KAPSARC
مركز الملك عبدالله للدراسات والبحوث البترولية
King Abdullah Petroleum Studies and Research Center

Designing Electricity Markets to Integrate Renewable Energy

June 2016 / KS-1630-WB029A

About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology, and the environment across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

Legal Notice

Key Points

The penetration of renewable energy in deregulated electricity markets is changing the behavior of wholesale electricity prices. Liberalized electricity markets work well when the penetration of renewable energy is low, but they are disrupted when the penetration is significant.

Renewable technologies have a cost structure that disrupts the traditional formation of wholesale electricity prices in liberalized markets — they have zero or near zero marginal costs.

In Europe, the decline in electricity prices is due to the extent of renewable energy deployment. These lower prices are artificial as the true cost of electricity is much higher, especially once public subsidies are taken into account.

The poor design of liberalized electricity markets is the cause of two inconsistencies:

- Although renewable energy results in lower prices, this is not the result of a decline in long-run full-cycle costs.
- The returns earned by renewable energy arise from the marginal costs set by fossil fuel technologies. Therefore, if fossil fuels were displaced from the market, current liberalized market rules would deny these returns.

Policymakers and market participants are still searching for a ‘best’ design, which facilitates the integration of renewable energy into the power market — a fertile area for future research.

Summary for Policymakers

In many regions of the world reducing fossil fuel use in electricity generation through transitioning to various forms of renewable energy has been given the highest priority as a policy objective. This transition toward a more sustainable energy mix has been particularly intense in the European Union and the U.S., where electricity systems were privatized and/or liberalized in the 1990s.

In liberalized wholesale markets, the price of electricity has traditionally been set by the technology with the highest marginal cost of production at any time. In other words, the price of electricity is equal to the operating costs (marginal costs) of the most expensive power plant that is generating electricity in each moment. This kind of market is known as a 'marginalist market'. This price, which can change in an instant, determines the flow of revenues for power generators. Under these market rules, technologies are not paid based on their total cost of producing electricity. If the price of electricity is sufficiently low for a long period of time, revenues simply do not compensate total full-cycle capital and operating costs and power generators suffer losses.

In liberalized markets that are based on fossil fuel technologies, however, generators can perform well financially, given the relatively high marginal costs of dispatch. Introducing renewable technologies to these markets disrupts wholesale electricity prices by reducing them because renewable technologies have zero or near-zero marginal costs. The outcome is to create a preference for dispatch of electricity with a higher overall cost of supply but a lower marginal cost.

Growth in renewable energy installations is shouldered by incumbent fossil fuel generators. This goes beyond a carbon price determined in the market. These traditional generators are forced to contend with both lower energy prices and the fluctuating output from wind and solar farms. A high penetration of renewable energy may substantially damage the value of incumbent utilities, making the cannibalization of their core business inevitable. The decline in wholesale electricity prices is a critical challenge for incumbent technologies and renewable technologies, though in the latter the problem is mitigated by the certainty of overall returns and avoiding being exposed to volatility in wholesale prices.

The installed cost of renewable capacity has fallen sharply in recent years, but current prices in liberalized markets still do not support investment under pure market conditions. Some argue that renewable energy policy has created a vicious circle: the financial support to renewable energy fosters deployment and deployment depresses electricity prices, increasing the need for additional financial support for not only renewables but even for the conventional technologies that are needed for integration and grid stability.

A consequence of this interaction between renewables and incumbent technologies is that liberalized markets may have to be redesigned. With the current structure of liberalized markets, there may be an argument for public ownership of the means to integrate renewables, as a form of public good, like other types of infrastructure. Alternatively, markets could be reorganized to recognize the long-term economic cost of renewable energy. The 'best' design of electricity markets, which facilitates the integration of renewable energy at the lowest possible societal cost, is still a fertile area for research.

Background to the Workshop

KAPSARC's March 2016 Energy Transitions workshop, Designing Electricity Markets to Integrate Renewable Energy, was attended by renewable energy and transition policy experts from international agencies, research organizations and laboratories, industry, governments and academia. Participants offered their perspectives on the impact of renewable technology on electricity markets and possible paths for integration of this energy. This workshop built on four previous workshops: A Framework for Fuel and Technology Transitions in Energy: Evaluating Policy Effectiveness (November 2013); Policy Support for Energy Transitions: Where is Public Money Best Spent? (May 2014); Energy Transitions Policy: What Matters Most (October 2014); and Renewable Energy in the GCC: Oasis or Mirage? (September 2015).

