CHANGING THE EUROPEAN DEBATE DAHRENDORF SYMPOSIUM

FOCUS ON CLIMATE CHANGE | 2013

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QUANTIFYING LONG-TERM ECONOMIC BENEFITS OF EUROPEAN ELECTRICITY SYSTEM INTEGRATION

Dahrendorf Symposium Paper Series

Summary

THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE
Stiftung Mercator
Hertie School of Governance

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Dr. Eva Schmid is a postdoctoral researcher in the domain Sustainable Solutions at the Potsdam-Institute for Climate Impact Research (PIK). In the group Energy Strategies Europe and Germany she is responsible for overseeing the group's energy-system modeling activities. She holds a MSc in Econometrics and a BSc in International Business from Maastricht University. During her PhD project at PIK, Eva developed a hybrid energy economy model for Germany that was applied to explore participatory mitigation scenarios. Her current research focus lies on the development and analysis of consistent transformation strategies for the German and European electricity system that are on the one hand based on formal energy system modeling and on the other hand embrace the perspectives of actors, institutions and technologies so as to address the question of how to implement the transition towards a low-carbon economy. In this context, Eva is particularly interested in the differences between a centralized and a decentralized energy transition.

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This paper was developed for the 2013 Dahrendorf Symposium, a joint initiative of the Hertie School of Governance, London School of Economics and Political Science (LSE) and Stiftung Mercator.

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Abstract
QUANTIFYING LONG-TERM ECONOMIC BENEFITS OF EUROPEAN ELECTRICITY SYSTEM INTEGRATION

European integration of the electricity system by means of expanding pan-European transmission infrastructure capacities is argued to be an economically beneficial means for achieving four key long-term energy and climate policy targets: it constitutes a pivotal option to (i) integrate high shares of renewables, leading to a reduction in greenhouse gas emissions through substituting fossil-based electricity generation. Also, it (ii) increases competition in the internal market for electricity, leading to lower prices. Further, it (iii) increases security of supply in the European Union through integrating remote areas in the European periphery, enabling a more diversified energy mix and reduced congestion. And, finally, progress in attaining these four climate and energy policy ends jointly contributes to the long-term European policy target of (iv) transitioning to a competitive low carbon economy. "Energy infrastructure" and its development is also a key word in the contributions to the consultation of the EU Commission for a 2030 framework for climate and energy policies. Despite these bold political statements, the respective arguments are given without any quantification, so the question is: How great are the long-term economic benefits of the European electricity system integration and what do they depend on?

In order to come up with a comprehensive quantitative answer based on a numerical model, one ideally needs to account for the full sets of system effects inherent to the future development of the European electricity system. Since computational limitations have inhibited such complexity to date, no comprehensive assessment has been performed yet; the literature provides only few contributions that selectively quantify the economic effects of a system-cost optimal transmission capacity expansion in Europe.

Hence, the aim of this paper is to add a quantitative estimate of the economic benefits of European electricity system integration to the sparsely covered field of literature, applying the European electricity system model LIMES-EU+. We compare model results from a set of scenarios that are characterised by different assumptions on the expansion rate of pan-European net transfer capacity (NTC) expansion and the development of specific investment costs for the variable renewable (vRES) technologies, wind onshore and offshore, solar photovoltaic and centralised solar power. The analysis is pursued given ceteris paribus assumptions on the future development of other influential system drivers and exogenously enforced CO2 emission reductions in the electricity sector as suggested by the European Commission´s "Roadmap for moving to a competitive low carbon economy in 2050".

We confirm earlier findings that, on aggregate, pan-European transmission capacity expansion constitutes a no-regret option. More NTC capacities lead to economically beneficial effects in terms of total discounted system costs and average electricity prices - albeit the magnitude of the effect is rather modest for both variables. It turns out that this result is robust across scenarios with varying vRES investment cost pathways, which leads to substantially different configurations of pan-European transmission infrastructure and distinct technology mixes. In technical terms, this can be interpreted as a flat optimum.

In this respect we expand the focus of previous work by identifying system effects that result from the interplay between transmission infrastructure and renewable generation capacity expansion. In particular the model results indicate that the system-cost-optimal

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configuration of the pan-European transmission infrastructure is driven by the integration of high-quality renewable resource sites in the periphery. This finding is robust for the different vRES investment cost scenarios. Yet, the question of which country-connections are especially important crucially hinges on the relative development of specific investment costs of vRES technologies. If prices of solar photovoltaic will continue its strong decreasing trend of the past decades, centralized solar power starts to exploit its learning-by-doing potential and wind technologies' specific investment costs stagnate or even increase, then the cost-optimal strategy would be a "Southern solution" that taps into the abundant solar potential of Southern Europe, particularly on the Iberian Peninsula and South-Eastern Europe. This would require a strengthening of the transmission corridors from these areas to central Europe. However, in case wind technologies' specific investment costs develop comparatively favourably, a "Northern solution" focusing on the integration of high-quality wind sites in Northern Europe, the Baltic countries and the islands of Ireland and Great Britain is the system-cost-optimal strategy.

A discussion of the model-based findings in the context of the political claims that pan-European transmission capacity expansion is an economically beneficial means for achieving four key long-term energy and climate policy targets revealed a number of promising areas for future research. It shows that broadening the scope of quantitative estimates of the economic benefits of European electricity system integration reveals important research questions. First, the question arises regarding who incurs the economic benefits from integrating more renewable electricity generated in the European periphery in the European electricity system as a whole. A second question is how distinct demand patterns, including elastic demand, and differently anticorrelated feed-in patterns of wind and solar capacities impact the quantitative estimates of economic benefits from an integrated approach. Thirdly, in order to further investigate security of supply issues, energy system models should at best be sequentially coupled to line-sharp infrastructure models. And, fourthly, how does one govern a pan-European energy transition on different levels in order to ensure a cost-efficient pathway?

An important implication of the finding that pan-European transmission capacity expansion is both a no-regret option and crucial for integrating high-quality renewable potential in the European periphery is that the speed of transmission capacity expansion needs to accelerate. Frequently, grid projects are jeopardized due to a lack of social acceptance. A transparent assessment that quantifies the economic benefits of transmission capacity expansion could play an important facilitating role in justifying grid development at the local level, and could also be a basis for determining eventual financial remunerations for those that experience local negative externalities of grid expansion.