Renewable electricity policy: feed-in tariffs versus tradable green certificates

El presente artículo ofrece una discusión sobre el sistema de primas ("*feed-in tariffs*") y el esquema de comercio de certificados verdes, que son los dos ejemplos más conocidos y populares de instrumentos de política de fomento de la electricidad renovable. Se comparan ambos esquemas en lo concerniente a su impacto en situaciones de incertidumbre, los riesgos de mercado y regulatorios, el impacto en la innovación tecnológica, el efecto sobre el precio de la electricidad y el saldo fiscal de las Administraciones, así como algunos aspectos del balance eficiencia/equidad (efecto "NIMBY"). El artículo describe también la situación de las políticas E-FER en la UE.

Artikulu honek primen sistemari (feed-in tariffs) eta egiaztagiri berdeen merkataritzako eskemari buruzko eztabaida eskaintzen digu; izan ere, bi aukera horiek dira argindar berriztagarria sortzeko politika sustatzeko tresnarik ezagunenak. Bi eskema horiek erkatu egiten dira, zalantzazko egoeretan zer nolako eragina daukaten ikusteko, merkatuko arriskuak eta arautzearenak nolakoak diren jakiteko, berrikuntza teknologikoak zer nolako eragina duen jakiteko, argindarraren prezioan eta administrazioen saldo fiskalean nola eragiten duen ikusteko, eta efizientzia/ekitatearen balantzea ("NIMBY") efektua zertan den aztertzeko. Artikuluak ere EIB-Eko politiken egoera eskaintzen ditu EBean.

The paper discusses feed-in tariffs (a price-based market-pull instrument) and tradable green certificates (quantity-based market-pull instrument) as the two prevailing support schemes for renewable electricity in Europe. It compares them for uncertainty, market and regulatory risks, cost-efficiency, technical innovation ("valley of death"), consumer electricity prices, public finance, NIMBY and local benefits. The paper also gives an overview of the status-quo of RES-E policies in the EU.

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1. INTRODUCTION

The promotion of renewable energies and higher energy efficiency is at the heart of the energy policies of the European Union and most industrial countries in the world. Electricity generated from renewable energy sources (RES-E)[1] is believed to be more expensive than conventional electricity production due to four reasons: (i) environmental costs are not fully internalized for conventional electricity generation technologies; (ii) the intermittent power production of some major sources of RES-E (wind power, photovoltaics) generates negative externalities; (iii) due to the lock-in of conventional technologies, RES-E have penetrated the market only little so far, leading to the absence of scale effects on costs. (iv) most RES-E technologies still requires innovation and have a long way to go along the learning-curve.

In order to overcome some of these disadvantages, many countries have decided to set targets and introduced dedicated policies to pull the market deployment of RES-E technologies. Those policies include the introduction of market pull instruments (or demand-pull instruments) which are complementary to technology push instruments, such as specific R&D policies. They form part of a string of policies aiming at technological innovation, which requires continuous investment throughout the whole innovation cycle. New technologies often fail at the "Valley of death" i.e. between prototype and commercial stage. As any new technology, RES-E technologies also meet these

* The opinions expressed in this paper belong to the authors only and should not be attributed to the institution they are affiliated to.

[1] A discussion on policies for bio-fuels and heat from renewable energy sources is beyond the scope of this paper.

classical entry barriers (Jaffe et al., 2002). The role of market-pull instruments is to overcome the "Valley of death" stage, common to any emerging innovative technology. A successful introduction of new technologies into a mature market crucially depends on both R&D policies and market-pull instruments and their correct timing in the process (IEA, 2000), as well as on the structure of the market the new technology is trying to land on.

Following failed attempts using systems of voluntary purchases of green electricity by consumers, demand-side strategic deployment policies have emerged as the preferred instrument in most countries. There are three instruments with such common character: feed-in tariffs (FIT), bidding instruments for the assignment of long-term purchase contracts (or tender) and Tradable Green Certificates (TGC) combined with quotas.

On the EU level, targets have been set for the share of renewable electricity and biofuels to be achieved by 2010. These shall help in meeting the overall objective for achieving a 12% share of renewables in total energy consumption by 2010. Additional targets for the year 2020 form part of the recent proposal of the directive on the Promotion of the use of energy from renewable sources (European Commission, 2008a).

This paper gives an overview of the discussion on price-based market-pull instruments and quantity-based market-pull instruments.

2. **DEPLOYMENT OF RES-E**

The share of renewable energy sources in primary energy consumption increased from 4.4% in 1990 to 6.7% in 2005 in the EU-27. The share of renewable energy sources in gross electricity consumption in the EU-27 grew from 11.9% in 1990 to 14% in 2005. This relative rise in the importance of renewable energy carriers was achieved despite a substantial growth (27%) of total gross electricity consumption and primary energy consumption (+9.8%) over this time period (Eurostat, 2008).

