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King Abdullah Petroleum Studies and Research Center

Commentary

Testing the Limits of Electricity Market Design

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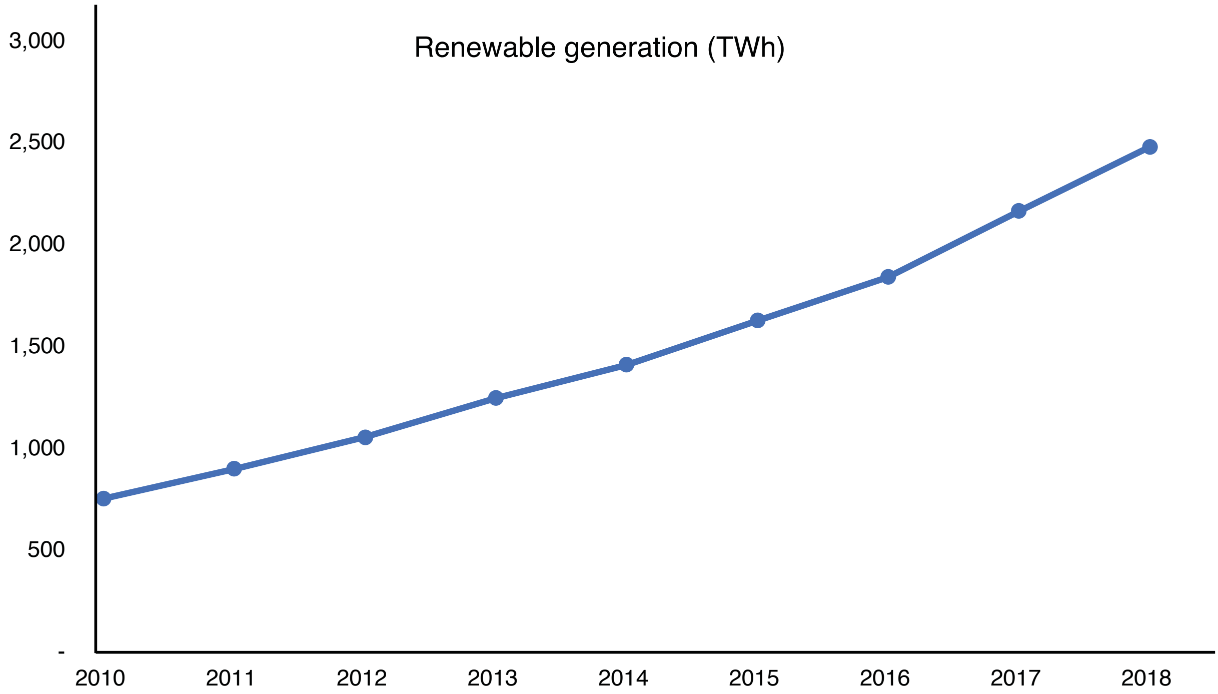
We live in an unprecedented time for the energy sector. According to the BP Statistical Review of World Energy 2019, electricity generated from renewable sources is at a historic high, with about 2,500 terrawatthours (TWh) produced in 2018 (Figure 1). This is more than three times that produced in 2010.

Figure 1. Renewable generation has tripled in the last decade.



Source: BP (2019).

