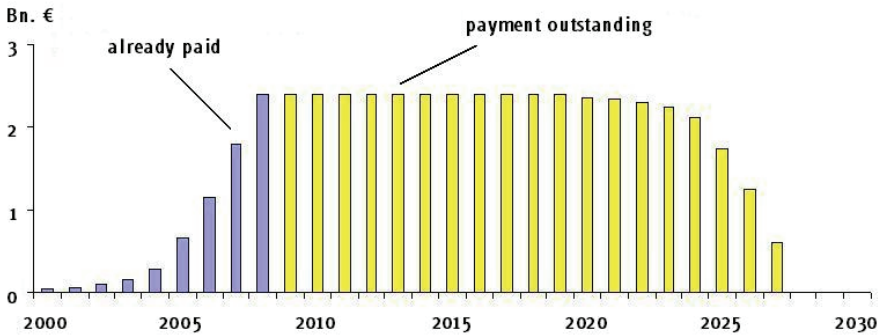


3. Long-Lasting Consequences for Electricity Consumers

The 2009 amendment to Germany’s EEG codifies the continued extension of generous financial support for renewable energy technologies over the next decades, with each newly established plant commonly being granted a 20-year period of fixed feed-in tariffs – already an original feature of the EEG when it was enacted in 2000. Hence, in contrast to other subsidy regimes, such as the support of agricultural production under the EU’s notoriously protective Common Agricultural Policy, the EEG will have long-lasting consequences. Even if the subsidization regime had ended in 2008, electricity consumers would still be saddled with charges until 2028 (Figure 4). Most disconcertingly, with each year the program is extended, the annual amount of feed-in tariffs for PV increases considerably because of the substantial addition of new cohorts of modules receiving the subsidy, as is displayed in Figure 4 for the case of extending the program to 2010.

In quantifying the extent of the overall burden, we focus on the total net cost of subsidizing electricity production by wind power plants and PV modules both for those plants and modules that were already installed between 2000 and 2008 and for those that may be added in 2009 and 2010. Costs incurred from support of biomass are also substantial, but their quantification is precluded by a highly complex schedule of feed-in tariffs that depend on the concrete technology applied. Moreover, biomass energy generation is widely distributed across a large number of small plants for which no centralized data repository exists.

Figure 4: Annual Amount of Feed-in Tariffs for PV for the cohorts 2000 through 2008



Any assessment of the real net cost induced by subsidizing renewable technologies requires information on the volume of green electricity generation, technology-specific feed-in tariffs, as well as conventional electricity prices, with the specific net cost per kWh being calculated by taking the difference between technology-specific feed-in tariffs and market prices at the power exchange. Our estimates are based on the past electricity production figures for wind and solar electricity for the years 2000 through 2008 and on forecasts of future capacity growth originating from a recent PV

study (SARASIN 2007) and a study by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU 2009a). The appendix presents the tables used for our detailed calculations and provides some explanation of their derivation (see also Frondel, Ritter, Schmidt 2008). Past and future market prices for electricity were taken from the "high price scenario" assumed by NITSCH et al. (2005), a study on the future development of renewable energy technologies in Germany.

This price scenario appears to be realistic from the current perspective: real base-load prices are expected to rise from 4.91 Cents per kWh in 2010 (in prices of 2007) to 6.34 Cents per kWh in 2020 (see Table A1). Uncertainties about future electricity prices, however, are hardly critical for the magnitude of our cost estimates, given the large differences between market prices of electricity and, specifically, of the feed-in tariffs for PV, which are as high as 43 Cents per kWh in 2009 (Table A 1).

3.1 Net Cost of Promoting PV

Taking these assumptions and the legal regulations into account and assuming an inflation rate of 2%, which is slightly lower than the average rate since the German reunification, the real net cost for all modules installed between 2000 and 2008 account for about 35 Bn € (in prices of 2007). Future PV installations in 2009 and 2010 may cause further real cost worth 18.3 Bn € (Table 4). Adding both figures yields a total of 53.3 Bn € for PV alone.

Table 4: Net Cost of Promoting PV

	Annual Increase	Nominal Specific Net Cost		Cumulated Net Cost	
		1 st year	20 th year	Nominal	Real
		Mio kWh	€ Cents/kWh	€ Cents/kWh	Bn €
2000	64	47.99	42.49	0.581	0.559
2001	52	47.94	42.15	0.469	0.442
2002	72	45.36	39.33	0.609	0.563
2003	125	42.90	36.63	0.989	0.897
2004	244	47.74	41.21	2.152	1.913
2005	725	50.23	44.85	6.919	6.027
2006	938	47.30	41.78	8.385	7.164
2007	1,280	44.50	38.86	10.705	8.969
2008	1,310	41.82	36.05	10.282	8.409
Total burden for past installations:				41.091	34.943
2009	1,600	37.85	31.96	11.269	9.032
2010	1,880	34.16	28.15	11.837	9.296
Total burden at the end of 2010:				64.197	53.272

Note: Sources of Column 1: 2000-2008: BMU (2009a), 2009-2010: SARASIN (2007). Columns 2 and 3: Differences between feed-in tariffs and market price for the first and the 20th year, respectively. Column 4: Nominal figures of Column 5, using an inflation rate of 2%. Column 5: Last row of Table A2 in the Appendix.

3.2 Net Cost of Promoting Wind Power

The promotion rules for wind power are more subtle than those for PV. While wind energy converters are also granted a 20 year-period of subsidization, the feed-in tariffs are not necessarily fixed over 20 years. In the first 5 years after instalment, each converter receives a relatively high feed-in tariff currently amounting to 9.2 Cents per kWh (Table A1), whereas in the following 15 years the tariff per kWh may be considerably less, depending on the effectiveness of the individual converter. If a converter's electricity output turns out to be low, which is actually the rule rather than the exception, the period of high tariffs can easily stretch to the whole 20 years of subsidization.

As there is no information about how large the share of converters is that are given a prolonged period of high tariffs, in what follows, we calculate both the upper and lower bounds of the net cost of wind electricity generation (Tables 5 and 6). Turning first to the upper-bound case, the net cost of the converters installed between 2000 and 2008 amounts to 19.8 Bn € in real terms if all wind converters were to receive the elevated initial feed-in tariff for 20 years. Future installations in 2009 and 2010 may cause further real cost, so that the wind power subsidies would total 20.5 Bn € if the EEG subsidization were to be abolished at the end of 2010.