In particular wind and solar power businesses are experiencing an unpreceded acceleration thanks to subsidies and regulatory incentives in Europe, the United States and many other countries. In the EU-25, the average annual growth rates between 1990 and 2004 were in the order of 36% and 43% for wind and photovoltaic electricity generation, respectively (EEA, 2008). In 2005, Germany was the world leader in wind power (18,430 MW of installed capacity), solar photovoltaics (1400 MWp of installed capacity), production of bio-diesel (1.9 billion liters), and, with China, overall investment in renewables. In 2005 Spain ranked second in the world in total installed wind power capacity (10,030 MW), and was among the top three in newly installed wind capacity (The Economist, 2006b).

As price decreases come with the volume of output through economies of scale and technological learning, the cost of wind-power generation has been reduced significantly over the past decades. An example from Californian wind farms indicates a price drop from around US$ 0.45 per kWh in the early 1980s to less than US$ 0.10 per kWh in the early 1990s. Also in Denmark, a reduction of prices by a factor of four could be observed between 1981 and 1998 (IEA WIND, 2001). Today, wind power generation costs can be as low as US$ 0.03-0.04 per kWh in the best production sites (IEA, 2006). Solar-power prices have dropped, too. Photovoltaic cells cost about US$ 100 000 per kilowatt peak of generating power at the end of the 1960s. By 2006 the price had fallen to about US$2000-3000 per watt (IEA, 2006)[2], whereas the efficiency of silicon-based solar cells improved from 6% to an average of 15%. It is assessed that for every doubling in cumulative production volume, the cost of modules has declined by about 20%. That translates to an annual reduction in manufacturing costs of about 5%. An example for the maturation of new energy technologies using market-pull instruments has already taken place in Japan, where the subsidies for solar power, introduced in 1994, were phased out in 2005 and Japan became the first market where customers have continued to buy PV solar systems without subsidy. This is (partially) thanks to the high retail electricity prices in Japan making it relatively easy for solar power to compete (The Economist 2005ab, 2006ab, 2007).

Although the cost gap between energy generated in conventional ways and that generated by alternatives has shrunk, it still exists. Burning natural gas-fuelled combined-cycle turbines is still a cheaper technology for power generation than wind turbines, and coal is in many cases the cheapest option without the internalization of external costs. For the time being, clean energy is competitive in only a few countries in certain specific instances (e.g. Japan and Brazil). Moreover, although the growth is strong, the industry of renewables remains vulnerable to policy decisions and external events.

[2] These figures exclude the costs of the balance of system such as mounting, converters connections, which can be in the same order as those of the module.

3. RES-E POLICIES IN THE EU

REN21 (2008) reckons that at least 60 countries have policies on renewable power generation in place, including 37 developed and transition countries such as all EU member states, Japan, the United States and 23 emerging economies such as Brazil, China and India. In Europe, renewable energy production has been supported over the past decades both on the EU and the Member States levels, motivated by concerns about energy supply security and the objective of reducing emissions of greenhouse gases. In particular since the 1990s, public support to renewable energies increasingly included policies for the market introduction of renewable energies, complementing support to research and development.

However, stimulating renewables using market pull instruments or other ways of subsidies or support is not without problems. An inadequate scheme of subsidies induces inefficient allocation of capital (and labour), attracting them to some nominated technologies to the detriment of other, possibly better or more needed technologies, analogous to the well-know crowding-out effect.

Innovation is a dynamic, cumulative, systemic and uncertain process, giving rise to path dependency and the potential for lock-in of technological and institutional systems. In other words, once a technology is chosen and the related industry has been built up to a competitive level, it is very difficult to leave this technology aside for a new technology. Unruh (2000, 2002) discusses how industrial countries have become locked-into fossil fuel-based energy systems through path dependent processes driven by increasing returns to scale. This lock-in of fossil fuel-based technology hampers the emergence of renewables and other new energy technologies.

The fundamental question that policymakers are confronted with is how to create market pull that avoids an early technological lock-in, without creating excessive costs for society, in other words how to speed up the development of new technologies in a cost-efficient way?

In order to approach this question, we will look into the existing and forthcoming legislation on renewables in the EU and its Member States in the following. A more detailed assessment of the two main policies – feed-in tariffs and tradable green certificates – will be the subject of chapters 4 and 5.

In 1997, the European Commission introduced the objective of fulfilling 12% of the EU-15's total energy demand from renewables by 2010 in the White Paper on Renewables (European Commission, 1997). It formed a basis for the current two cornerstones of the EU legislation on renewables:

— The directive on the promotion of electricity from renewable energy sources (2001/77/EC), which sets a target of 22.1% of gross electricity consumption to be met by renewables in the EU-15 in 2010. Complemented by national targets for the new EU Member States, included in the Accession Treaties, the EU-27 target for 2010 became 21%.

— The biofuels directive (2003/30/EC), which sets 'reference values' of 2% and 5.75% for the share of biofuels in transport diesel and gasoline consumption to be met by the end of 2005 and 2010, respectively. The directive obliges Member States to formulate national indicative targets, taking into account the proposed reference values.

