

Feed-in tariffs versus quotas : how to promote renewables and stimulate technical progress for cost decrease ?

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Abstract: Incentive schemes for the development of renewable energy sources may focus on quantities – defining national targets and setting up bidding systems, or quota systems providing for green certificate trading –, or they may focus on prices - feed-in tariffs. Whatever the system chosen, the role of the public authorities is quite specific: to stimulate technical progress and speed up the technological learning processes so that ultimately renewable energy technologies will be able to compete with conventional technologies, once the environmental costs have been internalised. A comparison of instruments must thus take into account the characteristics of the innovation process and adoption conditions – uncertainties regarding cost curves, learning effects – which means also looking at dynamic efficiency criteria. The paper concludes that a system of feed-in tariffs is more efficient than a bidding system, but highlights the theoretical interest of green certificate trading which must be confirmed through practice, given the influence of market structures and rules on the performance of this type of approach.

Introduction

Renewable energies sources (RES) are receiving increasing support from public authorities because of the environmental advantages they procure in comparison with conventional energy sources, particularly for controlling greenhouse gas emissions. With confirmation of the risk of climate change (IPCC, 2000), incentives to develop RES have been reinforced so that the greenhouse gas emissions reduction targets agreed to in the Kyoto Protocol can be achieved. The recent European Directive on renewable energies (EC, 2001), is an illustration of the new ambitious objectives assigned to RES.

The possibility of achieving the targets at a lower cost, which has until now been a relatively secondary concern given that the objectives were limited, has now become a central issue, making it necessary to examine the efficiency of the instruments used to promote RES.

These incentives frameworks are based typically on the same approaches as environmental policies: price-based approaches for systems where electric utilities are obliged to purchase electricity from green power generators at feed-in tariffs, quantity-

based approaches where the public authorities set an objective to be reached and organise competitive bidding processes, or where they impose quotas on electricity suppliers and set up a system of tradable green certificates.

Our analysis will focus on renewable energy technologies used to generate electricity for the grid (RES-E). Several electricity generation technologies are potentially concerned: micro-hydro, wind, bioelectricity, photovoltaic solar, etc. These technologies have reached different stages of maturity, and the type of support given to each must therefore be adapted (Christiansen, 2001). This paper examines only those policies designed to assist entry on the market of technologies that are nearly competitive with conventional technologies, such as biomass technologies and wind energy. The example of wind energy development will be used as the main reference for the analysis.

Choice of instruments to foster the development of RES-E

An examination of the policies used in the European countries over the last twenty years to promote the development of RES-E shows that the instruments used are very similar to environmental policy instruments. They are all concerned with the question of efficiency in the prices versus quantities debate.

Price-based or quantity-based approach:

In addition to research and development (R&D), support schemes fall into three main categories that are either price-based or quantity-based in their approach: feed-in tariffs, which constitute the oldest and most widely used support system ; bidding processes based on a fixed amount of renewable energy to be generated nationally and tradable green certificates schemes, where electricity suppliers are obliged to produce or distribute a certain quota of renewable energy.

- Feed-in tariffs

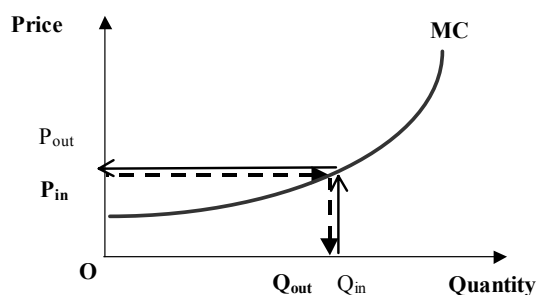
The feed-in tariff scheme involves an obligation on the part of electric utilities to purchase the electricity produced by renewable energy producers in their service area at a tariff determined by the public authorities and guaranteed for a specified period of time (generally about 15 years).

The feed-in tariff system operates as a subsidy allocated to producers of renewable electricity. It works in the same way as a pollution tax does for firms that pollute. Take the example of wind energy: producers are encouraged to exploit all available generating sites until the marginal cost of producing wind power equalises the proposed feed-in tariff P_{in} . The amount generated then corresponds to Q_{out} (Fig. 1). Q_{out} is not known a priori if the marginal cost curve for wind energy generation is not known, which is generally the case.

