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Rheinisch-Westfälisches Institut für Wirtschaftsforschung

Economic impacts from the promotion of renewable energies: The German experience

Final report

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Economic impacts from the promotion of renewable energies:

The German experience

Final report – October 2009

Report

Rheinisch-Westfälisches Institut für Wirtschaftsforschung

Economic impacts from the promotion of renewable energies: The German experience

Final report – October 2009

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Economic impacts from the promotion of renewable energies: The German experience

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Economic impacts from the promotion of renewable energies: 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. In the case of photovoltaics, Germany's subsidization regime has reached a level that by far exceeds average wages, with per-worker subsidies as high as 175,000 € (US $ 240,000)

The German experience

Executive Summary

An aggressive policy of generously subsidizing and effectively mandating "renewable" electricity generation in Germany has led to a doubling of the renewable contribution to electricity generation in recent years.

This preference came primarily in the form of a subsidy policy based on feed-in tariffs, established in 1991 by the Electricity Feed-in Law.

A subsequent law passed in 2000 guaranteed continued support for 20 years. This requires utilities to accept the delivery of power from independent producers of renewable electricity into their own grid, paying technology-specific feed-in tariffs far above their production cost of 2 to 7 Euro-Cents (2.9-10.2 Cents US $) per kilowatt hour (kWh).

With a feed-in tariff of 43 Euro-Cents (59 Cents US $) per kWh in 2009, solar electricity generated from photovoltaics (PV) is guaranteed by far the largest financial support among all renewable energy technologies.

Currently, the feed-in tariff for PV is more than eight times higher than the wholesale electricity price at the power exchange and more than four times the feed-in tariff paid for electricity produced by on-shore wind turbines.

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.

By 2008 this had led to Germany having the second-largest installed wind capacity in the world, behind the United States, and largest installed PV capacity in the world, ahead of Spain. This explains the claims that Germany's feed-in tariff is a great success.

Installed capacity is not the same as production or contribution, however, and by 2008 the estimated share of wind power in Germany's electricity production was 6.3%, followed by biomass-based electricity generation (3.6%) and water power (3.1%). The amount of electricity produced through solar photovoltaics was a negligible 0.6% despite being the most subsidized renewable energy, with a net cost of about 8.4 Bn € (US $12.4 Bn) for 2008.

The total net cost of subsidizing electricity production by PV modules is estimated to reach 53.3 Bn € (US $73.2 Bn) for those modules installed between 2000 and 2010. While the promotion rules for wind power are more subtle than those for PV,

we estimate that the wind power subsidies may total 20.5 Bn € (US $28.1 Bn) for wind converters installed between 2000 and 2010.

Consumers ultimately bear the cost of renewable energy promotion. In 2008, the price mark-up due to the subsidization of green electricity was about 1.5 Cent per kWh (2.2 Cents US $), meaning the subsidy accounts for about 7.5% of average household electricity prices.

Given the net cost of 41.82 Cents/kWh for PV modules installed in 2008, and assuming that PV displaces conventional electricity generated from a mixture of gas and hard coal, abatement costs are as high as 716 € (US $1,050) per tonne.

Using the same assumptions and a net cost for wind of 3.10 Cents/kWh, the abatement cost is approximately 54 € (US $80). While cheaper than PV, this cost is still nearly double the ceiling of the cost of a per-ton permit under Europe's cap-and-trade scheme. Renewable energies are thus among the most expensive GHG reduction measures.

There are much cheaper ways to reduce carbon dioxide emissions than subsidizing renewable energies. CO2 abatement costs of PV are estimated to be as high as 716 € (US $1,050) per tonne, while those of wind power are estimated at 54 € (US $80) per tonne. By contrast, the current price of emissions certificates on the European emissions trading scheme is only 13.4 Euro per tonne. Hence, the cost from emission reductions as determined by the market is about 53 times cheaper than employing PV and 4 times cheaper than using wind power.

