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REGULATORY DESIGN FOR RES-E SUPPORT MECHANISMS: LEARNING CURVES, MARKET STRUCTURE, AND BURDEN-SHARING

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Drawing from relevant experiences in power systems around the world, this paper offers a review of existing policy support mechanisms for RES-E, with a detailed analysis of their regulatory implications. While recent studies provide an account of current RES-E support systems, in this paper we focus on some of the impacts these mechanisms have on the overall energy market structure and its performance. Given the rising importance of RES-E in systems everywhere, these impacts should no longer be overlooked.

1 INTRODUCTION

In recent years, renewable energy sources for electricity (RES-E) have gained importance in electric power systems. These technologies are growing steadily to occupy a key role in electricity generation. Consider that in 2009, 60% of newly installed capacity in Europe came from RES-E. (REN21, 2010). Note that the European Commission's Directive 2009/28/EC establishes "mandatory national targets consistent with a 20% share of energy from renewable sources and a 10 % share of energy from renewable sources in transport in Community energy consumption by 2020." At national level in 2010, just to mention some of the most paradigmatic examples, in Denmark wind accounted for 20% of the gross electricity production (Danish Energy Agency, 2011), in Germany (BMU, 2011) RES-E's contribution to electricity supply was close to 17% (wind amounted for roughly a third of it),

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Spain relies on wind to supply over 15% of electricity (CNE, 2011) and in Texas wind represented 7.8% of the energy supplied (ERCOT, 2011).

RES-E's crucial role, particularly in EU's electricity sector, is expected to be even more important in the near future: for 2020, the Danish Government (2011) announced that more than 60% of electricity production will have renewable origin, while the target of the German Government (BMU, 2011) is a 35% share of RES-E in total gross electricity consumption and the Spanish government expects RES-E to contribute 42% of total electricity demand (MITyC & IDAE, 2010).

Yet, the still comparatively higher cost of RES-E technologies (as well as other impacts, as for instance on the grid structure or the system dispatchability) have made it virtually impossible for them to grow without regulatory intervention. There is still considerable uncertainty among governments and regulatory agencies about the kind of policy framework needed to manage the incorporation of these technologies into the larger generation mix of a country or region. Support mechanisms for RES-E are colliding with existing economic and industrial policies much more frequently; this clash often reflects political sensitivity to voters' perceptions and stakeholders' interests. More tangible concerns include the potential for RES-E to displace older and more polluting technologies, the impact costlier RES-E can have on energy prices, and the effects that the stochastic nature of some of the renewable fuels has on the delivery of electricity. Thus, while in this last decade the RES-E technology learning has been very important, the regulatory learning has not been so pronounced, and a large number of crucial regulatory questions are still waiting for a proper response.[1]

[1] See Pérez-Arriaga (2011) for a discussion of how power systems can properly manage large scale penetration of intermittent renewables and also some of the regulatory implications.

Prominent among these unsolved issues is how best to design subsidy regimes to ensure the proper development of RES-E. Currently, there are two different types of support methods:

- Indirect methods, i.e. implicit payments or discounts as well as institutional support tools that include: research and development funding, below-cost provision of infrastructure or services (costs of technical adaptations such as shadow connection charging (Auer et al., 2009) or costs of imbalances and ancillary services in general),[2] and positive discriminatory rules (such as regulations facilitating grid access for RES-E power, RES-E dispatch priority in the EU and other: net metering, building codes, etc.).

- Direct methods— these methods refer to investment supports, such as capital grants, tax exemptions or reductions on the purchase of goods and operating support mechanisms, i.e. price subsidies, obligations, tenders and tax exemptions on production (Commission of the European Communities, 2008).

Drawing from relevant experiences in power systems around the world, this paper offers a review of existing policy supports for RES-E, with a focus on direct methods. We provide a detailed review of the different schemes and design features implemented to date, keeping an analytical distinction between the two categories for direct methods: price-based supports, which fix the price to be paid for renewable electricity, and quantity-based supports, which determine a specific amount of electricity to be produced by RES-E. While recent studies

[2] For instance, in Italy, RES-E receive remunerations at the spot market price, but, in contrast to Spain's wind markets, Italian generating units are exempt from paying the cost of their imbalances in the short term. Incidentally, this provides them with a negative incentive to underestimate the expected production to be declared in the day-ahead market, since this bias increases the spot market price thus ensuring a higher remuneration. RES-E generating units need not worry themselves with penalties or the correction of imbalances that must take place in the secondary markets. Similar issues have been observed in Spain in the case of reactive control services (Imaz, 2007).

provide an account of current RES-E support systems, in this paper we focus on the impacts that these mechanisms have on the overall energy market structure and its performance in the short- and long-term. Given the rising importance of RES-E in systems everywhere, these impacts can no longer be overlooked.

2 RES-E DIRECT REGULATORY SUPPORT SCHEMES

2.1 Price-Based Mechanisms

2.1.1 Feed-in-Tariffs

The basic feature of feed-in tariffs (FIT) is to guarantee RES-E generators a specific price per MWh that is produced. To encourage development of new RES-E capacity, FIT must be high enough to ensure long-term recovery of costs for a given technology. In most power systems, FIT apply for at least during 10 years; in some cases, support is guaranteed for as many as 30 years. According to the most recent REN21 Global Status Report, by 2010 at least 50 countries and 25 states and provinces had instituted FIT supports for RES-E generators.

FIT have been in place for a good number of years now. As a result, FIT have progressively incorporated a variety of rules into the basic, original design, namely:

- Regulatory agreements or contracts: in some cases the FIT just takes the form of a regulatory commitment that is embedded in some law or specific decree (as is the case in Spain). The regulator defines a price to be paid for each megawatt hour produced and undertakes to pay this price for a number of years, but there is not a contractual endorsement with an explicit counterparty. In other cases, such as Germany, the FIT mechanism, besides being enacted in a law, it takes the form of a supply contract that has the System Operator as counter-party (Lipp, 2007).

