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# Germany's Solar Cell Promotion: An Unfolding Disaster

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# Germany's Solar Cell Promotion: An Unfolding Disaster


## Abstract

*This article revisits an analysis by Frondel, Ritter and Schmidt (2008) of Germany's Renewable Energy Act, which legislates a system of feed-in tariffs to promote the use of renewable energies. As in the original article, we argue that Germany's support scheme subsidizes renewable energy technologies not based on their long-term market potential, but rather on their relative lack of competitiveness, with the photovoltaics (PV) technology enjoying high feed-in tariffs, currently over double those of on-shore wind. The result is explosive costs with little to show for either environmental or employment benefits. Indeed, we document that the immense costs foreseen by Frondel and colleagues have materialized: Our updated estimate of the subsidies for PV, at 100 Bn €, exceeds their expectations by about 60%. Moreover, with installed PV capacities growing at a rapid rate, these costs will continue to accumulate, diverting resources from more cost-effective climate protection instruments.*



*JEL Classification: Q28, Q42, Q48*

*Keywords: Energy policy; employment effects; climate protection*

*July 2012*



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## 1 Introduction

For many years now, Germany has been regarded as a pioneer among nations in the implementation of renewable energy technologies, one that "sets a shining example in providing a harvest for the world" (The Guardian 2007). And no wonder. With the renewable share of total electricity production having increased from some 6% in 2000 (Schiffer, 2001:117) to about 20% in 2011, Germany is currently well on track to comply with targets set by the European Union (EU), as well as its own voluntary goal of a "green" electricity share of 35% foreseen for 2020.[1]

Most notably, the recent years' solar boom in Germany has directed the world's attention to the production of solar electricity based on photovoltaics (PV). With a share of about 37% in the globally installed PV capacities in 2011 (Figure 1), Germany is among the most important players in the global PV market, despite the fact that the solar intensity in the country, at 1,147 $kWh/m^2$, is some 40% lower than in Southern European countries, such as Greece or Spain (JRC, 2008). Nevertheless, owing to extremely generous subsidies, Germany has been the leading country in terms of annual PV capacity installations for many years, being outperformed just recently by only Italy, which installed 9,000 Megawatt (MW) or about a third of global PV capacity installations in 2011 alone (Figure 2). With 212 Watt per inhabitant, the density of photovoltaic capacity is highest in Germany. In Spain and Italy, this density is much lower, amounting to 83 and 58 Watt per inhabitant, respectively (EurObservER, 2011).

By drawing on the methodology presented in the study "Germany's Solar Cell Promotion: Dark Clouds on the Horizon" (Frondel, Ritter, Schmidt, 2008), the present article updates the former study's estimates of the cost of promoting Germany's alleged solar boom. In fact, as Frondel, Ritter, and Schmidt, (2008:4198) had feared, this boom has proved to be a highly costly undertaking that does not confer any of the benefits that the advocates of renewable technologies claimed would arise. Perhaps most poignantly, the predictions of employment creation have instead been contradicted by a series of bankruptcies in the PV manufacturing sector, with many of the job losses hitting the eastern part of the country, where unemployment is already relatively high. The besieged state prevailing across much of the PV industry is particularly distressing given that gross per-employee subsidies have reached a level that by far exceeds that of German hard coal production, another glaring example of over-subsidization (Frondel, Kambeck, Schmidt, 2007). We will argue that the government's support of renewables is an outstanding example of misguided political intervention, one mainly driven by industrial policy aims and lobbyism that has had little to show for its purported benefits, such as greenhouse gas reductions.

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

**Figure 1: Total Photovoltaics Capacities in Megawatt (MW) in 2011**

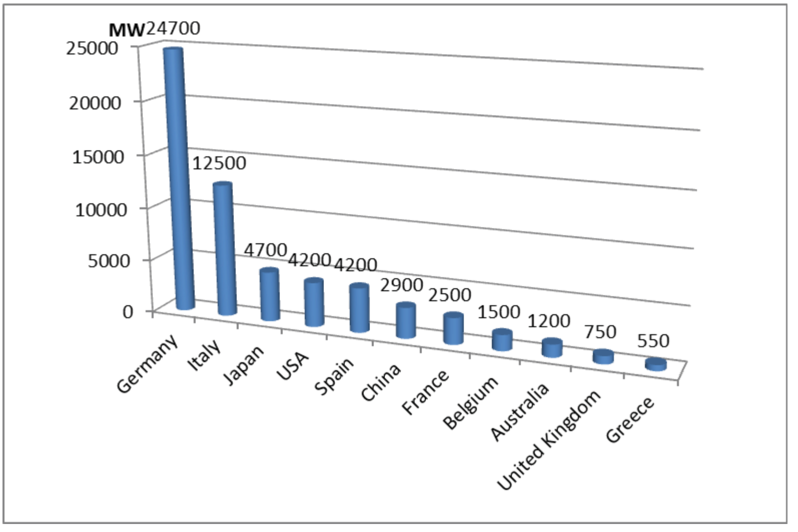
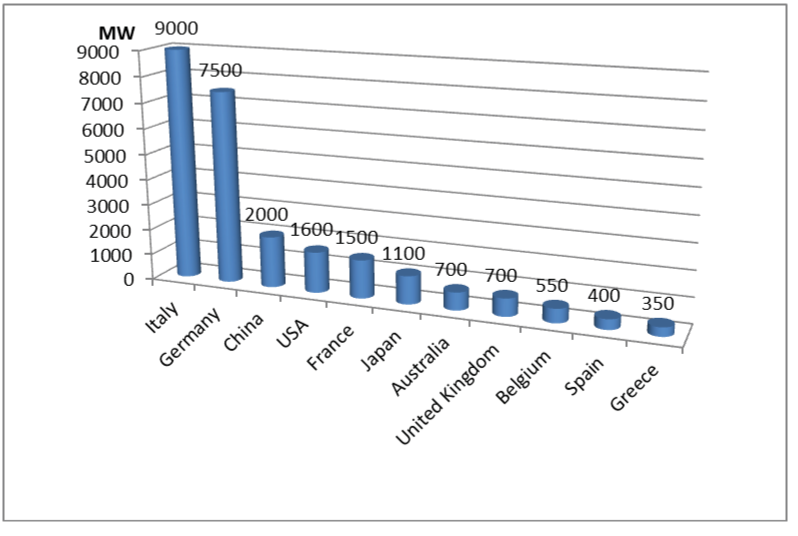