Moreover, the prevailing coexistence of the EEG and emissions trading under the European Trading Scheme (ETS) means that the increased use of renewable energy technologies generally attains no additional emission reductions beyond those achieved by ETS alone. In fact, since the establishment of the ETS in 2005, the EEG's net climate effect has been equal to zero.

While employment projections in the renewable sector convey seemingly impressive prospects for *gross* job growth, they typically obscure the broader implications for economic welfare by omitting any accounting of off-setting impacts. These impacts include, but are not limited to, job losses from crowding out of cheaper forms of conventional energy generation, indirect impacts on upstream industries, additional job losses from the drain on economic activity precipitated by higher electricity prices, private consumers' overall loss of purchasing power due to higher electricity prices, and diverting funds from other, possibly more beneficial investment.

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. Significant research shows that initial employment benefits from renewable policies soon turn negative as additional costs are incurred. Trade- and other assumptions in those studies claiming positive employment turn out to be unsupportable.

In the end, Germany's PV promotion has become a subsidization regime that, on a per-worker basis, has reached a level that far exceeds average wages, with per-worker subsidies as high as 175,000 € (US $ 240,000).

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.

Due to their backup energy requirements, it turns out that any increased energy security possibly afforded by installing large PV and wind capacity is undermined by reliance on fuel sources – principally gas – that must be imported to meet domestic demand. That much of this gas is imported from unreliable suppliers calls energy security claims further into question.

Claims about technological innovation benefits of Germany's first-actor status are unsupportable. In fact, the regime appears to be counterproductive in that respect, stifling innovation by encouraging producers to lock into existing technologies.

In conclusion, 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, Germany's principal mechanism of supporting renewable technologies through feed-in tariffs imposes high costs without any of the alleged positive impacts on emissions reductions, employment, energy security, or technological innovation. Policymakers should thus scrutinize Germany's experience, including in the US, where there are currently nearly 400 federal and state programs in place that provide financial incentives for renewable energy.

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.

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 not only to foster compliance with international agreements on greenhouse gas emission reductions, but also to provide opportunities for employment and regional development (EC 2009:16). The Commission has set 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. According to the German Environment Ministry, renewables are a central pillar in efforts to protect the climate, reduce import dependency, and safeguard jobs (BMU 2008:8).

Similar pronouncements characterize much of the current political discourse on energy policy in the US. President Obama has repeatedly spoken of the imperative of investing in "green technologies" to promote both environmental stewardship and stimulate the economy through job creation. To this end, the American Recovery and Reinvestment Act, signed into law in February, allocates more than $60 billion to clean energy investments to "jump-start our economy and build the clean-energy jobs of tomorrow" (White House 2009). In a recent hearing of the U.S. Senate Committee on Environment and Public Works (2009), Senator Barbara Boxer echoes this outlook, speaking of clean energy as a "win-win solution for our country–it helps to address the threat of global warming and it builds the foundation for long-term recovery and prosperity." President Obama has on numerous occasions cited Germany as an example in this regard.

Nevertheless, a closer look at Germany's experience, whose history of government support for renewable energies stretches back nearly two decades, suggests that its status as a model is without merit. 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 emissions reductions. The report 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

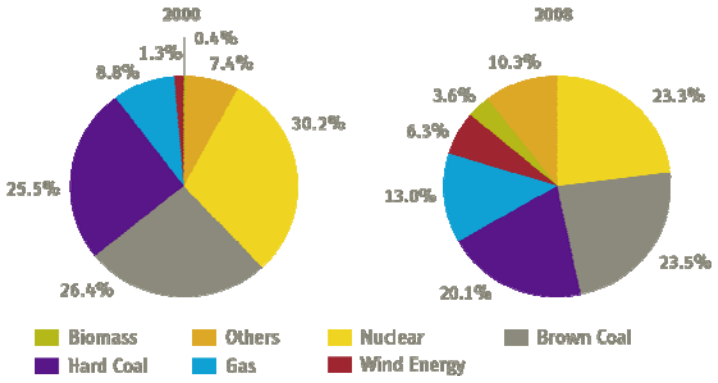
Through generous financial support, Germany has dramatically increased the electricity production from renewable technologies since the beginning of this century (IEA 2007:65). With a share of about 15% of total electricity production in 2008 (Schiffer 2009:58), Germany has more than doubled its renewable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

