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Geographic attribution of an electricity system renewable energy target: Local economic, social and environmental tradeoffs

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ABSTRACT

The 2014 Intergovernmental Panel on Climate Change (IPCC) report asserts that investment in low-carbon electricity production will need to rise by several hundred billion dollars annually, before 2030, in order to stabilize greenhouse gas concentrations in the atmosphere by 2100. In recognition of this urgent need to mitigate climate change, many governments have already established policies to spur renewable energy investment in the electricity sector. One such policy measure is a *renewable energy target* (RET), which sets a target percentage of electricity production to be generated from renewable sources by a specified date. Variations on this policy have been implemented around the world, from the EU 20-20-20 to diverse renewable portfolio standards in U.S. states and municipalities. This work analyzes economic, environmental and social aspects of a geographic attribution (*i.e.* Isolated, Regional or Country) of an RET to gain insights on the associated tradeoffs. In the case study of the Azores Islands, Portugal, the regional geographic attribution of an RET captures the best of all three tradeoffs.

Contents

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1. Introduction

In its most recent report (2014), the Intergovernmental Panel on Climate Change (IPCC) has, for the first time, specifically stated that investment in low-carbon electricity production is a "key measure" in climate change mitigation [1]. The IPCC (Table 1) stresses that investment in low-carbon electricity supply will need to support an increase from the current share of 30% production globally, to at least 80% by 2050. In order to achieve this goal, hundreds of billions of dollars annually, by 2030, will need to be invested in low-carbon electricity [1].

1.1. Renewable energy targets (RETs)

Climate change is an urgent problem, and political pressure to address it has already led to the development of numerous policy instruments to encourage investment in renewable energy. Many governments have issued renewable energy targets (RETs), which mandate that a certain percent of electricity production is generated from renewable sources by a specified date. The European Union (EU) famously enacted its EU 20-20-20 policy in 2007, which, among other targets, requires 20% of its total energy supply to come from renewable resources by the year 2020 [2]. In 2001, the Australian government implemented the world's first nationally mandated RET of 20% by 2020 [3].

In addition to the 27 EU member states and Australia, many major global players – including China and South Africa – have instituted RETs as policy tools to encourage investment in renewable energy. Though the United States (U.S.) does not have a federal energy policy, over half the states have implemented RET regulation, encouraging renewable energy development in the electricity sector. Two of the highest targets are in the states of Hawaii and California, with a 40% RET by 2030 [4], and a 33% RET by 2020 [5]. State-level renewable targets are so common [6] that the U.S. Department of Energy has established a database to track legislative targets and developments [7].

Table 1
List of abbreviations used throughout this paper.

Abbreviation	Description
ERSE	Entidade Reguladora dos Serviços Energéticos (Portuguese Energy Regulator)
EU	European Union
ETS	Emissions Trading Scheme
GEP	Generation Expansion Planning *model*
IPCC	Intergovernmental Panel on Climate Change
MAC	Marginal Abatement Cost *curve*
ReEDS	Renewable Energy Deployment System *model*
RET	Renewable Energy Target
U.S.	United States of America

1.2. RET policy analysis

Due to the worldwide prevalence of RET policies, work in several fields, including public policy [3,8,9], economics [10,11], and operations research [12], has been conducted to address the varying impacts of RET policies. To the best of the authors' knowledge, little analysis exists on how best to set an RET. Whether RETs are better set at the local, regional, or country level remains an unexamined question.

In practice, setting a renewable energy target is fundamentally political. Once an RET is agreed upon by the government, an analysis of the policy is usually undertaken, such as through a *Regulatory Impact Assessment* in the U.S., to ensure that the policy will not recklessly effect existing market players [13]. This type of evaluation typically involves *Marginal Abatement Cost (MAC)* curves, which are usually developed for a specific region and timeframe, to assess available technology options and associated costs. A recent study from the World Bank [14], however, asserts that MAC curves have a tendency to be misinterpreted, specifically when designing an RET policy. For an RET, it is usually most effective to implement the highest cost technologies first. The study also finds that RET targets set too low (below 25%) may be adversely effecting future investment in renewable energy, and hindering achievement of higher goals [14].

1.3. RET technical analysis

Despite the prevalence of RET policy and policy analysis, little has been done on the technical side to incorporate RETs into electricity system modeling for long term planning. Bird et al. [15] have used the U.S. National Renewable Energy Laboratory's (NREL) model, ReEDS [16], to examine the least-cost generation and transmission expansion plans under a renewable energy target policy, a carbon cap-and-trade policy, and a combination of the two. The highest RET considered, however, is 25%. Wave generation capacity is not considered as a technology option in their model.

Furthermore, to the best of the authors' knowledge, no studies have looked at the effects of the geographic attribution of an RET. The term *geographic attribution* defines the area (isolated, regional, or country) that must meet the target. Many RET policies are defined as a country goal, such as in China. Liu et al. [17] take the country RET for China and develop a model to decompose the national RET to the regional level. However, they do not determine whether the RET is best set at the isolated, regional, or country level.

Hiremath et al. [18] stress that socio-economic and environmental impacts should be evaluated by the model at the local level. Foley et al. [19] review numerous electricity system models and emphasize the need for electricity system models that can incorporate key policy changes, including targets to increase the share of renewable energy production. Zhou et al. [20] have