**Figure 2: Photovoltaics Capacity Increase in 2011 in Megawatt (MW)**




In line with the exponential growth of PV capacities in Germany in recent years, we find a dramatic increase in the overall subsidies: In real terms, for all those PV modules that were installed in Germany between April 2000 and the end of 2011, electricity consumers, who ultimately have to bear the burden of this alleged boom, are obliged to pay some 100 Bn € in the form of higher electricity bills. Only a small fraction, about 16%, of this huge amount has already been paid; the much larger part of this burden will increase consumers' electricity bills for another two decades, as producers of solar electricity enjoy legally guaranteed feed-in tariffs that are fixed for up to 21 years, with a minimum subsidization period of 20 years plus the remaining time period until the end of year of the PV module's installation.

The following section describes Germany's alleged solar boom and its legislative basis, the German Renewable Energy Sources Act (EEG). Section 3 presents cost estimates of subsidizing this inefficient renewable energy technology. To address the arguments that employment effects and greenhouse gas emission reductions warrant the subsidization of renewable technologies, Section 4 presents estimates of the carbon dioxide abatement cost, as well as the societal cost for each job created in Germany's PV sector. The last section summarizes and concludes. This closing discussion warns against the possibility of a public backlash against the EEG that could have the unfortunate consequence of spilling over into a backlash against renewable energies. We therefore advocate alternative instruments for promoting renewables to avoid this outcome.

## 2 Germany's Alleged Solar Boom

The substantial contribution of renewable energy technologies to Germany's electricity production is primarily a consequence of a 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. 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 (Erneuerbare-Energien-Gesetz, EEG), the support regime was amended in 2000 in order to guarantee stable feed-in tariffs for up to 21 years, thereby providing for favorable conditions for investments in "green" electricity production.

Under the EEG regime, utilities are obliged to preferentially 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. 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. The financial support stipulated by the EEG is indispensable for increasing the uptake of "green electricity"; without it, the high cost of most renewable energy technologies would make it impossible for them to compete with conventional electricity production.

With a share of 5.9% in Germany's electricity production in 2010, wind power is the most important renewable energy technology (Figure 3), whereas the share of electricity produced by PV installations was much lower, amounting to only about 2% —

despite the approximate exponential growth of annual capacity increases in recent years (Table 1). In fact, with newly installed PV capacities of 1,950 MW in 2008, about 3,800 MW in 2009, and some 7,400 MW in 2010, annual capacity growth almost doubled from year to year. Recently published data indicate that with around 7,500 MW of additional PV capacities in 2011 (BNetzA 2012), a new maximum in annual installations was reached, with an almost inconceivable capacity increase of some 3,000 MW in December 2011 alone. This increase within one month was larger than that of the whole year 2008 and all the years before (Table 1). These figures might be misinterpreted as an indication of a formidable solar boom. Unfortunately, the opposite holds true, with the dire problems of Germany's entire PV branch being manifested by the bankruptcies of a number of firms in recent months, such as Q-Cells, once the world's largest producer of solar cells.

**Table 1: Installed Capacity and Annual Increase of Photovoltaics Capacities in Megawatt (MW)**

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Annual Increase | 53 | 110 | 110 | 139 | 670 | 951 | 843 | 1,271 | 1,950 | 3,794 | 7,406 |
| Total Capacity | 76 | 186 | 296 | 435 | 1,105 | 2,056 | 2,899 | 4,170 | 6,120 | 9,914 | 17,320 |

Source: BMU (2011).

Equally disconcerting is the fact that the share of solar electricity in total subsidized green electricity production was as low as 14.5% in 2010 (ÜNB 2011), whereas the share of PV in total feed-in tariffs was as high as 38.6% (Table 2). In contrast, producing electricity on the basis of on-shore wind power capacities was economically much more efficient than solar electricity generation: With a share of 46.4% in total subsidized green electricity production (ÜNB 2011), on-shore wind power installations received just a quarter of total feed-in tariffs, which amounted to 13.2 billion € in 2010 (Table 2).

