**Economic analysis of energy vs. capacity focussed renewable support policies for the 2030 EU Power Market**

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## Overview

Policy makers across Europe have implemented renewable support policies with several policy objectives in mind. Among these are achieving ambitious renewable energy targets at the lowest cost and promoting technology improvement through learning-by-doing. Well designed subsidy mechanisms based on energy output are argued to be more cost-effective than capacity-oriented policies for achieving a certain renewable energy target in the short run (Meus et al. 2018). However, if learning-by-doing is a function of cumulative MW investment rather than cumulative MWh production, then policies that are tied to *capacity installation* rather than *energy output* might be more effective in reducing technology costs (Andor and Voss, 2016; Huntington et al., 2017; Newbery et al., 2018).

This paper addresses the cost and technology impacts of energy- versus capacity-based renewable policies using a detailed model of market-based generation investment and dispatch in Europe. The choice of capacity vs. energy-based subsidy could significantly affect the amount and mix of renewable energy investment, and its cost. In this paper, we ask what the outcomes would be in a much more realistic context – the European Union (including the UK, Norway, and Switzerland), accounting for varying market conditions, transmission limitations, and renewable energy development opportunities across Europe. In particular, we compare the impact of energy-focused (feed-in premium or renewable portfolio standard (RPS)) and capacity-focused (investment subsidies) renewable policies upon the EU-wide electric power market in 2030 using an EU-wide transmission-constrained power market equilibrium model. We also consider a more sophisticated variant of capacity-focused policy, promoted by Newbery et al. (2018), which would pay a per MWh subsidy, but only up to a maximum number of MWh per MW of capacity. The specific question we focus on is the following: *How do the different policies impact the mix of renewable and non-renewable generation investments, electricity costs, renewable output, the amount of subsidies, and consumer prices in the year 2030? Specifically, do capacity-based policies result in significantly more investment and possibly learning?* We also examine the interaction of energy and capacity policies with policies concerning trading of renewable energy credits across country borders. In particular, we evaluate the efficiency of national policy targets for renewable electricity production or capacity (as a whole or per technology) and compare these with a cost-effective EU-wide allocation of renewable energy investment, given resource quality, network constraints and the structure of the electricity system in the various EU countries.

We use a power market model in order to determine what renewable investments would earn from selling energy and the resulting net costs that the investment must then recover from subsidies. These net costs must account for the value of power at different times and places, which in turn depends on the simultaneous interaction of supply and demand throughout the network; analysis methods that focus only on renewable resource capital and operating costs will miss these crucial interactions.

## Methods

We use COMPETES, an EU-wide transmission-constrained power market model, which represents the EU 28 country market with 22 nodes, considering net transmission capability constraints between countries or regions. It uses a single linear program that is equivalent to a market with profit maximizing generators who invest and operate to maximize profits and a transmission operator who minimizes dispatch costs, all subject to policy constraints such as renewable energy or capacity targets and carbon prices. The calculated energy prices and renewable subsidies are the result of the clearing of supply and demand for energy as well as for renewable capacity or energy, depending on the policy. For practicality, we use a sample of 1200 hours (sampled from eight years of data from Gorm et al., 2015) to capture load and renewable output variability within a year, and a static (single year) equilibrium is calculated for the year 2030 rather than for a multiple year time horizon.

## Results

Fig. 1 compares the incremental cost of EU-wide renewable support policies achieving alternative levels of renewable energy and capacity targets with respect to a baseline scenario of no renewable policies. The renewable policies we consider, in general, assume a single EU-wide target without country-specific mandates, and furthermore assume that the same level of subsidy applies to all renewable sources.

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Fig. 1 Incremental generation cost/yr of meeting MWh vs MW targets under energy vs capacity policies

Although the capacity-focused policies result in similar costs for the less ambitious MWh targets, they become relatively more expensive as the targets get more ambitious. Using MWh feed-in premiums rather than capacity payments is cheaper because paying for the product that contributes directly to a desired target (MWh rather than MW) is the first-best way of meeting that target. We observe a reverse effect if the goal is instead to promote technology improvement through capacity installation. A capacity-focused policy is the cost-effective (first-best) way of reaching a certain capacity level for renewables, whereas achieving the same level of renewable capacity by an energy subsidy is more costly.

Furthermore, a higher carbon price motivates a greater penetration of renewables (53% of energy compared to 47%) without the need for additional subsidy. Second is that the inefficiency resulting from choosing one type of policy to meet a different type of goal is diminished. Fig. 1 (left) shows that the cost increase from using a capacity auction to meet an energy goal of 65% falls by more than half, from about €7B/yr (with CO2 price of €15/tonne) to less than €3B/yr (with CO2 price of €42/tonne) (right most points in the figure). Meanwhile, Fig. 1 (right) indicates that using an RPS energy-based policy to meet a capacity goal of 377 GW of renewable investments would cost about €3B/yr more than using a capacity policy under the lower carbon price, and only about €1.5B/yr more under the higher carbon price. Thus, our conclusion that there are inefficiencies on the order of a billion €/yr from using one kind of policy to meet an ambitious goal of the other type still holds, but the magnitude of the effect is less.

In sensitivity analyses, we also consider country- and technology-specific targets without trading renewable credits, consistent with present national targets compiled by ENTSO-E (i.e., Sustainable Transition (ST) scenario). This achieves a 52.7% EU-wide renewable electricity share with 225 GW of new renewable capacity investments at an incremental cost of 8.5 B€/yr compared to the baseline scenario. This cost is about *seven* times higher than the incremental cost of achieving the same level of renewable share by an EU-wide RPS mechanism (1.2 B€/yr). Moreover, the incremental cost of country-specific targets is *four* times higher than the incremental cost of achieving the same level of renewable capacity by an EU-wide capacity auction (2.0 B€/yr). In this case, an EU-wide capacity auction actually achieves a higher renewable share (54%) than the national targets. Roughly half of the cost increase is due to cost-ineffective technology mixes, and the other half is due to cost-ineffective locations.

## Conclusions

Our findings show that the efficiency of energy vs capacity-focussed renewable policies depends on the EU’s renewable energy goals. If the goal is to reach a certain share of renewable energy in total consumption, it is more efficient to use an energy subsidy to achieve a given renewable share target than to use capacity-based mechanisms. If the objective is to promote technology improvement through capacity installation, then it can be significantly less expensive to use capacity subsidy mechanisms to achieve a given capacity installation goal than to use an approach based on renewable energy subsidy. Moreover, the country-specific targets without renewable energy credit trading greatly increase the cost of renewable policies. Our analysis shows that there is considerable room for coordinating and improving renewable energy policies within Europe which will help reduce the total costs of realizing renewable energy production.

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