- Flat or stepped tariffs[3]: The cost of RES-E development can vary greatly depending on the choice of technology (wind vs. solar vs. biomass) and other characteristics such as siting or scale (e.g. onshore vs. offshore wind). For this reason, some governments offer so-called "stepped" tariffs—differentiated levels of remuneration according to the RES-E profile.[4] Tariff levels can be defined according to (mainly) technology, location or plant size. As stated in Brown et al. (2009), the chief aim of stepped tariffs is to try to minimize the "risk of overcompensating plants with efficient technologies or scale (excessive rents) and to reduce the cost of support or burden for consumers", in other words, the goal is to equalize profitability across technologies and scales. While it may appear sensible to distinguish among technologies such as wind or solar PV (a single tariff for all of them would lead to exploiting just the most cost-efficient technology in the short term)[5], applying stepped tariffs *within* a single technology according to plant size lead to significant inefficiencies, while due the consideration of additional social criteria discriminating according to location (e.g. PV in rooftops or marginal areas vs. productive ground) could make sense in certain contexts. Aside from the fact that differentiation significantly complicates the tariff-setting process, stepped mechanisms applied to a single technology (for example decreasing the payment as the capacity factor of the unit increases) also minimize the potential for tariffs to send an efficiency signal to market players, since these tariffs mitigate the incentive to invest in the most efficient alternatives first.

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[3] See Klein et al. (2008) for a detailed analysis.

[4] For instance, in Germany, FIT for rooftop solar PV vary depending on the size—up to 30 MW; between 30 kW and 100 kW; above 100 kW; and above 1,000 kW.

[5] Although there are many others, as for instance developing a local industry, it is important to note that the main objective of RES-E support mechanisms should not be to encourage the deployment of a single technology (e.g. the cheapest) in the short-term, but rather to improve the learning curve of a variety of RES-E types. This is because it is never clear which of RES-E type will become the most efficient in the long run.

- Constant or decreasing payment stream: FIT can follow either a constant or a decreasing payment structure through the contract period. In Germany, FIT for solar PVs maintain the same level of remuneration with contracts that usually last 20 years. In contrast, an alternative model is to design a larger payment in the first years of operation and reduce it progressively afterwards. This solution helps to reduce the need for substantial project finance. Sometimes, the reduction is proportional to the plant's performance in this first period, again with the goal of mitigating "excessive" rents.

- Tariff degression: in this approach remuneration for RES-E generators is scheduled to decrease overtime either at a pre-determined rate or according to the capacity that gets installed. There is considerable difficulty in correctly identifying the starting point for degression and the degression rate, especially if RES-E projects experience delays and changes in their long-term expenditures. Some countries, like Germany, set annual degression rates; percentage decreases are also technology-specific. Spain's degression rates are determined by the National Energy Commission (CNE) and applied not annually but every three months.[6] Degression is implemented as a way to counter RES-E energy surplus and is a reasonable way of preventing disproportionate deployment of a particular RES-E technology. As far as the general public opinion goes, disproportionate deployment fuels many of the political arguments against renewables—that it is too expensive, that supports are too generous, that RES-E places too much of a tariff burden on final consumers, etc.[7] On the other hand, degression can nonetheless pose a significant regulatory risk for investors: if the degression rates change during the project

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[6] Photovoltaic energy tariff for ground-based plants has been reduced every three months since 2008, decreasing by 60% between 2008 and the second quarter in 2011.

[7] This problem would not be as significant if the investors involved in RES-E were publicly owned entities. This is the case in Denmark, where 75% of RES-E market participants have some form of public participation.

development process, investors may not be able to meet their originally expected return requirements. This significantly increases RES-E investors' risk aversion in the following stages, increasing financing costs.

Some countries have begun to attach additional requirements to existing FIT regimes. For example, in Denmark, remuneration for renewable power is offered only if RES-E owners provide financial participation to property owners in the lands surrounding the plant site.

2.1.2 Feed-in Premiums

Feed-in-premiums (FIP) are payments guaranteed to RES-E generators on top of existing electricity market prices; thus, FIP operate much like a kind of 'renewable' capacity payment, although paid on energy basis, a sort of price uplift as it was the original mechanism implemented in the UK pool in the 90's. Similar to FIT, these premiums are valid for a specific contract period.

In Spain, as proposed in Pérez-Arriaga et al. (2005) and afterwards mandated by the Royal Decree 661/2007, premiums are offered only within a specific range, i.e. they have a floor and some sort of a cap.[8] In the case of Finland, the new subsidy scheme established in January 2011 consists of a FIP payable for 12 years, according to which wind installations receive the NordPool market price plus the difference between a target price (83.5 EUR/MWh, 105.3 €/MWh if the installation enters in operation before the end of 2015) and the average of the spot market price in the last 3 months (Holttinen, 2011).

[8] In the case of wind, the remuneration cannot fall below 73 EUR/MWh (which includes both the market price plus the premium); the premium is set to zero when the market price is above 87 EUR/MWh.

2.1.3 Fiscal Incentives and Other Price-Based Mechanisms

Tax Incentives

A variety of fiscal incentives usually complement RES-E support mechanisms. In the United States, this type of incentive is best exemplified by the Modified Accelerated Cost Recovery System (MACRS). Under MACRS, the U.S. government offers an accelerated depreciation schedule over a 5-year period to most RES-E technologies: solar PV and solar thermal, fuel cells and micro turbines, geothermal electric, direct use geothermal and geothermal heat pumps, small wind, and combined heat and power. Some biomass facilities are eligible for 7-year depreciation schedules, see DSIRE (2011). Other tax-based incentives include tax exemptions offered to RES-E generators on the basis of installed capacity as well as total renewable energy production. For instance, in Finland, the tax on fuels is determined on the basis of their carbon content (Ministry of Employment and the Economy, 2011).

