Manuel Frondel, Nolan Ritter,
and Christoph M. Schmidt

Germany's Solar Cell Promotion: Dark Clouds on the Horizon

#40

Ruhr Economic Papers

RWI ESSEN

Ruhr Economic Papers

Published by

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

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

Universität Duisburg-Essen, Department of Economics
Universitätsstraße 12, 45117 Essen, Germany

Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI Essen)
Hohenzollernstrasse 1/3, 45128 Essen, Germany

Ruhr Economic Papers #40

Responsible Editor: Christoph M. Schmidt

ISSN 1864-4872 (online) – ISBN 978-3-86788-038-1

Ruhr Economic Papers

#40

Manuel Frondel, Nolan Ritter,
and Christoph M. Schmidt

Germany's Solar Cell Promotion: Dark Clouds on the Horizon

RWI
ESSEN

Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

ISSN 1864-4872 (online)
ISBN 978-3-86788-038-1

Manuel Frondel, Nolan Ritter, and Christoph M. Schmidt*

Germany's Solar Cell Promotion: Dark Clouds on the Horizon

Abstract
This article demonstrates that the large feed-in tariffs currently guaranteed for solar electricity in Germany constitute a subsidization regime that, if extended to 2020, threatens to reach a level comparable to that of German hard coal production, a notoriously outstanding example of misguided political intervention. Yet, as a consequence of the coexistence of the German Renewable Energy Sources Act (EEG) and the EU Emissions Trading Scheme (ETS), the increased use of renewable energy technologies does not imply any additional emission reductions beyond those already achieved by ETS alone. Similarly disappointing is the net employment balance, which is likely to be negative if one takes into account the opportunity cost of this form of solar photovoltaic support. Along the lines of the International Energy Agency (IEA 2007:77), we therefore recommend the immediate and drastic reduction of the magnitude of the feed-in tariffs granted for solar-based electricity. Ultimately, producing electricity on this basis is among the most expensive greenhouse gas abatement options.

JEL Classification: Q28, Q42, Q48

Keywords: Energy policy, energy security, learning effects

March 2008

---

* Manuel Frondel, RWI Essen; Nolan Ritter, RWI Essen; Christoph M. Schmidt, RWI Essen, Ruhr-Universität Bochum and CEPR London. – We highly appreciate the valuable comments and suggestions by Colin Vance. – All correspondence to Dr. Manuel Frondel, Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI Essen), Hohenzollernstr. 1-3, 45128 Essen, Germany, e-mail: frondel@rwiessen.

1 Introduction

Through generous financial support, Germany has dramatically increased the electricity production from renewable technologies since the outset of this century (IEA 2007:65). With an estimated share of about 14 % of total electricity production in 2007, Germany has already significantly exceeded its target of at least 12.5% set for 2010. Currently, wind power is the most important renewable energy technology: In 2007, the estimated share of wind power in Germany's electricity production amounted to 7.4% (BWE 2008). In contrast, the electricity produced through solar photovoltaic (PV) was almost negligible: Its share is gauged to be 0.4%.

Without a doubt, the substantial contribution of renewable energy technologies to Germany's electricity production is primarily a consequence of the feed-in tariff regime established in 2000. Under this regime, which is based on the Renewable Energy Sources Act (EEG), 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 own production cost. The support stipulated by the EEG is indispensable for increasing the significance of "green electricity", since in terms of cost, renewable energy technologies can hardly compete with the conventional electricity production. Ultimately, though, it is the industrial and private consumers that have to bear the cost induced by the EEG – through an increase in the price of electricity. Wind power has so far exerted the strongest effect on electricity prices. This is a consequence of very high subsidies (MICHAELOWA 2005:192), which accounted for several billion euros or about half of the overall feed-in tariffs in 2007.

Solar electricity, however, is guaranteed by far the largest financial support per kilowatt hour (kWh). This is necessary for establishing a market foothold, with the still poor technical efficiencies of PV modules and the unfavorable geographical location of Germany being among a multitude of reasons for its grave lack of competitiveness. According to their proponents, the subsidies for PV, as well as for other renewable energy technologies, are frequently justified by highlighting their positive impact on energy security and employment, and, most notably, by emphasizing their role as vital environmental and climate protection measures.

