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Renewable energy scenarios for costs reductions in the European Union

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A B S T R A C T

In 2014, the European Commission proposed a new renewable energy sources (RES) target in energy consumption by 2030 “to be delivered collectively” by the European Union as a whole, leaving unresolved the question of allocation among member countries.

The aim of this paper is to propose and simulate a model of coordinated action among member countries based on two pillars, RES national binding targets and a quantitative cost minimization procedure based on a general translog function. We have considered RES national targets in three sectors: electricity, heating and cooling, transport. RES costs are differentiated according to learning-by-doing and RES productivity diffusion processes at the various RES production sites in the European Union. Three different scenarios are simulated and compared with the baseline case constituted by the 2020 cumulative RES target.

The results show that, compared with the baseline, the costs of achieving RES binding targets, with the proposed decision process, can be reduced by up to 13% by 2030. These cost evaluations indicate that it is more efficient to produce RES in those countries that face lower technology costs, according to the comparative advantages of their territorial localization and the importance of the initial RES policy efforts.

1. Introduction

Climate change has become an important pillar of European Union (EU) policies, aimed at accelerating the transition towards sustainable development and a future with a low emission of greenhouse gases [1]. The 2030 Framework represents the new EU energy and environmental policy for Climate and Energy Policies approved by the European Council [2], to drive the EU towards a low-carbon economy path, following the 2020 Climate and Energy Package.

The 2030 Framework sets new ambitious targets by 2030 for the EU, requiring to reduce CO_2 emissions at least 40% below the 1990 level, to increase the share of renewable energy source (RES) to at least 27% of the EU's energy consumption, to increase energy efficiency by at least 27%.

A controversial issue of the 2030 Framework for Climate and Energy Policies is represented by the means necessary to achieve the new EU target for the RES share of 27% in gross energy consumption, which is binding only at EU level but not for individual EU member countries. It differs from the previous 2020 Climate and Energy, as the new RES objective is a goal “to be delivered collectively” [2].

In order to ensure a better chance of success of such policy, the European Commission proposes the establishment of a regulatory framework of governance, based on national plans for competitive, secure and sustainable energy. These plans must be prepared by individual member countries through an iterative process involving at least the neighbouring states and be assessed by the European Commission in terms of their ability to meet the energy and environmental EU objectives. With reference to RES, national plans should set out a clear approach to achieve domestic RES goals. The National Renewable Energy Action Plans (NREAPs) represent an important instrument already in use within the Renewable Energy Directive for 2020 [3], adopted by each EU member country to reach the overall share of RES in gross final energy consumption and in the transport sector. The NREAPs contain measures and

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reforms to increase the proportion of energy use from RES, both reducing CO2 emissions and for the security of supply [4–6]. In particular, according to NREAPs, the share of RES is forecasted to increase from 14.9% in 2005 to 34.3% in 2020 in electricity consumption, from 10.2% in 2005 to 21.3% in 2020 in heating and cooling, from 3.1% in 2005 to 11.27% in 2020 in transport [7].

RES deployment offers great potential for sustainability and they may ensure a balance between economic, technical and environmental systems [8].

The effectiveness of the EU environmental policy depends to a large extent on its implementation at the national, regional and local levels. Several directives, regulations and decisions that influence these environmental issues are currently in force; however, the deficit in terms of their implementation and enforcement remains an important issue.

According to the recent literature [9], there are difficulties to achieve a coordinated governance mechanism due to political divisions among EU member countries, endangering the achievement of the RES target of 27% by 2030.

The discussion on RES support in Europe has a quite long history. Already in the context of the 2001 EU Renewables Directive (2001/77/EC) [10] which defined RES targets for 2010, several authors found that cooperation in RES could yield substantial cost savings [see among others [11,12]]. Voogt et al. [13] investigate cost savings for electricity supply from RES due to cooperation, quantifying the benefits of cooperation at the EU level for the achievement of the 2010 RES electricity targets. Some studies have analysed the implication of EU climate change policies for EU member countries in terms of cost effectiveness, exploring different scenarios for 2020 [14,15].

Recent literature has reported on the analysis of cooperation strategies and the achievement of RES goals beyond 2020 in the EU [16,17].

