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The renewable energy policy Paradox

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ABSTRACT

One major avenue for policymakers to meet climate targets is by decarbonizing the power sector, one component of which is raising the share of renewable energy sources (renewables) in electricity generation.

However, promoting renewables –in liberalized power markets– creates a paradox in that successful penetration of renewables could fall victim to its own success. With the current market architecture, future deployment of renewable energy will necessarily be more costly and less scalable. Moreover, transition towards a full 100% renewable electricity sector is unattainable. Paradoxically, in order for renewable technologies to continue growing their market share, they need to co-exist with fossil fuel technologies. Ignoring these findings can slow adoption and increase the costs of deploying new renewable technologies.

This paper spots the incompatibility between electricity liberalization and renewable policy, regardless of the country, location or renewable technologies. The Paradox holds as long as market clear prices with short term marginal costs, and renewable technology's marginal cost is close to zero and not dispatchable.

1. Introduction

Renewables with negligible marginal costs of dispatch – such as solar or wind – could fall victim to their own success after capturing large shares in liberalized power markets. Given existing liberalized market structures in most of the developed economies, future deployment of renewables could become more costly and less scalable because of their impact on electricity prices. Paradoxically, a too successful renewables policy could reduce the efficiency and effectiveness of future such policies.

In this paper, we ask to what extent concurrent policies of market liberalization and promotion of renewable technologies are compatible. Based on deduction reasoning we develop a general framework that permits us to theorize this relationship. Based on this approach, pursuing both policies are shown to be ultimately incompatible, regardless of the country, location, or type renewable technologies. This holds as long as the market clears with prices equal to short term marginal costs, and the renewable technology's marginal cost is close to zero, and is not dispatchable. This initial premise and resulting axiom are internally consistent and complete, which are postulated here as a foundation for future reasoning and empirical testing for different countries, market designs, and technological innovations.

Our postulate starts with the observation that current liberalized market mechanisms are based on two assumptions: positive marginal costs and the dispatchability of power (see for example [29,17]). Neither of these assumptions is applicable to renewable technologies -or at least to the most relevant ones: wind and solar- as they are largely intermittent, nonprogrammable and have almost zero marginal costs. These two characteristics explain why high market penetration of renewables leads to depressed and more volatile electricity prices.

In this scenario, renewables incentives become more expensive and lead to less deployment. Note that RES policy is setting progressively higher and higher targets. In 2008, the EU issued the 2020 Climate and Energy Package issued with a target of 20% of RES in 2020 [10] and more recently issued the 2030 Climate and Energy Policies Framework [11] with a target of 27% in 2030. In the US, NREL forecasts a target of 50% in 2050 [16].

Futuristic projections already envision the attainment of 100% RES share [13]. But based on existing market designs, 100 percent renewables penetration cannot be achieved because developers of renewable generation would be unable to earn a return on their investment without conventional technologies to provide a floor for electricity prices.

Our study suggests a potential theoretical and practical explanation for this puzzle:

- This paradox applies only to liberalized markets and not to centrally planned systems.
- Penetration of renewables capacity in the current configuration of liberalized markets has limits.

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- We focus on those renewable technologies that have the technological feature of having almost zero marginal costs and that have proven to be the most scalable types of technologies, wind and solar. If future developments allow to reduce these two technological features, zero marginal cost and intermittency, then the paradox may not hold.

Ignoring these findings can slow adoption and increase the costs of deploying new renewable technologies.

The rest of the paper is organized as follows: section two has a brief description of the functioning of liberalized electricity markets and the impact of renewable technologies on price formation. Section three explains why renewable technologies are difficult to integrate in liberalized markets. Section four explains the implications for renewable polices derived from the difficult integration of renewable technologies in liberalized markets. Section five explains the renewable energy policy paradox and explores the implications of the paradox. Section six presents our conclusions.

2. Electricity price formation in liberalized markets

Current liberalized electricity markets are the result of pro-market reforms that took place in the 1980s and 1990s to increase the competitiveness of the sector. Before the electricity system was previously organized as vertically integrated companies, as natural monopolies, and in most cases these were in public hands [20]. Liberalized spot electricity markets are designed using a marginalist approach. Existing power market designs operate on the assumption that electricity generation has a range of positive marginal costs that increase through some rank ordering, as is the case for thermal generators, based on technologies and fuel sources. This design is based on the construction of an efficient merit order through an implicit auction in the day-ahead market.