In this article, we argue that Germany's way of supporting PV in fact does not confer any of these benefits. First, as a consequence of the 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. Similarly disappointing is, second, the net employment balance, which is likely to be negative due to the very high opportunity cost of supporting PV.

Third, we argue that the subsidized market penetration of non-competitive technologies in their early stages of development diminishes the incentives to invest in the research and development necessary to achieve competitiveness. This argument seems to be particularly relevant for solar cells, whose technological efficiency is widely known to be modest. As this article demonstrates, it is all the more disconcerting that the large feed-in tariffs per kWh currently granted for PV constitute a subsidization regime that reaches a per-employee level comparable to that of German hard coal production, a notoriously outstanding example of misguided political intervention (FRONDEL, KAMBECK, SCHMIDT 2007). The PV subsidies also substantially exceed those for the promotion of biofuels, another recently established intervention of the German government (FRONDEL, PETERS 2007).

The following section describes the EEG's preferential treatment of PV. Section 3 presents cost estimates of subsidizing this particular renewable energy technology for two scenarios: first, if Germany's current renewable energy subsidization scheme had been abolished at the end of 2007 and, second, if it were to end with the year 2010. In Section 4, we assess the potential benefits of this support scheme for the global climate and the employment in Germany, which may justify the PV subsidization. The last section summarizes and concludes.

2 The Sunrise of PV

Certainly, the major reason for the boom of renewable technologies for electricity production in Germany is the feed-in tariff scheme, which is based on the Renewable Energy Sources Act (EEG) enacted in April 2000. Since then, the share of renewable energy in total electricity production has increased from about 3% to roughly 14% in 2007, while the annual amount of feed-in tariffs increased sixfold and reached a level that is twice as high as the subsidies for German hard coal production, a long-lasting and notorious example of Germany's misguided state aid policy (FRONDEL, KAMBECK, SCHMIDT 2007:3814). To neutralize its grave lack of competitiveness, solar electricity production received the highest support per kWh among all renewable energy technologies, being in stark contrast to any efficiency criteria.

With the amendment of the EEG in August 2004, the compensation granted for solar electricity was even raised, thereby immediately initiating a tremendous increase in the number of installed solar systems (Table 1). This figure more than doubled within one year, from 84,870 in 2004 to 172,810 in 2005 (Kiesel 2006:24), again rising substantially in 2006, to 233,557 (Kiesel 2007:47). The evident reason for this particularly pronounced growth is the attractive compensation, which is – as already stipulated in the original EEG version – granted for as long as two decades at the unvaried level valid for the year of installation (IEA 2007:68-69). For PV modules installed in 2006, for instance, the amended EEG granted 51.8 cents per kWh solar electricity, a remuneration that was almost ten times higher than the market price of conventionally produced electricity. While this compensation was six times the tariff granted for wind power (8.5 cents per kWh), the average feed-in tariff for electricity from renewable energy technologies was about 11 cents per kWh in 2006 (VDN 2007).

It bears noting that domestic production was unable to satisfy the boost in demand for PV modules in the aftermath of the EEG modification in 2004. Rather, the majority of the modules were imported in 2004 and 2005 (see Table 1), most notably from Japan. Only recently, new producers of PV modules entered the scene, being mainly located in East Germany, and managed to largely satisfy domestic demand. In addition to generous feed-in tariffs, the large demand has been fueled by a particular rule introduced with the EEG amendment in 2004: Each year, the tariff granted for the subsequent 20 years for newly installed PV modules decreases by 5%. This decrease was implemented to provide an incentive for producers to improve the economic efficiency of these renewable energy technologies. Since the largest remuneration is paid now, though, the most important result of this modification is a strong incentive for a soon installation of the currently available, inefficient technology. Consequently, it is perhaps not surprising that we observe shortages in high-quality silicon used for the production of solar cells.