Technology Mix in Gross Electricity Production in Germany (Schiffer 2009, BMU 2009a)

2000 and 2008



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 (59 Cents US $) 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 wholesale 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.

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 Cents (2.2 Cents US $) 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).

Table 1:

Technology-Specific Feed-in Tariffs in Euro Cent per kWh
2000 through 2009

	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
Photo-voltaics	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
Average 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, 2008).

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 € (US $ 1.4 – 13.2 Bn).

Table 2:

Share of Feed-in Tariff Expenditures Allocated to Major Technologies
2001 through 2008

	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%
Photo-voltaics	-	3.7%	5.9%	7.8%	15.1%	20.3%	20.2%	24.6%
Total, 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.

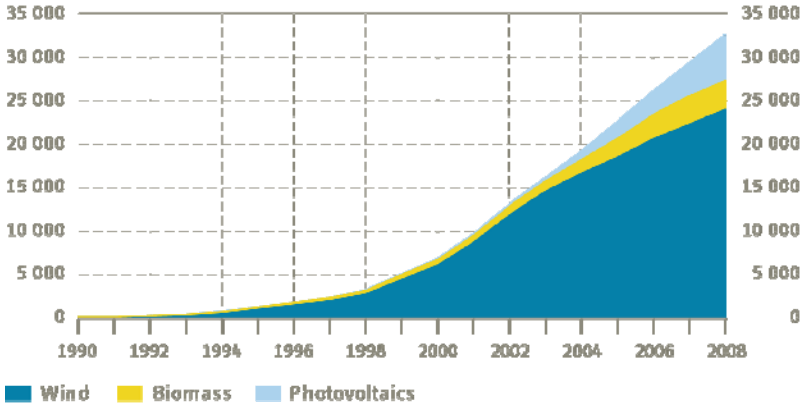
Some sense for the sheer magnitude of this figure can be gleaned from a comparison with the government's investment in R&D for renewable energies, which we will later argue to be a considerably more cost-effective means of fostering efficiency improvements. In 2007, this investment amounted to 211.1 Mio. € (US $ 289.3 Mio) (BMWi 2009), an inconsequential 3% of the total feed-in tariffs of 7.59 Bn € (US $ 10.4 Bn) in the same year.

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).

Figure 2:

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

1990 through 2008



The tremendous growth illustrated by Figure 2 and Table 3 explains why Germany's support scheme based on feed-in tariffs is globally touted 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.

Table 3:

Solar Electricity Capacities and Production in Germany

2000 through 2008

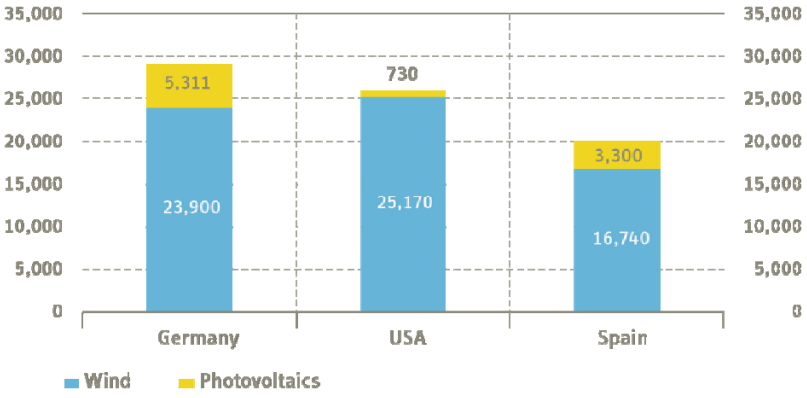
	2000	2001	2002	2003	2004	2005	2006	2007	2008
Capacity Installed, MW	100	178	258	408	1,018	1,881	2,711	3,811	5,311
Annual Increase, MW	-	78	80	150	610	863	830	1,100	1,500
Annual German Solar Cell Production	16	33	54	98	187	319	530	842	1,450