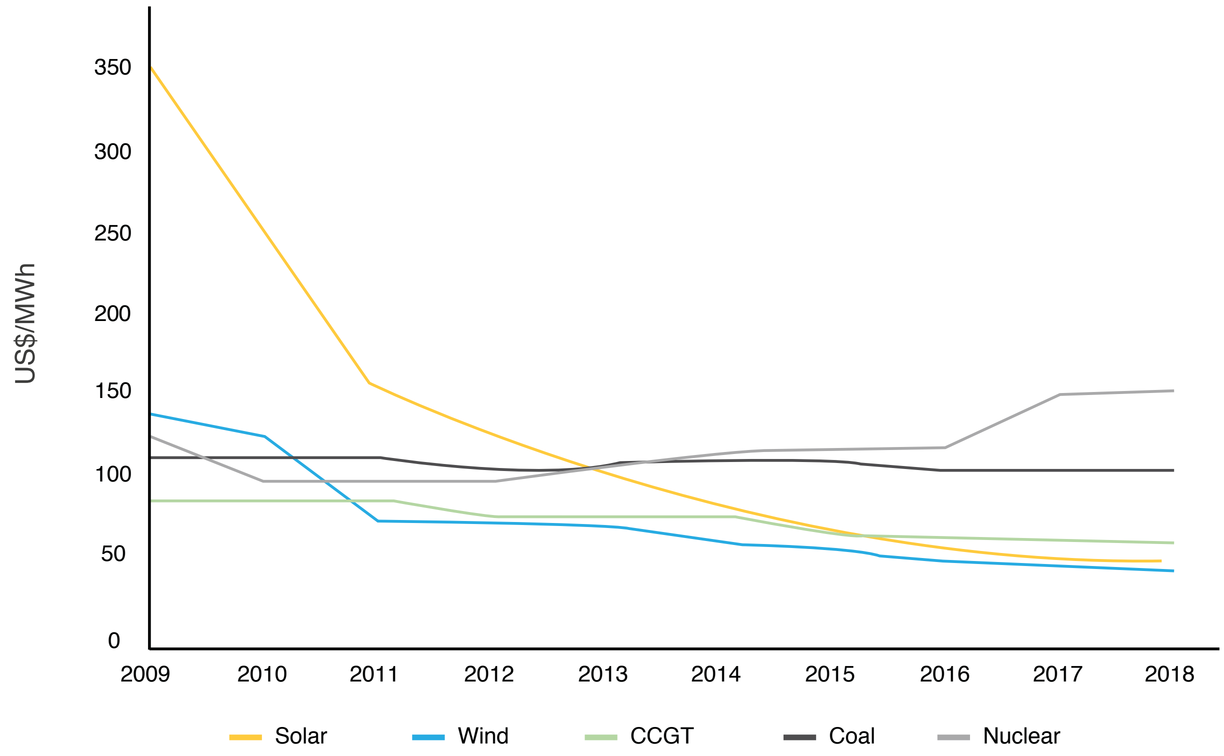
The costs of renewable technologies have fallen dramatically.

The costs of renewable technologies have also fallen dramatically. For example, the cost of solar photovoltaic (PV) technologies in 2010 was almost seven times higher than in 2018 (see Figure 2).

Thanks to these cost reductions, prices achieved at auctions for renewable capacity are frequently breaking world records, from Dubai and Saudi Arabia, to Mexico, Zambia and the United States (U.S.). These prices are frequently so low – around 2 U.S. cents per kilowatthour (KWh) – that *The Economist* has ventured to ask, What would happen if electricity was free? (The Economist 2017).

