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Rethinking how to support intermittent renewables

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ABSTRACT

Few intermittent renewable power projects would have been deployed if specific policy instruments had not been implemented. Common policy instruments include the feed-in tariff, the feed-in premium and the quota system. Based on a numerical analysis, this paper shows that these specific policy instruments do not necessarily facilitate the deployment of valuable energy sources because they ignore the cost of intermittency. A valuable intermittent energy source is defined here as a source of energy which requires little financial support and which limits the need for capacity payments in order to ensure the security of supply. Based on insights from the numerical analysis, a new policy instrument is suggested: a multiplicative premium. This type of policy instrument would be a least cost approach to securing a certain quantity of intermittent generation.

1. Introduction

Intermittent renewable energy generating technologies (e.g. wind and solar power) have a low carbon footprint and thus can be part of a larger solution to mitigate the anthropogenic impact on climate. In addition, such technologies can contribute to increased energy security if their deployment reduces the need for fossil fuel imports [27], they can reduce local air pollution [33] and they have the potential to address concerns on the projected depletion of fossil fuels.

Despite a continuous decrease in the cost of wind and solar power, intermittent renewable energy technologies are not competitive at current market prices [6] and few intermittent power projects would be realized without some type of support. As a consequence, specific policy instruments to stimulate investment in intermittent renewable energy technologies [9] have been put in place by countries seeking the benefits of these technologies.

The use of specific policy instruments directed towards renewable energy was found to be justified when a direct intervention such as a carbon tax, a first-best solution, may not suffice to stimulate enough deployment to generate learning which will lead to cost reductions [24,30], when a carbon tax cannot correct all externalities in the energy sector or when implementing a carbon tax is politically difficult [16]. Hence, a specific policy instrument is a feasible temporary pragmatic alternative to a first-best optimum [16].

Existing policy instruments can be distinguished between price-based (e.g. feed-in tariffs and feed-in premiums) and quantity-based instruments (e.g. quota systems, bidding processes) [24]. An issue associated to such policy instruments is that they are more complex to administer than a carbon tax [8]. As such, a significant amount of 'guessing' [19] is required from policy makers on the short and long-term costs and benefits of these technologies in order to make the policy instrument effective and efficient.

Many studies have concluded that feed-in tariffs have proven to be the most *effective* amongst the common policy instruments [1,4,8,24], because they provide the plant owner with long-term financial stability [20].[1] Nevertheless, a rapid development may not be *efficient*, especially if the policy instrument does not incentivize investors to build energy sources which deliver when energy is the most valuable [8].

Both effectiveness and efficiency of a policy instrument are traditionally measured in terms of the direct cost of energy and some researchers [8,9,15] are now suggesting a move towards instruments based on the realized value of energy instead. Two criteria shall be used in this study to define a valuable intermittent energy source: An intermittent source of energy is deemed valuable if it generates power during high-prices hours and if it limits the need for capacity payments implemented to guarantee the security of supply. The first criterion pertains to the direct cost of generating electricity, whereas the second criterion reflects the cost of intermittency. The emphasis is then put on how specific policy instruments perform at delivering valuable intermittent energy to the power system.

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[1] Effective policy instruments are those resulting in the rapid deployment of renewable energy supply.

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Based on a numerical analysis using historical day-ahead data for West Denmark, a general point made is that existing policy instruments do not necessarily reflect the value of energy and that there is consequently a need for a new system which will minimize the total cost of generation [17]. A uniform multiplicative premium is proposed, which would reward power station owners whose power production matches the market needs. Simple to administrate, such policy instrument would be more likely to facilitate the deployment of valuable intermittent renewable energy projects as the Danish example will illustrate. A multiplicative premium would be a least-cost approach to securing a given quantity of intermittent renewable generation.

The rest of the paper starts by theoretically defining a valuable intermittent source of energy in Section 2. Section 3 consists of a numerical analysis to determine how effective feed-in tariffs, feed-in premiums and quota systems are at facilitating the deployment of valuable intermittent renewable energy. An alternative policy instrument is proposed in Section 4. Finally, Section 5 concludes.

2. Definition of a valuable intermittent energy source

A number of authors have tried to define what a valuable intermittent energy project is. For instance, Ref. [9] defines a valuable intermittent energy source as a source of energy which production of electricity correlates with the load. Ref. [11] sees the market value of an intermittent energy source as the revenues a generator can earn on the market in the absence of subsidies. In a more advanced version, Ref. [17] thinks of the long-term marginal value of an intermittent power station as a function of the station's capacity factor and of the covariance between the production of electricity and the system marginal cost. The most valuable power projects are those which allow for a reduction of the capacity of dispatchable power plants while maintaining the same level of system reliability.