Table 1: Solar Electricity Capacities and Production in Germany

	2000	2001	2002	2003	2004	2005	2006
Production, Mio kWh	64	116	188	313	557	1,282	2,220
Annual Increase, Mio kWh	-	52	72	125	244	725	938
Capacity Installed, MW	62	125	210	308	788	1,762	2,405
Annual Increase, MW	-	63	85	98	480	974	643
Annual Solar Cell Production in Germany, MW	16	33	54	98	187	312	500

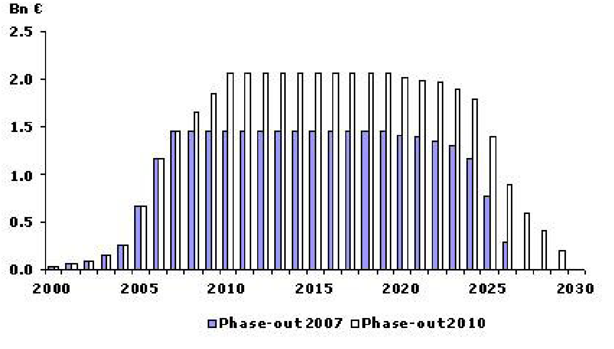
Sources: Production: BMU (2007), Capacity Installed: Kiesel (2007), German Production: BSW (2007).

In 2005 and 2006, annual growth in PV capacity in Germany significantly exceeded the global cumulative shipments from 1973 to 1995, which had just reached some 564 MW (NEIJ 1997:1102). In line with this enormous growth, Germany's support for solar electricity of about 1.18 billion (Bn) € reached a share of some 20% of the total support for "green" electricity in 2006 (VDN 2007). This magnitude stands in sharp contrast to its small share of about 3.2% in total electricity production from renewable energy technologies (KIESEL 2007:41). In other words, the PV's contribution to satisfying electricity demand is marginal: In 2006, roughly 2.2 Bn kWh of solar electricity were produced, corresponding to about 0.4% of gross domestic electricity consumption of 616.8 Bn kWh (SCHIFFER 2007:37, BMU 2007:9).

At first glance, it seems to be surprising that such a massive subsidization of a highly inefficient way of electricity production does not create a hot public and political debate. One reason is that renewable energy technologies are frequently seen as a chance to reinvigorate regions suffering from industrial decline, thereby mobilizing a coalition of local politicians, farmers, and trade unions (MICHAELOWA 2005:198). This holds particularly true for regions in Eastern Germany, where recently several solar PV parks have been established. Another, probably more relevant factor is that the cost are widely dispersed across the entire population (MICHAELOWA 2005:198). In fact, although the support for renewable electricity totaled 5.61 Bn € in 2006 (VDN 2007), the mean price effect on the 615.8 Bn kWh of gross domestic electricity consumption (Schiffer 2007:37) was a modest increase of about 0.9 cents per kWh. As average households consume some 3,500 kWh of electricity per year, this implies extra cost for "green" electricity of about 31.5 €, with about one fifth accounting for PV.

Even though the burden for individual consumers appears to be moderate, two important aspects must be taken into account. First, the private consumers' overall loss of purchasing power adds up to billions of Euro. Similarly, with the exception of the preferentially treated energy-intensive firms, the total investments of industrial energy consumers may also be substantially lower. Second, the EEG will have long-lasting consequences, since it grants fixed feed-in tariffs over a period of 20 years. For example, even if the subsidization regime had ended in 2007, consumers would have been charged until 2027 (Figure 1).