In China, the central government introduced the "Implementing Regulations for Enterprise Income Tax Law" in January of 2008. The law provides a 3-year tax exemption for enterprises developing projects focused on renewable energies and energy conservation technologies. Following the exemption period, these companies are also eligible for a subsequent 3-year period in which their income taxes are set at only 50% of the regular level (Ma, 2011).

Tax credits are a popular form of support in countries such as the United States (Schmalensee, 2009) and South America (Batlle & Barroso, 2011). The U.S. Federal Production Tax Credit program (PTC), originally created under the 1992 Energy Policy Act and renewed under the 2009 American Recovery and Reinvestment Act (ARRA), offers credits to RES-E generators over a 10-year period on a per-kWh basis (e.g. US$21/MWh for wind until the end of 2012). Eligible technologies include landfill gas, wind, biomass, hydroelectric, geothermal, solid waste, small hydroelectric, among others; solar technologies are excluded.

Aside from PTC, ARRA offered an additional support: Investment Tax Credits (ITC) that alleviate some of the development costs associated with new RES-E generation by reducing the regulatory risk linked to PTC. Since the tax credits apply to profits, they can be significantly less valuable for those developers who are not especially profitable, since, for these developers, taxes on income are comparatively low. For this reason, the U.S. Department of the Treasury offers cash grants to new RES-E developers. Both ITCs and cash grants apply to up to 30% of total costs.

Investment Incentives

There are other types of cash supports for RES-E developers. For example, investment subsidies offer upfront payments whose amount depends on the total installed capacity. In the U.S., all states provide some form of investment subsidy for RES-E (Schmalensee, 2009).

Financing Incentives

Additionally, soft loans are offered across a variety of administrative scales; governments such as Costa Rica have soft loan programs, while, on the other hand, the Inter-American Development Bank (IDB) has committed over US$1 billion in loans for renewable energy development in the Americas, including over US$900 million for hydropower and US$9 million in technical assistance grants (REN21, 2010). These loan programs usually have attractive features such as below-market interest rates and long repayment periods. Finally, some countries enact import duty restrictions in support of local RES-E developers.

2.2 Quantity-Based Mechanisms

2.2.1 Renewable Portfolio Standards

Renewable Portfolio Standards (RPS), also referred to as tradable green certificates (TGCs) or renewable obligations (ROs) in the EU, establish quota requirements for consumers, suppliers, and/or generators to ensure that a portion of their electricity comes from RES-E. Tradable certificates are awarded for every unit produced from RES-E; these certificates are then bought by those required to comply with the RES-E quota.[9]

Several options exist in the design and implementation of RPS:

- Non-compliance penalties: to enforce observance of RPS, countries such as Sweden have set buy-out penalties equivalent to 150% of the RES-E certificate price, the revenues of which are passed on to RES-E generators. In Chile, a fine of US$28/MWh applies if the requirement is not met; if there is a repeated lack of compliance over a three year period, the fine rises gradually up to US$42/MWh. In the US, most states have also alternative compliance payments.

- Banding provisions: as implemented in the United Kingdom, RPS requirements are set up differently depending on the source RES-E technology; see Department of Energy and Climate Change (2011). The objective is to ensure an overall push for RES-E by providing higher levels of support for higher cost technologies ("banding up") and to gradually decrease support for lower cost technologies ("banding down"). Support usually comes in the form of tradable certificates. For example, geothermal will receive more certificates per

[9] In some cases, the tradability of the obligations varies: in the US, for instance, the state of Colorado allows buying certificates all across the United States, while Texas allows in-state trading only.

MWh than wind; offshore wind will receive more certificates per MWh than onshore wind.

- Long-term contracting obligations: localities such as California, which has one of the most aggressive RPS schemes in the U.S., have attached long-term contractual obligations to these standards. The state requires stakeholders to source renewable energy from certified units for periods as long as 20 years.

- Minimum prices: RPS regimes can often add an additional support for RES-E through the establishment of minimum prices for renewable certificates, thus guaranteeing revenue safeguards to RES-E producers.

While not as prevalent as price-based mechanisms, RPS are nonetheless currently in place in at least 10 countries and 46 states and provinces. In the U.S., RPS have only been implemented at the state level; 29 states plus the District of Columbia have mandatory regimes and an additional 7 have set non-binding requirements.[10] At the federal level, there have been more than 25 unsuccessful attempts to establish a comprehensive RPS regime over the last decade (Till, 2011). In early 2011, President Barack Obama's administration announced the goal of doubling the share of clean electricity within the next 25 years. According to the Obama administration, "clean energy" currently accounts for 40% of total electricity. This assertion requires some qualification. According to the 2010 Clean Energy Act, the term "clean energy" refers to a wide variety of options, including solar, wind,

[10] In the U.S., RPS are considered to be a crucial mechanism to more efficiently and quickly deploy RES-E. Yet, it is worth noting that in Texas, often referred to as the paradigmatic example of success in the U.S., RPS appear not to have been the key factor. Overall RPS targets for the year 2025 (10,000MW) were met in 2010 by wind facilities alone—15 years head of schedule. As pointed out by the Texas State Energy Conservation Office (2011), there have been other explaining factors, such as competitive pricing, federal tax incentives, and the state's immense wind resources.

geothermal, ocean energy, qualified waste-to-energy, qualified nuclear (if the unit was incorporated on or after the 2010 Act), advanced coal generation, eligible retired fossil fuel generation, as well as any other clean energy source based on innovative technology "as determined by the Secretary" (U.S. Congress, 2010).

Additionally, there are proposals that seek to implement tradable "clean energy certificates" that could be awarded to generating units according to their efficiency and level of greenhouse gas emissions level. For example, combined cycle gas turbines would be less clean than wind or nuclear generation and receive fewer certificates. If the criteria used to define "clean energy" generation and to allocate the tradable certificates are based on carbon emission rates, then this approach yields similar results to CO2 emissions allowance-trading schemes.

2.2.2 Competitive auctions

Through auctions (tenders), governments and regulators set the amount of renewable capacity to be built during a specific period and carry out a bidding process in order to find the least-costly, most attractive offer from RES-E generators.[11] The winner of the bid is usually offered a long-term contract for the production of renewable electricity, thus reducing the uncertainty for RES-E developers while simultaneously helping regulators meet their own capacity growth objectives.