With the focus of this paper lying on renewable electricity, Table 1 lists the support policies in place for the EU-27 Member States. It demonstrates that the main support schemes are feed-in tariffs (or premiums), which are being applied by 18 Member States, and quotas in 7 Member States, often combined with tradable green certificates (6 Member States). Tenders are used in 3 Member States particularly for large renewable plants. A number of additional policies, e.g. soft loans and investment incentives, complement the main renewable support policies.

On 23 January 2008, the European Commission published a proposal for a directive on the promotion of the use of energy from renewable sources (European Commission, 2008a)[3]. It extends the EU's policy on renewable energies to the year 2020. As such, the directive aims to establish a 20% target for the share of renewable energy (i.e. renewable heat, electricity and transport fuel) in the final energy mix by 2020. This shall be achieved through differentiated binding targets for individual Member States. Those national targets range from 10% in Malta to 49% in Sweden, reflecting – among others- the current deployment, the local conditions and Gross Domestic Products. No sectoral targets for renewable-based electricity (RES-E) or heat generation are specified,

[3] Anno March 2008 this proposal by the European Commission had to be adopted by the European Parliament and (European) Council.

but for biofuels: all Member States shall achieve a uniform binding minimum biofuel share of 10% in transport diesel and petrol demand.

As part of the proposal, the concept of 'Guarantees of Origin' (GO) is strengthened. With the proposed directive, GO for renewable energy will become standardised and shall be transferable in order to help Member States in achieving their national renewable energy targets by 'virtual' trade of renewables from those Member States that have already achieved their (interim) targets. However, Member States can restrict the transfer of GOs under certain conditions. They might establish a system of prior authorisation for the transfer of GOs in order to ensure that GO trade does not impair a secure and balanced energy supply or undermines the environmental objective underlying the national renewable support scheme.

The proposal builds on the Conclusions of the European Council from March 2007 (European Council, 2007). Here, the Council endorsed the Commission's Strategic Energy Review (European Commission, 2007a), including the 2020 targets for the share of renewable energy and of biofuels formulated in the 'Renewable Energy Roadmap' (European Commission, 2007b).

If adopted, Member States would need to submit their National Action Plans to the Commission by 31 March 2010 at the latest, outlining their national strategies for achieving the renewable energy shares agreed.

4. FEED-IN TARIFF AND TRADABLE GREEN CERTIFICATE

Table 1 provides an overview of the support policies for electricity from renewables (RES) across EU Member States as of 2005. Three types of support models on the supply side of electricity seem to have sprung up, notably, feed-in tariffs, tenders and green certificates. In the remainder of the text we analyze feed-in tariffs and tradable green certificates (TGC) combined with quotas, which are the two prevailing ones.

Feed-in Tariff

Feed-in tariffs are a price-based policy which set the price to be paid for renewable energy per kWh generated (in the form of guaranteed premium prices). This is generally combined with a purchase obligation. Typically the costs are borne either by consumers or by the public budget. Certain solar projects in Germany will receive as much as €0.57 for each kilowatt-hour of electricity compared to around €0.05 for dirtier power. In Spain, solar thermal-power generation got a boost with a feed-in tariff of €0.22 per kWh granted for the first 500 MW of solar thermal capacity.

Table 1 shows that feed-in tariffs (and premiums) form a backbone of the renewable policies in 18 Member States. In 2000 more than 80% of the new wind power installed in the EU was put in countries with guaranteed prices, notably Denmark, Germany and Spain. They are used across various EU countries for different types of renewable power generation, including biomass, photovoltaic solar, thermal solar, geothermal, small hydro, tidal, onshore wind, and offshore wind (European Commission, 2007c; 2008c).

Feed-in tariffs rarely stand alone and are combined with other policy measures. Most

Table 1

Main RES-E support policies in EU Member States

Country	Feed-In Tariff (FIT), or Quota system (Q) with TGC (+TGC)	Additional support schemes:	2005 share of RES-E	2010 target for RES-E
Austria	FIT (full FIT for 10 years; declining afterwards; annual adjustments)	Regional investment incentives	57.4%	78.1%
Belgium	Q + TGC (Flanders and Wallonia)	Minimum prices for electricity from Renewables from the Federal government ('fall-back prices') Investment support	2.8%	6.0%
Bulgaria	FIT (premium prices)	Tax incentives, purchase obligation	11.8%	11.0%
Cyprus	FIT (15 years support)	Investment grant scheme (30-55%)	0.0%	6.0%
Czech Republic	FIT (15 years support; FIT levels announced annually)	Investment grants Selection possible between FIT and premium	4.5%	8.0%
Denmark	Premium & FIT (for biomass & -gas; technology dependent support 10-20 years)	Offshore wind: tender Photovoltaics: net metering	28.2%	29.0%
Estonia	FIT (7-12 years, not beyond 2015; single FIT for all technologies)		1.1%	5.1%
Finland		Energy tax exemption Investment incentives (40% for wind; 30% other RES-E)	26.9%	31.5%