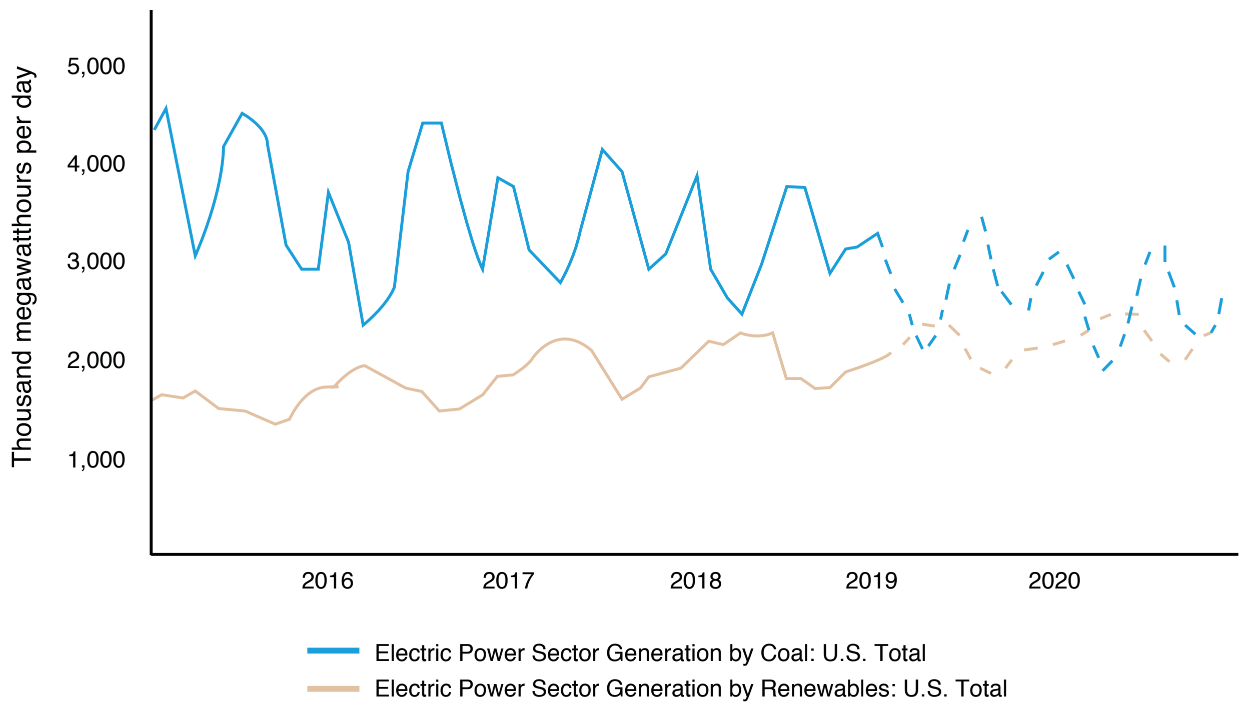
As a result of these cost reductions, the share of electricity produced by coal generation has fallen and been replaced with renewables. This is evident in the case of the U.S. (Figure 3) and the United Kingdom (U.K.). This shift has also led to outcomes that until recently were difficult to imagine. For example, during two weeks in May 2019, the U.K. did not use its coal plants at all to meet electricity demand.

Figure 2. The cost of solar PV in 2009 was seven times more expensive than in 2018.



Source: Solar Power Europe (2019).

Figure 3. Coal generation down, renewable generation up.