Table 5: Net Cost of Promoting Wind Power if elevated tariff holds for 20 years

	Annual Increase Bn. kWh	Nominal Specific Net Cost		Cumulated Net Cost	
		1 st year	20 th year	Nominal	Real
		€ Cents/kWh	€ Cents/kWh	Bn €	Bn € ₂₀₀₇
2000	7.55	6.47	0.97	5.839	5.884
2001	2.96	6.42	0.63	2.116	2.100
2002	5.28	6.27	0.24	3.347	3.281
2003	3.07	6.11	0.00	1.698	1.645
2004	6.65	5.86	0.00	3.032	2.906
2005	1.72	4.23	0.00	0.637	0.603
2006	3.48	3.86	0.00	1.056	0.990
2007	8.79	3.48	0.00	2.134	1.982
2008	2.23	3.10	0.00	0.423	0.389
Total burden for past installations:				20.282	19.780
2009	1.69	4.04	0.00	0.508	0.450
2010	1.38	3.70	0.00	0.341	0.299
Total burden at the end of 2010:				21.131	20.529

Note: Sources of Column 1: 2000-2008: BMU (2009a), 2009-2010: SARASIN (2007), Columns 2 and 3: Differences between feed-in tariffs and market price for the first and the 20th year, respectively. Column 4: Nominal figures of Column 5. Column 5: Last row of Table A2 in the Appendix.

Note that, given the assumed price scenario, electricity prices will eventually exceed the feed-in tariffs for wind power, resulting in zero net costs. Referencing the year 2002, for example, the difference between the feed-in tariff for wind converters installed in that year and electricity prices was 6.27 Cents per kWh (Column 2, Table 5). Twenty years hence, in 2021, the difference between the feed-in tariff for these same converters and future conventional electricity costs is projected to be just 0.24 Cents (Column 3, Table 5). By 2022, wind converters that had been installed 2003 are expected to be “competitive” in the sense that feed-in tariffs are then lower than the assumed price of electricity. As a consequence, investors in wind power converters may contemplate selling electricity at the power exchange rather than accepting the then lower tariffs.

Table 6: Net Cost of Promoting Wind Power if the elevated tariff holds for only 5 years

	Annual Increase Mio kWh	Nominal Specific Net Cost		Cumulated Net Cost	
		1 st year	20 th year	Nominal	Real
		€ Cents/kWh	€ Cents/kWh	Bn €	Bn € ₂₀₀₇
2000	7.55	6.47	0.00	3.072	3.320
2001	2.96	6.42	0.00	1.099	1.171
2002	5.28	6.27	0.00	1.719	1.808
2003	3.07	6.11	0.00	0.867	0.899
2004	6.65	5.86	0.00	1.505	1.540
2005	1.72	4.23	0.00	0.327	0.328
2006	3.48	3.86	0.00	0.595	0.585
2007	8.79	3.48	0.00	1.323	1.276
2008	2.23	3.10	0.00	0.290	0.274
Total burden for past installations:				10.797	11.201
2009	1.69	4.04	0.00	0.297	0.275
2010	1.38	3.70	0.00	0.216	0.196
Total burden at the end of 2010:				11.310	11.672

Note: Sources of Column 1: 2000-2008: BMU (2009a), 2009-2010: BMU (2008), Columns 2 and 3: Differences between feed-in tariffs and market price for the first and the 20th year, respectively. Column 4: Nominal figures of Column 5. Column 5: Last row of Table A2 in the Appendix.

Should wind converters receive the elevated feed-in tariff for only the first five years, tariffs will reach the electricity price level even earlier. In this lower-bound case, the wind converters installed in 2008 are expected to induce no further cost from 2013 onwards. Accordingly, the total sum of net cost is smaller than in the case of 20 years of elevated feed-in tariffs, amounting to some 11.2 Bn € in real terms for all converters installed between 2000 and 2008. Future installations in 2009 and 2010 may further

increase real cost, so that the wind power subsidies may total 11.7 Bn € in real terms, i.e. US \$16.6 Bn, at the end of 2010 (Table 6).

In any case, with cumulated real cost ranging between about 11.2 and 19.8 Bn € in 2008, the net cost of promoting wind power is substantially lower than the promotion of PV, whose net cost adds up to much more than 35 Bn € so far and can be expected to rise dramatically. Given the drastic price drop of PV modules of more than 30 % within the first half of 2009, the net cost for subsidizing PV may increase tremendously unless feed-in tariffs are not diminished accordingly in the coming years, with a sky-rocketing demand from Germany as a likely consequence.

Yet, in sharp contrast to the cost of subsidizing PV, which is significantly higher than for wind power, the amount of solar electricity produced is considerably smaller: Our cost estimates for PV modules installed between 2000 and 2008 are based on an overall solar electricity production of 96 Bn kWh during the 20 years of subsidization, while the wind converters installed in the same period of time produce 835 Bn kWh.

3.3 Cost-Effective Climate Protection?

The estimates presented in the previous section clearly demonstrate that producing electricity on the basis of renewable energy technologies is extremely costly. As a consequence, these technologies are far from being cost-effective climate protection measures. In fact, PV is among the most expensive greenhouse gas abatement options: Given the net cost of 41.82 Cents/kWh for modules installed in 2008 (Table 4), and assuming that PV displaces conventional electricity generated from a mixture of gas and hard coal with an emissions factor of 0.584 kg carbon dioxide (CO₂) per kWh (Nitsch et al. 2005:66), then dividing the two figures yields abatement costs that are as high as 716 € per tonne.

The magnitude of this abatement cost estimate is in accordance with the IEA's (2007:74) even larger figure of around 1,000 € per tonne, which results from the assumption that PV replaces gas-fired electricity generation. Irrespective of the concrete assumption about the fuel base of the displaced conventional electricity generation, abatement cost estimates are dramatically larger than the current prices of CO₂ emission certificates: Since the establishment of the European Emissions Trading System (ETS) in 2005, the price of certificates has never exceeded 30 € per tonne of CO₂.

Although wind energy receives considerably less feed-in tariffs than PV, it is by no means a cost-effective way of CO₂ abatement. Assuming the same emission factor of 0.584 kg CO₂/kWh as above, and given the net cost for wind of 3.10 Cents/kWh in 2008 (Table 6), the abatement cost approximate 54 € per tonne. While cheaper than PV, this cost is still more than threefold the current price of certificates in the ETS. In short, from an environmental perspective, it would be economically much more efficient if greenhouse gas emissions were to be curbed via the ETS, rather than by subsidizing

renewable energy technologies such as PV and wind power. After all, it is for efficiency reasons that emissions trading is among the most preferred policy instruments for the abatement of greenhouse gases in the economic literature (Bonus 1998:7).

4 Impacts of Germany's Renewables Promotion

Given the substantial cost associated with Germany's promotion of renewable technologies, one would expect significantly positive impacts on the environment and economic prosperity. Unfortunately, the mechanism by which Germany promotes renewable technologies confers no such benefits.

4.1 Climate Impact

With respect to climate impacts, the prevailing coexistence of the EEG and the ETS means that the increased use of renewable energy technologies attains no additional emission reductions beyond those achieved by ETS alone. In fact, the promotion of renewable energy technologies *ceteris paribus* reduces the emissions of the electricity sector so that obsolete certificates can be sold to other industry sectors that are involved in the ETS. As a result of the establishment of the ETS in 2005, the EEG's true effect is merely a shift, rather than a reduction, in the volume of emissions: Other sectors that are also involved in the ETS emit more than otherwise, thereby outweighing those emission savings in the electricity sector that are induced by the EEG (BMWA 2004:8).

