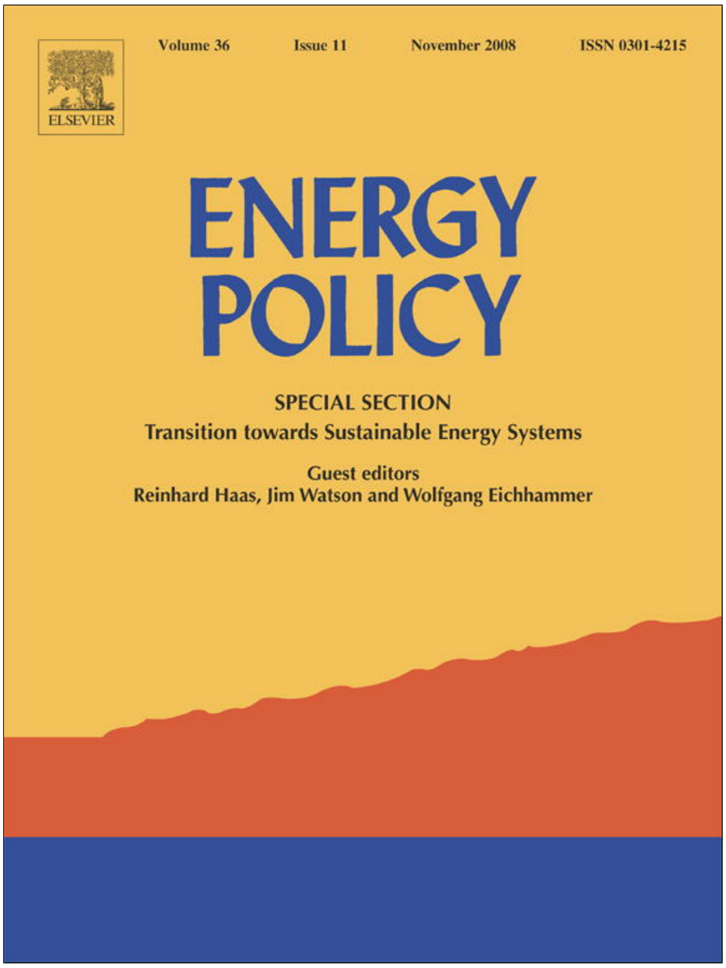
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Germany's solar cell promotion: Dark clouds on the horizon

Manuel Frondel [a,*], Nolan Ritter [a], Christoph M. Schmidt [a,b]

[a] *Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI Essen), Hohenzollernstr. 1-3, D-45128 Essen, Germany*
[b] *CEPR, London*

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ABSTRACT

This article demonstrates that the large feed-in tariffs currently guaranteed for solar electricity in Germany constitute a subsidization regime that 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 (PV) support. Along the lines of the international energy agency [IEA, 2007. Energy policies of IEA countries: Germany, 2007 review. International Energy Agency, OECD, Paris, p. 77], we 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.

1. Introduction

Through generous financial support, Germany has dramatically increased electricity production from renewable technologies since the outset of this century (IEA, 2007, p. 65). With an estimated share of about 14% of total electricity production in 2007, Germany has already significantly exceeded its minimum target of 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 photovoltaics (PV) was almost negligible: Its share is gauged to be 0.4% (Schiffer, 2007, p. 42).

The substantial contribution of renewable energy technologies to Germany's electricity production is primarily a consequence of a support regime based on feed-in tariffs, which was already 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% of the retail rate of electricity. The 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 in order to guarantee stable feed-in tariffs for up to 20 years, thereby providing for favourable conditions for investments in "green" electricity production. Given the premature overcompliance, 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.

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 own production cost. The support stipulated by the EEG is indispensable for increasing the significance of "green electricity", as in terms of cost, renewable energy technologies can hardly compete with the conventional electricity production. Ultimately, though, it is the industrial and private consumers who have to bear the cost induced by the EEG and, hence, subsidize the promotion of renewable energy technologies—through an increase in the price of electricity.