The evident reason for this particularly pronounced discrepancy is the attractive feed-in tariff for the production of solar electricity (IEA 2007:68-69). For PV modules installed in 2006, for instance, the German EEG granted up to 51.8 cents per kWh for solar electricity (Table A1), a remuneration that was almost ten times higher than the market price of conventionally produced electricity and six times the tariff granted for wind power (8.5 cents per kWh). This high rate was necessary for establishing a market foothold, with the 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.

Due to strong international competition, particularly from Asia, and large global overcapacities that, at least to some degree, are the result of the EEG with its highly attractive PV tariffs, prices of modules plummeted in recent years. Within one year, from the end of 2008 to the end of 2009, prices for end-installed PV capacities below 100 kW shrank by slightly more than 30% according to the price information provided by BSW (2012b). Between the second quarter of 2006 and the first quarter of 2012, these prices decreased by slightly more than 60%. This, in turn, prompted the legislator to successively shrink the feed-in tariffs for solar electricity. Nevertheless, the tariff reduction has always been much more moderate than the module price decreases (Figure 4) – otherwise, the huge boost in PV capacity installations in recent years would not have been possible.

**Figure 3: Germany's Electricity Mix in 2010**

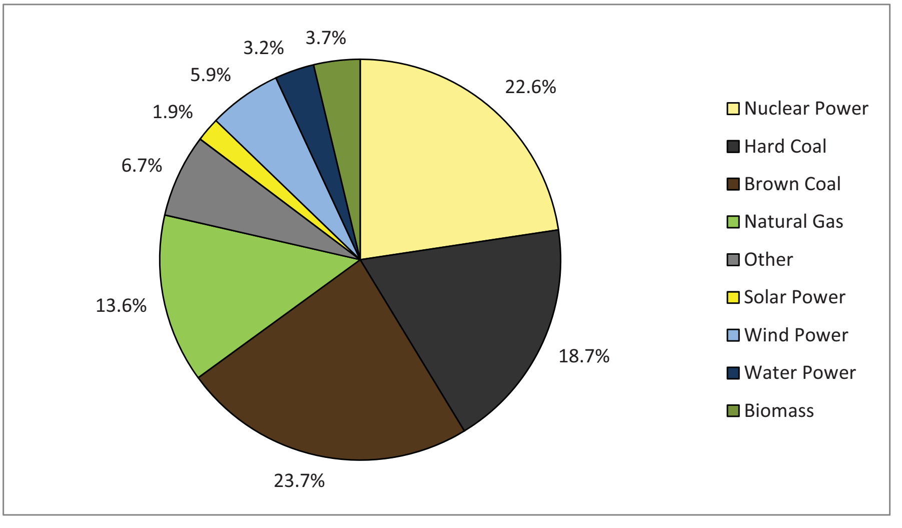


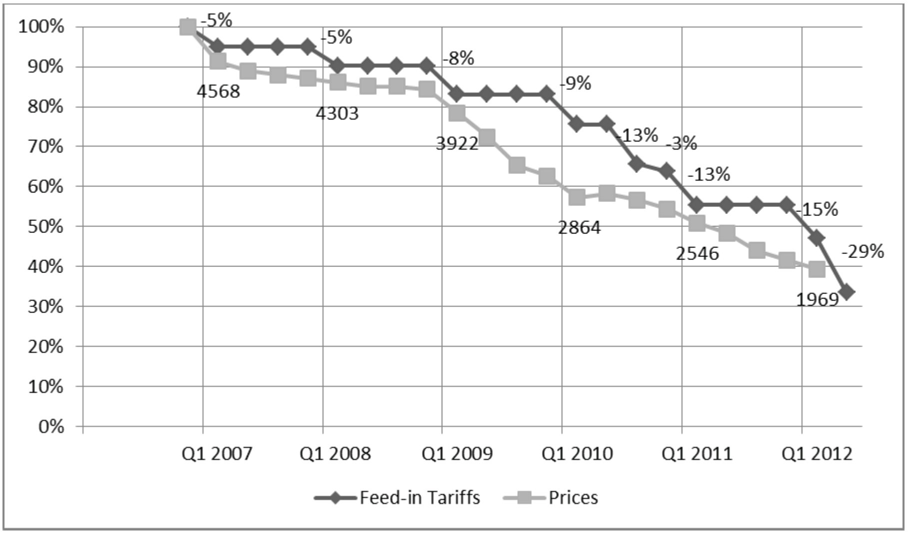

**Table 2: Total Feed-in Tariffs and the respective Shares of the most important Renewable Technologies**

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|
| Wind power | 64,5 % | 65,1 % | 63,7 % | 54,3 % | 47,1 % | 44,5 % | 39,5 % | 31,5 % | 25,2 % |
| Biomass | 10,4 % | 12,5 % | 14,1 % | 17,7 % | 23,0 % | 27,4 % | 29,9 % | 34,3 % | 32,2 % |
| Photovoltaics | 3,7 % | 5,9 % | 7,8 % | 15,1 % | 20,3 % | 20,2 % | 24,6 % | 29,3 % | 38,6 % |
| Total Tariffs in Bn € | 2.23 | 2.61 | 3.61 | 4.40 | 5.61 | 7.59 | 9.02 | 10.8 | 13.2 |

Sources: For 2002 to 2009: BDEW 2001-2010. For 2010: ÜBN (2011).