In the end, cheaper alternative abatement options are not realized that would have been pursued in the counterfactual situation without EEG: Very expensive abatement options such as the generation of solar electricity simply lead to the crowding out of cheaper alternatives. In other words, since the establishment of the ETS in 2005, the EEG's net climate effect has been equal to zero⁴.

These theoretical arguments are substantiated by the numerical analysis of Traber and Kemfert (2009:155), who find that while the CO₂ emissions in Germany's electricity sector are reduced substantially, the emissions are hardly altered at the European scale by Germany's EEG. This is due to the fact that Germany's electricity production from renewable technologies mitigates the need for emission reductions in other countries that participate in the ETS regime, thereby significantly lowering CO₂ certificate prices by 15% relative to the situation without EEG (Traber, Kemfert 2009:169). In essence, this permit price effect would lead to an emission level that would be higher than otherwise if it were not outweighed by the substitution effect, that is, the crowding out of conventional electricity production through CO₂-free green technologies.

⁴ Ultimately, this is because the ETS enforces a binding carbon dioxide emissions cap. It is frequently argued that if the abatement effects of any future promotion of renewable energy technologies have been anticipated and included in the then more ambitious emission cap than otherwise, as is done by the European Commission for the third trading period (2013-2020), the promotion of renewables nevertheless exerts a greenhouse gas effect. This is not true: ETS alone ensures the compliance with the more ambitious emission cap, even if the renewable promotion were to be abolished immediately.

4.2 Electricity Prices

While the EEG's net impact on the European emission level is thus virtually negligible, it increases the consumer prices for electricity in Germany by three percent according to the study of Traber and Kemfert (2009:170). Producer prices, on the other hand, are decreased by eight percent in Germany and by five percent on average in the EU25. As a result, the profits of the majority of the large European utilities are diminished substantially, most notably those of the four dominant German electricity producers. The numerical results indicate that Vattenfall's, Eon's, and RWE's profits are lowered by about 20%, with ENBW's profit loss being seven percent.

Only those utilities that are operating in non-neighbouring countries, such as Spain or Italy, and whose electricity production is carbon-intensive, benefit from Germany's EEG, as they face lower certificate prices, but do not suffer from a crowding out of conventional production through Germany's green electricity generation. This is why Germany's EEG increases the profits of Italy's Enel and Spain's Endesa by 9% and 16%, respectively (Traber, Kemfert 2009:172).

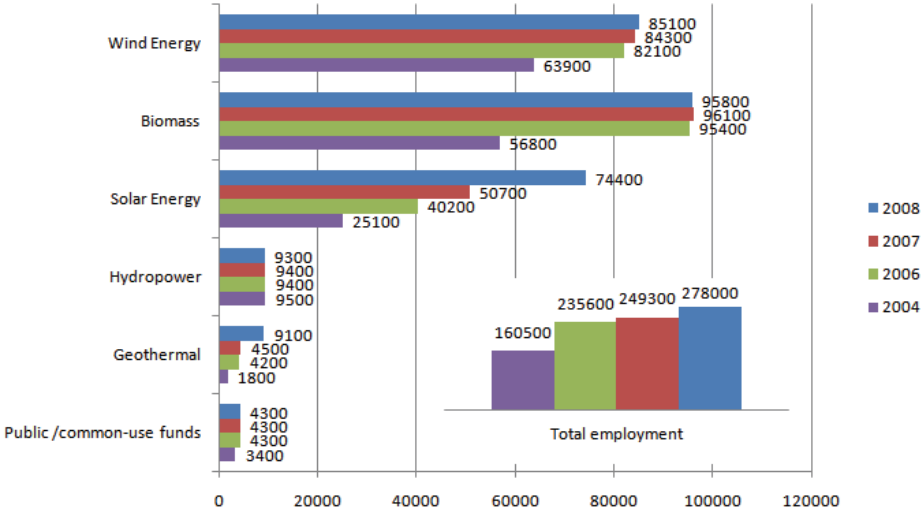
4.3 Employment Effects

Renewable energy promotion is frequently justified by the associated impacts on job creation. Referring to renewables as a "job motor for Germany," a publication from the Environmental Ministry (BMU) reports a 55% increase in the total number of "green" jobs since 2004, rising to 249,300 by 2007 (BMU 2008b:31). This assessment is repeated in a BMU-commissioned report that breaks down these figures by energy technology (O'Sullivan et al. 2009:9). As depicted in Figure 4, gross employment growth in the solar industry, comprising the photovoltaics and solar collector sectors, has been particularly pronounced, rising by nearly two-fold since 2004 to reach about 74,000 jobs in 2008. Given sustained growth in international demand for renewable energy and an attractive production environment in Germany, the BMU expects these trends to continue: by 2020, upwards of 400,000 jobs are projected in the renewables sector (BMU 2008b:31).

While such projections convey seemingly impressive prospects for gross employment growth, they obscure the broader implications for economic welfare by omitting any accounting of off-setting impacts. The most immediate of these impacts are job losses that result from the crowding out of cheaper forms of conventional energy generation, along with indirect impacts on upstream industries. Additional job losses will arise from the drain on economic activity precipitated by higher electricity prices. In this regard, even though the majority of the German population embraces renewable energy technologies, two important aspects must be taken into account. First, the private consumers' overall loss of purchasing power due to higher electricity prices adds up to billions of Euros. Second, with the exception of the preferentially treated energy-intensive firms, the total investments of industrial energy consumers may be

substantially lower. Hence, by constraining the budgets of private and industrial consumers, increased prices ultimately divert funds from alternative, possibly more beneficial, investments. The resulting loss in purchasing power and investment capital causes negative employment effects in other sectors (BMU 2006:3), casting doubt on whether the EEG’s employment effects are positive at all.

Figure 4: Gross employment in the renewable energy sector (O’Sullivan et al. 2009:9)



The latest BMU (2009b:36) report acknowledges these cost considerations, and states that “the goal of environmental protection is not primarily to create as many jobs as possible, but rather to reach environmental goals efficiently, that is, at the lowest possible cost to the overall economy”. The same report, however, contorts its own logic with the claim that an added benefit of environmental protection is net job creation, because the associated reallocation of resources is typically channelled to labor-intensive renewable sectors (BMU 2009b:36). Such conflating of labor-intensive energy provision with efficient climate protection clouds much of the discussion on the economic merits of renewable energy. In this regard, as Michaels and Murphy (2009) note, proponents of renewable energies often regard the requirement for more workers to produce a given amount of energy as a benefit, failing to recognize that this lowers the output potential of the economy and is hence counterproductive to net job creation.

