# Resource Adequacy with Increasing Shares of Wind and Solar Power: A Comparison of European and U.S. Electricity Market Designs

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## Executive summary

1. Motivations underlying the research

The installed capacity of renewable electricity generation technologies, in particular wind and solar, has increased rapidly in Europe and the United States in the last decade. At the end of 2016, Europe was generating 29.6% of its electricity from renewables, about twice as much as in the United States. Since 2005, most of the growth in renewables in both regions came from increased wind and solar energy, with hydropower generation remaining roughly constant.

Several factors have led to the rapid development of these variable renewable technologies. In Europe, the main support mechanism has been feed-in-tariffs, which provides a fixed payment per kWh of generation from selected technologies. However, there has been a recent trend towards governments conducting auctions to achieve renewable generation targets in a more cost-effective manner. In the U.S., the main policy instruments have been federal tax credits and state-level renewable portfolio standards. In both the U.S. and Europe, tariff structures such as net metering, where customers with local generation are compensated at the full retail rate, provide indirect support for renewables. Finally, a focus on distributed generation, microgrid solutions, and a growing interest in purchasing wind and solar from different consumer groups (households, local energy communities, corporations) that are willing to pay a premium for green products all have contributed to the demand for wind and solar power.

The rapid growth in variable renewable electricity generation is starting to make an impact on the prices in the electricity markets. Wind and solar energy have very low operating costs, which may even be negative when policy support schemes are considered. Hence, these resources displace generation from technologies with higher operating costs. This merit order effect tends to reduce electricity market prices, as observed particularly in some European markets. In addition, constraints on the system combined with occurrences of excess wind and solar generation has led to a significant increase in the frequency of negative prices in electricity markets on both continents. Of course, other factors also influence prices in the electricity market. In the U.S., several studies show that reductions in the cost of natural gas is the primary reason for the low electricity prices in recent years.

In principle, the revenues from the markets for energy and operating reserves should be sufficient to provide incentives for adequate investments in generation capacity. This is the premise for the so-called energy-only market design. However, the reductions in electricity market prices are making it harder for

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existing generators to make a profit. This has led to renewed discussions about the need for capacity mechanisms, which are additional compensation schemes designed to provide incentives for generation investments and system reliability. Several capacity mechanisms have been implemented in Europe, where some countries have relied on capacity payments or strategic reserves for a long time, and other countries recently have introduced capacity markets or obligations. However, many countries in Europe still rely on the energy-only market design. In the U.S., four electricity markets rely on centralized capacity markets, two on capacity obligations, whereas the market in Texas (ERCOT) is the only energy-only market. The current status clearly illustrates that no consensus exists on the best approach to incentivize capacity investments and maintain system reliability.

2. A short account of the research performed

Against the background compiled above, we raise the question if improvements to current energy-only markets in Europe and the U.S. could be sufficient to maintain resource adequacy in electricity markets or whether the rapid increase in wind and solar generation gives stronger arguments for additional capacity mechanisms. In detail, a comparative analysis of the European and the U.S. electricity market design is conducted in terms of both short-term electricity market operation and long-term resource adequacy. This comparative study reveals some fundamental differences, but also many similarities in electricity market design on the two continents. We highlight good-practice market design elements in each case and provide a list of general and specific recommendations for improved electricity markets in Europe and the United States.

3. Main conclusions and policy implications of the work

As a general recommendation, we argue that the most important challenge in electricity market design is to achieve good incentives for operations and investment in the short-term markets. A sharper price formation will provide better incentives for system flexibility from supply, demand, and energy storage resources. This can be obtained through increased demand response to market prices so that they better reflect consumers' preferences and willingness to pay for electricity. A particularly important issue is what happens to prices when supplies are short, as scarcity rents are critical for capital cost recovery. Ideally, improved scarcity pricing in short-term markets should follow from increase in the demand participation. However, administrative mechanisms, such as using demand curves for operating reserves rather than fixed reserves requirements will provide prices of energy and reserves that better reflect the value of reliability in situations with supply shortages. It would also be beneficial to move from technology specific incentive schemes for renewable technologies towards adequate pricing of carbon emissions, as it would have the effect of increasing the cost of emitting technologies rather than depressing wholesale electricity prices. We argue that these general recommendations, which apply to Europe as well as the United States, would foster a more market-compatible integration of wind and solar energy, better functioning energy only markets, and less reliance on (or, ideally, no need of) capacity mechanisms.

We also find that certain market design challenges differ in Europe and the U.S. For instance, a specific recommendation for Europe is to improve the representations of the transmission network in market clearing algorithms to obtain locational prices that better reflect congestion patterns. In addition, substantial benefits would be achieved from moving towards shorter time intervals in real-time balancing markets and from introducing integrated markets for energy and operating reserves, as is already done in some U.S. markets. In the United States, electricity markets should follow the European approach of using intraday markets to enable a more market-based balancing of system deviations that

arise, in part, from variable renewable electricity. Overall, as electricity markets continue the transition towards a low-carbon future on both continents, lessons can and should be learned in both directions.