Figure 4 points to a fundamental problem that generally afflicts renewable energy support subsidization regimes that are based on feed-in tariffs: Due to asymmetric cost information, it *a priori* remains an open question of whether any EEG adjustment adequately reflects past and future reductions in production costs. Policy-makers consequently find themselves in an on-going game of catch-up in their attempts to repeatedly recalibrate the tariff structure based on their understanding of the latest turn in market developments. With decision-making additionally falling under the influence of Germany's highly organized solar lobby, it is perhaps not surprising that such a large share of EEG support has gone to an energy source comprising such a small share of the country's renewable energy mix.

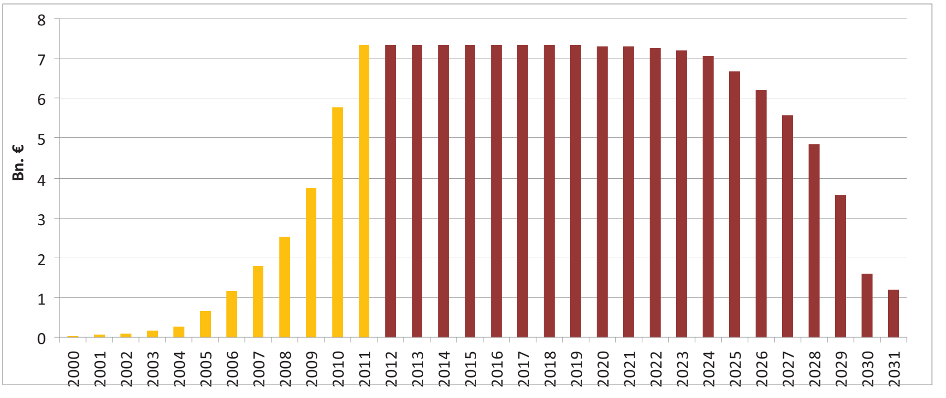
**Figure 4: Feed-in Tariffs and End-User Prices of PV Roof Panels of up to 100 kW**




Despite substantial reductions in PV tariffs, though, at the outset of 2012, the maximum feed-in tariff of almost 25 cents, which was granted for small PV installations of less than 30 kW capacities (Table A3), was still almost five times higher than the baseload-electricity prices at the power exchange EEX (European Energy Exchange) at Leipzig and about 3 times the tariff granted for electricity that is produced by on-shore wind power installations. In short, to neutralize its high costs, solar electricity production still receives the highest subsidy per kWh among all renewable energy technologies. It also bears noting that these subsidies are granted for as long as two decades at the unvaried level that is valid in the year of installation.

As a consequence, 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. For example, even if the subsidization regime had ended in 2011, consumers would still be saddled with charges until 2031 (Figure 5). This figure demonstrates that only a small fraction of the enormous burden due to over-subsidizing PV is already borne by the electricity consumers, while the overwhelming part, marked in Figure 5 by dark bars, must still be paid with their future electricity bills. Lastly, the exponential growth in annual PV capacity increases in recent years is reflected by soaring total tariffs for solar electricity production (Figure 5). In 2011, according to our estimations presented in the next section, PV tariffs accounted for about 7 Bn €, roughly 40% of the estimate of some 17 Bn € of the overall remuneration for electricity generation from renewable technologies (BDEW, 2012).

**Figure 5: Annual Feed-in Tariffs for PV**




It is not surprising that such a massive subsidization of a highly inefficient way of electricity production is currently the bone of contention of a hot public and political debate. On the one hand, renewable energy technologies are frequently seen as a chance to reinvigorate regions suffering from industrial decline, thereby mobilizing a coalition of local and regional politicians, farmers, and trade unions (MICHAELOWA 2005:198). This holds particularly true for the federal states in eastern Germany, where a large number of huge solar parks were established in recent years. Furthermore, among renewable energy technologies, PV is embraced by the German population almost without exception, with 91% stating in an opinion poll in 2012 that solar electricity is highly important for their future energy provision (BSW, 2012a).

On the other hand, even though the costs are widely dispersed across several decades and across the entire population, the burden to be borne by consumers is substantial. In fact, the mean effect on electricity prices was a mark-up of 3.53 cents per kWh in 2011, with about half accounting for PV. In terms of electricity prices, which amounted to about 25.5 cents per kWh in 2011 for an average household (BDEW, 2012:22), this means a cost share of almost 15% for renewables. Given that average households consume some 4,000 kWh of electricity per year, this implies an extra cost for "green" electricity of 141.2 € or about 12 € per month for such households, with about 6 € accounting for PV.

When taking account of the fact that the consumers are obliged to bear this add-on to their electricity bills for the up-coming 20 years, it adds up to some 2,800 € for an average household. This highlights the importance of calculating the overall burden induced by overly subsidizing PV in Germany. While updated in the subsequent section, these calculations demonstrate that the net cost of PV subsidization increased dramatically in recent years, even more than was expected by Frondel, Ritter, and Schmidt (2008) in their study "Germany's Solar Cell Promotion: Dark Clouds on the Horizon".