As it can be read in NYSERDA (2011), 'New York's RPS program uses a central procurement model, with NYSERDA as the central procurement administrator. (...)

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[11] Auctions are always categorized as quantity-based mechanisms, given that bidding processes begin only after regulators have set a specific capacity goal. However, in many cases, energy authorities determine a quantity-price curve that applies to the RES-E technology, keeping the ability to acquire more or less quantity, depending on the bids received.

NYSERDA pays a production incentive to renewable electricity generators selected through competitive solicitations for the electricity they deliver for end use in New York. In exchange for receiving the production incentive, the renewable generator transfers to NYSERDA all rights and/or claims to the RPS attributes associated with each MWh of renewable electricity generated.'

Auctions can be size- or technology-driven,[12] as it is the case of Brazil,[13] and also can be combined with other mechanisms. In Uruguay, winning bidders must incorporate locally manufactured content into the RES-E project.[14]

3 ANALYSIS OF RES-E SUPPORT MECHANISMS: PROS AND CONS

Below we provide an analysis of direct support mechanisms. We keep a special focus on the impacts that each regulatory design has on the overall energy market structure and the potential benefits and barriers that may result in each case.

[12] The state of California has set up the Renewable Auction Mechanism (RAM), a mechanism for renewable distributed generation (DG) projects up to 20 MW on the system side of the meter, see California Public Utilities Commission (2010).

[13] In the Brazilian case, RES-E technologies are entering the system through competitive long-term auctions, which have taken many different forms (Batlle & Barroso, 2011). Brazil has implemented auction rules that are meant to favor specific technologies, such as biomass; their bids are multiplied by a factor smaller than 1, thus reducing their costs and making these RES-E more competitive (Batlle & Rodilla, 2010). Peru has implemented a similar solution. In recent long-term auctions, bids from hydro plants were de-rated to make them more competitive.

[14] This is also the case of the FIT implemented in Ontario.

3.1 Price-based Mechanisms

3.1.1 FIT.

Pros

Guaranteed remuneration from FIT provides long-term certainty for RES-E developers, who are thus no longer exposed to risks associated with electricity market prices.[15] In addition, unlike quantity-based mechanisms such as RPS, FIT do not expose RES-E developers to risk in the certificates market, since there is no competition among RES-E providers (see RPS section below for a discussion of this type of risk).

FIT provide the appropriate kind of support for RES-E technologies that have moved beyond the R&D phase but that have not reached market maturity and a strong presence in the system. In other words, FIT can go a long way to foster the commercial viability of RES-E technologies. Conversely, in these recent years technologies such as solar PV have very rapidly had access to FIT in numerous countries; demand for PV panels has boosted way faster than what it would have been needed to realistically improve the technology learning curve. Thus, this has resulted in conditions of over-support and overpayment for PVs, to the extent that the technological improvements can hardly keep up with the regulatory enthusiasm for this RES-E.

FIT place a low administrative burden on regulators and basically have no associated regulatory barriers to RES-E generators who wish to benefit. For instance, FIT reduce

[15] This is not to say that RES-E do not face other risks, which, to provide simple examples, can range from unfavorable wind patterns (particularly when there are no sufficient historical records available) to operational risks, as for instance extreme weather conditions that can damage the turbines.

barriers to entry since investors do not need to find any electricity buyers (e.g. a retailer or another generator).

Importantly, since RES-E generating units under FIT receive a remuneration that does not depend on wholesale market prices, these plants do not contribute infra-marginal capacity for incumbent generators that operate both traditional generation assets in the energy market as well as RES-E, thus reducing their market power. If the remuneration of the RES-E installations is linked to the energy market price (for instance the day-ahead market price, as it is the case when FIP or RPS are designed), behaving strategically and thus increasing market prices also increase the remuneration of RES-E, and therefore when an incumbent generation adds RES-E to its portfolio, it increases its dominant position. In the case of FIT, since the remuneration of the RES-E installation is fixed and independent of spot prices. Consequently, FIT do not create a competitive advantage for incumbent generators and thus level off the playing field across both conventional as well as new RES-E generators.

Cons

The most evident disadvantage of FIT is that is extremely challenging to determine the right remuneration levels for RES-E. Specifically, there is information asymmetry between the regulator in charge of setting the FIT and the producers who will benefit—it is virtually impossible for the former to correctly assess the costs of the latter. There is a distinct risk that FIT will either fall short and fail to produce enough economic incentives for new RES-E developers to enter the electricity market, or that FIT will be too high and result in overinvestment at very high cost, without necessarily resulting in a proportional technological improvement. This is of special concern in RES-E technologies that have relatively similar deployment costs for all developers.[16]

A guaranteed revenue stream purely linked to production reduces the incentive for RES-E generators to appropriately react to market price signals by adjusting their production accordingly, as well as reducing any system imbalances between demand and supply. While the response to imbalances applies to all technologies (as shown in the FIP discussion below), only certain RES-E can be considered truly dispatchable, such as biomass and small hydro with reservoir storage, and thus can somehow manage and operate according to energy price signals. However, FIT can incorporate incentives for all RES-E technologies to contribute in reducing imbalances, at least by improving the forecast of their outputs.