The definition of a valuable intermittent renewable energy project used here is closest to Ref. [17] and is based on two metrics: the spot price and the cost of intermittency.

2.1. Spot price

Each intermittent renewable power station has a unique electricity production pattern, which depends on the technology and the location. For example, some wind farms located along a coastline generate most of their power in the morning and late in the afternoon when thermal inversion between land and sea occurs. If the general production pattern of an intermittent power station is known, the exact production pattern is stochastic, for example by cause of changing wind, cloud coverage and temperature. These production patterns will match differently the market needs (i.e. the spot price), hence making some renewable power stations more valuable than others.

In the absence of policy instrument and costs being equal between technologies, the expectation on future spot prices would be sufficient to lead to the construction of the most valuable power projects. However, the lack of competitiveness of the intermittent technologies in the current electricity market has forced policy makers to implement some type of policy instrument in order to facilitate their deployment.

Since the price perceived by the plant owner depends at least partly on the policy instrument in place, the design of such policy instrument becomes important. For instance, the revenues of power projects built under a feed-in tariff[2] come solely from the policy instrument rather than being market-based. The numerical analysis will show that a feed-in tariff does not incentivize investors to primarily deliver power projects which generate energy when market prices are high. As a consequence, the energy delivered may be of limited value to the system.

2.2. Cost of intermittency

The second metric defining a valuable intermittent energy project pertains to the cost of intermittency. The security of supply requires that consumers can obtain electricity when they need it. Given the inherent characteristics of intermittent renewable energy, the security of supply cannot be guaranteed by solely relying on intermittent renewable energy [29,33]. Therefore, dispatchable capacity is needed to compensate for the intermittency of some technologies and balance demand and supply of electricity at all times. While the dispatchable capacity is still needed in the presence of intermittent renewable energy, the economics of the extant generation mix is likely to be negatively impacted [14].

The levelized cost of energy of a power plant can be calculated using:

$$\mathrm{LCOE} = \frac{\mathrm{Cc}\cdot R}{f\cdot H} + l\cdot\frac{\mathrm{Co}^{\mathrm{fixed}}}{f\cdot H} + \underbrace{l\cdot\mathrm{Co}^{\mathrm{variable}} + l\cdot\mathrm{Cf}}_{\text{marginal cost}} \quad (1)$$

where Cc is the capital cost, Co is the series of annualized fixed and variable operation and maintenance (O&M) costs, Cf is the series of annualized fuel costs, H is the number of hours in a year, R is the capital recovery factor, f is the capacity factor and l is a levelization factor.[3]

The marginal cost of producing energy for a thermal power plant is equal to the sum of the variable and fuel costs incurred to generate electricity. The difference between the marginal cost and the spot price then serves to cover the fixed variable costs and capital costs, and to generate a profit. As long as the average market price per unit of electricity sold exceeds the levelized cost of the plant, the plant owner will realize a positive return over investment.

Everything else being equal, the deployment of intermittent renewable energy will pressure the economic viability of the extant dispatchable capacity. This is because the deployment of zero marginal cost energy will force dispatchable power plants to curtail their production of electricity.[4] Such reduction in electricity production will force existing power plants to spread their fixed costs over fewer units of energy (in Equation (1), f diminishes), hence augmenting their levelized costs. Past a threshold, this situation may lead to the retirement of a number of dispatchable power plants. Assuming that some of these plants are critical to ensure that sufficient capacity is available in times of high residual loads, retiring dispatchable capacity will threaten the security of supply. In such situation, policy makers may be forced to introduce some sort of capacity payment mechanisms[5] to improve the economic viability of dispatchable power plants and ensure that these plants remain online [23]. These capacity payments are thus a consequence of the intermittency issue of some renewable energy sources [28].

The need for compensating a producer depends on the combined electricity generation profile of all intermittent renewables.

[2] A feed-in tariff is a policy instrument which guarantees a fixed price for every unit of electricity sold.

[3] More information on Equation (1) can be found in Ref. [31].

[4] Intermittent power stations impose no operational costs of producing electricity, whereas most dispatchable power plants do, mainly because of their fuel costs. This creates a merit order between the dispatchable and intermittent technologies [28].

[5] A capacity payment compensates an electricity producer for the capacity it has available and provides a revenue stream in addition to revenues generated by the sale of electricity.