## 3 The Immense Financial Consequences of PV Promotion

Solely focusing on the direct impact on the electricity bills of Germany's electricity consumers, we calculate the total net cost of subsidizing electricity production by PV modules. We thereby ignore the indirect costs, such as the cost for regulating electricity supply required due to the volatility of electricity produced by solar power, as well as benefits, such as the reduced dependency on fossil fuel imports.[2] While such indirect costs are certainly not negligible,[3] they are hard to quantify, as are the benefits such as reduced import dependency. In particular, we deliberately refrain from accounting for further alleged benefits, such as the transient short-term phenomenon that is frequently called the merit-order effect (see e.g. Lechtenböhmer and Samadi, 2010), which strongly dampens peak-load prices at sunny days for several hours. This is because we are highly skeptical about (1) the persistence of the downward pressure on wholesale electricity prices due to the increasing production of solar electricity in the long-term, a skepticism that is shared by Erdmann (2011:53), as well as other authors, and (2) the alleged price-decreasing impact on consumer prices.

Following Frondel, Ritter, and Schmidt (2008), as well as other studies, such as Erdmann (2011), the net costs of producing one kilowatt hour (kWh) solar electricity are calculated by subtracting the market value of electricity, identified by wholesale prices, from the granted feed-in tariffs. Any assessment of the real net cost induced by subsidizing PV therefore requires information on the year-specific feed-in tariffs and past conventional electricity prices at the power exchange, both reported in Table A1 of the appendix, as well as assumptions on the annual solar electricity yields of the PV

[2] External costs of conventional electricity production, though, such as greenhouse gas abatement cost, are included to a certain extent, because market prices of electricity entail the prices of carbon dioxide emission certificates.
[3] Erdmann (2011) gauges these indirect costs of increasing the share of renewables in electricity production to 50% in 2030 and finds a total of about 85 Bn € in real terms. These indirect costs add to the direct costs, which are estimated by Erdmann (2012) to be as high as about 238 Bn € in real terms.

capacities that are newly installed in each year. These yields, which are presented in Table 3 and, for the sake of simplicity, are assumed to be constant over the subsidization period of two decades, result from the annual capacity increases multiplied by the full load hours[4]. In line with Frondel, Ritter, and Schmidt (2008), the full load hours, which are proportional, but not identical to the number of sunshine hours per year, are assumed to be 809 hours, approximately reflecting the mean value of the last decade.

To further ensure comparability with the study by Frondel, Ritter, and Schmidt (2008), we assume an inflation rate of 2%, which is slightly lower than the average rate since the German reunification, and we take future market prices for electricity from the same source by following the "high price scenario" assumed by NITSCH et al. (2005), a study on the future development of renewable energy technologies in Germany. It bears noting that this price scenario appears to be realistic from the current perspective: nominal base-load prices are expected to rise from 5.68 Cents per kWh in 2011 to 8.47 Cents per kWh in 2020 (see Table A1). In fact, the average base load-price amounted to 5.61 Cents per kWh in 2011 (BDEW, 2012:16).

**Table 3: Net Costs of Promoting PV in Germany**

| | Annual Capacity and Solar Electricity Yield Increases | | Cumulated Net Costs | |
|---|---|---|---|---|
| | MW | Mio. kWh | Nominal Bn € | Real Bn $€_{2011}$ |
| 2000 | 53 | 43 | 0.389 | 0.405 |
| 2001 | 110 | 89 | 0.802 | 0.819 |
| 2002 | 110 | 89 | 0.752 | 0.753 |
| 2003 | 139 | 112 | 0.889 | 0.873 |
| 2004 | 670 | 542 | 4.779 | 4.598 |
| 2005 | 951 | 769 | 7.338 | 6.919 |
| 2006 | 843 | 682 | 6.094 | 5.635 |
| 2007 | 1,271 | 1,028 | 8.595 | 7.795 |
| 2008 | 1,950 | 1,577 | 12.316 | 10.956 |
| 2009 | 3,794 | 3,068 | 19.810 | 17.296 |
| 2010 | 7,406 | 5,988 | 30.230 | 25.924 |
| 2011 | 7,500 | 6,064 | 20.669 | 17.448 |
| **Cumulated Costs 2000-2011:** | | | **112.663** | **99.421** |

Sources: Annual Capacity Increase: BMU (2011). Net Costs: Own Calculations, for further details, see Frondel, Ritter, and Schmidt (2008).

[4] The notion of full load hours is defined by the ratio of a PV installation's average annual production to its maximum capacity.

It also bears noting that due to uncertainties about future electricity prices, our calculations can only provide for a rough estimate of the true burden induced by Germany's PV subsidization, although such uncertainties appear to be of minor importance for the magnitude of our cost estimates, given the large differences between market prices of electricity and the feed-in tariffs for PV, which were as high as 29 Cents per kWh in 2011 and even much larger in the near past (Table A 1). Nonetheless, deviations of some 6% from the cost estimates presented by Frondel, Ritter, and Schmidt (2008), as calculated by Lechtenböhmer and Samadi (2010) due to different assumptions, for instance with respect to annual solar electricity yields, are clearly within the realm of estimation precision. For further details on our calculations, see the appendix and Frondel, Ritter, and Schmidt (2008).

Taking all the above assumptions and legal regulations regarding feed-in tariffs into account, the real net cost for all modules installed between 2000 and 2011 may easily account for about 100 Bn € (in prices of 2011), certainly an alarming figure given that PV currently accounts for about 3% of total electricity production. PV installations in 2010 alone caused real cost worth 25.9 Bn € (Table 3), that is, more than a quarter of the overall real net cost and roughly the amount that Frondel, Ritter, and Schmidt (2008:4201) expected for the cost obligations due to the PV capacity growth in the three-year-period from 2008 to 2010. For this period, we instead estimate real net cost of more than 60 Bn €. In other words, the cost explosion forecasted by Frondel, Ritter, and Schmidt (2008:4201) turned out to be even more dramatic than was expected by these authors.