Figure 1: Annual Feed-in-tariffs for PV



If the current support scheme were to be abolished in 2010, payments would be required until 2030. For these two scenarios, we now present estimates of the net cost of PV subsidization. The net cost per kWh are calculated by subtracting the market value of PV electricity, identified by wholesale prices, from the granted feed-in tariffs.[1]

3 The Long Shadows of PV

Any assessment of the real cost (in prices of 2007) induced by subsidizing PV requires information on the volume of PV electricity, feed-in tariffs, and alternative electricity prices. Our estimates are based on past production and price figures and the "most likely production scenario" as well as the "high price scenario" assumed by NITSCH et al. (2005), a recent study on the future development of renewable energy technologies in Germany. This study can even be considered conservative as it underestimated the recent developments: In 2005, for instance, 1.282 Bn kWh were produced (see Table 1), whereas NITSCH et al. (2005) only expected 0.84 Bn kWh. If the current promotion conditions are not changed, the forecasts presented in Table 2 will most likely also underestimate future PV electricity production. In this case, our cost estimates might be too conservative, even though the "high price scenario" assumed by NITSCH et al. (2005) seems to be rather moderate from the current perspective: real base-load prices are expected to rise from 4.91 cents per kWh in 2010 to 6.34 cents per kWh in 2020 (see Table A1 in the Appendix).

Total feed-in tariffs for each cohort of newly installed PV modules are displayed at in the last column of Table 2, assuming that the same annual amount of electricity is produced over the whole subsidization period of 20 years. Had the EEG ended in 2007, nominal tariffs would have totaled 29 Bn €. Assuming an inflation rate of 2%, the total real amount would be about 25 Bn € (in prices of 2007), certainly an alarming figure.

Of course, in addition to the product of the volume of solar electricity and feed-in tariffs, any assessment of net cost must also take account of the electricity's market value. Using past market prices and the "high price scenario" assumed by NITSCH et

[1]Further benefits and cost are ignored, such as the cost for regulating energy required due to the volatility of electricity produced by solar and wind power, since these cost are almost negligible compared to electricity prices and, in particular, feed-in tariffs. External cost are included to a certain extent, though, because market prices of electricity entail the prices of carbon dioxide emission certificates.

Table 1: EEG Support for PV

	Annual Increase Mio kWh	Specific Feed-in Tariff € cents/kWh	Annual Support 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	6.860
2006	938	51.80	485.9	9.717	8.266
2007	600	49.21	295.3	5.906	4.925
EEG Phase-out in 2007				**29.007**	**25.019**
2008	430	46.75	201.0	4.020	3.287
2009	450	44.41	198.5	3.970	3.204
2010	480	42.19	202.5	4.050	3.183
EEG Phase-out in 2010				**41.075**	**34.692**

Note: Column 1: 2000-2006: BMU (2007:9), 2007: BSW (2007), 2008-2020: NITSCH et al. (2005). 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%.

al. (2005), we thus calculate the real net cost induced by supporting PV as the difference between feed-in tariffs per kWh and market prices – see Tables A1 and A2 in the Appendix for our detailed calculations. Yet, because feed-in tariffs are much larger than electricity prices, the net cost do not differ substantially from the tariffs. For example, the cumulated real support of some 8.3 Bn €, reported in Table 2 for those modules that were installed in 2006, are quite close to the real net cost of about 7.2 Bn € (Table 3). Altogether, the real net cost for all modules that have been installed since the EEG went into force in 2000 account for about 21.8 Bn € (Table 3). Future PV installations between 2008 and 2010 may cause further real cost, cumulating to about 8 Bn €.

All these cost estimates demonstrate clearly that producing electricity on the basis of PV is among the most expensive greenhouse gas abatement options. Irrespective of the concrete assumption about the fuel base of the displaced conventionally produced electricity, abatement cost estimates are dramatically larger than current prices of carbon dioxide (CO_2) emission certificates. Since the establishment of the European Emissions Trading System (ETS) in 2005, these certificates have never been more expensive

Table 2: Net Cost of Promoting PV

	Annual Increase	Specific Cost		Cumulated Cost	
		1st Year	20th Year	Nominal	Real
Cohort	Mio kWh	€ cents/kWh	€ cents/kWh	Bn €	Bn $€_{2007}$
2000	0.064	47.99	42.49	0.581	0.559
2001	0.052	47.94	42.15	0.469	0.442
2002	0.072	45.36	39.33	0.609	0.563
2003	0.125	42.90	36.63	0.989	0.897
2004	0.244	47.74	41.21	2.152	1.913
2005	0.725	50.23	44.85	6.919	6.027
2006	0.938	47.30	41.78	8.385	7.164
2007	0.600	44.50	38.86	5.018	4.204
EEG Phase-out in 2007				**25.121**	**21.769**
2008	0.430	41.82	36.05	3.360	2.760
2009	0.450	39.25	33.36	3.277	2.641
2010	0.480	36.78	30.77	3.252	2.571
EEG Phase-out in 2010				**35.001**	**29.742**