Table 1 (continuation)

Main RES-E support policies in EU Member States

Country	Feed-In Tariff (FIT), or Quota system (Q) with TGC (+TGC)	Additional support schemes:	2005 share of RES-E	2010 target for RES-E
France	FIT (15 or 20 years depending on technology)	Tenders for plants > 12 MW (except wind)	11.3%	21.0%
Germany	FIT (20 years)	Soft loans	10.5%	12.5%
Greece	FIT (12 years; possible extension to 20 years)	Investment incentives	10.0%	20.1%
Hungary	FIT (no time limit defined)	Grants; Purchase obligation A green certificate scheme was prepared but no start data of implementation is fixed.	4.6%	3.6%
Ireland	FIT (15 years support)	FIT for biomass, hydropower and wind	6.8%	13.2%
Italy	Q + TGC	FIT for photovoltaic (20 years)	14.1%	25.0%
Latvia	Q	Tender for wind	48.4%	49.3%
Lithuania	FIT (10 years)	Purchase obligation	3.9%	7.0%
Luxembourg	FIT (10 years; 20 years for Photovoltaics)	Investment Incentive	3.2%	5.7%
Malta	FIT	Lower VAT rate	0.0%	5.0%
Netherlands	Premiums payments (abruptly abolished in August 2006)		7.5%	9.0%
Poland	Q +TGC	Exemption from excise tax	2.9%	7.5%

Table 1 (continuation)

Main RES-E support policies in EU Member States

Country	Feed-In Tariff (FIT), or Quota system (Q) with TGC (+TGC)	Additional support schemes:	2005 share of RES-E	2010 target for RES-E
Portugal	FIT (15 years)	Investment incentives (up to 40%) Tender for wind and biomass installations	16.0%	39.0%
Romania	Q + TGC	Annual minimum and maximum values of TGC set at 24-42 Euro per certificate (2005-12)	35.8%	33.0%
Slovakia	FIT	Tax incentives; Investment subsidies	16.5%	31.0%
Slovenia	FIT (Full FIT for 5 years, reduced after 5 and 10 years)	Selection possible between FIT and premium Investment funds (40%)	24.2%	33.6%
Spain	FIT (full FIT for 15, 20, 25 years; afterwards reduced FIT)	Selection possible between FIT and premium; Soft loans Tax incentives; Regional investment incentives	15.0%	29.4%
Sweden	Q + TGC	Wind energy: Investment incentives Offshore wind: premium tariff (transitory)	54.3%	60.0%
UK	Q + TGC	Exemption from the Climate Change Levy; Investment Grants; UK is currently considering introducing differentiated certificates for different RES-E technologies.	4.3%	10.0%

Sources: Ragwitz et al. (2007), Eurostat (2008), European Commission (2008b).

important, feed-in tariffs are complemented with the obligation to purchase the renewable electricity by the grid operator. In Spain, the feed-in tariffs of wind technology are complemented with low-interest loans, capital grants, exemption of balancing costs and support for manufacturing of turbines. In Germany, the fast deployment of wind power benefited not only from the feed-in tariff but also from spatial planning.

Tradable Green Certificate

Tradable Green Certificates (TGC) are issued when electricity is generated using renewable energy technology. The TGC belong to the group of flexible market instruments for environmental policy. They can be traded separately from the electricity produced. The generated electricity and its quality label, in the form of a certificate, are detached at the point of generation. As such, a distinct market for the environmental value is created. In the TGC scheme, each electricity company gets a quota for the amount of electricity derived from renewables. For each unit renewable electricity delivered to the grid the company receives a green certificate in addition to the electricity price. Companies that do not generate enough energy to fulfil their quota from renewables can buy the certificates from companies that have certificates in excess. RES-E investors receive an extra allowance for their investment, in addition to the market price of the produced electricity, namely the market price of the certificate. This way, RES technologies are at least partly compensated for the environmental benefits they provide. This generates more supply of renewable-generated electricity, favouring competition between the lower-cost suppliers (and technologies). The TGC schemes may stimulate the development of green power if the imposed shares of green power in total sales are significant and if the fine level of non-compliance is high enough to enforce the quota.

In the EU, national or regional TGC markets are used in the Netherlands, Sweden, Italy, Belgium, Poland, Romania and the UK (see Table 1). The establishment of these national/regional TGC markets is very much in line with the fixed targets for renewables adopted by the Member States under the EU renewables electricity directive (2001/77/EC). However, the different countries have chosen for different concepts of TGC and the integration of these national TGC systems may not be straight forward. Verhaegen et al. (forthcoming) illustrate the challenges of a EU TGC market with the example of the harmonization of the 4 TGC schemes in Belgium. National consumption targets seem a better option than domestic production targets as the latter undermine the cost-effectiveness of harmonization. To establish an effective European TGC market, they recommend coordination between the responsible national bodies, smoothening of peak-loads in trade, common agreement on the TGC technologies, that all penalty levels should be higher than the common TGC price, common market stabilisation mechanisms, penalties, common banking and borrowing rules, etc.