## 4 Employment and Environmental Implications of Germany's PV Promotion

The proponents of PV frequently justify these tremendous subsidies, as well as those for other renewable energy technologies, by highlighting their positive impact on employment, economic prosperity, and, not least, by emphasizing their role as a vital environmental and climate protection measure. In line with Frondel, Ritter, and Schmidt (2008), we argue that Germany's way of supporting PV, in fact, does not confer any of these benefits. For starters, the net employment balance is likely to be negative for Germany due to, first, the very high opportunity cost of supporting PV and, second, because the majority of modules are imported, mainly from China, with a steadily increasing tendency due to significant price advantages. Second, 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 and sets a binding cap on CO2 emissions, 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. Indeed, to the extent the EEG is effective in reducing emissions, this will ultimately reduce the price of emissions certificates on the ETS, allowing other industries to buy them up more cheaply and pollute more. In short, while there are certainly substantial greenhouse gas reductions in the German electricity sector (positive gross effect), the net effect on a European scale is zero.

Even if one were to ignore this argument and solar electricity production were to save emissions of greenhouse gases, such as carbon dioxide ($CO_2$), it must be noted that PV is among the most expensive greenhouse gas abatement options: Given the net cost of 41.82 Cents/kWh for modules installed in 2008 (Table A1), 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 € per tonne (Frondel et al., 2010:4052). Of course, while the abatement cost have been shrinking substantially with the tariff decreases of recent years, it must also be noted that the abatement costs of solar electricity produced by PV modules that were installed before 2008 are even higher than 716 € per tonne.

The magnitude of this abatement cost estimate is in accordance with the IEA's (2007:74) even larger figure of around 1,000 € per tonne, which results from the assumption that PV replaces gas-fired electricity generation. Irrespective of the concrete assumption about the fuel base of the displaced conventional electricity generation, abatement cost estimates are dramatically larger than the current prices of $CO_2$ 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 $CO_2$. "In other words, the promotion of solar power is not based on economic efficiency considerations and promotes a rather expensive method of reducing carbon dioxide emissions" (Wackerbauer, Lippelt, 2012:72).

Similar to the EEG's environmental impact, gross and net employment effects are to be distinguished. Without a doubt, with about 150,000 people that were employed in 2011 in Germany's solar sector, including the production of solar heat collectors (BSW 2012b), the gross employment effect is positive. On a per-capita basis, however, Germany's PV promotion is a subsidization regime with huge employment costs that by far exceed average wages: Given our net cost estimate of about 17.4 Bn € for 2011 reported in Table 3, the minimum per-employee subsidy turns out to be almost 100,000 €, if we – incongruent with reality – assume that all the 150,000 people were employed in the PV sector alone.

Yet, given that about two thirds of all modules were imported from abroad in 2010 (Wackerbauer, Lippelt, 2012:73), any other result than a negative net employment balance of the German PV promotion would be surprising. The drain of purchasing power and investment capital of private and industrial electricity consumers resulting from the massive PV subsidies causes negative employment effects in sectors other than the PV branch (BMU 2006:3). In contrast, we would expect substantial positive employment effects in export countries such as China, since these countries do not suffer from the EEG's crowding-out effects of conventional electricity production, nor from negative income effects on electricity consumers. In fact, while having been the global leader in solar cell production since 2008, China's production was twenty times higher than its domestic PV installations in 2010 (Wackerbauer, Lippelt, 2012:72, 73), as there is hardly any promotion of solar electricity at the national level, but merely some local feed-in incentives (EPIA, 2011).

An equally untenable argument points to the alleged long-term returns that accrue from establishing an early foothold in the renewable energy market (first-mover advantage). According to this argument, which has been in vogue for some 20 years now, the support afforded by the EEG allows young firms to expand their production capacities and gain familiarity with renewable technologies, thereby giving them a competitive advantage as the market continues to grow. This first-mover advantage, however, if it ever existed, has been completely lost to PV companies from abroad: In 2011, there were no German representatives among the world's top ten PV firms and, given the large number of bankruptcies in recent months, there is hardly any hope that any German firm will ever be among the top ten again. In fact, apart from the bankruptcy of Q-Cells, which was once the world's number one among the producers of solar cells, the same fate hit other German PV companies, such as Odersun, Scheuten Solar, Solarhybrid, Solon, Sunconcept, as well as the German branch of the U.S. firm First Solar. Negative prospects exist for many other firms, such as Phoenix Solar and Conenergy.

A major reason for this negative outcome is that technological progress 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. According to this contortion of economic logic, larger PV installations with higher capacities and, hence, strong economies of scale receive lower feed-in tariffs than smaller, much less efficient installations.

Rather than affording PV tremendous subsidies it would make more sense to extend a uniform subsidy per kWh of electricity from renewables. This would harness market forces, rather than political lobbying, to determine which types of alternative technologies could best compete with conventional energy sources. While saving societal resources, such an EEG reregulation would set stronger cost-saving incentives. This is all the more important because recent years' very strong PV demand in Germany is a clear indication of an overly generous level of feed-in tariffs.