Finally, contrary to what it is often assumed, one must not ignore the fact that FIT are subject to the customary regulatory risks, since they are just a regulatory instrument that is backed-up by a regulatory commitment. FIT are embodied in special decrees or in electricity acts and require the government to allocate the incurred additional costs to electricity consumers or to taxpayers. Yet, as governments and political preferences change, so the regulations that govern FIT might also change (although they should not do so retroactively, as it immediately affects the regulatory risk perception not just for the electricity sector but for the whole country's economy, turning into larger costs in the long run). In the Czech Republic, FIT were recently reduced retroactively after the government determined that RES-E were enjoying unusually high benefits, and a similar situation has taken place in the Spanish case for the case of solar PV installations, where recently

[16] In other words and to provide a simple example, if it is relatively easy for anyone to purchase and install solar panels for rooftops or solar farms, unnecessarily high FIT will incentivize virtually everyone to pursue this technology, resulting in over-deployment without having to make any special effort in innovation to reduce costs.

retroactive measures have been implemented reducing the remuneration that was committed in previous regulations[17]. Moreover, there may be a number of financial reasons why a government or a system operator decides to stop paying for RES-E, as it was the case for instance in Ecuador. In contrast, a power supply contract offers more protection since it affords legal recourse to an aggrieved party.

3.1.2 FIP

Pros

Unlike FIT, premiums do not suppress incentives for RES-E generators to adjust their production according to price signals. It is worth noting that this is true for RES-E technologies that are 'dispatchable,' i.e. sources that can increase production in response to high prices: biomass plants can burn more feedstock according to price signals, while windmills are not able to do this. However, wind producers as well as other less dispatchable RES-E generators can still find incentives to more properly manage operations and maintenance as well as forecasting, e.g. wind generators will find it wise to ensure they can produce during the most profitable hours.[18]

[17] In an astonishing declaration, in 2010 the Spanish Minister of Industry denied that the reduction of the feed-in tariffs to be paid from that point on to the RES-E generating units that had been installed to date was a retroactive measure. In his opinion, the new regulation would have been retroactive only if these installations would have been asked to pay back part of the income already received in the past.

[18] For instance, one of the clear positive consequences of the implementation of FIP in Spain is that currently 90% of the wind installations can be remotely monitored and controlled. The operator of each balancing region has real-time knowledge of the status of each plant with respect to operating conditions, output, and availability. The operator is also able to communicate timely instructions to the plants, regarding frequency control, voltage control, or curtailment orders.

Cons

Premiums are granted on top of the market prices and thus experience higher risks. As mentioned, at worst, FIP can create an incentive for generators not just to avoid predicting generation but even to engage in gaming via the prediction, which could lead to inefficient electricity dispatch and therefore to potentially higher prices and higher premiums.

The market risks associated with FIP result in more barriers to entry for new RES-E developers and give a competitive advantage to vertically integrated companies (e.g. generation and retail). Therefore, FIP create an incentive for integration of different technologies, which is not necessarily a negative outcome but can nonetheless create market power problems. Conventional generators may expand their portfolio by investing in RES-E technologies and thus gain market power by maintaining infra-marginal capacity, as mentioned in the discussion of FIT. While this may not be of concern in systems where RES-E do not yet occupy a prominent role, it does have an impact in countries such as Spain, where, as mentioned above, wind already provides 15% of total electricity. Indeed, in the Spanish case FIP replaced FIT in 2004. Before this year, many new small independent investors were responsible for a very significant amount of wind installations. Notably, after the change, it is the incumbent generators who own most new installations.

3.1.3 Fiscal and Other Incentives

Pros

Fiscal options have the clear advantage of reducing the cost of financing for the RES-E developers, mainly through flexible or accelerated depreciation over a specific time period. Moreover, mechanisms such as tax credits do not place a direct burden on electricity consumers through increased tariffs. Instead, fiscal incentives become part of the government's or the relevant governmental agency's budget. Needless to say, this characteristic raises other political questions, which will be discussed in the conclusion.

Cons

The most salient problem with fiscal incentives is that they are beneficial only from an equity perspective. In other words, tax credits and other incentives are most useful to RES-E developers who have a large revenue stream and can turn these mechanisms into cash for their own operations. Some RES-E generators may choose to enter into ad-hoc, tax-oriented partnerships and joint ventures with companies with higher profits who would find the fiscal incentives more beneficial. This has been a big deal in the US and is a source of inefficiency, see for instance Gorence & Mackler (2011). Also, these fiscal incentives turn to be an entry barrier to international investment. Only business with national tax liability can benefit from the incentive, as opposed to foreign investors.

Also, if the ultimate goal is to encourage the production of renewable electricity, regulators should keep in mind that investment incentives facilitate investment but may no necessarily yield higher levels of production.

Also, from the burden sharing point of view, tax incentives or any other funded directly from the national budget and not from the electricity tariffs set up an implicit cross-subsidy between tax-payers and electricity consumers. This allocation criterion has significant implications particularly in developing countries.

Finally, as is the case with FIT, which can change according to government priorities, fiscal incentives that are part of the state's budget items are especially vulnerable to regulatory risks and adjustments.

3.2 Quantity-based Mechanisms

3.2.1 Renewable Portfolio Standards

Pros

Ideally, under perfect market conditions and if properly deployed, RPS and similar quota-based mechanisms are the most economically efficient way to bring in a desired amount of RES-E. Determining the target percentage for renewable sources allows for market competition between RES-E developers and for a better determination of energy prices. Moreover, certificate trading encourages overall efficiency and gives generators some flexibility in other to meet government targets. Trading can take place across different geographies and systems, thus increasing the trans-national and trans-state efficiencies. This trading, as well as banking can be also restricted, as it is the case in some US states.

Also, as MIT Professor Richard Schmalensee sarcastically suggested in one of his lectures, one practical "political advantage" of RPS mechanisms (this is true of fiscal incentives as well) is that the cost of supports are "less visible", since they are embedded in final energy prices, unlike FIT, which have more explicitly defined support levels. As Prof. Schmalensee properly argues, from a social and economic point of view, this turns to be a clear disadvantage.

Cons

As inferred in the FIT section above, RES-E providers are subject to different types of market risk. The first is associated with fluctuations in electricity prices in the wholesale market; RES-E and other generators are all vulnerable to this risk. The second risk comes from trading; for example, with tradable RPS certificates, it is possible that overinvestment in RES-E would lead to low prices for certificates, thus further exposing participants in the market. FIT avoid this altogether. Also, RES-E providers are significantly exposed to being undercut by future technology before investment is recovered.