Wind power has exerted the strongest effect on electricity prices so far. This is a consequence of very high subsidies (Michaelowa, 2005, p. 192), which accounted for several billion euros in 2007, or about half of the overall amount of feed-in tariffs. 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 low technical efficiencies of PV modules and the unfavorable geographical location of Germany being among a multitude of reasons for the grave lack of competitiveness of solar electricity. According to their proponents, the subsidies for PV, as well as for other renewable energy

* Corresponding author.
E-mail address: frondel@rwi-essen.de (M. Frondel).

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technologies, are frequently justified by highlighting their positive impact on energy security and employment, and, most notably, by emphasizing their role as a vital environmental and climate protection measure.

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 prevailing coexistence of the Renewable Energy Sources Act (EEG) and the EU Emissions Trading Scheme (ETS), which was established in 2005, 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. Second, the net employment balance is likely to be negative due to the very high opportunity cost of supporting PV.

Third, we argue that in the early stages of development of non-competitive technologies, it appears to be more cost-effective to invest in research and development (R&D) to achieve competitiveness, rather than to promote their large-scale production. This argument seems to be particularly relevant for solar cells, whose technological efficiency is widely known to be modest and, hence, should be first increased substantially via R&D. 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 policy that reaches a gross per-employee level that by far exceeds that of German hard coal production, a notoriously outstanding example of misguided political intervention (Frondel et al., 2007). The PV subsidies are also dramatically larger than those for the promotion of biofuels, another recently established intervention of the German government (Frondel and Peters, 2007).

The following section describes the EEG's preferential treatment of PV. Section 3 presents cost estimates of subsidizing this 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, i.e. right after the subsequent federal elections in 2009. Depending upon the results of this election, the EEG subsidization regime may be significantly changed. In Section 4, we assess the potential benefits of this subsidization scheme for the global climate and employment in Germany, which may justify the PV subsidization. The last section summarizes and concludes.

2. The preferential promotion of PV

Without a doubt, 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 6% to roughly 14% in 2007, while the annual amount of feed-in tariffs has grown eightfold, to 7.4 billion euros (Schiffer, 2008, pp. 41–42; Schiffer, 2001, p. 117; BDEW, 2008). To neutralize its grave lack of competitiveness, solar electricity production receives the highest subsidy per kWh among all renewable energy technologies. With the amendment of the EEG in August 2004, the compensation granted for solar electricity was even raised, thereby triggering an immediate increase in the number of installed solar systems (Table 1). This figure more than doubled within 1 year, from 84,870 in 2004 to 172,810 in 2005 (Kiesel, 2006, p. 24), again rising substantially in 2006 to 233,557 (Kiesel, 2007, p. 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 that is valid in the year of installation (IEA, 2007, pp. 68–69). For PV modules installed in 2006, for instance, the amended EEG granted 51.8 cents/kWh solar electricity, a remuneration that was almost 10 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/kWh), the average feed-in tariff for electricity from renewable energy technologies was about 11 cents/kWh in 2006 (VDN, 2007).

Table 1
Solar electricity capacities and production in Germany

	2000	2001	2002	2003	2004	2005	2006
Production, Mio kWh	64	116	188	313	557	1282	2220
Annual increase, Mio kWh	–	52	72	125	244	725	938
Capacity installed, MW	62	125	210	308	788	1762	2405
Annual increase, MW	–	63	85	98	480	974	643
Annual solar cell production in Germany	16	33	54	98	187	319	530

Sources: production: BMU (2007), capacity installed: Kiesel (2007), German cell production: BSW (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. Instead, the majority of the modules had to be imported in 2004 and 2005 (see Table 1), most notably from Japan. In addition to generous feed-in tariffs, the large demand had been fuelled by a special 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%. While this annual decrease was implemented to provide for an incentive for producers to improve the economic efficiency of these renewable energy technologies, it must also be recognized that this modification may foster the consumers' desire to rapidly install the currently available, yet not the best technology.

In line with Germany's enormous PV demand growth in recent years, the support for solar electricity of about 1.18 billion (Bn) € reached a share of some 20% of the total amount of feed-in tariffs provided for "green" electricity in 2006 (VDN, 2007). This magnitude sharply contrasts with the small share of PV of about 3.2% in total electricity production originating from renewable energy technologies (Kiesel, 2007, p. 41). In other words, the contribution of PV 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 617 Bn kWh (Schiffer, 2007, p. 37; BMU, 2007, p. 9).

