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Market design for a high-renewables European electricity system

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ABSTRACT

This paper presents a set of policy recommendations for the market design of a future European electricity system characterized by a dominant share of renewable energy supply (RES), in line with the stated targets of European governments. We discuss the market failures that need to be addressed to accommodate RES in liberalized electricity markets, review the evolution of the EU's RES policy mechanisms, and summarize the key market impacts of variable RES to date. We then set out economic principles for wholesale market design and use these to develop our policy recommendations. Our analysis covers the value of interconnection and market integration, electricity storage, the design of RES support mechanisms, distributed generation and network tariffs, the pricing of electricity and flexibility as well as long-term contracting and risk management.

1. Introduction

In 2014, the European Council confirmed the EU's 2030 targets for tackling climate change as a reduction of at least 40% against 1990 greenhouse gas emissions and increasing the share of renewable energy in total gross energy production to 27%. Across Europe, governments are putting in place the legislation to deliver on these targets.

Given the difficulties of decarbonizing transport and heating, the electricity sector will continue to bear a significant burden arising from economy-wide decarbonization. Achieving this will require high shares of renewable energy supply (RES) in the electricity system, in light of the limited opportunities for expansion of hydro power and widespread resistance to nuclear power. Fortunately, rapid technological progress in wind and solar energy, combined with increased use of interconnection, existing hydro resources, new battery technologies and an increased role for the demand side (facilitated by smart meters) suggests that a high-RES electricity system is not only a necessary outcome of the 2030 policy targets but also a realistic future scenario.

To date, Europe has made remarkable progress in creating liberalized and competitive wholesale markets for trading electricity within and across national boundaries. The liberalization process, beginning in the 1990s, was accompanied by large-scale private investment in gas-fired power generation, which cut costs, reduced CO_2 emissions and improved environmental quality. The creation of competitive wholesale markets with hourly or half-hourly varying prices was the central mechanism for matching supply and demand, and until the mid-2000s in some countries also for directing generation investment.

The advent of variable RES with high upfront capital costs but very low short-run running costs has led to a reduced role for the market in guiding investment.[1] Governments now dominate by setting the subsidy regimes and capacity mechanisms that determine new generation investment.[2] The share of renewables in EU-28 electricity production has

Abbreviations: AC, Alternating current; CO_2, Carbon dioxide; COP21, 21st Conference of the Parties (2015 United Nations Climate Change Conference); DC, Direct current; DG, Distributed generation; DNO, Distribution network operator; EES, Electrical energy storage; ETS, Emissions Trading Scheme; EU, European Union; EU-28, 28 countries of the European Union; EV, Electric vehicle; FIP, Feed-in premium; FiT, Feed-in tariff; GB, Great Britain; GDP, Gross domestic product; GHG, Greenhouse gas emissions; GW, Gigawatt; GWh, Gigawatt hour; kW, Kilowatt; kWh, Kilowatt hour; LMP, Locational marginal price; MS, Member State (of the European Union); MW, Megawatt; MWh, Megawatt hour; OPEX, Operating expenditure; PFiT, Premium feed-in tariff; PPA, Power purchase agreement; PSP, Pumped storage plant; PV, Photovoltaics (solar); R&D, Research and development; RD&D, Research, development and demonstration; RES, Renewable energy supply; RES-E, Renewable energy supply of electricity; RO, Reliability option; ROC, Renewable obligation certificate; SO, System operator; TEM, Target Electricity Model (in the European Union); TW, Terawatt; TWh, Terawatt; UK, United Kingdom

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[1] We use the term “variable RES” to encompass fluctuating renewables sources (e.g. wind and solar power). Other terms used in the literature include “intermittent” and “non-dispatchable” generation.

[2] Capacity markets are now used in tighter markets in the face of low energy prices and reluctance to invest in the firm and flexible capacity (e.g., fossil fuel generation plants, storage) that are currently needed to meet reliability standards.

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increased remarkably over the past decade to reach 28% in 2015, driven by generous subsidies and priority dispatch connection terms. However, raising the renewables (energy) share to around 50% or more[3] by 2030 will be challenging without substantial modifications to the current “1st generation” market design.

In this paper, we review the evolution of liberalized electricity markets and EU renewables and climate policy to date. We note the unintended problems which have arisen under the current market design and existing RES subsidy schemes. We then outline key elements of a “2nd generation” high-RES market design, which provides better price signals, better incentives for RES investment and operation, and greater system flexibility.

We begin by advancing six principles of good electricity market design. These include: correcting as directly as possible the market failures in current market designs; allowing for appropriate cross-country variation in market design; using price signals and network tariffs to reflect the value of all electricity services; collecting network fixed costs in as efficient and equitable a way as possible; de-risking low-carbon investment; and retaining the flexibility to respond to new information on the attractiveness of different low-carbon technologies. We then provide a more detailed analysis of the key elements of a new market design and present a number of policy recommendations.