This second risk, which is linked to the price volatility of RECs, can be significantly reduced if stakeholders are not just subject to a quota requirement, but also compelled to fulfill their commitment by entering into long-term contracts with renewable developers, as it is the case of California, as previously mentioned, and also some other US states with RPS regulations.

In those systems in which the retail market has not been fully deregulated or the unbundling between regulated consumers and generation companies levels are weak, a crucial factor for the success of this approach is the mechanism to provide the regulator with sufficient warranties that these purchases are made in a transparent and competitive way, so load serving entities are allowed to pass-through the cost of the contract to consumers. In this context, as it is the case of New York State, centralized auctions appear as the natural solution to avoid complicated monitoring processes on a case by case basis.

In contrast to mechanisms like stepped tariffs, RPS usually, often in the US, do not differentiate across technologies. As a result, generators and other stakeholders will likely prefer the most cost-efficient technologies in a specific market to meet RPS targets. To fix this shortcoming, as already outlined, the UK and other countries have implemented banding provisions, which provide differentiated levels of trading certificates in support of each one of the technologies (for example awarding solar developers with double amount of certificates than wind ones). Another alternative is to explicitly define different quotas for different RES-E technologies, forcing for instance a minimum quota of wind and another of solar. The risk with this approach is that it reduces competition within each band and reduces the liquidity of RES-E markets.

Similar to FIP, RPS create incentives for conventional generators to integrate RES-E into their overall portfolios and achieve vertical integration. Again, this tendency can create barriers to entry for new RES-E participants and may result in increased market power for large players; for example, retailers required to abide by RPS will prefer to source renewable electricity from their own affiliates than to purchase power from new RES-E generators.

For example, in Chile, where the market for RES-E is still very recent, conventional generators are required to purchase renewable electricity to meet RPS. The Chilean regulation imposes penalties to enforce compliance when generators fail to meet RES-E targets, the revenue from which is passed on to installed RES-E generating units. Recent experiences in Chile suggest that generators are far from meeting RPS targets. Conventional generators themselves own the few installations already in place (they are not buying renewable power from generating units not affiliated to them). These conventional generators have no problem paying penalties for non-compliance, since the associated costs are unavoidably passed on to consumers and their own RES-E stand to benefit since they are the ultimate recipients of these penalties. Thus, RPS penalties can become *de facto* feed-in-tariffs.

3.2.2 Auctions

Pros

Auctions share many of the advantages from FIT mechanisms: reduced risk for RES-E generators as a result of guaranteed remuneration, comparatively low administrative and transaction costs (although larger than FIT's) and a reduction of barriers to entry. However, auctions have a distinct advantage over FIT: they relieve the regulator from the task of having to identify the costs associated with RES-E and instead it is the market participants who have to 'reveal' the appropriate support levels through bidding. In addition, the long-term contracts that usually come with a winning bid reduce long-term regulatory risk for RES-E generators.

Auctions effectively centralize the process for RES-E development in the overall system and can thus facilitate economics of scale. In contrast to RPS, where participants such as small retailers must observe and meet specific targets on an individual basis, centralized auctions offer an opportunity for market players subject to the purchase obligation to create partnerships and succeed in building or entering into long-term contracts with more cost-effective and efficient RES-E projects.

Cons

Auctions are most effective if the RES-E industry is mature enough to profit from the bidding process and the benefits given to the winning bidder. As the experience in the United Kingdom (UK) has shown, auctions offered at an immature stage can yield no results. In the nineties, as part of the country's overall move toward deregulation, the UK drafted a number of orders, known collectively as the Non-Fossil Fuel Obligation (NFFO), to support the delivery of renewable electricity in the system. Consequently, the country carried out a series of auctions for RES-E which were met with great enthusiasm. However, winning bidders underestimated the development costs for what were then still-immature technologies and failed to deliver on their projects. A similar situation took place in China. In 2003 the government organized the first call for national wind farm concession tenders. As described in Ma (2011), some developers, especially state-owned enterprises, committed to unreasonably low prices. Since these bids were used to form the benchmark price for on-grid wind tariffs, many companies could not recover their costs. In successive rounds of tenders, bids incorporated the true costs, thus allowing companies to recover their actual investment[19].

Failure to finish RES-E projects is a critical issue in energy systems that have binding RES targets. In Brazil, for instance, there has been an intense competition in recent rounds of auctions, some of which have ended with winning bids of US$67/MWh, which is a significantly lower figure than others seen in comparatively more mature markets, such as the U.S. There is a legitimate fear that winning bidders will not be able to deliver at these levels. Only time will tell whether these windmills will get installed, but, in any case, the harm from potential delays or lack of development is significantly lower, since Brazil (or Peru, where also auctions were implemented) must not meet any targets by a given date, contrary to the case of EU member states, which have 2020 targets. To counter this risk, auction winners are required to produce financial warranties, which offer an additional mechanism for enforcement. Overall, auctions can be extremely advantageous but require careful and flexible regulatory and rule design in each power system.

Currently, auctions appear to be the unavoidable heirs to successful FIT programs. That is, if too many parties are interested in participating in the RES-E market and benefitting from FIT, governments and regulators soon find themselves with the difficult task of having to allocate limited supports to a large pool of interested parties; there is thus no other option but to switch to auctions. For example, in Spain, current FIT for wind have resulted in more than 40,000 MW applications to the System Operator of interested capacity when the government target is only 2,000 MW per year.

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[19] The tendering mechanism was replaced by a feed-in tariff in 2009, according to which four different prices have been set according to the wind availability of the different regions.

4 DISCUSSION

This paper provides a review of direct RES-E support mechanisms, ranging from price-based (FIT, FIP, and tax incentives) to quantity-based schemes (RPS and tenders). We discuss the different components that these designs may include, highlighting the advantages and disadvantages of each one. While most studies of the regulatory design of RES-E support mechanism focus on assessing the effectiveness and efficiency of the different alternatives, our discussion pays special attention to a research area that has not received enough attention in the literature: how the different RES-E support schemes impact the performance of the energy market, how they define the interaction between this market and the RES-E sector, and the overall effects on the ownership structure of the RES-E sector.