At first glance, it seems to be surprising that such a massive subsidization of a highly inefficient way of electricity production has not already created 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, p. 198). This holds particularly true for regions in Eastern Germany, where several large solar parks have recently been established. Another, probably more relevant factor is that the costs are widely dispersed across the entire population (Michaelowa, 2005, p. 198). In fact, although the subsidy for renewable electricity totalled 5.61 Bn € in 2006 (VDN 2007), the mean price effect on the 617 kWh of gross domestic electricity consumption was a modest increase of about 0.9 cents/kWh. As average households consume some 3500 kWh of electricity per year, this implies an extra cost for "green" electricity of about 31.5 €, with about a fifth accounting for PV.

Even though the burden for individual consumers appears to be moderate, and a majority of the German population embraces

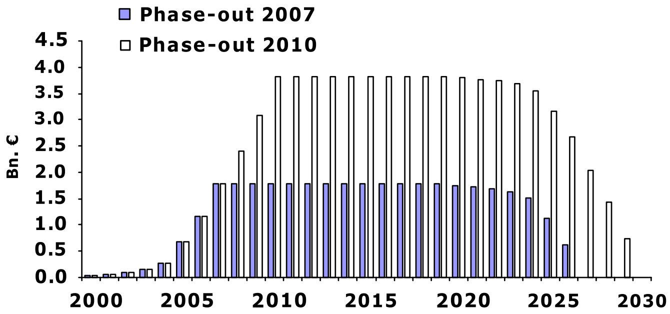

Fig. 1. Annual feed-in tariffs for PV

renewable energy technologies, two important aspects must be taken into account. First, the private consumers' overall loss of purchasing power adds up to billions of euros. Similarly, with the exception of the preferentially treated energy-intensive firms, the total investments of industrial energy consumers may be substantially lower. Second, in contrast to other subsidy regimes, such as the support of agricultural production, the EEG will have long-lasting consequences, because it grants fixed feed-in tariffs for over a period of 20 years. For example, even if the subsidization regime had ended in 2007, consumers would still be charged until 2027 (Fig. 1).

If the current subsidy 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 costs per kWh are calculated by subtracting the market value of PV electricity, identified by wholesale prices, from the granted feed-in tariffs.[1] This comparison makes it obvious that the net cost will increase dramatically if we maintain this subsidization regime just 3 additional years.

3. The long-lasting financial consequences of PV promotion

Any assessment of the real cost induced by subsidizing PV requires information on the volume of PV electricity generation, feed-in tariffs, and conventional electricity prices. Our estimates are based on the past solar electricity production figures displayed in Table 1 and on estimates of future production originating from a recent PV study (Sarasin, 2007). It bears noting that this study's estimation anticipated the EEG amendment in 2008. According to this re-regulation, the future subsidization of PV will be more reduced than it is stipulated under the prevailing subsidization regime. Rather than by 5% as in 2008, feed-in tariffs for PV will be reduced by 8% in each of the years 2009 and 2010.

Taking these alterations into account, total feed-in tariffs for each cohort of newly installed PV modules are displayed in the last column of Table 2 and calculated by assuming that the same annual amount of electricity is produced over the whole subsidization period of 20 years. Had the EEG ended in 2007, overall tariffs would have totalled roughly 35.7 Bn €. Assuming an inflation rate of 2%, the total real amount would be about 30.6 Bn € (in prices of 2007), certainly an alarming figure.

Of course, in addition to the volume of solar electricity and feed-in tariffs, any assessment of the 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 al. (2005), a study on the future development of renewable energy technologies in Germany, we thus calculate the real net cost induced by subsidizing PV as the difference between feed-in tariffs per kWh and market prices—see Tables A1–A3 in Appendix A for our detailed calculations. The price scenario by Nitsch et al. (2005) appears to be rather moderate from the current perspective: real base-load prices are expected to rise from 4.91 cents/kWh in 2010 (in prices of 2007) to 6.34 cents/kWh in 2020 (see Table A1). Uncertainties about future electricity prices, however, are not critical for the magnitude of our cost estimates, given the large differences between market prices of electricity and feed-in tariffs for PV, which were as high as 49.21 cents/kWh in 2007 (Table 2).