Several recent investigations of the German experience support such skepticism. Taking account of adverse investment and crowding-out effects, both the IWH (2004)

and RWI (2004) find negligible employment impacts. Another analysis draws the conclusion that despite initially positive impacts, the long-term employment effects of the promotion of energy technologies such as wind and solar power systems are negative (BEI 2003:41). Similar results are attained by Fahl et al. (2005), as well as Pfaffenberger (2006) and Hillebrand et al. (2006). The latter analysis, for example, finds an initially expansive effect on net employment from renewable energy promotion resulting from additional investments. By 2010, however, this gives way to a contractive effect as the production costs of power increase.

In contrast, a study commissioned by the BMU (2006:9) comes to the conclusion that the EEG's net employment effect is the creation of up to 56,000 jobs until 2020. This same study, however, emphasizes that positive employment effects critically depend on a robust foreign trade of renewable energy technologies (BMU 2006:7). Whether favourable conditions on the international market prevail for PV, for example, is highly questionable, particularly given negligible or even negative net exports in recent years. While the imports totaled 1.44 Bn €, the exports merely accounted for 0.2 Bn € (BMU 2006:61). Actually, a substantial share of all PV modules installed in Germany originated from imports (BMU 2006:62), most notably from Japan and China. In 2005, the domestic production of modules was particularly low compared with domestic demand. With 319 MW, domestic production only provided for 32% of the new capacity installed in Germany (Table 3). In 2006 and 2007, almost half of Germany's PV demand was covered by imports (Sarasin 2007:19, Table 1). Recent newspaper articles report that the situation remains dire, with the German solar industry facing unprecedented competition from cheaper Asian imports.

Hence, any result other than a negative net employment balance of the German PV promotion would be surprising. In contrast, we would expect massive employment effects in export countries such as China, since these countries do not suffer from the EEG's crowding-out effects, nor from negative income effects. In the end, Germany's PV promotion has become a subsidization regime that, on a per-capita basis, has reached a very high level that by far exceeds average wages: Given our net cost estimate of about 8.4 Bn € for 2008 reported in Table 4, per-capita subsidies turn out to be as high as 175,000 € (US \$ 257,400), if indeed 48,000 people were employed in the PV sector (BSW Solar 2009).

Even this large figure, however, likely underestimates the true cost of subsidizing employment in this manner, because the new green jobs are filled by workers who were previously employed (Michaels, Murphy 2009:3). Hence, the gross employment effect is overestimated. Moreover, given that the green technology sector needs medium- and high-skilled workers, which have been seriously lacking in Germany in recent years, there is strong competition for such employees, thereby casting further doubt on the net employment effects of the EEG. Finally, it is frequently ignored that other industries, not

favoured by green subsidies, must draw on a pool of unemployed workers reduced by the EEG, so that job creation in “non-green” sectors may be lower than it otherwise would have been (Michaels, Murphy 2009:3).

4.4 Energy Security

Increased energy security from decreased reliance on fuel imports is another common refrain in support of renewable energy promotion, but one that is predicated on an abundance of sun and wind. As such conditions are highly intermittent in Germany, back-up energy systems that use fossil fuels must consequently be in place to ensure against blackouts. Not only is the maintenance of such systems costly – amounting to some 590 Mio. € in 2006 (Erdmann 2008:32) – but any increased energy security afforded by PV and wind is undermined by reliance on fossil fuel sources – principally gas – that must be imported to meet domestic demand. With some 36% of gas imports originating from Russia (Frondel, Schmidt 2009), a country that has not proven to be a reliable trading partner in recent years, the notion of improved energy security is further called into doubt.

4.5 Technological Innovation

An equally untenable argument points to the alleged long term returns that accrue from establishing an early foothold in the renewable energy market. According to this argument, the support afforded by the EEG allows young firms to expand their production capacities and gain familiarity with renewable technologies, thereby giving them a competitive advantage as the market continues to grow. Progress on this front, however, is critically dependent on creating the incentives conducive to the innovation of better products and production processes.

In this regard, the incentives built into the EEG actually stifle innovation by granting a differentiated system of subsidies that compensates each energy technology according to its lack of competitiveness. This allowed PV to become the big winner in the unlevel playing field thereby created, although it is the most expensive and, hence, most subsidized renewable energy. Rather than affording PV a tremendous advantage, it would make more sense to extend a uniform subsidy per kWh of electricity from renewables. This would harness market forces, rather than political lobbying, to determine which types of renewables could best compete with conventional energy sources.

An additional distortionary feature of the EEG is a degressive system of subsidy rates that decrease incrementally, usually by 5% each year. Although this degression was introduced to create incentives to save cost and innovate, it instead does just the opposite by encouraging the immediate implementation of existing technology. Doing so, helps investors to secure today’s favourable subsidy for the next 20 years at an unvaried level, free from the imperative of modernizing with the latest technology. One

manifestation of this perverse incentive is bottlenecks in the production of silicon solar cells, whose production cost are a multiple of those of thin film modules.

Even if such a degressive system had spurred the intended cost-saving and technologically benign effects, they would have been counterbalanced by the EEG amendments of 2004 and 2008, which re-established the formerly higher feed-in tariff levels. For example, the 2009 tariffs for electricity produced from biomass and wind converters are above the levels of the year 2000 (Table 1). In other words, the repeated legal amendments have entirely destroyed even the modest cost-diminishing impacts of this degressive system.

This demonstrates that this support mechanism is a classic example of an unsound energy policy that is highly prone to lobbyism. It is very unlikely that such government-directed programs, picking winners and losers, would yield a more efficient energy mix than what would be determined in the market absent massive government intervention (Michaels, Murphy 2009:5).

5 Summary and Conclusion

Although renewable energies have a potentially beneficial role to play as part of Germany's energy portfolio, the commonly advanced argument that renewables confer a double dividend or "win-win solution" in the form of environmental stewardship and economic prosperity is disingenuous. In this article, we argue that Germany's principal mechanism of supporting renewable technologies through feed-in tariffs, in fact, imposes high costs without any of the alleged positive impacts on emissions reductions, employment, energy security, or technological innovation.

First, as a consequence of the prevailing coexistence of the Renewable Energy Sources Act (EEG) and the EU Emissions Trading Scheme (ETS), the increased use of renewable energy technologies triggered by the EEG does not imply any additional emission reductions beyond those already achieved by ETS alone, if the two instruments are not coordinated. This is in line with Morthorst (2003), who analyzes the promotion of renewable energy usage by alternative instruments using a three-country example. If not coordinated, this study's results suggest that renewable support schemes are questionable climate policy instruments in the presence of the ETS.

Second, numerous empirical studies have consistently shown the net employment balance to be zero or even negative in the long run, a consequence of the high opportunity cost of supporting renewable energy technologies. Indeed, it is most likely that whatever jobs are created by renewable energy promotion would vanish as soon as government support is terminated, leaving only Germany's export sector to benefit from the possible continuation of renewables support in other countries such as the US. Third, rather than promoting energy security, the need for backup power from fossil fuels means that renewables increase Germany's dependence on gas imports, most of which

come from Russia. And finally, the system of feed-in tariffs stifles competition among renewable energy producers and creates perverse incentives to lock into existing technologies.