All projects of course benefit from the tariff P_{in} , including those whose marginal production costs are considerably lower than the proposed tariff. The difference in quality of the various sites leads to the attribution of a differential rent, to the advantage of those projects which have the lowest production costs. The overall cost of reaching the objective is given by the area $P_{in} \times Q_{out}$.

The cost of subsidising producers of RES-E is covered either through cross-subsidies among all electricity consumers (Spain, Italy) or simply by those customers of the utility obliged to buy green electricity (Germany until 2000), or by the taxpayer, or a combination of both systems (Denmark)¹. Calling simply on customers of local companies to finance green power generation is considered unfair and mechanisms are therefore often adopted to share the burden more equitably (cf. infra).

Figure 1 : Prices vs quantity-based approach



- Competitive bidding processes

In the case of competitive bidding processes, the regulator defines a reserved market for a given amount of RES-E and organises a competition between renewable producers to allocate this amount. Electric utilities are then obliged to purchase the electricity from the selected power producers².

Competition focuses on the price per kWh proposed during the bidding process. Proposals are classified in increasing order of cost until the amount to be contracted is reached. Each of the renewable energy generators selected is awarded a long term contract to supply electricity at the pay-as-bid price. The marginal cost P_{out} is the price paid for the last project selected which enables the quantity Q_{in} to be reached (Fig 1). The implicit subsidies attributed to each generator correspond to

the difference between the bid price and the wholesale market price.

The competitive bidding procedure enables the marginal production costs of all the producers to be identified (ex post). The overall cost of reaching the target is given by the area situated under the marginal cost curve. The differential rent which, in a system of feed-in tariffs, is paid to renewable energy generators, does not in this case have to be borne by consumers.

Another difference between competitive bidding and feed-in tariffs is that the exact amount of renewable electricity concerned by the bids is in this case a priori known. On the other hand, since the precise shape of the cost curve is not known (ex ante), the marginal cost and the overall cost of reaching the target cannot be determined.

Finally, the extra cost is financed in much the same way as in the previous case. It is either added to electricity bills in the form of a special levy (England), or the cost is covered through cross-subsidisation among all electricity consumers (France).

- Green certificates

In this type of scheme, a fixed quota of the electricity sold by operators on the market has to be generated from RES. Liable entities then have the possibility of generating the required amount of electricity themselves, purchasing through long term contracts from a specialised renewable energy producer, or purchasing certificates for specific amounts of green electricity from other operators (Berry, T. et al, 2001; Voogt, M. et al. 2000).

The amount of green electricity to be generated is decided for the whole country, as in the case of bidding schemes, and is then divided among each of the operators (consumer, retailer, distributor or producer). Since operators do not all benefit from the same opportunities to develop renewable energy sources and thus have different marginal production cost curves, green certificates enable quotas to be allocated in an efficient way. Without such a flexibility mechanism, operators with identical obligations would incur different marginal costs, which would be a source of inefficiency. With a certificates system, the burden is shared efficiently: marginal production costs are equalised among operators and specialised producers are encouraged to enter the market.

As a result, the global target Q_{in} attributed to the operators is reached at the market price of the certificates P_{out} . Clearly the same results could be achieved without flexibility mechanisms by assigning different objectives to each operator. But, in a situation where the public authority - and probably also the operators themselves - have only incomplete information, it is very difficult to allocate efficient quantities which would equalise marginal costs. Under the green certificate system, specific objectives (Q_A , Q_B , etc.) can be assigned to

¹ In Germany, the new tariffs for wind energy are 0.091 euros/kWh during 5 years, after which the rate decreases depending on the site; in Denmark, the tariff is fixed at 85% of the domestic tariff supplemented by the reimbursement of the carbon tax.

² Competitive bidding systems have been used in the United Kingdom under the Non-Fossil Fuel Obligation (NFFO) set up in 1991 and which concerned different renewable energy technologies. Similar schemes existed in France with the Eole 2005 program set up in 1996 to promote wind energy.

all the operators while at the same time minimising the overall cost of reaching the production target through equalisation of the marginal production costs.