Actually, because feed-in tariffs are much larger than electricity prices, the overall net cost do not differ substantially from the total amount of tariffs. For example, the cumulated tariffs 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 26.5 Bn € (Table 3). Future PV installations between 2008 and 2010 may cause further real cost of the same magnitude, cumulating to about 27 Bn €.

All these cost estimates clearly demonstrate 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 conventional electricity, abatement cost estimates are dramatically larger than the current prices of carbon dioxide (CO_2) emission certificates. Since the establishment of the ETS in 2005, these certificates have never been more expensive than 30 €/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 the emission factor of 0.584 kg CO_2/kWh (Nitsch et al., 2005, p. 66), abatement costs are as high as 760 €/tonne if we refer to 44.5 cents/kWh, the additional cost of 2007 (Table 3).

The magnitude of these abatement costs is in accordance with the IEA's (2007, p. 74) even larger estimate of around 1000 €/tonne, which results from the assumption that PV replaces gas-fired electricity generation. 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 PV. 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 PV promotion

Given the substantial cost associated with the promotion of PV, one would expect significantly positive impacts on climate and employment. Unfortunately, the way in which Germany promotes PV does not confer any such benefits. First of all, we argue that—as a result of the prevailing coexistence of the EEG and the ETS—the increased use of renewable energy technologies generally implies 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. 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, p. 8).

[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 costs are almost negligible compared to electricity prices and, in particular, feed-in tariffs. External costs, though, are included to a certain extent, because market prices of electricity entail the prices of carbon dioxide emission certificates.

Table 2
EEG support for PV

	Annual increase, Mio kWh	Specific feed-in tariff, € cents/kWh	Annual amount of Feed-in tariffs, Mio €	Cumulated over 20 years	
				Nominal Bn €	Real Bn $€_{2007}$
2000	64	50.62	32.4	0.648	0.671
2001	52	50.62	26.3	0.526	0.494
2002	72	48.09	34.6	0.692	0.638
2003	125	45.69	57.1	1.142	1.031
2004	244	50.58	123.4	2.468	2.184
2005	725	54.53	395.3	7.906	6.680
2006	938	51.80	485.9	9.717	8.266
2007	1280	49.21	629.9	12.598	10.506
EEG phase out in 2007				35.670	30.600
2008	1310	46.75	612.4	12.248	10.014
2009	1600	43.01	688.2	13.764	11.032
2010	1880	39.57	743.9	14.878	11.692
EEG phase out in 2010				76.590	63.337

Note: Column 1: 2000–2006: BMU (2007, p. 9), 2007: BSW (2007), 2008–2010: Sarasin (2007). Column 2: feed-in tariff for PV in € cents per kWh. Column 3: product of Columns 1 and 2. Column 4: Column 3 times 20. Column 5: inflation-corrected figures of Column 4 using a rate of 2%.

Table 3
Net cost of promoting PV

	Annual increase	Specific cost		Cumulated cost	
	Mio kWh	1st year € cents/ kWh	20th year € cents/kWh	Nominal Bn €	Real 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	1280	44.50	38.86	10.705	8.969
EEG phase-out in 2007				30.808	26.534
2008	1310	41.82	36.40	10.282	8.446
2009	1600	37.85	32.31	11.269	9.081
2010	1880	34.16	28.52	11.837	9.359
EEG phase-out in 2010				64.196	53.420

Note: Column 1: 2000–2006: BMU (2007, p. 9), 2007: BSW (2007), 2008–2010: Sarasin (2007). Columns 2 and 3: differences between feed-in tariffs and market price for the first and the 20th year, respectively. Column 4: nominal figures of Column 5. Column 5: last row of Table A2 in Appendix A.

