Applied Energy 187 (2017) 228–242

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Towards a comprehensive policy for electricity from renewable energy: Designing for social welfare

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HIGHLIGHTS

- RES-E support policy design space is systematically explored using 'design elements' and agent based modelling
- Bounded rationality is incorporated in investment decisions to reflect true uncertainty.
- Uncertainties significantly impact design elements, and corresponding RES-E schemes.
- Design elements matter, irrespective of the RES-E scheme.

ARTICLE INFO

Article history:
Received 1 July 2016
Received in revised form 6 November 2016
Accepted 9 November 2016
Available online 22 November 2016

Keywords:
Electricity market
RES-E policy analysis
Agent based modelling
Policy design

ABSTRACT

The governance of renewable electricity in Europe beyond 2020 is still uncertain. The only certain aspects are that national level targets will be abolished beyond 2020, and that most renewable electricity support schemes will take the form of competitive bidding. The objective of this paper is to assess the impact of policy choices, the so-called Design Elements, related to renewable electricity support schemes on social welfare. Presently, simulation and optimisation models are commonly applied for assessing the value of policy choice. Typically however, such models do not account for bounded rationality, and true uncertainty in investment decisions, and assume perfect information. However such assumptions can hardly be expected to hold in the real-world, especially in sectors where investment decisions which happen under knowledge of past trends and imperfect foresight, are a major determinant of welfare outcomes. The approach employed in this work is fundamentally different in that firstly, there is a shift from a 'policy' view to a 'design element' based approach of renewable electricity support assessment, and secondly investment decisions are simulated using agent-based modelling. We find that the combination of design elements that provides the highest increase in social welfare is the quantity warranty, with electricity market price accounted for ex-ante, and with technology specificity. Given the current debate on the governance of renewable energy generation in the European Union beyond 2020, the present paper offers guidance to policy makers and analysts who would like a better understanding of the relationship between policy design and social welfare.

1. Introduction

1.1. Motivation and research objective

In a recent article on the transition towards a green economy David Newbery [2] argues for the merits of a renewable support policy comprising of a Contract for Differences (CfD) with a standard Feed-in-Tariff (FiT) as opposed to a Premium FiT, proposed by the 2015 EU Energy Union Package [3]. It has been more a decade since the first Renewable Energy Sources (RES) directive, and the debate on how best to design support for renewable electricity is still raging. The European commission only specifies that there will be no national level targets beyond 2020, and that most Renewable Energy Sources for Electricity (RES-E support schemes should take the form of competitive bidding. It still remains to be seen whether these choices will lead to the triad of competition, sustainability, and affordability being achieved in the energy sector.

Since the first RES-E Directive was released in 2001, there have been numerous works that have evaluated renewable support schemes from theoretical and empirical standpoints; refer for

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http://dx.doi.org/10.1016/j.apenergy.2016.11.035
0306-2619/

Nomenclature

Abbreviations

NPV	Net Present Value
WACC	Weighted Average Cost of Capital
$WACC_{rev}$	WACC adjusted for risk aversion

Subscripts

$*$	asterisk in the exponent denotes equilibrium values.
g	power plant index
rep	repetition index per scenario
s	segment index
t	time step in years

Symbols

$a_{g,s}$	available capacity of power plant g, in segment s [in MW]
$CF_{Op,g}$	expected cash flow for power plant g, during operation [in Eur]
$fc_{g,t+n}$	fixed costs of power plant g, in time $t+n$ [in Eur/MW h]
I_g	investment cost of power plant g in t [in Eur]
K_g	nominal capacity of power plant g [in MW]
n	number of years ahead of current tick, for which value is being computed
n_{rep}	number of repetitions per scenario [1]
n_{tick}	number of ticks per repetition [1]
$p_{s,t+n}$	electricity spot market price for segment s, estimated at time t, for a period n years ahead
$payment_{g,t}$	payment of subsidy to RE producer for plant g at time t [in Eur]
r_D	rate of debt
r_{Eb}	basic rate of equity
r_{Ep}	price risk component of rate of equity
r_E	rate of equity
$r_{g,t+n}$	running hours of power plant g, at time $t+n$ [in hours]
$rGen_t$	total renewable energy generation at time t [in MW h]
t_b	power plant construction time
t_D	power plant depreciation time
$target_t$	total target for renewable energy generation at time t [in MW h]
$vc_{g,t+n}$	variable costs of power plant g, in time $t+n$ [in Eur/MW h]
$Xante_g$	total subsidy per MW h of generation for plant g, discounted to present value [in Eur/MW h]
$Xpost_g$	total cost per MW h of plant g, discounted to present value [in Eur/MW h]