Differences in Characteristics between FIT and TGC

It is difficult to draw general conclusions when comparing the different instruments, because of the different ways market-pull schemes can be designed (Langniss and Wiser, 2003; Finon and Perez, 2007). First, each instrument has many variants, each with varying levels of efficiency and ability to address inefficiencies. Second, references to empirical observations are somewhat misguiding because instruments cannot be isolated from the policy context. E.g. some factors create obstacles, such as the planning permission procedures and the relation to the grid operators for the recovery of connection costs. In this section we will discuss how FIT and TGC relate with uncertainty, market and regulatory risks, cost-efficiency, technological innovation, consumer prices, public finance, the NIMBY effect and local benefits.

Uncertainty: prices versus Quantities

As the feed-in tariff system is a price-based incentive, policymakers can not precisely predict the amount of RES-E produced in a given time period. On the other hand, TGC seem better suited to policies focused on quantities rather than on prices.

Analogous with the seminal study by Weitzman (1974) for environmental instruments, various authors (e.g. Menanteau et al., 2003; Finon and Perez, 2007; Söderholm, forthcoming) acknowledge that the shape of the marginal cost and marginal benefit (or, alternatively, marginal damage) curves for RES-E will influence the cost-efficiency of price-based (i.e. FIT) versus quantity-based instruments (i.e. TGC). If the policy maker has complete information about the marginal cost of renewable and conventional electricity (as well as of electricity demand), price-based and quota-based instruments would be equivalent. Here it would be straightforward to determine the level of the feed-in or premium tariff in order to reach the policy target for RES-E. Alternatively, the same policy target could be obtained with TGC, with the price of TGC being equal to the tariff (or premium) level. Thus, in the absence of any market uncertainty, the policy maker would remain indifferent between the two support instruments[4].

With the real world's incomplete information, the assessment of the marginal cost curves is essential for choosing an efficient support instrument for RES-E. If the marginal cost curve is flat (as argued by Jansen, 2003), a quantity-based instrument (TGC) is favoured. With a flat marginal cost curve, a slight variation in the proposed feed-in tariff may have significant effects on the production capacity produced. Here, an (even slightly) overestimated feed-in price, would result in a large amount of subsidies which may need an increase of electricity prices (if FIT is paid by consumers) or public resources (if FIT is paid by government). In this case, a quantity-based instrument would control the production capacity (and its cost) as the quantity of certificates is fixed.

On the other hand, steep marginal cost curves tend to favour the FIT instrument under uncertainty conditions. If a quantity-based instrument is chosen, small variations in the prescribed target would induce large fluctuations in the price. Here, price-based FIT schemes could be chosen.

In addition to the considerations about uncertainties in the marginal cost curve, there is also the risk to overestimate/underestimate the social value of the environmental goods with respect of the

[4] Ignoring different transaction costs, monitoring costs or burden on the public finances.

cost of the different RES-E. If the marginal benefit curve is relatively steep, small variations of a FIT may result in quantities too low/high with respect to the social optimum. However, if the shape of the marginal benefit curve is rather flat marginal benefit (as argued for RES-E in EU by Söderholm, forthcoming) a price-based instrument (FIT) would be preferred.

Market risks and Regulatory risks

Recently, various authors have devoted importance to the risks faced by RES-E generators, preventing large-scale deployment of renewable technologies (including, among others, Agnolucci, 2008; Foxon et al., 2005; Wiser et al., 2004). One could distinguish two types of risks: markets risks and regulatory risks. The markets risks include uncertainties of the prices of inputs (e. g. capital costs) and more conventional electricity technologies (e.g. the price of fossil fuels), the fear that the generators may not be able to deliver the agreed quantity; and the overall electricity demand. Regulatory risks are the result of the fact that renewable markets are very dependent on the policy context. The latter are prone to changes in policy priorities and governments. Hence, the burden and benefits of investors in RES-E are vulnerable to be altered. Because of this uncertainty, investors may forego opportunities with positive net present value. In economic literature and contract theory, some of the regulatory risks are known as the "hold-up problem" (see e.g. Edlin et al., 1996). Hold-up problems describe situations where cooperation between two parties (here, investor in RES-E and policy maker) may be efficient, but they refrain from doing so due to the concern that cooperation may decrease their own profits and increase the bargaining power of the other party. In RES-E, the investors lose bargaining power when the investment has been realized, as their invested capital goods cannot (or very difficultly) be used for alternative projects. Dinica and Arentsen (2006) discuss the effect of regulatory instability on the willingness of investors to commit to long-term projects for the Netherlands. They conclude that some potential developers who chose not to invest there might have been discouraged by the frequent and unpredictable changes in the fiscal and financial instruments used by the government. Mitchell et al. (2006) compare the renewable electricity policies in England and Wales (i.e. Renewable Obligation) and in Germany (i.e. FIT). They conclude that the German feed-in tariff is more effective at increasing generating capacity than the English and Welsh policies because the latter fail to reduce the risks borne by the investors.

