The Implicit Carbon Price of Renewable Energy Incentives in Germany
Executive Summary

Overview

Incentives for the development of renewable energy (RE) have increasingly become an instrument of climate policy, that is, as a means to reduce GHG emissions. This research analyzes the German experience in promoting RE over the past decade to identify the *ex post* cost of reducing CO2 emissions in the power sector through the promotion of renewable energy, specifically, wind and solar. To this propose, we calculated the *RE carbon surcharge* and an *implicit carbon price* for the years 2006-2010. The RE carbon surcharge is calculated as the ratio of the *net cost* of RE over the *CO2 emission reductions* due to the RE injections into the electric power system. It measures the additional cost to reduce CO2 emissions in the power sector over and above the carbon price resulting from the EU ETS. The implicit carbon price is the sum of the average EU ETS carbon price paid by conventional generators and the RE carbon surcharge and provides an estimation of the CO2 abatement efficiency of the renewable energy incentives (REI). The quantity of CO2 abated as a result of injections of wind and solar energy for the years 2006-2010 was estimated by Weigt et al. (2012) using a deterministic unit commitment model of the German electricity system. This paper is devoted to estimate the net costs associated with the development of wind and solar energy. The *net cost* is given by the sum of the *costs* and *cost savings* due to the injection of renewable energy into the electric power system. Other benefits -whether they are expressed as energy security, innovation, jobs, non-CO2 emissions, etc.- are not included, nor are costs associated with transmission and distribution. The costs are: the *remuneration to RE generators,* which accounts for the direct cost of the RE incentives (REI), the *additional cycling costs* of conventional thermal generation and the *additional balancing cost*. Additional cycling costs and additional balancing cost are due to the intermittency of wind and solar energy. The cost savings are: the *fuel cost saving*, the *carbon cost saving* and the *capacity saving*. They are related to the reduction of energy generated from conventional capacity due to the injection of renewable energy.

Methodology

Remuneration to RE generators. The relevant law in Germany provides producers of RE a 20-year guaranteed fixed feed-in tariff (FIT). Since the level of the FIT diminishes in value over time both in nominal and real terms, taking the amount paid for the FIT in a given year would make RE appear more expensive in the first years of activities, when the payments are relatively generous, and cheaper in the following years. Consequently, the structure of payments over time is equalized along the lifetime of the power plants to avoid over- and understating cost in the early and later years of the facilities life. To this purpose we estimated the *equalized remunerations* in the following way. First we estimate the annual remunerations for each vintage of capacity for all the lifetime of the power plants, which is assumed to be 25 years. Second, we discount the remunerations at a fixed rate of 7% to the first year of activity and we sum them to get the initial net present value (NPV). Third, we redistribute the NPV in a 25-year mortgage using the same interest rate. The equalized annual remuneration is given by the sum of the mortgage rates of the capacity in service in that year.

CO2 emission reductions, *fuels cost saving, carbon cost saving and additional start-up cost.* For the estimation of the fuel cost saving and carbon cost saving we make use of the model of Weigt et al. (2012). The model is a deterministic unit commitment model of the German electricity market for the period 2006-2010. It was developed to estimate the CO2 emissions in two scenarios: the observable (*OBS*) scenario, which corresponds to the historical scenario, and the counterfactual scenarios wherein no energy would have been produced by the relevant form of RE (eg., *No Wind* or *No Solar*). The CO2 emission abatement due to RE is calculated as the difference in total CO2 emissions between the *No Wind* or *No Solar* and the *OBS* scenario. The model was used also to calculate the total fuel cost and total carbon cost which are the costs for conventional generators of buying the fossil fuel needed to generate electricity and the allowances to comply with the EU ETS. Like the CO2 emission abatement, the fuel cost saving and carbon cost saving are calculated as the difference in the total fuel costs and total carbon cost between the *No Wind* or *No Solar* scenarios and the *OBS* scenario. Regarding cycling costs, due the limitations of the model, we could consider only the star-up cost, which is the cost of the additional fuel needed to start-up the plant. They are calculated similarly to the fuel cost saving.

Capacity saving and additional balancing cost for wind. We make an estimation of the capacity benefit and additional balancing cost for wind, based on results from existing literature and on simple and transparent assumptions. Our goal is not so much an accurate calculation of these costs and cost savings as it is an estimation of their order of magnitude in comparison with other costs and cost savings. The capacity saving is the economic benefit from the savings in capital cost and fixed O&M cost of the conventional plants displaced by the wind capacity credit. We assume that the wind capacity installed up to 2010 would provide a capacity credit of 7% and that the cost savings are realized in 2015. This means that in Germany, in 2015 the constructed conventional capacity will be lower by 7% of the wind capacity installed in the period 2000-2010 than it would be otherwise. We assume that the 70% of the wind capacity credit will be use for coal and 30% for gas. Regarding balancing cost, a number of studies have examined the additional balancing cost due to wind energy. Estimations are in the order of €1-4/MWh of wind energy at wind penetrations of up to 20%. We consider a value of €2/MWh.