Hence, although Germany's promotion of renewable energies is commonly portrayed in the media as setting a "shining example in providing a harvest for the world" (The Guardian 2007), we would instead regard the country's experience as a cautionary tale of massively expensive environmental and energy policy that is devoid of economic and environmental benefits. As other European governments emulate Germany by ramping up their promotion of renewables, policy makers should scrutinize the logic of supporting energy sources that cannot compete on the market in the absence of government assistance.

Nevertheless, government intervention can serve to support renewable energy technologies through other mechanisms that harness market incentives or correct for market failures. The European Trading Scheme, under which emissions certificates are traded, is one obvious example. Another is funding for research and development (R&D), which may compensate for underinvestment from the private sector owing to positive externalities. In the early stages of development of non-competitive technologies, for example, it appears to be more cost-effective to invest in R&D to achieve competitiveness, rather than to promote their large-scale production. This argument seems to be particularly relevant for solar cells, whose technological efficiency is widely known to be modest and, hence, should be first increased substantially via R&D.

Appendix

Table A1: Electricity Prices and Net Cost of PV

	Real Electricity Price € Cents ₂₀₀₅ /kWh	Nominal Electricity Price € Cents/kWh	Feed-in Tariffs PV € Cents/kWh	Feed-in Tariffs Wind € Cents/kWh
2000	2.90	2.63	50.62	9.10
2001	2.90	2.68	50.62	9.10
2002	2.90	2.73	48.09	9.00
2003	2.90	2.79	45.69	8.90
2004	2.90	2.84	50.58	8.70
2005	4.30	4.30	54.53	8.53
2006	4.42	4.50	51.80	8.36
2007	4.53	4.71	49.21	8.19
2008	4.66	4.93	46.75	8.03
2009	4.78	5.16	43.01	9.20
2010	4.91	5.41	39.57	9.11
2011	5.06	5.68	36.01	9.02
2012	5.21	5.96	32.77	8.93
2013	5.36	6.26	29.82	8.84
2014	5.52	6.57	27.13	8.75
2015	5.69	6.90	24.69	8.66
2016	5.81	7.19	22.47	8.57
2017	5.94	7.49	20.45	8.48
2018	6.07	7.80	18.61	8.40
2019	6.20	8.13	16.93	8.32
2020	6.34	8.47	15.41	8.24

Table A2: Net Cost in € Cents₂₀₀₇ per kWh by Cohort for PV

Cohort	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2000	55.13										
2001	53.99	53.99									
2002	52.87	52.87	50.08								
2003	51.78	51.78	49.04	46.44							
2004	50.70	50.70	48.02	45.47	50.66						
2005	48.19	48.19	45.56	43.06	48.15	52.26					
2006	47.04	47.04	44.46	42.01	47.00	51.03	48.24				
2007	45.91	45.91	43.38	40.98	45.87	49.82	47.09	44.5			
2008	44.79	44.79	42.31	39.96	44.75	48.62	45.95	43.41	41.00		
2009	43.69	43.69	41.26	38.95	43.65	47.45	44.82	42.34	39.98	36.38	
2010	42.61	42.61	40.22	37.96	42.57	46.29	43.72	41.27	38.96	35.43	32.19
2011	41.52	41.52	39.18	36.97	41.48	45.13	42.61	40.21	37.94	34.49	31.31
2012	40.45	40.45	38.16	35.98	40.41	43.99	41.52	39.17	36.94	33.56	30.44
2013	39.39	39.39	37.15	35.01	39.36	42.86	40.44	38.14	35.95	32.63	29.58
2014	38.35	38.35	36.15	34.06	38.31	41.75	39.37	37.12	34.98	31.72	28.73
2015	37.32	37.32	35.16	33.11	37.28	40.65	38.32	36.11	34.01	30.82	27.88
2016	36.34	36.34	34.23	32.22	36.31	39.61	37.33	35.16	33.34	30.22	27.34
2017	35.38	35.38	33.31	31.34	35.35	38.59	36.35	34.23	32.45	29.38	26.56
2018	34.44	34.44	32.40	30.47	34.40	37.58	35.39	33.55	31.58	28.57	25.80
2019	33.50	33.50	31.51	29.62	33.47	36.59	34.43	32.65	30.71	27.76	25.05
2020		32.58	30.63	28.77	32.55	35.61	33.50	31.76	29.85	26.96	24.30
2021			29.81	27.99	31.70	34.69	32.62	30.88	29.01	26.18	23.57
2022				27.22	30.85	33.79	31.76	30.05	28.23	25.45	22.89
2023					30.02	32.90	30.91	29.25	27.46	24.73	22.22
2024						32.03	30.08	28.45	26.70	24.02	21.57
2025							29.26	27.68	25.95	23.34	20.93
2026								26.90	25.21	22.65	20.28
2027									24.50	21.98	19.66
2028										21.32	19.05
2029											18.45
Bn kWh	0.064	0.052	0.072	0.125	0.244	0.725	0.938	1.280	1.310	1.600	1.880
Bn €	0.559	0.442	0.563	0.897	1.913	6.027	7.164	8.969	8.409	9.032	9.296

The specific net cost is calculated by subtracting actual or expected market prices of electricity from feed-in tariffs. While tariffs are fixed for each cohort of installed solar modules for a period of 20 years, of course, market prices change over time. Therefore, the specific net cost per kWh varies accordingly. The cumulative net cost induced by an individual cohort, reported in the last row, results from adding up the products of the real net cost per kWh and the solar electricity produced by each cohort displayed in the penultimate row. Net cost for wind is calculated in the same manner.

Table A3: Net Cost in € Cents₂₀₀₇ per kWh by Cohort for Wind Power (elevated tariff for 20 years)