RES-E, and particularly wind and solar power, have only recently reached significant levels of penetration in some countries, but they are expected to grow considerably in the next few decades. In some electric power systems (e.g. Denmark, Germany, Spain, and Texas), RES-E technologies currently have an important influence on the performance of the energy market by significantly affecting price dynamics, regulatory requirements, the need to balance reserves and manage network congestions, etc. Moreover, RES-E in these systems have a strong impact on electricity tariffs. Therefore, regulatory analyses need to widen their scope to carefully assess how the different support mechanisms affect the energy market performance in the short- (i.e. operations) and in the long-run (expansion), as well as on how to review current energy market rules in order to optimize performance in both time horizons.

We argue that, when remuneration of RES-E installations is tied to short-term energy market prices, RES-E receive market signals that may lead to more efficient operations, but, conversely, this approach also creates incentives for incumbent generators to increase their market power by assembling a generation portfolio that includes both RES-E infra-marginal capacity and conventional units.

This dual effect calls for a careful redesign of current RES-E mechanisms. Our recommendation is to distinguish between two different types of RES-E, dispatchable, such as biomass, small hydro, geothermal, etc., and non-dispatchable, such as wind and solar. In the case of non-dispatchable RES-E, linking remuneration to spot prices (from the day-ahead energy market, typically) does not result in any clear efficiency improvements, since these generators have almost no means to adapt their output to the price signals. Additionally, as our discussion shows, linking remuneration to market prices has some negative impacts on the level of competition in both the electricity market and the RES-E investment market, since RES-E additions increase the inframarginal capacity of existing generators. However, there is no doubt that exposing RES-E installations –for both dispatchable and non-dispatchable technologies– to the cost of imbalances in the shorter term (i.e. after the day-ahead market) enhances their ability to properly estimate their production, minimizing the cost of reserves for the whole system[20]. Thus, the more suitable alternative would be to set a fixed remuneration per MWh produced from non-dispatchable RES-E, regardless of the value of spot prices. However, to encourage the improvement of the forecast of the output of these non-dispatchable plants, generators should be exposed to the balancing markets and be responsible (partly, at least) for the costs incurred by deviations from their declared schedule.

The second major conclusion, as it has also been discussed in IEA (2008) or Newbery et al. (2011), is that the adequate RES-E support mechanism for a given power system depends on the sectoral maturity of the RES-E industry. In other words, some regulatory options are more appropriate for less mature technologies, while others are ideal for more proven ones. The experiences discussed above suggest that, as RES-E technologies and industries

[20] Recent developments in wind generators, for instance, allow them to adjust their output to a certain point adjusting the pitch of their blades, therefore providing high quality operating reserves (NERC, 2009).

improve over time and competition grows, regulators can follow some kind of evolution in the support mechanisms and gradually and with certainty substitute the existing schemes according to the most recent information, also taking into account the need for regulatory stability.

Our recommendation is to gradually move from price-based mechanisms (FIT and FIP), which are best suited to less mature RES-E technologies, to auctions, which can accommodate players in more developed RES-E markets. In particular, for non-dispatchable RES-E, such as wind and solar, regulators should use FIT, but including also incentives to minimize imbalances, as mentioned above. For dispatchable RES-E, FIT can be used during the very early stages of deployment, and then they can then be replaced by FIP. Once the market gains sufficient expertise and a healthy level of competition among RES-E generators, regulators should progressively move from FIT and/or FIP to auctions. Contracts awarded in auctions should respect the differentiation between dispatchable and non-dispatchable RES-E regarding spot price-based remuneration. In all events, in order to mitigate the potential regulatory risks, RES-E installations should make use of long-term contracts that could include the System Operator as counter-party.

Finally, we close with an important remark: regardless of the preferred regulatory design, RES supports have broad and multiple effects in the complete energy model and thus require an equally comprehensive and efficient approach to cost-sharing. Currently, countries and regions around the world are experiencing a growing need for renewables, not only for the power and transport industries but also for the entire economy, mostly due to climate change commitments. This need, coupled with governments' perennial concerns about political sensitivity to increasing energy and fuel rates, especially for electric power, has highlighted the importance of energy tariff design as a critical component of RES and energy system regulation. In Denmark, in 2010, the taxes imposed on the electricity price in order to finance subsidies to renewables and energy research represented 9% of the total price of electricity (DERA, 2011). As of January 2011, electricity consumers will have to pay a EEG reallocation charge (EEG Umlage) of 3.53 Cent/kWh (Lang & Mutschler, 2010). In 2010, Spain's support expenditures for RES technologies reached €5300 million, 21% of the total electricity bill (Samaniego, 2011). The Finish government has announced the new FIT will be funded directly from the national budget.

The better the methodology for allocating these costs, the smaller is the risk of public dissatisfaction and hence the larger the amount of total RES that can be deployed, see for instance Newbery (2005) or Batlle (2011) for proposals to deal with this particular topic.

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REFERENCES

Auer, H., Resch, G., Haas, R., Held, A. & Ragwitz, M., 2009. "Regulatory instruments to deliver the full potential of renewable energy sources efficiently." European Review of Energy Markets - volume 3, issue 2, June 2009.

Batlle, C., 2011. "A Method for Allocating Renewable Energy Source Subsidies among Final Energy Consumers". Energy Policy, vol. 35, iss. 5, pp. 2586-2595, doi: 10.1016/j.enpol.2011.02.027.

Batlle, C., Barroso, L. A., 2011. "Support schemes for renewable energy sources in South America". MIT-CEEPR Working Paper 11-001.

BMU, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2011. Renewable energy sources 2010. 23 March 2011. Available at www.bmu.de.

Brown, M., Omom, D., and Madden, B., 2009. "Qualitative issues in the design of the GB feed-in tariffs. A report to the Department of Energy and Climate Change (DECC)." Pöyry Energy Consulting and Element Energy, URN 09/D/698.