The objective of KAPSARC's latest workshop was to discuss the challenges for liberalized electricity markets represented by integrating renewable energy in the most cost-effective manner. The workshop took a holistic approach through analyzing the competitive dynamics between renewable and incumbent technologies, existing utilities and electricity markets and asked:

- Should the costs of renewables be borne by incumbent generators and utilities that are forced to accept renewable energy under dispatch priority?
- Should the role of incumbent fossil fuel generators with dispatchable plants that provide backup capacity to renewable energy be recognized or compensated?
- What impact does the roll-out of renewable energy have on consumers and business, and could the supply of renewable energy be brought about more cheaply?
- More broadly, are liberalized markets for electricity suited to a transition to renewable energy?
- If present market structures are not suited to renewable energy, what modifications to market design and structure should be considered?

Renewable Energy Penetration and its Impact on Liberalized Electricity Markets

In the European Union and the U.S., reducing fossil fuel use in electricity generation has increasing priority as a policy objective. As a result of these policies, renewable energy has a significant presence in the electricity system of these countries and this has changed market conditions.

In liberalized markets for electricity, increasing the proportion of renewable energy creates costs. This is for two reasons:

> Renewable energy reduces wholesale electricity prices and increases price volatility. In some circumstances, a high penetration of renewable energy could lead to negative electricity prices, i.e., some fossil fuel generators could be required to pay to produce electricity.

> Stagnant growth in power consumption across much of the OECD means that new renewable power plant is displacing incumbent plant rather than augmenting capacity. It therefore competes with the marginal cost of conventional generation, making the de-carbonization agenda more costly while, at the same time, increasing the burden on conventional fossil fuel generators.

Renewable energy is not only an innovative source of energy, it is also a source of energy that changes the behavior of liberalized electricity markets. This change in market conditions is not neutral among technologies: it harms the economic profitability of power generators with high marginal costs of supply and discourages investment in fuel-consuming technologies, including biomass. This adverse impact on the financial health of incumbent fossil fuel generators cannot simply be ignored, especially as they may be required to support and back up intermittent renewable technologies.

"Can we (utilities) tolerate the 'canyoning effect' of renewables."

In the U.S., the decline in electricity prices resulted mostly from the shale gas revolution. Lower prices reflect a real change in the cost of generation, since natural gas is cheaper. In Europe, the decline in power prices was due to the increased use of renewable energy. In this case, the lower price of wholesale electricity can be considered 'artificial' since the true cost of electricity is in fact much higher once public subsidies are taken into account. However, in both circumstances, the economic case for renewable energy under market conditions is unclear. In general terms, lower electricity prices mean the deployment of renewable energy can have expensive consequences.

In theory, and under current rules for liberalized electricity markets, if renewable penetration reaches 100 percent, the wholesale price of electricity would be zero, which is not a sustainable outcome. This suggests that a transition toward a more sustainable energy mix will require that electricity markets be reformed to maintain economic efficiency as penetration of renewables increases.

The Impact of Renewable Technology on Traditional Utilities

Despite the disruptive impact on electricity markets, the policy drivers for renewable energy, such as energy diversification and de-carbonization aims among others, remain robust. According to the IEA, in 2014 renewable electricity accounted for more than 45 percent of net additions to world electric power capacity, although somewhat less in terms of the share of electricity generated. The effect of high levels of policy support could leave incumbent energy companies potentially with significant stranded assets, which may further depress the prices of power from conventional assets. The penetration of renewable energy is not only changing the behavior of electricity markets, but also jeopardizing current utilities' assets, as evidenced by €104 billion of asset writedowns among European utilities since 2010.

In liberalized markets with high penetration of zero marginal cost power, electricity prices have ceased to perform their main functions of providing incentives for efficient operation and investments, remunerating energy resource providers and providing effective signals for consumers. Lower prices reflect markets that are ill-designed for their new task rather than improvements in renewable technology.

Poor market design is the cause of two interesting inconsistencies in liberalized traded electricity markets. First, although renewable energy results in lower prices because it is an almost zero cost marginal technology, it does not reflect any decline in long-term costs. Second, the profitability of renewable energy technologies depends on the existence of dispatchable, mainly fossil fuel, technologies. Both the revenues and the economic viability of renewable technologies depend on the market price of electricity — or alternatively the level of public support — which is determined by the marginal costs of dispatch, set currently by fossil fuel generators.