## 5 Summary and Conclusion

Among the most important market failures in energy markets are environmental externalities. The single most efficient policy would be to price those externalities both directly and appropriately (Borenstein, 2012:86-87). Yet, despite the existence of the European emissions trading system (ETS) and, hence, the pricing of environmental externalities within the European Union (EU), additional targeted programs to promote specific alternatives to conventional electricity generation technologies are prevalent, with 18 of the 27 EU Member States fostering the diffusion of renewable energy technologies, and especially photovoltaics (PV), by means of remunerating the production of "green" electricity through so-called feed-in tariffs (REN 21, 2011). This additional promotion of renewable technologies is frequently justified by benefits other than reducing environmental externalities (see e.g. Lehmann, Gawel, 2011), such as pushing technological development and enhancing the employment situation and economic prosperity of a country.

The German feed-in tariff system, originally implemented in 1990, has emerged as a role model in Europe and beyond. While estimating the real net cost of the installation of PV capacities between 2000 and 2011 at approximately 100 Bn € (in prices of 2011), this article has demonstrated that one cannot expect any such benefits for Germany's way of promoting PV. The key reason for this judgment is that the tremendous subsidies for PV impose a substantial drain on the budgets of private and industrial consumers, diverting funds from alternative, most likely more beneficial, investments. Arguably, the main employment effect of Germany's PV support has been the creation of many jobs abroad, as the majority of PV modules was imported in recent years, most notably from China. Furthermore, prospects for massive future exports are tenuous at best, given the lack of technological excellence and the low international competitiveness of Germany's PV sector that was evidenced recently by the large number of bankruptcies of German firms.

The result of this unfolding disaster is a steady increase in electricity prices for consumers that, ultimately, may endanger the acceptance of Germany's PV promotion policy and of renewable energies, in general. An increasingly urgent problem in this context is that the current support scheme in the form of a uniform add-on to electricity prices has a strong regressive impact on private households (German Council of Economic Experts, 2011:249): Due to low income elasticities of their electricity consumption, private households with low incomes suffer more from the renewable contribution than those with high incomes. This distributional aspect will be exacerbated if the future shares of renewable technologies in electricity generation rise in order to reach the national goal of 35% in 2020. It also bears noting that Grösche and Schröder (2011) estimate the median of the willingness-to-pay for a share of 20% of renewables in the electricity mix at some 1.3 Cent/kWh, which is much lower than the mark-up of 3.59 Cent/kWh for renewables in 2012.

The potential loss of the acceptance for all renewable technologies, rather than PV alone, due to strong further increases in electricity prices may have been reason enough that even advocates of renewable energy technologies, such as the German Advisory Council on the Environment, voted for limiting the increase of PV capacities (SRU, 2011) at an annual level of 1,000 MW at most (Hohmeyer, 2011). Similar limits exist in many other countries, such as Spain and Switzerland.

To save substantial societal resources that are not available for alternative investments and policy goals, such as mitigating social disparity, the German Council of Economic Experts (2011:252), as well as the Monopolies Commission (2011), suggest a fundamental reform of Germany's support scheme for renewable energy technologies. Recognizing that Germany is a relatively cloudy country, the Council demands a new scheme that is more market-oriented and exploits the advantages of a more efficient distribution of capacities all over Europe, such as installing solar power capacities in sunnier Southern European countries. The Council argues that in the end, the European Commission's renewables targets could be reached more efficiently through a support scheme that is harmonized on a European scale, for instance by establishing a quota system that is complemented by a trading scheme for so-called green certificates.

This suggestion is in line with the International Energy Agency that in its country report on Germany's energy policy recommends considering "policies other than the very high feed-in tariffs to promote solar photovoltaics" (IEA 2007:77). The IEA's 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).

Finally, while proponents of the current feed-in tariff scheme argue that quota systems lack opportunities for stimulating technological progress, it must be recognized that, generally, it is more efficient to address distinct targets with different instruments, rather than with solely one, here the EEG. The German government would therefore be well-advised to additionally apply target-specific instruments to support technological development. In the end, funding R&D in order to trigger significant technology improvements appears to be a more promising avenue to efficiently achieve substantial cost reductions, particularly in early technology stages, than the heavy subsidization of market penetration, a policy alternative where technological improvements are rather by-products.

## Appendix

**Table A1: Electricity Prices and Net Cost of PV modules with a capacity of less than 30 kW**

| | 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 | 38.14 | 32.73 |
| 2011 | 5.06 | 5.68 | 28.74 | 23.06 |
| 2012 | 5.21 | 5.96 | n.a. | n.a. |
| 2013 | 5.36 | 6.26 | n.a. | n.a. |
| 2014 | 5.52 | 6.57 | n.a. | n.a. |
| 2015 | 5.69 | 6.90 | n.a. | n.a. |
| 2016 | 5.81 | 7.19 | n.a. | n.a. |
| 2017 | 5.94 | 7.49 | n.a. | n.a. |
| 2018 | 6.07 | 7.80 | n.a. | n.a. |
| 2019 | 6.20 | 8.13 | n.a. | n.a. |
| 2020 | 6.34 | 8.47 | n.a. | n.a. |

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%, weighted feed-in tariffs for 2009-2011 (see Table A2), for projected feed-in tariffs for 2012-2016, see Table A3. Column 4: Difference between Columns 3 and 2.