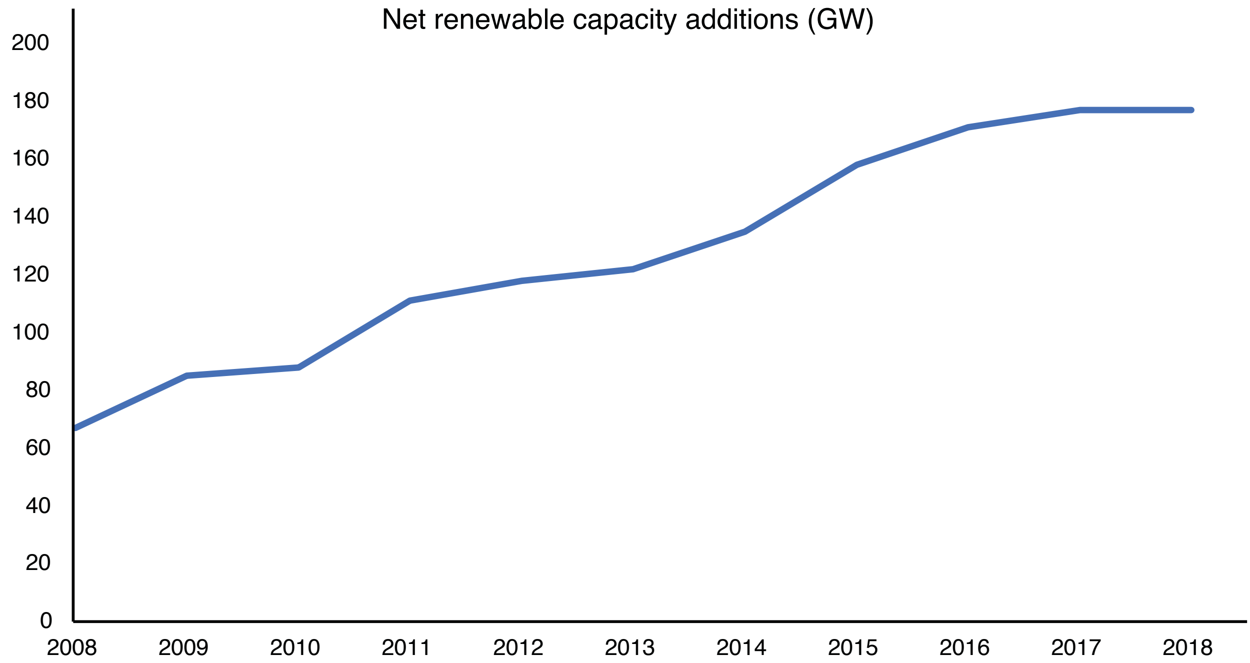


Source: U.S. Energy Information Administration (EIA).

We live in a time of massive, low-cost, renewable generation.

Our message thus far is that this is as good as it gets: We live in a time of massive, low-cost, renewable generation. The International Energy Agency (IEA) announced in May 2019 that, in 2018, new investments in renewable energy stagnated year-on-year for the first time (IEA 2019). This was driven by a loss of dynamism in solar and wind technologies.

Figure 4. New renewable capacity investment stagnated in 2018.



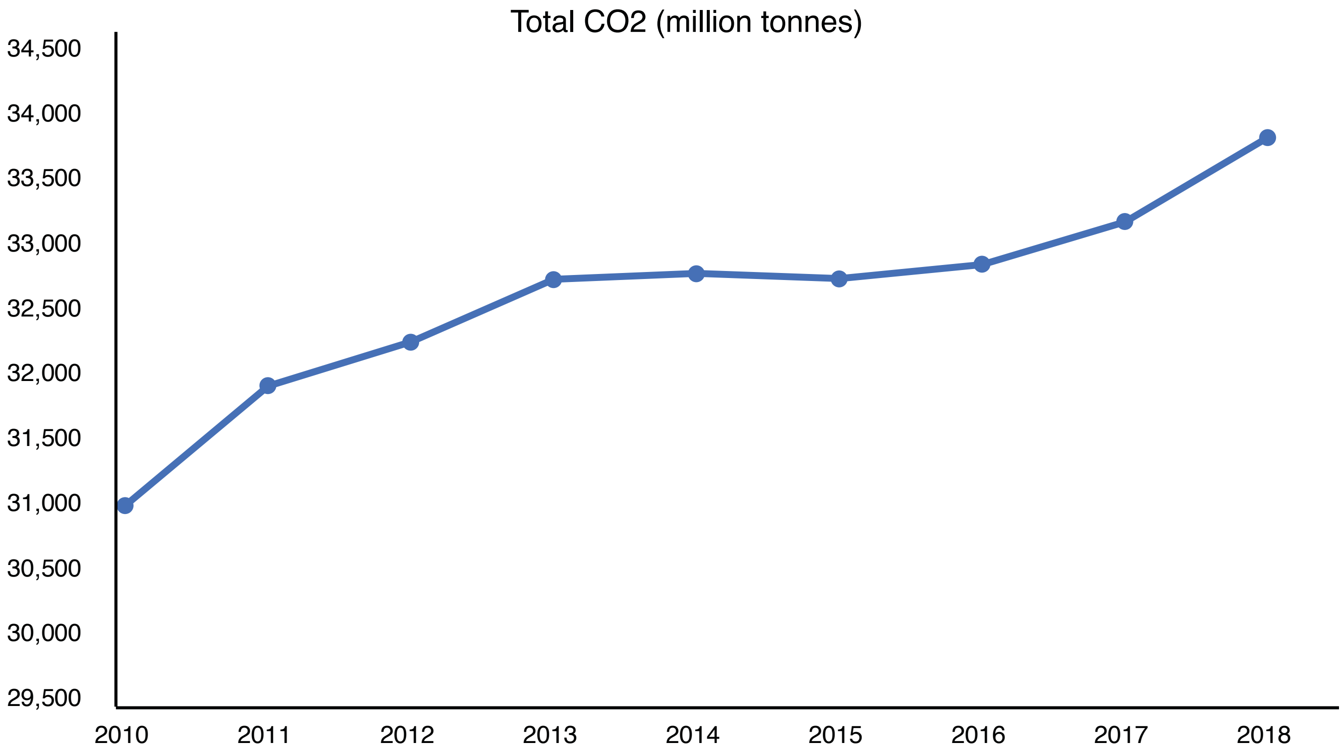
Source: IEA.