Cohort	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2000	7.44										
2001	7.23	7.23									
2002	7.03	7.03	6.92								
2003	6.83	6.83	6.72	6.62							
2004	6.64	6.64	6.53	6.43	6.22						
2005	4.99	4.99	4.89	4.79	4.58	4.40					
2006	4.69	4.69	4.59	4.49	4.28	4.11	3.94				
2007	4.39	4.39	4.29	4.19	3.99	3.82	3.65	3.48			
2008	4.08	4.08	3.99	3.89	3.69	3.53	3.36	3.19	3.04		
2009	3.78	3.78	3.69	3.59	3.40	3.23	3.07	2.91	2.75	3.88	
2010	3.48	3.48	3.39	3.29	3.10	2.94	2.78	2.62	2.47	3.57	3.49
2011	3.16	3.16	3.07	2.98	2.79	2.64	2.48	2.32	2.17	3.25	3.17
2012	2.84	2.84	2.75	2.66	2.48	2.33	2.17	2.02	1.87	2.93	2.85
2013	2.52	2.52	2.43	2.35	2.17	2.02	1.87	1.72	1.57	2.61	2.53
2014	2.20	2.20	2.11	2.03	1.85	1.71	1.56	1.41	1.27	2.29	2.21
2015	1.88	1.88	1.79	1.71	1.54	1.39	1.25	1.10	0.97	1.96	1.89
2016	1.60	1.60	1.52	1.43	1.27	1.12	0.98	0.84	0.71	1.40	1.61
2017	1.32	1.32	1.24	1.16	0.99	0.85	0.72	0.58	0.44	1.12	1.33
2018	1.04	1.04	0.96	0.88	0.72	0.59	0.45	0.31	0.18	0.84	1.05
2019	0.77	0.77	0.69	0.61	0.45	0.32	0.18	0.00	0.00	0.57	0.77
2020		0.49	0.41	0.33	0.18	0.05	0.00	0.00	0.00	0.34	0.50
2021			0.18	0.11	0.00	0.00	0.00	0.00	0.00	0.11	0.27
2022				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
2023					0.00	0.00	0.00	0.00	0.00	0.00	0.00
2024						0.00	0.00	0.00	0.00	0.00	0.00
2025							0.00	0.00	0.00	0.00	0.00
2026								0.00	0.00	0.00	0.00
2027									0.00	0.00	0.00
2028										0.00	0.00
2029											0.00
Bn kWh	7.55	2.96	5.28	3.07	6.65	1.72	3.48	8.79	2.23	1.69	1.38
Bn €	5.884	2.100	3.281	1.645	2.906	0.603	0.990	1.982	0.389	0.450	0.299

Table A4: Net Cost in € Cents2007 per kWh by Cohort for Wind Power (elevated tariff for five years)

Cohort	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2000	7.44										
2001	7.23	7.23									
2002	7.03	7.03	6.92								
2003	6.83	6.83	6.72	6.62							
2004	6.64	6.64	6.53	6.43	6.22						
2005	1.97	4.99	4.89	4.79	4.58	4.40					
2006	1.72	1.72	4.59	4.49	4.28	4.11	3.94				
2007	1.48	1.48	1.39	4.19	3.99	3.82	3.65	3.48			
2008	1.23	1.23	1.14	1.05	3.69	3.53	3.36	3.19	3.04		
2009	0.99	0.99	0.90	0.80	0.32	3.23	3.07	2.91	2.75	3.88	
2010	0.74	0.74	0.65	0.56	0.09	0.00	2.78	2.62	2.47	3.57	3.49
2011	0.47	0.47	0.39	0.30	0.00	0.00	0.00	2.32	2.17	3.25	3.17
2012	0.21	0.21	0.13	0.04	0.00	0.00	0.00	0.00	1.87	2.93	2.85
2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.61	2.53
2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.21
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2021			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2022				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2023					0.00	0.00	0.00	0.00	0.00	0.00	0.00
2024						0.00	0.00	0.00	0.00	0.00	0.00
2025							0.00	0.00	0.00	0.00	0.00
2026								0.00	0.00	0.00	0.00
2027									0.00	0.00	0.00
2028										0.00	0.00
2029											0.00
Bn kWh	7.55	2.96	5.28	3.07	6.65	1.72	3.48	8.79	2.23	1.69	1.38
Bn €	3.32	1.17	1.81	0.90	1.54	0.33	0.59	1.28	0.27	0.28	0.20

Table A5: Annual Net Cost in Bn €₂₀₀₇ per Annum and by Cohort for PV

Cohort	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
2000	0.04											0.04
2001	0.03	0.03										0.06
2002	0.03	0.03	0.04									0.10
2003	0.03	0.03	0.04	0.06								0.15
2004	0.03	0.03	0.03	0.06	0.12							0.27
2005	0.03	0.03	0.03	0.05	0.12	0.38						0.64
2006	0.03	0.02	0.03	0.05	0.11	0.37	0.45					1.08
2007	0.03	0.02	0.03	0.05	0.11	0.36	0.44	0.57				1.62
2008	0.03	0.02	0.03	0.05	0.11	0.35	0.43	0.56	0.54			2.12
2009	0.03	0.02	0.03	0.05	0.11	0.34	0.42	0.54	0.52	0.58		2.65
2010	0.03	0.02	0.03	0.05	0.10	0.34	0.41	0.53	0.51	0.57	0.61	3.19
2011	0.03	0.02	0.03	0.05	0.10	0.33	0.40	0.51	0.50	0.55	0.59	3.10
2012	0.03	0.02	0.03	0.04	0.10	0.32	0.39	0.50	0.48	0.54	0.57	3.02
2013	0.03	0.02	0.03	0.04	0.10	0.31	0.38	0.49	0.47	0.52	0.56	2.94
2014	0.02	0.02	0.03	0.04	0.09	0.30	0.37	0.48	0.46	0.51	0.54	2.86
2015	0.02	0.02	0.03	0.04	0.09	0.29	0.36	0.46	0.45	0.49	0.52	2.78
2016	0.02	0.02	0.02	0.04	0.09	0.29	0.35	0.45	0.44	0.48	0.51	2.73
2017	0.02	0.02	0.02	0.04	0.09	0.28	0.34	0.44	0.43	0.47	0.50	2.65
2018	0.02	0.02	0.02	0.04	0.08	0.27	0.33	0.43	0.41	0.46	0.49	2.58
2019	0.02	0.02	0.02	0.04	0.08	0.27	0.33	0.42	0.40	0.44	0.47	2.51
2020		0.02	0.02	0.04	0.08	0.26	0.32	0.41	0.39	0.43	0.46	2.42
2021			0.02	0.04	0.08	0.25	0.31	0.40	0.38	0.42	0.44	2.33
2022				0.03	0.08	0.25	0.30	0.38	0.37	0.41	0.43	2.25
2023					0.07	0.24	0.29	0.37	0.36	0.40	0.42	2.15
2024						0.23	0.28	0.36	0.35	0.38	0.41	2.02
2025							0.28	0.35	0.34	0.37	0.39	1.74
2026								0.34	0.33	0.36	0.38	1.42
2027									0.32	0.35	0.37	1.04
2028										0.34	0.36	0.70
2029											0.35	0.35
Total	0.56	0.44	0.56	0.90	1.91	6.03	7.16	8.97	8.41	9.03	9.30	53.27

The columns in Table A5 inform about the net cost per cohort of annually installed modules, while the rows show the real net cost per year. A particularly striking result of the presentation is the dramatic cost increase related to the cohort installed in 2005, the year following the EEG amendment in 2004. Annual net cost for wind is calculated in the same manner.