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

Figure 3:

Installed Capacities of Wind Power and PV (REN21)

2008



3. Long-Lasting Consequences for Electricity Consumers

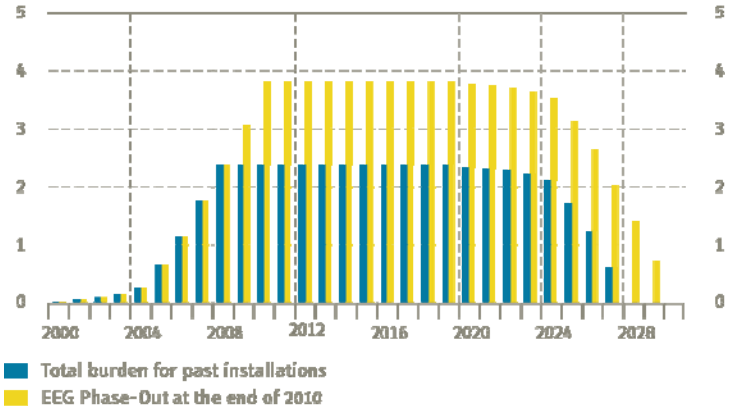
The 2009 amendment to Germany's EEG codifies the continued extension of generous financial support for renewable energy technologies over the next decades, with each newly established plant commonly being granted a 20-year period of fixed feed-in tariffs – already an original feature of the EEG when 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 Feed-in Tariffs for PV in Bn. Euro$_{2007}$

2000 through 2029



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 the figures' 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 (6.7 Cents US $) per kWh in 2010 (in prices of 2005) to 6.34 Cents (8.7 Cents US $) 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 were as high as 43 Cents (59 Cents US $) 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 € (US $ 48 Bn) (in prices of 2007). Future PV installations in 2009 and 2010 may cause further real cost worth 18.3 Bn € (US $ 25.5 Bn) (Table 4). Adding both figures yields a total of 53.3 Bn € (US $ 73.2 Bn) for PV alone.

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 (12.6 Cents US $) 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 € (US $ 27.1 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 € (US $ 28.1 Bn) if the EEG subsidization were to be abolished at the end of 2010.

Table 4:

Net Cost of Promoting PV

For the cohorts 2000 through 2010

Cohort	Annual Increase	Nominal Specific Net Cost		Cumulated Net Cost	
		1st year	20th year	Nominal	Real
	Mio kWh	€ Cents/ kWh	€ Cents / kWh	Bn €	Bn €2007
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	8.446
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.

Table 5:

Net Cost of Promoting Wind Power if high tariff holds for 20 years

For the cohorts 2000 through 2010

	Annual Increase	Nominal Specific Net Cost		Cumulated Net Cost	
		1st year	20th year	Nominal	Real
	Bn. kWh	€ 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 A3 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 (5.93 Cents US $) 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 in 2003 are expected to be "competitive" in the sense that feed-in tariffs are then lower than the assumed wholesale 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

For the cohorts 2000 through 2010

	Annual Increase	Nominal Specific Net Cost		Cumulated Net Cost	
		1st year	20th year	Nominal	Real
	Mio kWh	€ 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 A4 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, which amount to some 11.2 Bn € (US $ 15.3 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 $16.0 Bn, at the end of 2010 (Table 6).