Asymmetry of price-based/quantity-based approaches in situation with imperfect information

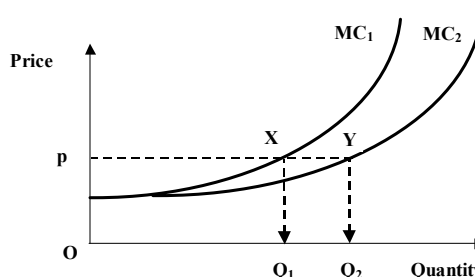
In the case of pollution control methods, when all the necessary information is available, price-based and quantity-based schemes produce very similar results. The administrative authority can fix the "price" in the case of the tax, or the "quantity" in the case of permits, so as to reach the same pollution control target.

Price-based and quantity-based approaches are not equivalent in situation where information is incomplete (uncertainty). When the depollution cost curves are not known, the tax provides a certain control over the cost of measures to be used. However, it will not a priori provide an indication of the amount of pollution avoided, nor therefore of the overall cost of the pollution control measure.

Similarly, a quantity-based approach will not enable the total cost of pollution control to be estimated since the marginal cost of the technical options to be used is not known. However, a quantity-based approach ensures direct control over the authorised amounts of pollution.

In situation of incomplete information, the symmetry between the price-based and quantity-based approaches is not total. It is thus understandable that incentives based on feed-in tariffs have been criticised for their excessively high overall cost. If it is assumed that the wind energy cost curves are, at the present stage, relatively flat³ it can be seen that a slight variation in the feed-in tariff proposed leads to substantial increase in the quantities produced from Q_1 to Q_2 (Fig.2), and consequently in subsidies, whether financed by electricity consumers or the public budget. On the other hand, this risk has been limited by quantity-based schemes, since successive tendering procedures have made it possible to maintain indirect control over prices and to anticipate the level of subsidies.

Figure 2: Price-based approach in a situation of uncertainty



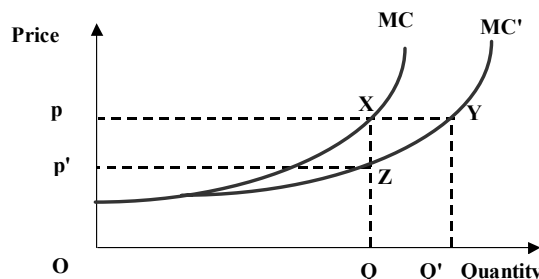
Differences in dynamic efficiency: the impact on technical change

The question of encouraging technical progress involves two different problems. The first concerns cost reductions resulting from the pressure of competition between projects, based on the portfolio of available technologies. The second concerns the effort devoted to seeking technological innovations made possible by new R&D investments financed by the surplus obtained from selling RES electricity.

In the first case, the pressure to reduce costs is encountered only in the case of competitive bidding and green certificates, investors being price-takers in order to anticipate the profitability of their projects. The system of feed-in tariffs does not provide the same kind of incentive. The dynamic effect must also be assessed in relation to the installed capacities (technological learning). In this respect, competitive bidding systems are limited in their effects since their performance in terms of installation is poor in comparison with the feed-in tariff system (cf. infra).

In the second case, the basic premise is that once producers and their equipment suppliers attain a certain level of profit, they invest in R&D in order to lower costs and increase their profit. We must therefore look at the surplus resulting from technical change and how it is shared out between producers and consumers (or taxpayers) depending on the type of incentive used, feed-in tariffs, competitive bidding or green certificates.

Figure 3: Feed-in tariffs and technical change



In the case of a guaranteed price level p , when technical change is included in the calculation, production costs are reduced from MC to MC' , and renewable energy generation is increased from Q to Q' (Fig. 3). With such a hypothesis, where prices remain constant, the community benefits from the

³ The precise shape of the cost curves is not known. Intuitively, it can be assumed that these curves are relatively flat for a given technology, since the best sites (coastal areas) have so far hardly been exploited.

increased generation of RES-E and producers keep the surplus created by technical change (area O'XY).