The market clearing price is set at the marginal cost of production of the last unit sold, which is the most expensive. In practice, power generators offer different quantities of electricity at various prices, which are ranked from cheapest to most expensive. Then, and for a given demand, the cheapest power plants supply electricity while the more expensive ones do not operate. Plants with marginal production costs that are lower than the market clearing price will be able to earn incremental revenues, which contribute to their fixed costs. The marginal plant will only be able to cover its variable operating and maintenance cost.

But this market design, when combined with the deployment of renewable technologies on a massive scale, is leading to a decline in wholesale electricity prices and an increase in price volatility, in particular in Europe. For example, Browne et al. [6] say that increasing wind penetration reduces spot market electricity prices due to the merit order effect in the short term. Clò et al. [7] conclude that solar deployment in Italy over the period 2005–2013 reduced wholesale electricity prices and amplified their volatility. De Vos [8] states that negative electricity prices result from a market distortion caused by renewable support mechanisms. Würzburg et al. [34] explore the impact renewable deployment in electricity prices in Germany and Austria. Paraschiv et al. [30] find that the deployment of renewable energies lead to extreme changes in electricity prices in the case of Germany. Dillig et al. [9] state that electricity prices in Germany, and also in Europe, dropped due to an excess of renewable energy. Azofra et al. [1] and Ballester and Furió [2] find that the renewable generation tend to decrease the price and tend to increase its volatility in the Spanish electricity market.

Fig. 1 explains the theoretical impact of renewable with a text-book model of electricity market. This figure shows that new renewable facilities “shifts” the supply curve, which in turn decreases prices. Given the intermittence of these technologies, the supply curve will increase and decrease depending upon climatologic conditions, which increases further the inherently –as large scale storage is not yet available- volatile electricity markets. The more penetration of renewables the larger the shift in the supply curve and the larger the price volatility.

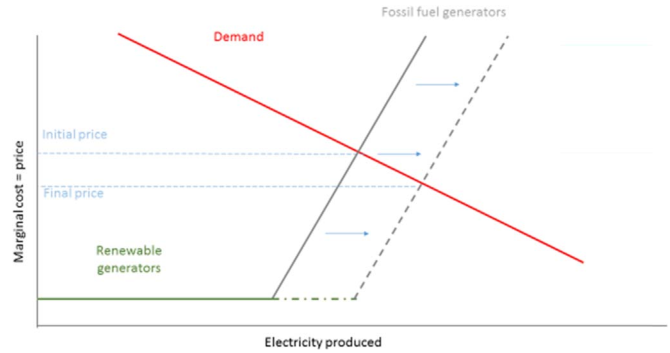

Fig. 1. Impact of renewable technology in liberalized electricity market.

However, this price drop does not reflect a true decline in the full cycle cost of producing electricity, though, but reflects the very low marginal cost of dispatch for renewables. This was not necessarily a problem in the context of vertically integrated utilities as they were more able to incorporate intermittent zero marginal cost output by distributing the costs within their overall rate structure. A liberalized market, on the other hand, makes this cost more transparent.

At the early stages of renewables deployment it was difficult to price the risk of these new untested technologies. Subsequently, more mature renewables entered the liberalized market and started to compete at almost zero marginal cost, with a relatively small and well-assessed risk, which investors found attractive. The rise of penetration of renewable technologies have been massive in recent years. According to the International Energy Agency [18], renewable deployment exceeded those of fossil fuels and nuclear for the first time in 2015. Currently, the world's renewable technology generation capacity at around 1 985 GW exceeds that of coal. The paradox is that Renewables’ success could also lead them to their downfall.

3. An analysis of the Paradox from the market side perspective

The paradox is that the same market design and renewables policies that led to current success become increasingly less successful in the future as the share of renewables in the energy mix grows. The renewable energy policy paradox results from the interaction between several factors, including:

- the (almost) zero marginal costs of renewables
- the intermittent nature of renewables
- the interplay between price volatility and renewable technologies.

The first feature above explains why renewables have priority of dispatch.[1] The structure of renewable technologies, which have a high levelized cost of electricity but almost zero marginal cost of production, gives renewable energy priority in the order of dispatch. However, renewable technologies are often not the cheapest in terms of total cost, not marginal cost.

This leads to a divergence between the true cost of the system and the evolution of price of electricity in wholesale markets, in markets with high penetration of renewable energy. To illustrate this point, we performed simple calculations for three European countries using Eurostat[2] data which show a sharp decrease in wholesale prices that

[1] One could argue that low marginal cost generation is nothing new in competitive whole sale markets. This is true and in fact is a key characteristic of baseload technology. But our argument is that it the combination of both, low marginal cost and intermittency, what makes this case different.

[2] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_204&lang=en.