In other words, since the establishment of the ETS in 2005, the EEG's net effect has been equalling zero,[2] as the ETS enforces a binding carbon dioxide emissions cap. 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.

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, pp. 84–89) report that 17,400 people were employed in the PV sector in 2004, this figure clearly reflects gross employment effects, as 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 employment effects in other sectors (BMU, 2006, p. 3). This casts doubt on whether the EEG's employment effects are positive at all.

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 draws the conclusion that the overall employment effects of the promotion of energy technologies such as wind and solar power systems are negative, although it indicates initially positive impacts (BEI, 2003, p. 41). Similar results were attained by Fahl et al. (2005) as well as Pfaffenberger (2006). In contrast, a study commissioned by the BMU (2006, p. 9) comes to the conclusion that the EEG's net employment effect is the creation of up to 56,000 jobs until 2020. This study, however, emphasizes that positive employment effects critically depend on a robust foreign trade of renewable energy technologies (BMU, 2006, p. 7).

This implies that the net employment effects may turn out to be negative if net exports are negligible or even negative, as was the case for PV in Germany in recent years. In 2004, for instance, about 48% of all modules installed in Germany were imported (BMU, 2006, p. 62), most notably from Japan and China. While the imports totalled 1.44 Bn €, the exports merely accounted for 0.2 Bn € (BMU, 2006, p. 61). In 2005, the domestic production of PV modules was particularly low compared with domestic demand. With 312 MW, domestic production only provided for 32% of the new capacity installed in Germany (see Table 1). In 2006 and 2007, almost half of Germany's PV demand was covered by imports (Sarasin 2007, p. 19, Table 1).

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 Japan, since these countries do not suffer from the EEG's crowding out nor from negative income effects. In the end, Germany's PV promotion has become a subsidization regime that, on a per-capita basis, has reached a very high level that by far exceeds average wages. Given our net cost estimate of about 7.2 Bn € for 2006 reported in Table 3, per-capita subsidies turn out to be as high as 205,000 €, if indeed 35,000 people were employed in the PV sector (BSW, 2007).

[2] This result only holds true 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.

In line with an energy policy that seems prepared to widely disregard cost aspects, a 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, p. 1102). Although the average commercial module efficiency has increased considerably over the years, from hardly more than 5% in 1975 to about 15% in 2001, the best laboratory cell efficiencies are still much higher, being almost as high as 25% in 2001 (Nemet, 2006, p. 3228). These figures, together with the fact that 10 of the 16 breakthroughs in efficiency since 1980 were due to R&D programs (Nemet, 2006, p. 3227), suggest that one should have abstained from strongly subsidizing the market penetration of relatively immature PV technologies.

Rather, from an economic perspective, R&D funding should have been increased first. This view is supported by the fact that the rapid rise in laboratory cell efficiency from 1983 to 1990 immediately followed the unprecedented $1.5 bn investment in worldwide PV R&D in the previous 5 years (IEA 2004). Furthermore, technological efficiency is according to NEMET (2006:3228) among the most important factors affecting the cost of PV. NEMET'S (2006:3218) empirical investigation indicates, however, that, although subsidized market penetration triggers learning effects in the construction and implementation of PV modules, these effects do not substantially improve module efficiency.

In short, funding R&D in order to trigger significant technology improvements appears to be a more promising avenue to efficiently achieve substantial cost reductions in early technology stages than the heavy subsidization of market penetration, a policy alternative where technological improvements are rather by-products. This is all the more relevant as PV module prices have remained high since 2004, despite the significant cost reductions that arise from economies of scale. 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. Actually, more than half of the world market volume was due to Germany's PV demand in 2005 and 2006 (Sarasin, 2007, p. 19).