In any case, with cumulated real cost ranging between about 11.2 and 19.8 Bn € (US $ 15.3 – 27.1 Bn) at the end of 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 € (US $ 48 Bn) so far and can be expected to rise dramatically. Recently, RWI calculated for the German weekly magazine ZEIT (2009) that the net cost for PV may easily exceed 77 Bn € (US $ 106 Bn) by 2013 if the European Photovoltaic Industry Association's (EPIA 2009) forecasts prove correct with regard to the expansion of PV capacities in Germany.

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?

These 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 (Cents 63.00 US $) per kWh for modules installed in 2008 (Table 4), and assuming that PV displaces conventional electricity generated from a mixture of gas and hard coal with an emissions factor of 0.584 kg carbon dioxide (CO_2) per kWh (Nitsch et al. 2005:66), then dividing the two figures yields abatement costs that are as high as 716 € (1,050 US$) 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 CO_2 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 CO_2.

Although wind energy receives considerably less feed-in tariffs than PV, it is by no means a cost-effective way of CO_2 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 (Cents 4.6 US $) per kWh in 2008 (Table 6), the abatement cost approximate 54 € (US$ 80) per tonne. While cheaper than PV, this cost is still nearly double the 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.

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

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 zero[1].

[1] *Ultimately, this is because the ETS enforces a binding carbon dioxide emissions cap. This result only holds true, however, if the abatement effects of any future promotion of renewable energy technologies have not yet been anticipated and included in the emission cap, making it more ambitious than otherwise. Germany's cap set for the first ETS period (2005-2007), however, did not appear to be a strong restriction, a fact that applies to the overwhelming majority of EU countries.*

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.

4.2 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).

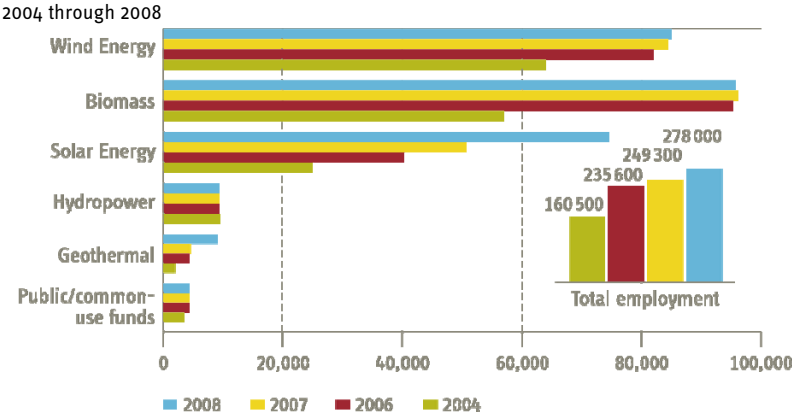
4.3 Employment Effects

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 5, 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).

Figure 5:

Gross employment in the renewable energy sector (O'Sullivan et al. 2009:9)
2004 through 2008



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.

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 € (US $1.8 Bn), the exports merely accounted for 0.2 Bn € (US $ 0.25 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). A recent article in the German Financial Times reports that the situation remains dire, with the German solar industry facing unprecedented competition from cheaper Asian imports (FTD 2009).

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-worker basis, has reached a level that by far exceeds average wages: Given our net cost estimate of about 8.4 Bn € (US $ 11.5 Bn) for 2008 reported in Table 4, per-worker subsidies are as high as 175,000 € (US $ 240,000), if indeed 48,000 people were employed in the PV sector (see BSW 2009).

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. € (US $ 741 Mio.) in 2006 (Erdmann 2008:32) – but any increased energy security afforded by PV and wind is undermined by reliance on fuel sources – principally gas – that must be imported to meet domestic demand. With 36% of gas imports to Germany in 2007 originating from Russia, 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 (Frondel, Schmidt, in press).