Note: Column 1: 2000-2006: BMU (2007:9), 2007: BSW (2007), 2008-2010: NITSCH et al. (2005). 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.

than 30 € per tonne of CO_2. Assuming, for instance, that PV displaces conventional electricity generated from a mixture of gas and hard coal and, hence, basing our calculation on an emission factor of 0.584 kg CO_2/kWh, abatement costs are as high as 760 € per tonne if we refer to 44.5 cents/kWh, the additional cost of 2007 (Table 3). The magnitude of these abatement cost is in accordance with the IEA's (2007:74) even larger estimate of around 1,000 € per tonne, where it is assumed that PV replaces gas-fired electricity generation. After all, from an environmental perspective, it would be economically much more efficient if greenhouse gas emissions were to be curbed via the ETS, rather than subsidizing PV. For efficiency reasons, emissions trading is among the most preferred policy instruments for the abatement of greenhouse gases in the economic literature (BÖHRINGER, LÖSCHEL 2002).

4 Impacts of Germany's PV Promotion

Given the substantial cost associated with the promotion of PV, one would expect significantly positive impacts on climate and employment. Unfortunately, Germany's way of promoting PV does not entail any such benefits. First of all, we argue that – as a result of the coexistence of the EEG and the ETS – the increased use of renewable energy technologies generally implies no additional emission reductions beyond those already achieved by ETS alone. In other words, the EEG's net effect equals zero, as there is a binding carbon dioxide emissions cap already in place under the ETS regime.[2] Ultimately, the promotion of renewable energy technologies reduces the emissions of the electricity sector. As a consequence, cheaper alternative abatement options are not realized that would have been pursued in the counterfactual situation without EEG. As a result, the EEG's true effect since the establishment of the ETS is merely a shift, rather than a reduction in the volume of emissions: Other industrial 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).

Second, the promotion of renewable energy technologies is often justified by the argument that it would create jobs. Similar to the EEG's environmental impact, however, gross and net employment effects should be distinguished. When the German Federal Ministry of Environment, Nature Conservation, and Nuclear Safety (BMU 2006:84-89) reports that 17,400 people were employed in the PV sector in 2004, this figure clearly reflects gross employment effects, since opposing impacts are ignored. Yet, apart from direct crowding-out effects on conventional energy production and indirect negative impacts on upstream sectors, supporting renewable energy technologies ultimately raises the price of electricity. The resulting drain of purchasing power and investment capital of private and industrial electricity consumers causes negative employments effects in other sectors (BMU 2006:3). This casts doubt on the ministry's

[2]This result only holds true if the abatement effects of any future promotion of renewable energy technologies have not 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.

claim that the EEG can be called a job machine (BMU 2006:3-4).

Several recent investigations support such doubts. Taking account of adverse investment and crowding-out effects, the IWH (2004) finds a negligible employment impact. Another analysis (BEI 2003:41) draws the conclusion that the overall employment effects of the promotion of energy technologies such as wind and solar power systems are negative, even though it indicates initially positive impacts. Similar results were attained by FAHL et al. (2005) as well as PFAFFENBERGER (2006). In contrast, a study commissioned by the BMU (2006:9) comes to the conclusion that the EEG may create up to 56,000 jobs until 2020. This result, however, raises concerns about the 157,000 people that – according to the same study – were already employed in the renewable energy sector in 2004 (BMU 2006:89). Furthermore, it is emphasized that positive employment effects critically depend on a robust foreign trade of renewable energy technologies (BMU 2006:7).

