# Grid Investment and Support Schemes for Renewable Electricity Generation

*Johannes Wagner*[*]

## Executive summary

The unbundling of formerly vertically integrated utilities in liberalized electricity markets led to a coordination problem between investments in the regulated electricity grid and investments into new power generation. At the same time investments into new generation capacities based on weather dependent renewable energy sources such as wind and solar energy are increasingly subsidized with different support schemes. This paper analyzes the influence of the subsidy scheme for renewable electricity generation on the locational choice of renewable energy investors and on the required grid investments to integrate the generation capacities into the system. Additionally, anticipatory behavior of the transmission operator and network charges for renewable energy producers are assessed as potential remedies for arising inefficiencies.

The contribution of the paper is to explicitly model interactions between the renewable support scheme and grid investments. Therefore the paper intends to close the gap between the literature streams on renewable support schemes and on the coordination problem between generation investment and grid investment in unbundled electricity systems.

To analyze the described issues a highly stylized model with one demand node, two possible locations for renewable generation investment and lumpy transmission investment is developed. Electricity generation at the two locations is stochastic with different total expected generation and imperfectly correlated generation patterns. Renewable energy investments are subsidized either by a feed-in tariff scheme, a feed-in premium system or direct capacity payments in order to reach an exogenous renewable target. In order to identify inefficiencies three dynamic model configurations are assessed. The first case is a central planner who jointly invests into generation and transmission capacities. The second case is reactive transmission investment, which means that renewable investors move first and transmission investment reacts to renewable investment. The third case is anticipatory transmission investment, which means that the transmission operator invests first in order to actively influence renewable investors. The analysis is conducted for wind power, however the results apply for all intermittent and location dependent renewable energy sources.

I find that private investors do not choose system optimal wind locations in feed-in tariff schemes, feed-in premium schemes and subsidy systems with direct capacity payments. In feed-in tariff schemes the inefficiencies result from the lack of internalization of the market value of the produced electricity into the investment decision. Under feed-in premium schemes and capacity subsidies the market value is internalized, but the system integration costs are not. Consequently, all three subsidy systems can result in inefficient system configurations if the transmission operator follows wind power investments.

[*] Corresponding author, Department of Economics and Institute of Energy Economics, University of Cologne, Vogelsangerstraße 321a, 50827, Cologne, Germany. E-mail: johannes.wagner@ewi.uni-koeln.de

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The described inefficiencies can be prevented if a benevolent transmission operator anticipates investment decisions of private investors and steers investment in a system optimal way. However, benevolent behavior is only applicable under perfect regulation. In absence of perfect regulation, incentives to implement the system configuration that maximizes the revenue of the transmission operator inside the regulatory constraints arise. A possibility to directly influence investment decisions of private investors and to internalize the system integration costs are location dependent grid charges for power producers.

Based on the results of the analysis three policy recommendations can be derived. First, support schemes for renewable electricity generation should be designed with awareness for the consequences on the locational choice of investors. Second, policy makers should assign a more active role to transmission operators, which acknowledges the importance of anticipative investment behavior. However, inefficient steering of renewable investments by transmission companies as a result of imperfect regulation should be of concern. Third, power systems which internalize not only the market value of electricity but also the location dependent integration costs for generation capacities into private investment decisions should be designed.

**Keywords** Renewable energy investment, transmission investment, coordination problem, external effects.

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