Transition towards a renewable European electricity system

Summary

The research presented in this dissertation identifies and addresses part of the challenges ahead of the energy transition in the European Union. More specifically, it looks at how the increasing share of power generated by variable renewable energy (VRE) technologies affects the existing power system and the electricity markets, and discusses the technological and economic implications of a fully renewable European power system.

Chapter Two puts forward an analytical framework to understand how different energy generation and balancing technologies can contribute to a 100% renewable European power system. The first part investigates whether different power technologies -of generation, storage and transmission – behave as either complements or substitutes in a decarbonized European power system. Having a clear understanding of how each energy technology can contribute to a clean power system and how its contribution impacts the contribution of other technologies – by either displacing or supporting it – is crucial to the design of a cost-optimal, clean European power system. The second part zooms in on how these technology and cost interactions change across five scenarios of power trade integration.

This framework emphasizes the importance of policy coordination among member states. As countries increase their reliance on power trade, their optimal energy mixes change – as does the aggregate European optimal energy mix. The findings of this chapter suggests that a cost-optimal European energy system in which power trade is restricted to 25% of an individual country's demand has a very different energy technology mix than a European power system where trade among member states is unrestricted. Understanding the cost and technology implications of these different scenarios provides a starting point for discussing the importance of energy policy coordination among EU member states.

Chapters Three and Four focus on the effects of electricity from VRE on the electricity market. The current electricity markets of most developed countries have been designed decades ago for entirely different energy technology portfolios and market structures. The recent upsurge of intermittent power from VRE technologies has challenged

the appropriateness of the current electricity market design for a VRE-intensive power system.

One of the challenges which VRE raises for the electricity market refers to its effect on the electricity price and its volatility. More specifically, liberalized power systems function on the microeconomics principle whereby the price is determined by the marginal cost which, in turn, for conventional power technologies, is determined by the fuel price. Since VRE and in particular wind and solar power technologies have zero fuel cost, they have a downward effect on electricity prices, during periods of high wind speed or high solar radiation. In the current design of electricity markets, this makes it difficult for conventional power technologies to remain competitive, even though they are important for the stability of the power grid. On this background, Chapter Three looks at the effects of power generated by VRE on the main variables of interest of the electricity market – i.e. the electricity price and its volatility. The research findings discussed in this Chapter suggest that the volatility of electricity prices is expected to increase, as VRE take up a higher share in the energy mix. However, this effect is mainly due to power generated by wind power plants alone.

Chapter Four looks at the relation between the increasing share of electricity from VRE technologies and the process of integration of the different national power systems into a pan-European system. Over the past few decades, the European agenda of energy policy has been dominated by two main items: the integration of the electricity systems of individual countries into a pan-European electricity system, and the transition to a power system that is less reliant on fossil fuels and more intensive in cleaner, renewable energy resources. These two ambitions have historically been addressed individually, at both national and supra-national European levels – as is also reflected in two separate strands of literature – with different results. Indeed, the literature on the effect of VRE on electricity markets is unambiguous in its findings that an increase in VRE has a downward effect on electricity prices. On the other hand, the literature looking at power trade integration between different national power systems reports mixed results in terms of the effect of increased levels of power trade on electricity prices, finding both positive and negative relations between VRE and electricity price convergence. In Chapter Four it is argued that the two ambitions overlap in many respects and that a clear understanding of the relation between intermittent power generation from VRE and electricity market integration can reveal more efficient ways of pursuing this dual goal. As electricity markets become more integrated and electricity is freely traded among more countries, the price differential between these countries decreases. To this end, Chapter Four develops a framework that looks at these two issues jointly and tackles the following question: what is the effect of intermittent power, generated by VRE, on the process of electricity price convergence? Using data for eight European, the research

finds that there is an inverted U-shaped relation between VRE and electricity prices convergence, i.e. for very low and very high levels of VRE, the price differential is large, whereas for intermediate levels of VRE, prices tend to converge, thus reducing the price differential. The results point to the fact that an acceleration of interconnector capacity developments is required in order to benefit from the price-reduction effect of VRE, at the European level. Furthermore, increased policy coordination in different countries would mitigate the short-term negative effects of price divergence, e.g. the difference in consumer welfare in different countries, in the context of a pan-European energy system, following from unilateral decision making.

Finally, Chapter Five summarizes the main findings of the research presented in this dissertation and discusses several concluding remarks and implications for European energy policy-making. It also highlights some limitations of the research and points to key areas for future research into the process of the transition towards a clean European power system.

Taken together, the research results presented in this dissertation shed light on several economic and political challenges that the transition to a low-carbon electricity system in Europe is expected to face. These findings aim to contribute to an informed discussion on weighing the different economic, social and environmental implications of the ambitious task ahead of decarbonizing the European power sector.