This implies that employment effects may turn out to be negative if net exports are negligible or even negative, as was observed for PV in the past. In 2004, for instance, about 48% of all modules installed in Germany were imported (BMU 2006:62), most notably from Japan and China. While the imports totaled 1.44 Bn €, the exports merely accounted for 0.2 Bn € (BMU 2006:61). In 2005, the domestic production of PV modules was particularly low compared with domestic demand. With 312 MW (see Table 1), domestic production only provided for 32% of the new capacity installed in Germany. Hence, any other result than a disappointing net employment balance of the German PV promotion would be surprising, whereas we would expect massive employment effects in export countries such as Japan, since these countries neither suffer from the EEG's crowding-out nor negative income effects.

In the end, the promotion of PV has become a subsidization regime that, on a per-capita basis, has by far exceeded the level of the German hard coal production, one of the most prominent examples of misguided government intervention in Germany: Given our net cost estimate of about 7.2 Bn € for 2006 reported in Table 3, per-capita capita subsidies turn out to be as high as 205,000 €, if indeed 35,000 people were employed in the PV sector (BSW 2007). By comparison, with roughly the same number of employees and hard coal subsidies of 2.5 Bn €, each job in the German hard coal sector was subsidized by an already outrageous 70,000 € in 2006 (FRONDEL, KAMBECK, SCHMIDT 2007:3807).

In line with an energy policy that seems prepared to wholly disregard any consideration of cost, the major reason for the particularly large subsidies granted for PV is that technological efficiencies of solar cells are far below their theoretical potential (NEIJ 1997:1102). Although their efficiency has increased considerably over the years, this fact would quite obviously suggest that one should currently abstain from subsidizing market penetration. Rather, from an economic perspective, one should intensify research and development (R & D). Substantially improving technological efficiencies would by far be the better energy policy for Germany. Given the widely known low technological efficiencies of about 20% for crystalline-silicon cells and 10% for amorphous-silicon cells (NEIJ 1997:1102), funding R & D appears indeed to be a promising avenue to achieve substantial cost and, hence, price reductions.

In Germany, prices have remained quite high, though, despite the significant cost reductions that arise from economies of scale and learning effects. The reason for this fact is that the attractive incentives provided by the EEG have led the demand for PV modules to outrun domestic supply. In fact, according to recent studies on experience and learning effects in PV production in Japan (1979-1988) and the U. S. (1976-1992), the cost of producing PV modules tends to shrink by more than 20 % with each doubling of production (NEIJ 1997:1102). Using more recent PV data for Germany, Switzerland, and the U. S. (1992-2000), PAPINEAU (2006:426) finds cost reductions in the range of 3 to 17%, with those for Germany lying between 12% and 15%. Given the tremendous growth in recent PV installations in Germany (see Table 1), annual cost reductions should also be of this order of magnitude. Thus, the current decrease in feed-in tariffs of 5% per year seems inappropriately low. Consequently, any further amendment of the EEG should incorporate much larger than the prevailing decreases in tariffs. This would set strong cost-oriented incentives and save societal resources. Ultimately, rather than generously remunerating the production of solar electricity, public funding of solar cell R & D should be increased.

5 Summary and Conclusion

The generous financial support for solar photovoltaic (PV) stipulated in Germany's Renewable Energy Sources Act (EEG) currently provides for the largest demand for PV modules in the world, thereby leading to high prices for solar cells and shortages in high-quality silicon used for their production. In this article, we have gauged the net cost of this subsidization regime for two scenarios: first, if it had ended in 2007 and, second, if it were to be abolished in 2010. For the first scenario, we have estimated a net cost of approximately 22 Bn €, while an abolition in 2010 comes at further cost of about 8 Bn € (in prices of 2007).

Given the substantial cost associated with this regime of PV promotion, one would expect significantly positive impacts on climate and employment. Unfortunately, Germany's way of promoting PV does not confer any such benefits. First, since the introduction of the EU Emissions Trading Scheme (ETS) in 2005, the growing use of renewable energy technologies generally does not imply any additional emission reductions beyond those already achieved by ETS alone. Second, not only is the net climate effect of EEG zero, we have also demonstrated that it is quite doubtful whether its net employment effects are positive at all. Most importantly, subsidies for PV impose a substantial drain on the budgets of private and industrial consumers, leading funds away from alternative, possibly more beneficial investments. Until recently, though, Germany's PV support has created many jobs abroad, since a significant share of PV modules has had to be imported, most notably from Japan and China.