There is evidence that cooperation at the EU level would increase the cost effectiveness of RES deployment [18]. However, the actual support policies remain decentralized on the level of EU member countries and cooperation is scarce [9,19,20]. The IPCC [21] has highlighted that “existing and proposed international climate change agreements vary in the degree to which their authority is centralized”.

The aim of this paper is to design and simulate a model of coordinated action among EU member countries to reach the share of RES deployment by 2030, through an optimal cost-efficient allocation mechanism. Operationally, we define an optimal governance mechanism, which minimizes the total EU cost given country-specific unit costs. We provide a general methodology that is broad enough to be applied to other targets defined by the EU's environmental policies.

Our paper fits into the current literature by designing a model for the economic evaluation of the new 2030 EU energy policy, estimating different cost patterns that could be taken into account by EU institutions in designing RES policies.

The present study builds on data gathered from NREAPs for three sectors: the electricity sector, where we have analysed the electricity mix taking into account the main technologies that are photovoltaic (P), wind (W), biomass (B) and hydropower (H); the heating and cooling sector (H&C); the transport sector (TR[1]) of each EU member country [7]. The study intends to explore the relationships among the energy costs, learning-by-doing and productivity of RES technologies in relation to production sites.

Our policy proposal envisions an ambitious legally binding agreement of the European Parliament and the European Commission, as leading international bodies, for negotiating energy and environmental policies. This proposal fits. in the current debate on international cooperation and climate change mitigation [22,23], contributing with a general model to determine benefits from cooperation for the EU as a whole to 2030. Through the simulation of our model, we analyse the economic and environmental benefits of having a “centralized authority” defining 2030 RES biding target compared with the current RES policy envisaged by almost all Member States for the period up to 2020. Our results might be a useful basis for research studying cooperation mechanisms among countries to reach RES′ targets [19].

The paper proceeds as follows. Section 2 describes the method. Section 3 presents the results. Section 4 discusses the main findings. Section 5 concludes the paper and outlines policy implications.

2. Method

2.1. The model

We model a coordinated governance mechanism at the EU level as a legally binding agreement among member countries for RES deployment, which can be represented by a set of country preferences. These preferences are modelled assuming the existence of a EU social welfare (utility) function, which shows the aggregation of the preferences of member countries for the deployment of RES quantities given prices [24–27].

This model of optimal RES allocation in the EU explicitly takes into account that innovation and learning-by-doing cause costs to decline over time. Indeed, for many technologies, such as RES, unit costs decrease with the expansion of capacity and production [28,29]. This model relies on the positive effect of competition on innovation. A high degree of competition reduces pre-innovation rents, but then increases incremental profits once a firm innovates and becomes a leader [30–32].

Formally, the welfare function is:

$$W_j = (w_{ij}, E_{ij}) \tag{1}$$

where W_j is the aggregate measure of social welfare derived from the deployment of RES technologies j in the investigated sectors, where $j = P, W, B, H, H\&C, TR$; w_{ij} are specific preference weights in the welfare function; E_{ij} is the quantity of RES allocated to country i of the specific RES j where $i = 1,2, \ldots 27$. In the social welfare function the weights should incorporate the value judgement resulting from the country agreement about the relative importance of the individual members. In practice, this means establishing a metric that evaluates the importance of the contribution of each country to the EU emissions. In economics, duality theory allows for the equivalent reformulation of the preference structure of a social welfare function in terms of a new social cost function. Operationally, we minimize the cost function for RES deployment assuming a specific structure of local country unit prices, a specific EU preference structure and an overall EU quantity target. In this way the hypothetical EU coordinated governance mechanism is able to both maximize the social welfare to achieve the RES target and minimize the cost of deploying the same RES target. Standard economic theory allows for solving for the optimal vector of RES quantity using an estimated measure of the RES unit price.

Formally, there exists a cost function for each RES, c_j, derived from equation (1):

$$c_j = c_j(p_j, E_j) \tag{2}$$

where the total quantity of the specific RES is E_j; the price vector p_j

[1] We consider in TR the main technologies that are bioethanol and biodiesel.