Our review of the literature suggests that there are still substantial short-term benefits of further European cross-border market integration (equal to around 2–3% of overall generation costs) and significant potential value in increased interconnection. Interconnectors exploit differences in wind and sun conditions across regions and so reduce supply variability; higher RES penetration further raises the value of market integration. We argue that it should be a policy priority to ensure proper remuneration of the services provided by interconnectors so as to incentivize efficient private investment, including for more connection to market areas with large hydro reserves such as Norway.

Next, we discuss the challenges around the widespread uptake of electrical energy storage. We observe that the potential of electric storage, including from electric vehicles (EVs), remains tiny compared to existing pumped and hydro storage. Battery storage looks likely to play two main future roles: deferring upgrades in transmission and distribution systems by shaving peak use, and improving the management of power flows on the electricity network by varying the charging rates of EVs. The surrounding incentives and business models that will allow batteries to capture this value still need to be clarified.

We then examine possible improvements to the design of renewable support mechanisms, which yield better signals around where to locate renewables across Europe. We suggest a move from current output-based (per MWh) feed-in-tariffs to support more based on capacity, for which procurement prices are determined by auctions. As the system becomes more capital-intensive (rather than fuel-intensive), such competitive RES auctions can reduce current market distortions and help further bring down the cost of capital.

We identify issues arising from the current pricing of transmission and distribution services. We suggest that network charges for distributed generation (DG), such as rooftop solar PV, need to be made more efficient. Current charging mechanisms have led to distortions and wealth transfers from poorer to richer households; these are rising in magnitude in the face of potentially large uptakes of solar PV, electric vehicles (EV) and distributed electric energy storage (batteries) and need to be considered alongside other policy objectives. We recommend that the apportionment of charges between fixed, off-peak and peak use of system charges needs to be changed to be more cost-reflective.

We then turn to improvements to the design of power and ancillary service markets. A system dominated by variable RES enhances the need for more granular pricing of electricity over space and time. The scope for nodal pricing of electricity has increased in tandem, given recent improvements in computing power and smart metering. A move towards more granular electricity prices will help improve location decisions for generation investment, and enhance the value of greater system decentralization.

Finally, we discuss risk management and long-term contracting in a high-RES system. We suggest less reliance on politically-backed long-term indexed price contracts that have recently been used to support renewables and nuclear investment. The preferred design of capacity auctions should employ “reliability options” because these help retain efficient spot prices. Policy should support the deepening of markets for forward contracts and employ long-term procurements contracts only where necessary to reduce risk and the cost of capital.

While our arguments are applicable across different European countries, many of our specific examples are drawn from Germany, Italy, the island of Ireland, Spain and the UK. We touch on other elements of market design only as by-products of this analysis, including demand-side response, related issues arising for retail electricity markets, and optimal support mechanisms for low-carbon RD&D. Other important topics such as the impact of future electrification of heat are beyond the scope of this paper.

The paper proceeds as follows. Section 2 reviews the economics of liberalized electricity markets and the EU's renewables and climate policies.[4] Section 3 gives an overview of the market impacts—good and bad—that renewables have had to date. Section 4 sets out principles for electricity market design in a high-RES world. Section 5 presents our analysis and recommendations for (i) interconnectors and market integration, (ii) electric energy storage, (iii) RES support mechanisms, (iv) distributed generation, (v) short-term pricing as well as (vi) long-term contracting and risk management. Section 6 offers broader concluding remarks on policy design for a high-RES future.

2. Liberalized electricity markets and EU renewables policy

2.1. Liberalized electricity markets and market failures

Electricity involves a range of services: its wholesale value is made up of the energy value (kWh), the value of reliability (i.e., the ability to meet demand) provided by capacity (kW), and the quality of service at a particular location, as provided by ancillary services (e.g., frequency response).

Electricity generation involves several market failures. Perhaps the most important such failure lies in environmental externalities, notably air pollution and carbon emissions [5]. Renewables such as wind and solar PV are cleaner than fossil fuels, but more capital-intensive than traditional generation assets, and pose new challenges to managing the electricity system due to the non-synchronous nature of variable generation [6]. Their deployment comes with substantial learning benefits that spill over to other market participants; without proper support, learning and R&D in such new technologies may therefore be insufficient from a social viewpoint [7].

Legislative packages since 1996 have opened the EU electricity sector to vertical unbundling and competition. In liberalized markets, large players in the wholesale market may be able to exercise market power to drive up prices—especially when capacity is tight [8]. This is one motivation behind wholesale price caps, which limit market power in the short run. However, they in turn lead to the problem of “missing money” [9]: prices do not fully reflect scarcity in tight market conditions, reducing profitability and leading to underinvestment in capacity over the longer haul. Similarly, the presence of “missing markets” [10], such as the lack of forward prices over longer horizons for all products

[3] The 2016 EU Reference Scenario [1, p. 64] shows that current policies are expected to result in a 43% RES share in electricity by 2030. Meeting the EU's 2030 energy and climate targets is modelled to require a 48–55% RES share [2, p. 73].

[4] For a useful book-length analysis of liberalized electricity markets and EU climate and energy policy, see respectively Stoft [3] and Buchan and Keay [4].