Clean Energy Standard Act of 2010 (Introduced in Senate - IS). S 20 IS. 111th CONGRESS. 2d Session.

CNE, Comisión Nacional de Energía, 2011. "Informe sobre los resultados de la liquidación provisional Nº 13 DE 2010 y verificaciones practicadas sector eléctrico. Periodo de facturación: desde el 1 de enero de 2010 al 31 de enero de 2011." In Spanish. March 10th, 2011. Available at www.cne.es.

Commission of the European Communities, 2008. The support of electricity from renewable energy sources. Accompanying document to the Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources {COM(2008) 19 final}. Commission staff working document. SEC(2008) 57. Brussels, 23.1.2008.

California Public Utilities Commission. 2010. RAM Decision D.10-12-048. Available at www.cpuc.ca.gov.

Danish Energy Agency, 2011. Monthly Statistics. Available at www.ens.dk.

DERA, Danish Energy Regulatory Authority, 2011. Results and Challenges 2010. May 2011. Available at www.dera.dk.

Department of Energy and Climate Change. 2011. Eligible Renewable Sources and Banding Levels. http://www.decc.gov.uk/

DSIRE, Database for State Incentives for Renewable Energy, 2011. Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008-2012). Available at www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US06F.

ERCOT, 2011. ERCOT Region Electricity Use Up 3.5% in 2010. Press release. January 10, 2011. Available at www.ercot.com.

Gorence, N., Mackler, S., 2011. Reassessing Renewable Energy Subsidies: Issue Brief. Bipartisan Policy Center. March 25, 2011. Available at www.bipartisanpolicy.org.

Holttinen, H., 2011. Cold climate wind power. Experiences in Finland. Winterwind 2011, Umeå, 9th Feb, 2011. Available at windren.se/WW2011/13a_Finland_VTT_Holttinen.pdf.

International Energy Agency (IEA), 2008. "Deploying Renewables: Principles for Effective Policies." Available at www.iea.org/w/bookshop/add.aspx?id=337

Imaz, 2011. "Electricity system operation with a high level of renewable penetration: Impacts on network and System Operation (Technical aspects)." FSR 1st Executive Seminar "Regulation of electricity systems with high penetration of generation based on Renewable Energy Sources (RES)," Florence, 6 - 8 April 2011.

Klein, A., Pfluger, B., Held, A., Ragwitz, M., Resch, G, Faber, T., 2008. Evaluation of Different Feed-in Tariff Design Options – Best Practice Paper for the International Feed-In Cooperation. EEG and Fraunhofer Institute Systems and Innovation Research.

Lang, M & Mutschler, U, 2010. 72% Increase in EEG Renewable Energy Reallocation Charges for 2011. Available at www.germanenergyblog.de.

Lipp, J., 2007. Lessons for effective renewable electricity policy from Denmark, Germany and the United Kingdom. Energy Policy, vol. 35, pp. 5481–5495.

Ma, J., 2011. On-Grid Electricity Tariffs in China: Development, Reform, and Prospects. Energy Policy, vol. 39. pp. 2633-2645.

Ministry of Employment and the Economy, 2011. Energy taxes. www.tem.fi.

MITyC & IDAE, Ministerio de Industria, Turismo y Comercio & Instituto para la Diversificación y Ahorro de la Energía, 2010. "Plan de acción nacional de energías renovables de España (PANER) 2011 – 2020." 30 de junio de 2010. Available at http://www.mityc.es.

NERC, North American Electric Reliability Corporation, 2009. Accomodating High Levels of Variable Generation. April 2009. Available at www.nerc.com.

Newbery, D., Olmos, L., Rüster, S., Liong, S.J., Glachant, J. M., 2011. Public Support for the Financing of RD&D Activities in New Clean Energy Technologies. European Commission FP7 project THINK. January 2011. Available at www.eui.eu.

Newbery, D. N., 2005. Why Tax Energy? Towards a More Rational Policy. Energy Journal, vol. 26, iss. 3, pp. 1-40. July, 2005.

NYSERDA, 2011. New York State Renewable Portfolio Standard Performance report. Program Period ending April 2010. Available at www.nyserda.org/publications/2010_rps_report.pdf.

Pérez-Arriaga, I. J., Batlle, C., Rivier, M., Rodilla, P., 2005. "Libro Blanco sobre la reforma del marco regulatorio de la generación eléctrica en España". (White Paper for the reform of the regulatory scheme of the power generation in Spain), ISBN 978-84-4785-6, July 2005.

Pérez-Arriaga, I. J., 2011. "Managing large-scale penetration of intermittent renewables. A framework presentation." 2011 MITEI Symposium Cambridge, April 20th, 2011. Available at http://web.mit.edu/mitei/intermittent-renewables.

Ragwitz, M., 2010. "Developments and achievements of Feed-In Systems - Key findings from an evaluation conducted for the IFIC." 8th Workshop of the International Feed-In Cooperation (IFIC). 18th/19th November 2010, Berlin.

REN21, 2010. Renewables 2010 Global status report. September 2010. Available at www.ren21.net.

Schmalensee, R. 2009. "Renewable Electricity Generation in the United States." MIT-CEEPR Working Paper 09-017.

Samaniego, M., J., 2011. "Regulation of electricity systems with high penetration of generation based on Renewable Energy Sources. Evolution in Spain." FSR 1st Executive Seminar "Regulation of electricity systems with high penetration of generation based on Renewable Energy Sources (RES)". Florence 6-8 April 2011.

Texas State Energy Conservation Office. 2011. Texas Renewable Portfolio Standard. www.seco.cpa.state.tx.us/re_rps-portfolio.htm.

The Danish Government, 2011. Energy Strategy 2050 – from coal, oil and gas to green energy. February 2011. Available at www.kemin.dk.

Till, D., 2011. Renewable Energy Standards – California and Congress Moving in Different Directions. March 17, 2011. Available at www.martenlaw.com.