In its country report on Germany's energy policy, the International Energy Agency even recommends considering "policies other than the very high feed-in tariffs to promote solar photovoltaics" (IEA 2007:77), since "the government should always keep cost-effectiveness as a critical component when deciding between policies and measures" (IEA 2007:76). Instead, in line with our arguments, the IEA proposes policy instruments that favor research and development. Yet, so far Germany's support scheme of renewable energy technologies, in particular of PV, resembles traditional active labor market programs, which have been demonstrated in the literature to be counterproductive (KLUVE 2006:13). The long dark shadows of this support will last for another two decades even if the EEG were to be abolished immediately. From a social welfare perspective, we therefore recommend the rapid reduction of these subsidies, taking account of recent estimates of annual reductions in production cost, which are on the order of 12% to 15%.

6 Appendix

Table A1: Electricity Prices and Net Cost of PV

	Real Price € $cents_{2005}$/kWh	Nominal Price € cents/kWh	Feed-in Tariff € cents/kWh	Net Cost € cents/kWh
2000	2.90	2.63	50.62	47.99
2001	2.90	2.68	50.62	47.94
2002	2.90	2.73	48.09	45.36
2003	2.90	2.79	45.69	42.90
2004	2.90	2.84	50.58	47.74
2005	4.30	4.30	54.53	50.23
2006	4.42	4.50	51.80	47.30
2007	4.53	4.71	49.21	44.50
2008	4.66	4.93	46.75	41.82
2009	4.78	5.16	44.41	39.25
2010	4.91	5.41	42.19	36.78
2011	5.06	5.68	40.08	34.40
2012	5.21	5.96	38.08	32.12
2013	5.36	6.26	36.18	29.92
2014	5.52	6.57	34.37	27.80
2015	5.69	6.90	32.65	25.75
2016	5.81	7.19	31.02	23.83
2017	5.94	7.49	29.47	21.98
2018	6.07	7.80	28.00	20.20
2019	6.20	8.13	26.60	18.47
2020	6.34	8.47	25.27	16.80
2021	6.43	8.76	24.01	15.25
2022	6.52	9.06	22.81	13.75
2023	6.61	9.37	21.67	12.30
2024	6.71	9.68	20.59	10.91
2025	6.80	10.02	19.56	9.54
2026	6.89	10.35	18.58	8.23
2027	6.98	10.70	17.65	6.95
2028	7.08	11.05	16.77	5.72
2029	7.17	11.42	15.93	4.51
2030	7.27	11.81	15.13	3.32

Note: Column 1: Real electricity prices according to Nitsch et al. (2005).
Column 2: Nominal market prices based on Column 1 and an inflation rate of 2%.
Column 3: Feed-in tariffs. Column 4: Difference between Columns 3 and 2.