While revenues of the plants already built have often been shielded when altering renewable electricity policies, this guarantee is normally not granted in the case of changes occurring in other types of regulation affecting RES-E investments (Katofsky and Frantzis, 2005). Moreover, when a negative regulatory change is announced, shielding the investments before a certain deadline, investors often take the opportunity of being remunerated according to the existing policy. In the US, the tax break for wind generation (i.e. Production Tax Credit) expired biennially, causing the industry to loose momentum until the credit was renewed again. Annual additions of wind generating capacity boomed in the years when the credit was scheduled to expire (i.e., 1999, 2001, and 2003) while in the off years development lagged (Bird et al., 2005). It would seem logical to conclude that such an unstable interest in renewable technologies puts unneeded strain on the industry providing material inputs and expertise, and in some cases it could prevent its development (Agnolucci, 2008).

A feed-in tariff with a long-term contract can partly remove the investor's financial insecurity and risk involved with a massive deployment of a new technology. The highest costs of the innovation system appear on the point of market introduction, especially as capital costs are high compared to operational costs for most renewable energy types. That is the time when important investments are needed with large financial risks. These initial costs can be reduced as guaranteeing revenue stability allows the investor to borrow at lower interest rates. The profits are therefore expected in a later phase of deployment. This predictability of policy support is important to encourage the private sector involvement and allow market actors to carry out resource allocation plans on safe grounds; e.g. in Germany the feed-in tariff is fixed for 20 years declining over time. In other Member States (e.g. Slovenia), a long term favourable tariff is granted but with annual adjustments, which allows to take into account changing conditions (but possibly increasing the risk for investors).

TGC may increase the financial risks of the potential investors as the prices of TGC may fluctuate (e.g. Menanteau et al., 2003; Meyer, 2003; Meyer and Koefoed, 2003; Mitchell et al., 2006). However, the negative correlation between volumes and the price of certificates guarantees somewhat the stability of the revenues (Mozumder and Marathe, 2004). Some studies (e.g. Lauber, 2004; van der Linden et al., 2005) stress the importance of long-term contracts for the amount of additional capacity delivered by TGCs and for the price of certificates in order to reduce the market and regulatory risks for investors. Agnolucci (2007) underlines the important role of the design of the quota and penalty levels. He recommends that the penalty should be known in advance and not be recycled back to the firms holding certificates (as in UK) in order to prevent strategic behaviour. Further, he argues that financial constraints and technological progress can make investors cautious about building new plants because of doubts regarding their future ability to sell certificates and make a profit. If this occurs, investors will hold back renewable capacity for fear of being undercut by later –more cost-effective– installations, therefore keeping the price of certificates near the penalty level. Borrowing certificates could have a similar effect as long-term contracts, but it also opens the possibility for strategic behaviour, such as later vintages undercutting current capacity, even before the former enter the market.

Cost-Efficiency

The feed-in tariffs tend to distort the market significantly. Due to its geographical situation, Germany would not be a first choice to install PV solar power compared to sunnier countries. Moreover, the country does not have problems of grid accessibility; a condition that normally makes solar power more attractive. But thanks to generous feed-in tariffs, it is the biggest PV solar market in the world (The Economist, 2006b). Moreover, long-term minimum prices do not provide producers of sustainable energy with an incentive to work cost-efficiently (Verhaegen, et al., 2008).

TGC is a market-based instrument as investors decide to install RES-E based on the price of electricity and the (observed or expected) price of TGC. Therefore, producers are given an incentive to work cost-efficiently. TGC integrates better RES-E into a liberalized electricity market, give a continuous incentive on renewable producers to seek cost reductions (e.g through technological innovation) and they can be designed so that these cost reductions are passed on to consumers (Berry and Jaccard, 2001; del Rio and Gual, 2004). In general, TGC can be designed in a fully competitive-neutral way if targets equally apply to all retail electricity suppliers (Wiser et al., 2005).

In the long run, harmonization of TGC could constitute a way of complying with the European Union's RES-E policies at a minimum overall cost to society, just as the internalization of carbon dioxide allowance markets opens up for the possibility to achieve carbon emissions reductions cost-effectively (Söderholm, forthcoming). On the other hand, several simulation studies also show that harmonized FIT levels can yield substantial cost savings (e.g., Voogt et al., 2001; del Rio, 2005; Huber et al., 2006).

Trade in a EU TGC market would ensure a more cost-effective policy of renewables due to differences of marginal costs across EU Member States. The renewable technologies would be established in countries with the lowest cost to produce renewable electricity. These low-cost countries may sell their excess certificates to high-cost countries in short of green certificates. The larger the differences between marginal costs, the larger are the benefits from an EU TGC market.

