Reduction of carbon emissions due to renewables – methods and approaches

Carl-Philipp Anke, TU Dresden, +49 35146339896, Carl-Philipp.Anke@tu-dresden.de
Jascha Benjamin Fischer, TU Dresden, +49 35146333297, jascha_benjamin.fischer@mailbox.tu-dresden.de
Dominik Möst, TU Dresden, +49 35146333297, Dominik.Möst@tu-dresden.de

Overview

The expansion of renewable energies is a strategic element in the international climate process as it strongly contributes to global carbon emission reductions. In order to monitor that process, the participating countries of the Paris agreement have committed themselves to report reductions of carbon emissions by renewables. However, analysing the contribution of renewables on carbon emission reductions, especially in meshed electricity systems, is not a trivial task, as several factors impact carbon emissions in energy systems. Furthermore there is so far no uniform method for determining carbon emission reduction through renewable energy sources.
The contribution of this paper is twofold:

1. Existing methods for analyzing the impact of renewables on carbon emission reductions will be examined. This includes displacement calculations, econometric methods and dispatch models. Thereby, the questions what are the strengths and weaknesses of the methods and which method is most appropriate for determining the impact of renewables on carbon emission reductions should be answered.
2. In a second step, the most accurate methodology – a dispatch model for electricity markets - will be used to determine the contribution of renewables on carbon emission reductions in electricity markets. This methodology also allows to estimate long-term effects of renewables on carbon emissions. Emissions savings resulting from renewables in Germany will be calculated for several years and conclusion on the further development will be drawn.

Methods

The different methods - displacement calculations, econometric methods and dispatch models – will be illustrated and qualitatively compared with the help of different criteria. Afterwards a dispatch model is applied using the electricity market model ELTRAMOD, which is based on a cost minimization approach with a time resolution of 8760 hours. Due to reasons of calculation times, the corresponding modelling problem is split in two models: ELTRAMOD-INVEST and ELTRAMOD-DISPATCH. ELTRAMOD-INVEST determines power plant investments and investment decisions in the European electricity markets with a lower time resolution, whereas ELTRAMOD-DISPATCH is used for the analysis of the European power plant dispatch. Both models are coupled in order to be able to include the long term effect of renewables. In its basic spatial resolution, the model includes the EU-27 states as well as Switzerland, Norway and the Balkan countries, each with a detailed representation of regional energy supply structures. In this contribution, the focus is on the renewable expansion in Germany and its impact on carbon emission reductions.

Results

The qualitative comparison shows that displacement estimations have advantages with low data requirements and their simplicity but fail to take trade and dynamic effects into account. Econometric methods can capture these effects but have higher data requirements and are more complex. Using the timely context of emissions and renewable feed in econometric methods struggle with non fluctuating renewables. Furthermore they as well as displacement estimations do not capture the long-term effects of renewables on electricity markets such as changed investments. Only fundamental models can address this challenge.
In consequence, a combination of an invest and dispatch models is applied and results will be shown for the years 2013 to 2016 for the German electricity market. In Germany renewables reduce carbon emissions between 0.7 – 0.8 t CO2 per MWh renewable feed-in. This figure is significantly higher than the average CO2-emissions per MWh in the German power plant portfolio, which is about 0.53 t/MWh. Beside the absolute models, the methodology also allows to determine the impact parameters: about 10% of reduction effect results from long effects, which corresponds to the fact that coal power plants have not been build. This estimation is based on a contrafactual scenario, which represents a world without German renewables or in other words, what types of power plants are

substituted by renewables. Furthermore, results indicate that the ongoing expansion of renewable energies further decreases carbon emissions in Germany by the fact that more and more coal is substituted by renewable energies.

Conclusions

All methods to quantify carbon emission reductions due to renewables have their justification: due to the low data requirements, displacement methods are good to quickly and easily get insights to the effect of renewables on national carbon emissions. However, if good data availability is guaranteed, the best results, for all renewables and considering trade, can be achieved using dispatch models. The application of an investment model improves the explanatory power further by taking into account the long-term effect of renewable energies.
Results for Germany show that renewables significantly contribute to a carbon emission reduction. Carbon emissions can currently be reduced in Germany by 0.7 to 0.8 t CO2 per MWh renewable feed-in. It is most likely that further installed renewable capacities will contribute in this magnitude as still lignite and coal power plants will most probably be substituted. Having this high figures in mind, it is clear that the carbon emission reduction by renewables strongly depends on the power plant portfolio of the country under examination.