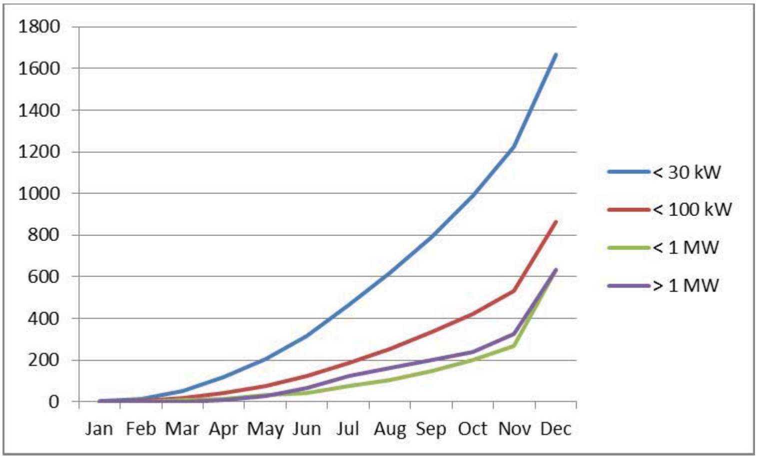
In our calculations, we weight the feed-in tariffs for the years 2009-2011 according to the shares of capacity categories reported in Table A2. For the years 2000-2008, we use the feed-in tariffs for PV modules smaller than 30 kW, rather than weighting tariffs, as no data on the installation of the distinct capacity categories are available before 2009. Figure A1 shows that in 2009 almost half of the installed total capacity of 3,800 MW were installations with a capacity of less than 30 kW. Before 2009, the shares of these installations with the smallest capacities were even much higher.

**Table A2: Feed-in Tariffs in € Cents/kWh and Shares of Annual Increase in Capacities (in parentheses)**

| | < 30 kW | < 100 kW | < 1 MW | > 1 MW | Weighted Tariff |
|---|---|---|---|---|---|
| 2009 | 43.01 (43.8 %) | 40.91 (22.8 %) | 39.58 (16.7 %) | 33.00 (16.7 %) | 40.29 |
| Jan-Jun 2010 | 39.14 (20.5 %) | 37.23 (13.1 %) | 35.23 (11.4 %) | 29.37 (7.2 %) | 33.55 |
| Jul-Sept 2010 | 34.05 (8.4 %) | 32.39 (5.6 %) | 30.65 (5.5 %) | 25.55 (3.2 %) | |
| Oct-Dec 2010 | 33.03 (6.5 %) | 31.42 (4.6 %) | 29.73 (5.5 %) | 24.79 (8.3 %) | |
| 2011 | 28.74 (31.0 %) | 27.33 (16.8 %) | 25.86 (21.3 %) | 21.56 (30.8 %) | 25.67 |

Note: Shares of annual increase are calculated according to BNetzA (2012).

**Figure A1: Cumulated Increase of Photovoltaics Capacities in 2009 in Megawatt (MW)**




Source: BNetzA (2012)

On March 29, 2012, the German Federal Parliament decided to adjust the feed-in tariffs for solar electricity once again. While the tariffs had been decreased on an annual basis before, a regular monthly decrease of 1%, beginning in May 2012, is foreseen. In addition, a drastic cut of tariffs is planned for April 1, 2012. Table A3 shows the foreseen feed-in tariffs for the year 2012, with the new legislation being valid as of April 2012.

**Table A3: Foreseen Feed-in Tariffs for 2012 According to the Draft Law of April 2012**

<table>
<tr><th></th><th>< 30 kW</th><th>< 100 kW</th><th>< 1 MW</th><th>> 1 MW</th></tr>
<tr><td>Jan</td><td>24.43</td><td>23.23</td><td>21.98</td><td>18.33</td></tr>
<tr><td>Feb</td><td>24.43</td><td>23.23</td><td>21.98</td><td>18.33</td></tr>
<tr><td>Mar</td><td>24.43</td><td>23.23</td><td>21.98</td><td>18.33</td></tr>
<tr><td></td><td>< 10 kW</td><td colspan="2">< 1 MW</td><td>< 10 MW</td></tr>
<tr><td>Apr</td><td>19.50</td><td colspan="2">16.50</td><td>13.50</td></tr>
<tr><td>May</td><td>19.31</td><td colspan="2">16.34</td><td>13.37</td></tr>
<tr><td>Jun</td><td>19.11</td><td colspan="2">16.17</td><td>13.23</td></tr>
<tr><td>Jul</td><td>18.92</td><td colspan="2">16.01</td><td>13.10</td></tr>
<tr><td>Aug</td><td>18.73</td><td colspan="2">15.85</td><td>12.97</td></tr>
<tr><td>Sep</td><td>18.54</td><td colspan="2">15.69</td><td>12.84</td></tr>
<tr><td>Oct</td><td>18.36</td><td colspan="2">15.53</td><td>12.71</td></tr>
<tr><td>Nov</td><td>18.18</td><td colspan="2">15.38</td><td>12.58</td></tr>
<tr><td>Dec</td><td>17.99</td><td colspan="2">15.23</td><td>12.46</td></tr>
</table>

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