Carbon emissions have continued to grow at record levels.

A few months after the IEA's announcement, the U.K. suffered a massive blackout, the worst in a decade, which raised alarm bells about the reliability of its grid. The BP Statistical Review of World Energy 2019 also showed that carbon emissions growth has continued at record levels.

Why are alarming signals starting to appear? Our KAPSARC discussion paper, “The Renewable Energy Policy Paradox” (Blazquez et al. 2017a), anticipated the problems currently surfacing associated with renewable energy. We argued that they are due to a structural issue, explained, at least partially, by a paradox in renewable energy policy, in which the liberalization of the electricity market and a push policy for renewables are fundamentally incompatible. This paradox is the logical conclusion of a general framework that allows us to theorize the relationship between renewable technology penetration and the liberalization of the electricity market.

Figure 5. Carbon emissions continue to grow.

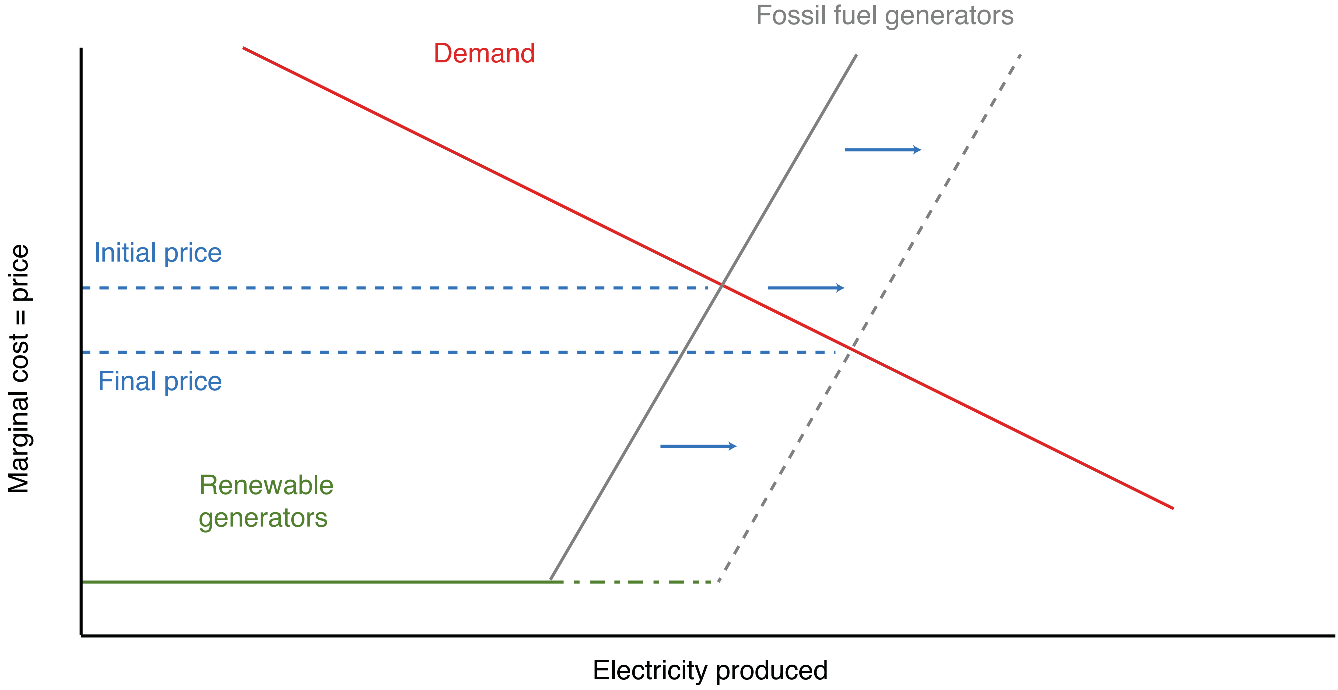


Source: BP (2019).