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 expand. 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. As shown above, PV, which is the most expensive and also most subsidized renewable energy, is the big winner in the unlevel playing field thereby created. Rather than affording PV this unfair advantage, it would make more sense to extend a uniform subsidy per kWh of electricity from renewables. This would allow 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 innovate, it instead does just the opposite by encouraging the immediate implementation of existing technology. Doing so allows producers 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 silicium solar cells, whose production cost are a multiple of those of thin film modules.

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. This is in line with Morthorst (2003), who analyzes the promotion of renewable energy usage by alternative instruments using a three-country model. 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. Such scrutiny is also warranted in the US, where there are currently nearly 400 federal and state programs in place that provide financial incentives for renewable energy (DSIRE 2009).

History clearly shows that governments have an abysmal record of selecting economically productive projects through such programs (Kahn 2009). 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.

In its country report on Germany's energy policy, the International Energy Agency recommends considering ''policies other than the very high feed-in tariffs to promote solar photovoltaics'' (IEA, 2007:77). This recommendation is based on the grounds that ''the government should always keep cost-effectiveness as a critical component when deciding between policies and measures'' (IEA, 2007:76). Consequently, the IEA proposes policy instruments favouring research and development. Lesser and Su (2008:986) concur with this viewpoint: ''Technologies that are theoretically promising, but unlikely to be competitive for many years, may be best addressed under other policies, such as publicly funded R&D''. This reasoning is particularly relevant for solar cells, whose technological efficiency is widely known to be modest and, hence, should be first increased substantially via R&D.

Instead of a policy instrument that aims at pushing technological improvements, however, Germany's support scheme of renewable energy technologies resembles traditional active labour market programs, which have been demonstrated in the literature to be counterproductive (Kluve, 2006:13). It bears particular noting that the long shadows of this economic support will last for another two decades even if the EEG were to be abolished immediately.

Appendix

Table A1:

Electricity Prices and Net Cost of PV

2000 through 2020

	Real Price	Nominal Price	Feed-in Tariffs PV	Feed-in Tariffs Wind
	€ Cents$_{2005}$/kWh	€ Cents/kWh	€ Cents/kWh	€ 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

Sources: Nitsch et al. (2005), EEG (2000, 2004, 2008)

The specific net cost shown in Table A2 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).

Table A2:

Net Cost in € Cents$_{2007}$ per kWh by Cohort for PV

For the cohorts 2000 through 2010

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

Table A3:

Net Cost in € Cents$_{2007}$ per kWh by Cohort for Wind Power (elevated tariffs for twenty years)

For the cohorts 2000 through 2010

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 € Cents$_{2007}$ per kWh by Cohort for Wind Power (elevated tariff for five years)

For the cohorts 2000 through 2010

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

For the cohorts 2000 through 2010

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

Table A6:

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

For the cohorts 2000 through 2010

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)

For the cohorts 2000 through 2010

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

The columns in Table A5 show 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 given by Table A2 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 and A7).

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

Table A8:

Effect of Subsidization on Electricity Prices

2000 through 2008

	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: AGEB (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, A10, and A11 and calculated by assuming that the same annual amount of electricity is produced over the whole subsidization period of 20 years.

Table Ag:

Total feed-in tariffs for PV

For the cohorts 2000 through 2010

	Annual Increase,	Specific Feed-in Tariff	Annual Feed-in Tariffs,	Cumulated over 20 years	
	Mio kWh	Cents/kWh	Mio €	Bn €	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 tariffs for twenty years)

For the cohorts 2000 through 2010

	Annual Increase,	Feed-in-Tariff, €	Cumulated over 20 years	
	Mio kWh	Cents/kWh	Bn. €	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)

For the cohorts 2000 through 2010

	Annual Increase,	Feed-in-Tariff, first 5 years,	Feed-in Tariff, last 15 years,	Cumulated over 20 years	
	Mio kWh	€ Cents/kWh	€ Cents/kWh	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%.

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