Table A2: Net Cost in € Cents$_{2007}$ per kWh by Cohort

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	44.50			
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	43.33	39.97	37.72	
2010	42.16	42.16	40.22	37.95	42.57	46.29	43.72	41.28	38.96	36.75	34.66
2011	41.52	41.52	39.18	36.97	41.48	45.13	42.16	40.22	37.95	35.78	33.73
2012	40.45	40.45	38.16	35.98	40.41	43.99	41.52	39.17	36.94	34.82	32.81
2013	39.39	39.39	37.15	35.01	39.36	42.86	40.44	38.14	35.96	33.88	31.91
2014	38.35	38.35	36.15	34.06	38.31	41.75	39.37	37.12	34.98	32.94	31.01
2015	37.32	37.32	35.16	33.11	37.28	40.65	38.32	36.11	34.01	32.02	30.12
2016	36.34	36.34	34.23	32.22	36.31	39.61	37.33	35.16	33.10	31.15	29.29
2017	35.38	35.38	33.31	31.34	35.35	38.59	36.35	34.23	32.21	30.29	28.47
2018	34.44	34.44	32.40	30.47	34.40	37.58	35.39	33.30	31.32	29.44	27.66
2019	33.50	33.50	31.51	29.62	33.47	36.59	34.43	32.39	30.45	28.61	26.86
2020		32,58	30.63	28.77	32.55	35.61	33.50	31.49	29.59	27.78	26.07
2021			29.81	27.99	31.70	34.69	32.62	30.66	28.79	27.02	25.34
2022				27.22	30.85	33.79	31.76	29.83	28.01	26.27	24.62
2023					30.02	32.90	30.91	29.02	27.23	25.53	23.91
2024						32.03	30.08	28.23	26.47	24.80	23.21
2025							29.26	27.44	25.72	24.08	22.53
2026								26.67	24.99	23.38	21.86
2027									24.26	22.69	21.19
2028										22.01	20.54
2029											19.90
2030											
Bn kWh	0.064	0.052	0.072	0.125	0.244	0.725	0.938	0.600	0.430	0.450	0.480
Bn €	0.559	0.442	0.563	0.897	1.913	6.027	7.164	4.204	2.760	2.641	2.571

The net cost shown in Table A2 are calculated by subtracting actual or expected market prices of electricity from feed-in tariffs. While these are fixed for each cohort of installed solar modules for a period of 20 years, market prices of course tend to change over time. Therefore, the net cost per kWh displayed in the columns vary 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.

References

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.

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

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

BÖHRINGER, C., LÖSCHEL, A. (2002) Assessing the Costs of Compliance: The Kyoto Protocol. *European Environment* 12, 1-16.

BSW (2007) German Solar Industry Association, Statistische Zahlen der deutschen Solarwirtschaft, Juni 2007, www.bsw-solar.de.

BWE (2008) German Wind Energy Association, Fact Sheet 2007, www.wind-energy.de, 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. , KAMBECK, R. , SCHMIDT, C. M. (2007) Hard Coal Subsidies: A Never-Ending Story? *Energy Policy* **35 (7)** 3807-3814.

FRONDEL, M. , PETERS, J. (2007) Biodiesel: A New Oildorado? *Energy Policy* **35 (3)**, 1675-1684.

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.

KIESEL, F. (2007) Ergebnisse der BDEW-Erhebung "Regenerativanlagen" 2006, *ew* **106 (25-26)**, 40-47.

KIESEL, F. (2006) Ergebnisse der VDEW-Erhebung "Regenerativanlagen" 2005, *ew* **105 (26)**, 20-25.

KLUVE, J. (2006) The Effectiveness of European Active Labor Market Policy, *RWI:Discussion Paper* **37**, Essen.

MICHAELOWA, A. (2005) The German Wind Energy Lobby: How to Successfully Promote Costly Technological Change. *European Environment* **15(3)**, 192-199.

NEIJ, L. (1997) Use of Experience Curves to Analyse the Prospects for Diffusion and Adoption of Renewable Energy Technology. *Energy Policy* **23 (13)**, 1099-1107.

NITSCH, J., STAISS, F., WENZEL, B., FISCHEDICK, M. (2005) Ausbau der Erneuerbare Energien im Stromsektor bis 2020: Vergütungszahlen und Differenzkosten durch das Erneuerbare-Energien-Gesetz, Stuttgart, Wuppertal.

PAPINEAU, M. (2006) An Economic Perspective on Experience Curves and Dynamic Economies in Renewable Energy Technologies. *Energy Policy* **34 (4)**, 422-432.

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

SCHIFFER, H.W. (2007) Deutscher Energiemarkt 2006. *Energiewirtschaftliche Tagesfragen* **57 (3)**, 32-42.

VDN (2007) Erneuerbare-Energien-Gesetz Jahresabrechnung 2006, Verband der Netzbetreiber e.V., http://vdn-archiv.bdew.de, Berlin.