The paradox is characterized by the fact that a successful renewable energy policy may fall victim to its own success: The decarbonization of electricity sectors through the use of renewables will be more expensive and less scalable as the penetration of renewable technologies increases. Paradoxically, it is necessary to maintain thermal technologies in order to facilitate the penetration of renewable energies in the electricity market. This is because it is necessary to have a mode of generation that does not have zero marginal cost in order to establish market prices. The origin of this contradiction is that electricity markets are based on two fundamental assumptions. To recreate a supply curve, generation technologies should 1) have positive marginal costs and 2) should be able to control the quantity of electricity produced (i.e., technologies are dispatchable). Renewable technologies do not meet either of these requirements. Therefore, as the penetration of renewable technologies used for electricity generation increases, the more difficult it is to establish prices based on the marginal cost of production because it is zero for these technologies. Increasing this zero marginal cost generation would not necessarily reduce the cost of the system, but it would depress prices (Figure 6 [green line]). The intermittent nature of renewables would also make electricity prices more volatile (Figure 6 [gray dotted line]). Any asset whose future price is likely to decline, would, all else being equal, attract lower levels of investment. Increased price volatility means increased uncertainty. Investors generally demand high positive returns from their investments. Unless costs decrease faster than the combined effect of declining prices and lower rates of return, investments will stall.

A renewable energy policy may fall victim to its own success.

Figure 6. The supply and demand framework of renewable and fossil fuel technologies.



Source: Blazquez et al. (2018).

In a scenario of very high renewable penetration, prices fail to fulfill their ultimate function in economics, which is signaling scarcity for the two primary functions of the electricity sector, operations and investment. Imagine an extreme case where a given electricity market transitions from 99% to 100% renewable generation. Also, assume that this market sets prices efficiently at the level of the system's marginal cost. The resulting electricity price in this market would be zero if supply and demand coincided, or negative if demand was lower than the quantity offered (i.e., producers would pay consumers to consume electricity). This is clearly an economic anomaly: It violates the fundamental principle governing economic decisions that nothing is free.

Does this mean that governments must stop promoting renewables? The answer is no. The phenomenon that we are describing manifests differently depending on the initial conditions of a given electricity sector and the degree of penetration of renewable sources. For example, the Gulf Cooperation Council (GCC) countries are embarking on transforming their power sectors, with a dual agenda of liberalization and decarbonization. Sector liberalization, combined with renewable policies, can make it possible to avoid using oil for electricity generation. This could produce a triple dividend of economic efficiency and decarbonization in the short term and diversification from oil and gas in the long term (Blazquez and Fuentes 2018).

Every megawatt of installed renewables would save a certain number of barrels of oil from being consumed by an oil-producing nation (Blazquez et al. 2017b). This would confer macroeconomic benefits on oil-producing countries, which would more than compensate for the potential inefficiencies produced in their electricity sectors (Gonand 2016; Blazquez et al. 2017b). An inverse argument would apply to net fuel importers of gas, for example. These countries should be able to enjoy similar macroeconomic benefits, as they substitute imports with domestically produced renewable electricity.

The message of this commentary is that, structurally, and until new ways of organizing electricity markets are found, renewable penetration has its limits. Ignoring this message could lead to a stagnation in new investments and slower decarbonization of electricity sectors. Researchers at KAPSARC are working to find a market design that helps solve this paradox, to enable more efficient and cleaner electricity markets.

Researchers at KAPSARC are working hard to find a market design that enables more efficient and cleaner electricity markets.

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