The experiences gained so far with RES-E support in EU Member States, however, reveals that feed-in-tariffs are not necessarily less efficient than (national) TGCs. Ragwitz et al. (2007) show that the support levels for onshore wind power in 2004 under FIT schemes are not generally above those of certificate prices in Member States with TGC schemes. This finding may nevertheless be influenced by the fact that the TGCs are a relatively new instrument in the countries assessed and therefore suffer from 'significant transient effects'.

Technological Innovation and "Valley of Death"

To meet the social welfare maximisation criteria, development of RES-E occurs to the point where marginal cost of RES-E and the marginal social utility are equalised, i.e., the point of static efficiency. This level of RES-E is developed at least costs by utilising the best available RES-E technologies at the best sites. However, if we consider dynamic efficiency, there is an advantage in differentiating support between technologies. In the long run, if we use a unique price for all technologies in the FIT, or a single TGC scheme the immature and non-competitive technologies will not have progressed when resource potentials of the cheapest RES-Es are exploited and more expensive, less mature technologies have to take over the previous ones. Consequently, marginal costs will increase sharply. With the FIT system, governments can (and do) differentiate rates between technologies. Typically, TGC[5] does not discriminate across all the eligible

[5] With the bidding system/ tender differentiation is allowed by separation of auctions in different "technology bands". In the bid system organised by "technology band" the regulator may fail by discouraging one technology in terms of target.

technologies, and an eventual differentiation of TGC by technologies may reduce the liquidity of TGC trade exchanges. To allow technology differentiation in a cost-efficient way requires the public authority to know the marginal cost curves of each RES-E technology with a certain degree of accuracy. Yet with the FIT system, it is possible to overestimate the marginal cost curves for some of the technologies and underestimate others (Finon and Perez, 2007). This is part of the rationale for the regular adjustments of FIT schemes in many Member States.

Feed-in tariffs may be easily differentiated across technologies in order to stimulate various technologies at different stages of maturity. As such, feed-in tariffs are a well-suited instrument for bridging the “Valley of death”. Obviously not every technology is in the same phase; e.g. wind energy on land is almost competitive with fossil fuels, whereas photovoltaic and the fuel cell have a long way to go before they are ready for massive deployment. This is illustrated in the high degree of differentiation of German feed-in tariffs between technologies. Tariffs above €0.50 per kilowatt-hour for photovoltaics and below €0.10 per kilowatt-hour for wind illustrate the difference in commercial maturity between the two technologies. Moreover, a differentiation in FIT also allows for taking into account the externalities of particular technologies.

When technologies at different stages of development and with different costs compete on the same market, TGC will choose for the cheapest ones (Meyer and Koefoed, 2003). In particular, wind power is likely to take most of the market, biomass and small hydro might be competitive in special cases while the role of solar electricity will be negligible (Meyer, 2003). In general, a TGC system seems less efficient in stimulating the development of new renewable energy technologies. A TGC would fail, in principle, to differentiate between the different technological stages corresponding to different technologies. This may lead to a technological lock-in of mature, established renewable technologies. This is an argument for also having supplementary feed-in tariffs at early stages of technological development to bridge the “Valley of death”. Alternatively, complementary instruments such as investment cost subsidies may support a broader technological diversity than otherwise would occur under a low-cost TGC approach.

Taking a dynamic innovation perspective on renewables, one can argue that feed-in tariffs and certificate markets should be seen as complementary regulatory instrument targeting subsequent steps in the product innovation cycle. The feed-in tariff only exposes the technology to a benchmark cost model for the relevant technology, whereas the TGC market stimulates a cross-technology competition improving overall efficiency.

However four mechanisms have been suggested to promote more costly and/or emerging technologies with TGC:

(i) introducing technological bands, i.e., creating technologically differentiated TGC markets;

(ii) using renewable energy credit multipliers, i.e., providing more certificates per MWh of produced electricity to more expensive technologies;

(iii) using other instruments, e.g., technology specific-investment subsidies, simultaneously with the TGC;

(iv) The integration of feed-in tariffs in a TGC scheme, offering the investor a guaranteed minimum price for the certificate as e.g. in Belgium (van der Linden et al., 2005; Verbruggen, 2004; Verhaegen et al., forthcoming; Voogt and Uyterlinde, 2006; Wiser et al., 2005).

Consumer Prices

The on-going electricity market liberalization process makes that consumers more able to choose between competing offers and more likely to switch to suppliers with lower prices. In a fully liberalized cross-European energy market the question arises on how to harmonize the national or regional feed-in tariffs in order to avoid transboundary and/or cross-sectoral distortions. A harmonisation of support schemes is desirable in the long run, while the currently relatively low levels of competition in the energy sector would allow for a continuation of national support schemes for the time being (European Commission, 2008c).