Table A6: Annual Net Cost in Bn €₂₀₀₇ per Annum and by Cohort for Wind Power (elevated tariff for 20 years)

Cohort	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
2000	0.56											0.56
2001	0.55	0.21										0.76
2002	0.53	0.21	0.37									1.10
2003	0.52	0.20	0.35	0.20								1.28
2004	0.50	0.20	0.34	0.20	0.41							1.65
2005	0.38	0.15	0.26	0.15	0.30	0.08						1.31
2006	0.35	0.14	0.24	0.14	0.28	0.07	0.14					1.37
2007	0.33	0.13	0.23	0.13	0.27	0.07	0.13	0.31				1.58
2008	0.31	0.12	0.21	0.12	0.25	0.06	0.12	0.28	0.07			1.53
2009	0.29	0.11	0.19	0.11	0.23	0.06	0.11	0.26	0.06	0.07		1.47
2010	0.26	0.10	0.18	0.10	0.21	0.05	0.10	0.23	0.06	0.06	0.05	1.39
2011	0.24	0.09	0.16	0.09	0.19	0.05	0.09	0.20	0.05	0.06	0.04	1.25
2012	0.21	0.08	0.15	0.08	0.17	0.04	0.08	0.18	0.04	0.05	0.04	1.11
2013	0.19	0.07	0.13	0.07	0.14	0.03	0.06	0.15	0.04	0.04	0.03	0.97
2014	0.17	0.07	0.11	0.06	0.12	0.03	0.05	0.12	0.03	0.04	0.03	0.83
2015	0.14	0.06	0.09	0.05	0.10	0.02	0.04	0.10	0.02	0.03	0.03	0.69
2016	0.12	0.05	0.08	0.04	0.08	0.02	0.03	0.07	0.02	0.03	0.02	0.57
2017	0.10	0.04	0.07	0.04	0.07	0.01	0.02	0.05	0.01	0.02	0.02	0.45
2018	0.08	0.03	0.05	0.03	0.05	0.01	0.02	0.03	0.00	0.02	0.01	0.33
2019	0.06	0.02	0.04	0.02	0.03	0.01	0.01	0.00	0.00	0.01	0.01	0.21
2020		0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.08
2021			0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02
2022				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2023					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2024						0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025							0.00	0.00	0.00	0.00	0.00	0.00
2026								0.00	0.00	0.00	0.00	0.00
2027									0.00	0.00	0.00	0.00
2028										0.00	0.00	0.00
2029											0.00	0.00
Total	5.88	2.10	3.28	1.65	2.91	0.60	0.99	1.98	0.39	0.45	0.30	20.53

Table A7: Annual Net Cost in Bn €₂₀₀₇ per Annum and by Cohort for Wind Power (elevated tariffs for five years)

Cohort	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
2000	0.56											0.56
2001	0.55	0.21										0.76
2002	0.53	0.21	0.37									1.10
2003	0.52	0.20	0.35	0.20								1.28
2004	0.50	0.20	0.34	0.20	0.41							1.65
2005	0.15	0.15	0.26	0.15	0.30	0.08						1.08
2006	0.13	0.05	0.24	0.14	0.28	0.07	0.14					1.05
2007	0.11	0.04	0.07	0.13	0.27	0.07	0.13	0.31				1.12
2008	0.09	0.04	0.06	0.03	0.25	0.06	0.12	0.28	0.07			0.99
2009	0.07	0.03	0.05	0.02	0.02	0.06	0.11	0.26	0.06	0.07		0.74
2010	0.06	0.02	0.03	0.02	0.01	0.00	0.10	0.23	0.06	0.06	0.05	0.63
2011	0.04	0.01	0.02	0.01	0.00	0.00	0.00	0.20	0.05	0.06	0.04	0.43
2012	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.05	0.04	0.16
2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.08
2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2019	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2021			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2022				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2023					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2024						0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025							0.00	0.00	0.00	0.00	0.00	0.00
2026								0.00	0.00	0.00	0.00	0.00
2027									0.00	0.00	0.00	0.00
2028										0.00	0.00	0.00
2029											0.00	0.00
Total	3.32	1.17	1.81	0.90	1.54	0.33	0.59	1.28	0.27	0.28	0.20	11.67

Table A8 shows the cost of subsidisation in € Cents/kWh for the years 2000 through 2008 that were calculated by dividing the total amount of feed-in tariffs by the gross electricity consumption.

Table A8: Effect of Subsidization on Electricity Prices

	Electricity Consumption	Feed-in Tariffs	Cost of Subsidization
	Bn. kWh	Bn. Euro	€ Cents/kWh
2000	579.6	0.87	0.15
2001	585.1	1.58	0.27
2002	587.4	2.23	0.38
2003	598.6	2.61	0.44
2004	608.0	3.61	0.59
2005	612.1	4.40	0.72
2006	617.0	5.61	0.91
2007	618.4	7.59	1.23
2008	616.6	9.02	1.46

Sources: AGEBA (2009), BDEW (2001 through 2009)

Total feed-in tariffs for each cohort of newly installed PV modules and wind converters are displayed in the last columns of Tables A9 through A11 and calculated by assuming that the same annual amount of electricity is produced over the whole subsidization period of 20 years.

Table A9: Total feed-in tariffs for PV

	Annual Increase, Mio kWh	Specific Feed-in Tariff, € Cents/kWh	Annual Amount of Feed-in Tariffs, Mio €	Cumulated over 20 years	
				Nominal Bn €	Real Bn € ₂₀₀₇
2000	64	50.62	32.4	0.648	0.671
2001	52	50.62	26.3	0.526	0.494
2002	72	48.09	34.6	0.692	0.638
2003	125	45.69	57.1	1.142	1.031
2004	244	50.58	123.4	2.468	2.184
2005	725	54.53	395.3	7.906	6.680
2006	938	51.80	485.9	9.717	8.266
2007	1,280	49.21	629.9	12.598	10.506
2008	1,310	46.75	612.4	12.248	10.014
Total burden for past installations:				47.945	40.484
2009	1,600	43.01	688.2	13.764	11.032
2010	1,880	39.57	743.9	14.878	11.692
Total burden at the end of 2010:				76.587	63.208

Note: Column 1: 2000-2008: BMU (2009a), 2009-2010: SARASIN (2007). Column 2: Feed-in tariff for PV in € cents per kWh. Column 3: Product of Column 1 and 2. Column 4: Column 3 times 20. Column 5: Inflation-corrected figures of Column 4 using a rate of 2%.

Table A10: Total feed-in tariffs for Wind Power (elevated tariff for twenty years)

	Annual Increase, Mio kWh	Feed-in Tariff, € Cents/kWh	Cumulated over 20 years	
			Nominal Bn. €	Real Bn. € ₂₀₀₇
2000	7.55	9.10	13.74	13.16
2001	2.96	9.10	5.39	5.06
2002	5.28	9.00	9.50	8.75
2003	3.07	8.90	5.47	4.94
2004	6.65	8.70	11.57	10.24
2005	1.72	8.53	2.93	2.55
2006	3.48	8.36	5.82	4.95
2007	8.79	8.19	14.40	12.01
2008	2.23	8.03	3.58	2.93
Total burden for past installations:			72.40	64.59
2009	1.69	9.20	3.12	2.50
2010	1.38	9.11	2.51	1.97
Total burden at the end of 2010:			78.03	69.06

Note: Column 1: 2000-2008: BMU (2009a), 2009-2010: BMU (2008), Column 2: Feed-in tariff for PV in € cents per kWh. Column 3: Product of Column 1 and 2. Column 4: Column 3 times 20. Column 5: Inflation-corrected figures of Column 4 using a rate of 2%.