instance [4,5,1,6,7]. Such literature so far on renewable support schemes has mainly focussed on comparing different policies[1] or support schemes [2] that have been implemented in various member states of the European Union (EU). The key here however is not a choice between policy A or B, but between how either policy instrument should be designed. This allows the policy maker such as the European Commission to decide what design features are essential in an RES-E scheme, rather than propose an entire scheme itself. This idea has been upheld by several authors such as [8–10].

We propose that any RES-E policy can be broken down into a closed set of components that are common to all renewable electricity support schemes. We refer to these components as 'design elements'; the design elements now form the smallest level of analysis. The objective of this research is to assess the impact of design elements of Renewable Energy Source Electricity (RES-E) support schemes on a single (isolated, uncongested) region modelled approximately similar to the power sector in the Netherlands, using a long-term agent-based model of the electricity market, with endogenous investment. We introduce the design elements in Section 2.1, and demonstrate that it is possible to model elements individually in Section 2.3. The policies are then modelled as combinations of design elements. The design elements analysed are *price warranty versus quantity warranty*, electricity market revenue accounted for *ex-post or ex-ante*, and *technology specificity versus technology neutrality*. The performance indicators in this study are effectiveness of policy in terms of cost and target achievement, and social welfare and distributional implications on producer, consumer, and the government.

The following subsection comprises of a review of literature in the field, and outlines how this work contributes to literature. This is followed by Section 2, which includes a detailed description of the methodology used: the design elements considered, the model, the hypotheses and experiment design. The subsequent section includes the results and their discussion. This is then followed by the conclusion.

1.2. Literature review

The current work relates to two strands of literature, one where RES-E schemes have been analysed, and the other where they have been modelled.

RES-E schemes have been compared analysed at great depth since the first RES-E directive. Recent literature in the field still indicates that policy comparisons dominate the field [2,11–14]. Nevertheless, perceiving RES-E support schemes in terms of design elements has been done qualitatively before by some authors. For instance, [15] and the beyond2020 project by [16] present a list of design elements for RES-E support schemes. Del Rio and Linares (2014) [8] provide an in-depth review of auction schemes for renewable electricity around the world; they identify and assess design elements of such auctions and propose a coherent integration of several design elements to improve auction designs. The design elements described in the above papers however are not common across all policies, thus still making them policy-specific; the disadvantage being that it is not possible to objectively analyse the impacts of specific features of a policy on the system. Also importantly, all the aforementioned works only qualitatively discuss design elements, but provide no quantitative analysis regarding their long-term dynamic effects and welfare distributional implications.

There have been several quantitative modelling efforts to evaluate the effectiveness of RES-E support schemes. Capros et al. [17] provide a detailed description of seven large scale EU energy economy models that have been used to model decarbonisation pathways. Works which use models that have simulated and quantitatively compared different RES-E support policies in some detail include the Green-X model [18], the REBUS (Renewable Energy Burden Sharing) model [19], the PERSEUS-RES-E (Programme-package for Emission Reduction Strategies in Energy Use and Supply-Certificate Trading) model by [20], and an

[1] Policy is a general term used to describe a formal decision or a plan of action adopted by an actor, such as the government, to achieve a particular goal.

[2] The word *policy* is used interchangeably with the word *scheme* in this work.