The question is, therefore, how can traditional utilities survive under current market rules and configurations? Most likely, utilities will have to change their business model in order to integrate new technologies, including smart grids, decentralized producers and renewable energy, but a reform in liberalized market rules would also bear some of the burden. Initial policies proposed include capacity market/payments, but more creative ideas may stem from new utility models or even taking renewables out of the liberalized market framework altogether.

Are Deregulated Electricity Markets Encouraging Renewable Energy?

It could be argued that, in liberalized wholesale markets, there is a negative relationship between wholesale electricity prices and penetration of renewable energy, i.e. the penetration of renewable energy reduces the price of electricity. In these markets, the price of electricity is equal to the operating cost or marginal cost of the most expensive power plant that is generating electricity in each moment. This price, nonetheless, does not reflect the total cost of producing electricity. Once a wind turbine or a solar module is installed, then whenever the sun is shining or the wind is blowing, the cost of producing electricity is (near) zero. Given this characteristic of renewable power generation, as its penetration increases, the marginal cost of production decreases and the price of electricity also falls. The integration of renewable technology is disrupting liberalized markets since these new technologies have very low marginal costs, leading to a decline in wholesale electricity prices.

> **"Markets should be designed to give you more money, the more flexible you are."**

Some developed countries with liberalized electricity markets have been developing renewable energy policies over the last decades, with high success in terms of increasing deployment.

The success of a renewable policy can be measured by three metrics:

- The cost involved.
- The amount of technology deployed.
- The speed at which it may be adopted.

All of these metrics are shaped by local market conditions. Attempting to meet all three objectives simultaneously is difficult. Each policy tool, such as feed-in tariffs, production tax credits, investment credits, etc., has pros and cons in terms of cost, quantity and speed. However, lower electricity prices lead to a higher policy cost or to lower levels of renewable deployment. The reason is that lower electricity prices result in lower revenues for power generators, a decrease in the return on renewable projects and, ultimately, a decrease in the deployment of renewables. Some policy tools provide a minimum and guaranteed price for renewable energy generators, sheltering their revenues from a decline in market prices but, at the same time, increasing the cost of the policy. The decline in electricity prices creates a renewable energy policy paradox: an increase in renewables penetration, resulting from the success of renewables policy, diminishes the effectiveness of the overall renewables policy, leading to higher costs and lower adoption.

Some policy instruments that promote renewable energy appear to be disconnected from electricity prices. This is the case for a constant feed-in tariff or what is known as a contract-for-difference. But even in these cases the cost of the policy increases as the price of electricity decreases. This is because the cost of the policy is the difference between the financial support for the technology and the real value of the technology, which is the exact price of electricity. It is true that under this approach the

"The decline in electricity prices and the increase in volatility, due to a successful renewable policy, ironically, reduces the effectiveness of this same renewable policy."

indirect positive effects of renewable energy may not be taken into consideration in the absence of a carbon price. However, this conclusion holds even when the positive effects are taken into account.

The current structure of liberalized electricity markets designed before widespread penetration of renewables is no longer ideal for the promotion of renewable energy and places a disproportionate burden on incumbent producers. By contrast, state-owned utilities with administered prices could integrate renewable energy in a less disruptive way. The key question is whether the benefits of competition outweigh the additional costs of incorporating renewables into liberalized markets — once rules have been modified to better manage the transition — when compared with public investment or regulation of a monopoly in electricity markets.

Potential Reforms to Electricity Markets

There is growing consensus about the necessity to modify liberalized electricity markets to integrate renewable energy, while maintaining their competitive structure. However, there is still no consensus about the best way to reform these markets, though some potential alternatives are being discussed. One possible reform of the market is based on the idea of rewarding renewable energy according to its levelized cost of electricity (LCOE) in the ancillary market, through a pay-as-bid system.

Relying on liberalized markets to invest in renewable technologies requires changing relative prices to promote investment or to attempt to price CO2, neither of which is easy. An alternative way of thinking about integrating renewable energy is as a public good that has to be provided by the government. With this approach, instead of trying to bend existing markets to encourage renewable energy, it should be looked upon as a public good, which lends itself to investment by the public sector.

"Renewable subsidies are like unemployment subsidies."

Another possibility for minimizing the negative impact of renewable energy on incumbent generators is via subsidies to fossil fuel generators, through capacity payments. However, if society is required to subsidize both renewable energy and fossil fuel generators, then the economic rationale for liberalized markets for electricity is questionable.