In contrast to prices, however, the cost of producing PV modules tends to shrink significantly. According to recent studies on PV production in Japan (1979–1988) and the US (1976–1992), the cost of producing PV modules decreases by more than 20% with each doubling of production (Neij, 1997, p. 1102). Using more recent PV data for Germany, Switzerland, and the US (1992–2000), Papineau (2006, p. 426) finds respective cost reductions to be in the range of 3–17%, with those for Germany lying between 12% and 15%. Given the recent strong global growth in PV installations,[3] annual cost reductions are most likely to have been much larger than the annual decrease in feed-in tariffs of 5%, while future cost reductions can be expected to be even higher. Furthermore, it is to be expected that the global PV growth will in fact accelerate in the near future, not least due to enhanced subsidization in Spain and the US (Sarasin, 2007, pp. 15–19). For this reason, the intensified tariff reductions of 8% valid for both 2009 and 2010, as well as 9% for 2011, appear to be highly warranted. While saving societal resources, this EEG re-regulation sets stronger cost-saving incentives and is all the more important because the very strong demand in Germany is a clear indication of a generous level of feed-in tariffs that keeps PV module prices high. Due to asymmetric cost information, though, it remains an open question of whether this EEG adjustment adequately reflects past and future reductions in production costs—a problem that generally afflicts renewable energy support regimes that are based on feed-in tariffs.

[3] With 974 MW and 643 MW in 2005 and 2006, respectively (see Table 1), Germany's PV production alone significantly exceeded the global cumulative production from 1973 through 1995, which had just reached some 564 MW (Neij, 1997, p. 1102).

5. Summary and conclusion

The very generous financial support for solar PV stipulated in Germany's Renewable Energy Sources Act (EEG) currently provides 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, that is, in the year following the next federal elections. Depending on the results of this election, the EEG subsidization regime may be significantly changed. For the first scenario, we have estimated real net cost of approximately 26.5 Bn €, while an abolition in 2010 comes at similarly large additional net cost of about 27 Bn € (in prices of 2007).

Given the substantial cost associated with this policy 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 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, but we have also demonstrated that it is quite doubtful whether its net employment effects are positive at all. Most importantly, the large subsidies for PV impose a substantial drain on the budgets of private and industrial consumers, leading funds away from alternative, possibly more beneficial, investments. In fact, the main employment effect of Germany's PV support has been the creation of many jobs abroad, as a significant share of PV modules has had to be imported so far, most notably from Japan and China.

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, p. 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, p. 76). Consequently, the IEA proposes policy instruments favouring research and development, which is in line with our arguments and Lesser and Su (2008, p. 986): "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".

Instead of a policy instrument that aims at pushing technological improvements, however, Germany's support scheme of renewable energy technologies, in particular PV, resembles traditional active labour market programs, which have been demonstrated in the literature to be counterproductive (Kluve, 2006, p. 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. From a social welfare perspective, increasing public funding of solar cell R&D may have been a much better policy alternative than generously remunerating the production of solar electricity.

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Appendix A

The specific net cost shown in Tables A1and A2 is calculated by subtracting actual or expected market prices of electricity from

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	43.01	37.85
2010	4.91	5.41	39.57	34.16
2011	5.06	5.68	36.01	30.33
2012	5.21	5.96	32.77	26.81
2013	5.36	6.26	29.82	23.56
2014	5.52	6.57	27.14	20.57
2015	5.69	6.90	24.69	17.79
2016	5.81	7.19	22.47	15.28
2017	5.94	7.49	20.45	12.96
2018	6.07	7.80	18.61	10.81
2019	6.20	8.13	16.93	8.80
2020	6.34	8.47	15.41	6.94

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: annual decreases of feed-in tariffs 2005–2008: 5%, 2009–2010: 8%, 2011–2020: 9%. Column 4: difference between Columns 3 and 2.

Table A3
Annual net cost in $€_{2007}$ per annum and by cohort

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	8.45	9.08	9.36	53.42

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	44.5			
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	35.4	33.34	30.22	27.34
2017	35.38	35.38	33.31	31.34	35.35	38.59	36.35	34.47	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
2030											
Bn kWh	0.064	0.052	0.072	0.125	0.244	0.725	0.718	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	8.446	9.081	9.359

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 costs per kWh and the solar electricity produced by each cohort displayed in the penultimate row.

The columns in Table A3 inform about the net cost per cohort of annually installed modules, while the rows show the real net cost per year. A particularly striking result of the presentation given by Table A3 is the dramatic cost increase related to the cohort installed in 2005, the year following the EEG amendment in 2004.

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