Table A11: Total feed-in tariffs for Wind Power (elevated tariff for first five years)

	Annual Increase, Mio kWh	Feed-in Tariff, first 5 years, € Cents/kWh	Feed-in Tariff, last 15 years, € Cents/kWh	Cumulated over 20 years	
				Bn. €	Bn. € ₂₀₀₇
2000	7.55	9.10	6.19	10.45	10.17
2001	2.96	9.10	6.19	4.09	3.91
2002	5.28	9.00	6.10	7.20	6.74
2003	3.07	8.90	6.00	4.13	3.79
2004	6.65	8.70	5.50	8.38	7.56
2005	1.72	8.53	5.39	2.12	1.88
2006	3.48	8.36	5.28	4.21	3.65
2007	8.79	8.19	5.17	10.42	8.86
2008	2.23	8.03	5.07	2.59	2.16
Total burden for past installations:				53.59	48.72
2009	1.69	9.20	5.02	2.05	1.69
2010	1.38	9.11	4.97	1.65	1.33
Total burden at the end of 2010:				57.29	51.74

Note: Column 1: 2000-2008: BMU (2009a), 2009-2010: BMU (2008), Column 2: Feed-in tariff for PV in € cents per kWh. Column 3: Product of Column 1 and 2. Column 4: Column 3 times 20. Column 5: Inflation-corrected figures of Column 4 using a rate of 2%.

References

AGEB (2009) Energieverbrauch in Deutschland im Jahr 2008, Arbeitsgemeinschaft Energiebilanzen e.V., Berlin.

BDEW (2001 through 2009) Bundesverband der Energie- und Wasserwirtschaft e.V., EEG Jahresabrechnungen, Berlin.

BEI (2003) Ermittlung der Arbeitsplätze und Beschäftigungswirkungen im Bereich der Erneuerbaren Energien, Bremer Energie Institut, Bremen.

BMWA (2004) Zur Förderung erneuerbarer Energien, Federal Ministry of Economics and Technology, Berlin.

BMWi (2009) Energiestatistiken, Bundesministerium für Wirtschaft und Technologie, <http://www.bmwi.de/BMWi/Navigation/Energie/energiestatistiken.html>, Berlin.

BMU (2006) Erneuerbare Energien: Arbeitsmarkteffekte, Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, Berlin.

BMU (2007) Renewable Energy Sources Act (EEG), Progress Report 2007, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin.

BMU (2008a) Leitstudie 2008 – Weiterentwicklung der "Ausbaustrategie Erneuerbarer Energien vor dem Hintergrund der aktuellen Klimaschutzziele Deutschlands und Europas, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

BMU (2008b) Bruttobeschäftigung durch erneuerbare Energien in Deutschland im Jahr 2008, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin.

BMU (2009a) Erneuerbare Energien im Jahr 2008, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin.

BMU (2009b) Umweltwirtschaftsbericht 2009, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin.

BSW (2009) Statistics for the German solar power industry (photovoltaics), German Solar Industry Association, May 2009, www.bsw-solar.de.

Bonus, H. (1998) Umweltzertifikate. Der steinige Weg zur Marktwirtschaft. Herausgeber des Sonderheftes 9, *Zeitschrift für Angewandte Umweltforschung*.

EC (2009) DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, Brussels.

EPIA (2009) "Global Market Outlook for Photovoltaics until 2013", European Photovoltaic Industry Association, March 2009, Brussels.

Erdmann (2008) Indirekte Kosten der EEG-Förderung, Kurz-Studie im Auftrag der WirtschaftsvereinigungMetalle (WVM), August 2008, Berlin.

Fahl, U., Küster, R., Ellersdorfer, I. (2005) Jobmotor Ökostrom? Beschäftigungseffekte der Förderung von erneuerbaren Energien in Deutschland. *Energiewirtschaftliche Tagesfragen* 55 (7), 476-481.

Frondel, M., Ritter, N., Schmidt, C. M. (2008) Germany's Solar Cell Promotion: Dark Clouds on the Horizon. *Energy Policy* 36 (11), 4198-4202.

Frondel, M., Schmidt, C. M. (2008) Measuring Energy Security: A Conceptual Note, Ruhr Economic Paper 52, forthcoming in *Energy Economics*.

Hillebrand, B., H.-G. Buttermann, M. Bleuel und J.- M. Behringer (2006), The Expansion of Renewable Energies and Employment Effects in Germany. *Energy Policy* 34, 3484-3494. Elsevier, Oxford.

IEA (2007) Energy Policies of IEA Countries: Germany, 2007 Review. International Energy Agency, OECD, Paris.

IWH (2004), Beschäftigungseffekte durch den Ausbau Erneuerbarer Energien. Steffen Hentrich, Jürgen Wiemers, Joachim Ragnitz. Sonderheft 1/2004, Institut für Wirtschaftsforschung Halle.

Michaels, R., Murphy, R.P. (2009) Green Jobs: Fact or Fiction?, Institute for Energy Research, January 2009, Washington DC.

Morthorst, P. (2003) National environmental targets and international emission reduction instruments. *Energy Policy* 31(1), 73-83.

Nitsch, J., Staiss, F., Wenzel, B., Fishedick, M. (2005) Ausbau der Erneuerbare Energien im Stromsektor bis 2020: Vergütungszahlen und Differenzkosten durch das Erneuerbare-Energien-Gesetz, Stuttgart, Wuppertal.

O'Sullivan, M., Edler, D., Ottmüller, M., Lehr, U. (2009) Gross Employment from Renewable Energy in Germany in the Year 2008 – A first estimate, March 2009, Berlin.

Pfaffenberger, W. (2006) Wertschöpfung und Beschäftigung durch grüne Energieproduktion? *Energiewirtschaftliche Tagesfragen* 56 (9), 22-26.

REN21 (2009), Renewables Global Status Report 2009 Update, Renewable Energy Policy Network for the 21st Century, Paris.

Sarasin (2007) Bank Sarasin & Cie AG, Nachhaltigkeitsstudie: Solarenergie 2007, Der Höhenflug der Solarindustrie hält an, November 2007, Basel.

Schiffer, H.W. (2009) Deutscher Energiemarkt 2008. *Energiewirtschaftliche Tagesfragen* 59 (3), 52-66.

The Guardian (2007) Germany sets shining example in providing a harvest for the world, Ashley Seager, *The Guardian*, 23th July 2007, Manchester, U.K.

Traber, T., Kemfert, C. (2009) Impacts of the German Support for Renewable Energy on Electricity Prices, Emissions, and Firms. *The Energy Journal* 30(3), 155-178.

Voosen, P. (2009) A cautionary tale about feed-in tariffs, Environment & Energy Publishing, <http://www.eenews.net/public/Greenwire/print/2009/08/18/1>. Retrieved August 2009.