About the Workshop

KAPSARC convened its fifth Energy Transitions workshop in March 2016 with some 35 international experts to facilitate a dialogue on the progress of the framework we are developing at KAPSARC for understanding fuel and technology transitions. The workshop was held under Chatham House rules.

List of Participants:

Salvador Acha Izquierdo, research fellow, Imperial College London

Iqbal Adjali, senior research fellow, KAPSARC

Naif Alabbadi, director general, Saudi Energy Efficiency Center (SEEC)

Shahad Albardi, research analyst, KAPSARC

Mohammad Al-Enezi, director, Kuwait Institute for Scientific Research (KISR)

Malak Al-Nory, assistant professor, Effat University

Yasir Alturki, assistant professor, King Saud University

Carlos Batlle, senior associate research professor, Comillas

Leila Benali, corporate advisor, Saudi Aramco

Jorge Blazquez, research fellow, KAPSARC

Andrea Bollino, professor, University of Perugia

David Broadstock, associate professor, Research Institute of Economics and Management, Southwestern University of Finance and Economics

Aurélie Bros, associate research fellow, Russia/NIS Center

Rejean Casaubon, councilor, Institute of Energy Economics, Japan

Wei Du, deputy director, CNPC Economics & Technology Research Institute

Sameh El Khatib, assistant professor, MASDAR

Amro Elshurafa, senior research associate, KAPSARC

Antony Froggatt, senior research fellow, Chatham House

Rolando Fuentes, research fellow, KAPSARC

Richard Green, professor, Imperial College Business School

Lawrence Haar, visiting research fellow, KAPSARC

Lester Hunt, senior research fellow, KAPSARC

Hill Huntington, executive director, Stanford University's Energy Modeling Forum

Jose Labeaga, professor of economics, Universidad Nacional de Educación a Distancia

Bradley Liddle, vice president, Asia Pacific Energy Research Centre

Reinhard Madlener, director, E.ON ERC

Lawrence Makovich, Chief Power Strategist, IHS Energy

Andrew Mills, research associate, Lawrence Berkeley National Laboratory

Nora Nezamuddin, senior research analyst, KAPSARC

Francis O'Sullivan, director, MIT Energy Initiative

Daniah Orkoubi, economist, King Abdullah City for Atomic & Renewable Energy

David Ryan, professor emeritus, University of Alberta

Fiona Shepherd, energy policy manager, ScottishPower Renewables

Yves Smeers, professor, Université Catholique de Louvain

Stephen Thomas, professor of Energy Policy, University of Greenwich

Salvatore Vinci, deputy head, International Renewable Energy Agency

Yanjia Wang, professor, Tsinghua University

Matthew Wittenstein, energy analyst, International Energy Agency

About the Team

Shahad Albardi

Shahad Albardi is a research analyst working in the field of energy policy with a focus on renewable energy and its interaction with conventional fuels. She holds a BSc in Electrical and Computer Engineering from Effat University in Jeddah, Saudi Arabia.

Jorge Blazquez

Jorge is a research fellow specializing in energy and economics. He has a PhD in Economics from Universidad Complutense de Madrid.

Amro Elshurafa

Amro is a senior research associate working on renewable energy policy with a focus on the solar industry supply chain. Credited with over 30 papers and several patents, he holds a PhD in Electrical Engineering and an MBA in Finance.

Lawrence Haar

Lawrence Haar, PhD, is a senior research fellow at KAPSARC working on the financial economics of renewable energy.

Nora Nezamuddin

Nora is a senior research analyst, focusing on transition policy. She holds a BSBA in Business Administration and International Studies from American University, Washington, DC.

Tamim Zamrik

Tamim is a research associate specializing in energy transitions and policy design. He holds a PhD in Mathematical Finance from Imperial College London.

About the Project

The goal of this project is to understand how policy can expedite renewable energy transitions in a cost-effective way, while allowing competitive national industries to develop. In line with this objective, a wide range of policy instruments, designed and implemented to promote renewable energy, are being assessed. Furthermore, the project takes a holistic approach by analyzing how the competitive dynamics between renewable technologies and incumbent technologies evolve.

The workshop series, in line with KAPSARC's overall mission, fits into the overall project by providing a space for dialogue, collaboration, feedback on current work, and setting future research directions.

Notes

Notes

Notes

www.kapsarc.org