Results

Table 1 shows annual RE carbon surcharges and annual implicit carbon prices as a result of the injection of wind and solar energy into the power system in euro per tCO2. The net cost is given by the sum of the costs minus cost savings. The RE carbon surcharge for wind(solar) is the net cost for the year divided by CO2 emission reduction. The implicit carbon price is the RE carbon surcharge plus the average EU ETS carbon price paid by conventional generators. Average is the average annual CO2 abatement costs weighted over CO2 emission reductions. Three main results can be drawn. (1) There is a large difference between the abatement costs of wind and solar energy. For wind, the RE carbon surcharge for the period 2006-2010 is on average €45/tCO2 and the implicit carbon price is €57/tCO2. In contrast, for solar, the annual RE carbon surcharges and the implicit carbon prices are very high, the average for 2006-2010 is €537/tCO2 for the first and €552/tCO2 for the latter. (2) There is a large disparity among different costs and cost savings. Equalized remuneration to generators is by far the largest cost; the additional start-up cost and the balancing cost represent just a few percentage of it. Fuel cost saving is the largest savings while carbon cost saving and the capacity saving are much lower although not irrelevant. (3) CO2 abatement cost can change considerably from year to year. These changes in net cost mostly reflect changes in annual fuel cost saving and carbon cost saving, which are correlated with variations of fossil fuel prices and the carbon price. Under several sensitivity analyses, the RE carbon surcharge and the implicit carbon price always remain of the order of few tens €/tCO2 for wind energy, while these same indicators for solar energy are always of the order of hundreds of €/tCO2. Learning effects do not significantly change these results, even if such effects can be attributed to these capacity additions.

WIND		**2006**	**2007**	**2008**	**2009**	**2010**	**Average**
Equalized remuneration	[M€]	2684	2873	3056	3291	3486	
Additional start-up cost	[M€]	-6	-14	-5	2	4	
Additional balancing cost	[M€]	61	79	81	77	76	
Fuel cost saving	[M€]	1204	1578	1913	1326	1352	
Carbon cost saving	[M€]	381	31	438	402	402	
Capacity saving	[M€]	106	117	130	145	158	
Net cost	[M€]	1050	1212	651	1498	1654	
CO2 emission reduction	[tCO2]	22	26	32	30	27	
RE carbon surcharge	[€/tCO2]	**47**	**47**	**21**	**51**	**62**	**45**
Implicit Carbon Price	[€/tCO2]	**64**	**48**	**34**	**64**	**77**	**57**

SOLAR		**2006**	**2007**	**2008**	**2009**	**2010**	**Average**
Equalized remuneration	[M€]	966	1351	1893	2882	4503	
Additional start-up cost	[M€]	-2	-3	-1	-10	0	
Fuel cost saving	[M€]	107	124	212	234	417	
Carbon cost saving	[M€]	28	1	81	65	113	
Net cost	[M€]	828	1223	1599	2574	3937	
CO2 emission reduction	[tCO2]	2	2	4	5	7	
RE carbon surcharge	[€/tCO2]	**552**	**627**	**439**	**557**	**547**	**537**
Implicit Carbon Price	[€/tCO2]	**571**	**627**	**461**	**571**	**562**	**552**

Conclusions

Our study suggests that if we look at RE only as a climate instrument, and at REI only as a policy to abate CO2 emissions in the power sector, the German support for wind energy has reduced CO2 emissions in the years 2006-2010 at a cost generally higher than the historically observed EUA price, but on the same order of magnitude. In contrast, for this same period and until recently for new installations, supporting solar energy through these deployment incentives has proven to be a very expensive way of reducing CO2 emissions. Lower levels of remuneration, such as those effected by the recent revision of the German FIT for solar energy, can significantly change these results, at least for new installations. Similarly, higher fossil fuel prices than those observed in 2006-2010 would significantly reduce both the RE carbon surcharge and the implicit carbon price in subsequent years. Of course, the opposite would also apply if future fossil fuel prices are lower than in 2006-2010.

References

Weigt, H., Delarue, E. and Ellerman, A. D. (2012), “CO2 Abatement from RES Injections in the German Electricity Sector: Does a CO2 Price Help?”, *EUI working paper*, RSCAS 2012/18.