In countries like Germany the regional network operators with a large number of –expensive- renewable energy had a competitive disadvantage, as their consumers switched to the lower prices of operators with more conventional energy generation. The (German) Renewable Energy Act balances these expenses among different operators. Further, the level and longevity of feed-in tariffs must be tailored carefully to insure against significant price changes.

An advantage of an EU TGC market is the higher price stability thanks to the higher degree of liquidity (Del Rio, 2005; Menanteau et al., 2003; Morthorst, 2000). Finon and Perez (2007) prefer TGC because this instrument allows better control over consumer costs, whilst retaining market incentives.

Public Finance

Long-term feed-in tariffs are often preferred to lower the market and regulatory risks for the investors. However, if the feed-in tariff is financed from the government budget (as an alternative to financing by the consumers as in Germany and Spain[6]), the RES-E policy competes with other policies for public money (e.g. education, environment, social policy, defence, etc.). RES-E policies would then impose a high burden on the public finances of the government (Morthorst, 2000; Agnolucci, 2008). Moreover, the Marginal Cost of Public Funds (MCPF) makes the feed-in tariffs (and, subsidies in general) more expensive than just the amount of euros that is transferred from the government to the beneficiary. The MCPF measures the marginal costs to the economy of each additional euro in the public budget. E.g. a lump-sum tax[7] is non-distorting, i.e. it does not distort the economy, as there is no way to escape this tax. Its MCPF is (close to) 1. Unfortunately, most taxes, e.g. labor and capital taxes, are distorting, and their use implies additional costs. E.g. people may decide not to work or go the black market due to high labor taxes; alternatively capital may leave the country due to high capital

[6] However, the translation of costs to final consumer prices can be temporarily modulated by price regulations affecting the wholesale electricity price for domestic and industrial consumers.

[7] E.g. the poll tax "per head" introduced by the Thatcher adminstration in the UK.

taxes. Devarajan en Robinson (2002) survey a number of country studies on MCPF. They estimate the MCPF to be between 1.2-2.2. This means that each euro received by the public government costs an additional 0.2 -1.2 euro to the economy. Similarly, Kleven and Kreiner (2006) assess the MCPF in various taxes in OECD countries and their effects on the labor market. They find a MCPF between 1.09 (UK) and 2.52 (Belgium), reflecting an additional cost of 0.09-1.52 euro. de Palma et al. (2007) recommend to take the MCPF into account for a complete cost-benefit analysis.

NIMBY and Local Benefits

Agnolucci (2007) argues that a EU harmonization of TGC may lead to a (cost-efficient) concentration of RES-E projects in a small number of locations. This concentration induces NIMBY (Not-in-my-Backyard) concerns[8] by local population and their governments. Muñoz et al. (2007) assume that the marginal benefits of RES-E have major local components (e.g. local employment and less local air pollutants) which may avoid this NIMBY behaviour. These local benefits also back the differentiation of support schemes across regions and countries. Söderholm (forthcoming), however, advocates for harmonization of support schemes as he gives more importance to EU wide benefits as EU energy security and less greenhouse gas emissions.

[8] Frey et al. (1996) define NIMBY projects as all undertakings that increase overall welfare (public good, e.g. less air pollutants or higher energy security) but impose net costs on the individuals living in the host community (private bad, e.g. the local nuisance of renewable installations).

5. CONCLUSIONS

The paper discusses feed-in tariffs and tradable green certificates as examples of price-based and quantity-based instruments in the public policy for RES-E. We compare both instruments for uncertainty, market and regulatory risks, cost-efficiency, technological innovation ("Valley of death"), consumer electricity prices, public finance, NIMBY and local benefits. It is difficult to draw general conclusions because of the different ways market-pull schemes can be designed, as each instrument has many variants, each with varying levels of efficiency and ability to address inefficiencies. Moreover, references to empirical observations are somewhat misguiding because instruments can not be isolated from the policy context and the local circumstances. Taking a dynamic innovation perspective on renewables, one can argue that feed-in tariffs and certificate markets should be seen as complementary regulatory instruments targeting subsequent steps in the product innovation cycle. The feed-in tariff only exposes the technology to a benchmark cost model for the relevant technology, whereas the TGC market stimulates a cross-technology competition improving efficiency. In the long run, a market of TGC may be appropriate for relatively more mature RES-E technologies in a liberalised energy market. However, FIT may be still considered to support more innovative, and more expensive technologies. The diversity of renewable support schemes across the EU Member States reflects varying national conditions (e.g. electricity markets, resources, consumer perception). A sudden change between different schemes may entail uncertainty and slow down the deployment of RES-E.

Obviously there are a number of caveats in this overview. First, it may be interesting to have a closer look to the interaction of TGC and FIT with other policy instruments (e.g. capital subsidy). This analysis may be supported by real world evidence across the globe. Second, a more detailed analysis is needed on the sequence and timing of the demand-push instruments and the demand-pull instruments in order to bridge the "Valley of death". Third, the question remains how an ambitious RES-E policy influences the Emission Trading System (ETS), and vice versa.

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