

## GUEST EDITORIAL

### THE ZERO MARGINAL COST ELECTRICITY MARKETS

Luiz Barroso and Hugh Rudnick

Decarbonization goals have created a technological revolution that has enabled renewables — in particular solar and wind generation — to be in the center of most electricity markets all over the world. Renewables are inherently characterized by high production variability combined with limited predictability and controllability, which have brought significant flexibility challenges for power systems planning and operations all around the world.

Renewables also produce electricity at an almost zero marginal cost. In the presence of high shares of renewables, restructured electricity markets based on marginal pricing to set locational marginal prices also will be challenged, as electricity prices can fall to zero, or even to negative values, if abundant renewable generation is observed. Conversely, prices can rise quickly and may reach high figures if renewables are not producing and if scarcity takes place. These effects can be exacerbated in the presence of transmission bottlenecks and high levels of distributed generation.

In the abundant presence of (almost) zero-marginal cost resources, important questions have been posed recently on the power system economics side about the future of current electricity market designs and companies, such as: how will remuneration of generation assets take place? How will financing arrangements be structured? Will revenue uncertainty compromise generation adequacy in the face of new capacity needs due to decommissioning of existing fossil resources combined with load growth? Can scarcity pricing, revealed through variability in short-term price signals for generation services, create adequate incentives for long-term investments? Are long-term reliability and energy contract markets the way to go? Or do capacity markets suffice to create efficient

incentives for investments? How can demand-side services and demand response be brought into the market as resources, while balancing political considerations and consumers' aversion to risk in electricity pricing? With increasing decarbonization goals in power systems all over the globe, these are examples of relevant questions to be discussed by policymakers and stakeholders.

The objective of this special issue of the IEEE Power and Energy Magazine is to debate these zero marginal cost futures and discuss relevant topics related to generation adequacy and wholesale markets, focusing on conceptual and practical discussions. The issue features authors with wide experience from both academia and industry who focus on the regulatory and market challenges ahead.

Carlos Batlle, Pablo Rodilla, and Paolo Mastropietro open this issue with the conceptual problem statement. The authors discuss how, in the more than three decades since the first power markets were implemented in the 1980s, key aspects of market structure need to be revisited: the interplay between regulation (centralized planning) and market forces, and the relations between transaction characteristics and contractual and other governance structures. But this is not the only matter that needs to be properly addressed. They argue that short-term pricing mechanisms will continue to be instrumental in guiding optimal operation and investment decisions but will also need to be properly coordinated with regulatory-driven long-term markets. They discuss what and how mechanisms should be designed, and what other market rule modifications are needed to allow for an efficient interaction between short-term market prices and long-term complementary signals.

The second article, by Frank Wolak, also discusses conceptual issues, and presents a proposal for a Market Design in a Zero Marginal Cost Intermittent Renewable Future. Wolak suggests key improvements to the design of an efficient short-term wholesale

market and posits a long-term resource adequacy mechanism for a system with a large share of zero marginal cost intermittent renewables. He argues that his conceptual proposal ensures long-term resource adequacy at a reasonable cost for final consumers while also allowing for the short-term wholesale volatility necessary to finance investments in storage and other load-shifting technologies that will be required to manage a large share of renewables.

We then move to the first of three articles on practical experiences. Erik Ela, Andrew Mills, Eric Gimon, Mike Hogan, Nicole Bouchez, Anthony Giacomoni, Hok Ng, Jim Gonzalez and Mike DeSocio discuss potential Pathways of Electricity Market Designs without Fuel Costs in the United States and Canada. They navigate through some key challenges and the efforts to improve market designs today before describing potential options for future designs of electricity markets with these characteristics. This includes arrangements to incentivize investment in and operation of the future supply fleet.

A team of twelve authors from Europe led by Goran Strbac discuss the European setting by reviewing European policy initiatives to address the market design challenges. They discuss some EU efforts in five selected areas: the “missing money” problem, integration of renewables in energy and ancillary services markets, carbon markets, value of distributed flexibility, cross-border market integration, and the coordination of emerging local energy markets. Open issues and innovative designs are identified to enable a cost-effective and secure decarbonized European electricity system.

Luiz Barroso, Francisco D. Muñoz, Bernardo Bezerra, Hugh Rudnick, and Gabriel Cunha show that some hydroelectric dominated countries in Latin America (in particular Brazil) have operated with lots of generation with zero marginal cost for decades and still managed to incentivize investment in new generation capacity. However, in those settings, long-term markets for financial energy contracts with

sufficient liquidity are essential to secure generation financing due to the high volatility of spot prices. The authors discuss the role of long-term markets that have been implemented in the region for decades and potential improvements.

Our last article comes from a team of lenders. Tonci Bakovic, Debabrata Chattopadhyay, Fernando Cubillos, and Marcelino Madrigal present a view from development banking practitioners on the challenges to generation financing in markets with high penetration of renewables. Financing is essential to attract capital in order to expand or retain generation capacity. Focusing on developing countries, they argue that policymakers must address both market design and institutional design. Supporting the arguments of the previous articles, they claim in particular that long-term contracts to stabilize revenues will continue to be a key design feature to attract competitive generation investments, but that more flexible arrangements – such as liquid markets for short to medium term contracts that can be rolled over – can be alternatives to avoid the technology lock-up brought by the super long-term commitments that have emerged in many developing countries.

Finally, Alberto Pototschnig, an economist who served as the first Director of the European Union Agency for the Cooperation of Energy Regulators (ACER) and is currently with the Florence School of Regulation, brings his experience to a debate in the “In My View” column. He focuses his discussion on reliability options as a preferred capacity adequacy mechanism to address residual adequacy concerns raised by the high penetration of renewables. Focusing on the European Union, he argues that reliability options should be designed such that strike prices do not interfere with the functioning of the energy market – under normal or even tight conditions – and that penalties should be imposed to reinforce the incentives for adequacy resources to be available at time of scarcity.

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Electricity markets will be dramatically changed in the decades to come and the discussion of how best to adapt market designs for high shares of renewables will be ongoing. The consequences of the zero marginal cost electricity industry go well beyond the wholesale markets discussed in this issue, and we are sure the IEEE will continue contributing to these discussions.

We would like to thank the authors for the time, dedication, and articles provided, which shed light on the key topics related to this very relevant discussion. We thank IEEE Power & Energy Magazine for providing us with the opportunity to reflect on and analyze such challenging matters, which have taken us and the authors out of our comfort zones to consider many new ideas. A special thank-you goes to the Editor-in-Chief, Steve Widergren, Associate Editor Antonio Conejo, and Immediate Past Editor-in-Chief, Michael Henderson for continuing to provide the conditions for IEEE Power & Energy Magazine to remain an IEEE flagship publication.