In a bidding system, if we take the same amount Q and include technical change, we get the equilibrium point Z. If prices are attributed according to the "pay as bid" price, the surplus O'XZ resulting from technical progress goes to the consumer, or to the taxpayer. In the case of a green certificates scheme, for an amount Q, the equilibrium price will be established at p'. Some of the surplus will go to the producers (O'Zp') but compared to the previous situation it will be reduced by the area pXZp'

The three instruments produce different results in terms of how the surplus is shared. In the case of feed-in tariffs, technical change tends to increase the producers' surplus, thus encouraging them to innovate. Inversely, with quantity-based approaches, the surplus that goes to the producers is limited (as in the case of green certificates), or it may be attributed entirely to consumers ("pay-as-bid" price). Producers are therefore not encouraged to innovate by the prospect of an increased surplus. However, they are compelled to remain competitive and so must try to benefit from technical progress because of the pressures of bidding processes and the certificates market. In an open economy, this situation may encourage them to turn to foreign technology.

The comparative efficiency of the different incentive schemes

A number of renewable energy technologies have benefited to varying degrees from support of incentive programs introduced in the industrialised countries over the last 20 years. The impact of these instruments has been particularly felt in the case of wind energy, which is now nearly competitive with conventional technologies. The example of wind energy is therefore used here for reference purposes.

Since 1990, the two main incentives used in the European countries to support the development of wind energy have been feed-in tariffs and competitive bidding systems, which have given very different results. The impact of these policies will be analysed according to different criteria:

- capacity to stimulate renewable electricity generation
- net overall cost for the community
- incentives to reduce costs and prices
- incentives to innovate.

Green certificate systems are difficult to analyse at this stage on the basis of these criteria because of the limited experience acquired. On the other hand, we shall examine their potential effectiveness in an international market, as part of a joint effort by

several countries to combat climate change. This will be the case for the European Member States, which have been assigned individual renewable energy generation targets within the framework of the new European Directive on RES-E.

Feed-in tariffs and bidding systems

In the following analysis, reference will be made to the four criteria mentioned above.

- Stimulation of RES-E generation: incentives to enter the market

The two systems exhibit radically different market entry incentives in terms of future profitability, risks and transaction costs. The feed-in tariffs in operation in Germany, Denmark and Spain have led to sustained development of wind power, both in terms of installed capacity and at the industrial level (Chabot, 2000; Gutermuth, 2000; Wagner, 2000). Thus, these three countries alone accounted for over 80% of additional installed capacity in Europe in 2000 (cf. Table 1).

The prospect of obtaining a good return on investment offered by relatively high prices levels is the main explanation for the efficiency of this system. The success of the incentive scheme can also be explained by the low risk run by project developers, since subsidies are granted to all new projects and continue throughout the pay off period⁴. At this point, the market risk is non-existent and the profitability of projects depends essentially on the ability of investors to control their costs. Finally, the transaction costs (project preparation, selection procedure) are lower than for the other system, which is laborious and costly to implement. To add impetus to wind power development, France has recently opted for the feed-in tariff system, just a few years after its not totally convincing introduction of a programme based on tendering procedures (Eole 2005).

Table 1: installed wind power capacity in Europe (MW)

Incentives	Country	Installed cap (end 2000)	Add. cap. (in 2000)
Feed-in tariffs	Germany	6113	1668
	Spain	2402	872
	Denmark	2297	555
	TOTAL	10812	3095
Bidding systems	UK	409	53
	Ireland	118	45
	France	79	56
	TOTAL	606	154

Source: *WindPower Monthly*, The Windindicator (<http://www.wpm.co.nz>), April 2002

⁴ Under new German legislation, purchase prices are indexed to the wholesale price of electricity and thus likely to change for new arrivals, but they are fixed once and for all for completed projects. Previously, feed-in tariffs were those for the current year with no guarantee for the long term.

The considerably lower purchase prices obtained through bidding systems under the pressure of competition limit the margins with respect to risk and thus result in much more limited installed capacities (cf. Table 2). The substantial difference in results between bidding systems and feed-in tariffs might also be explained by the relatively flat cost curves for wind power in the present phase, a virtual doubling of the marginal cost leading to a significant increase in associated capacities.

Table 2: Comparison of wind power prices in Europe in 1998 (in Euros/kWh)

Feed-in tariffs		
Germany	Denmark	Spain
0.086	0.079	0.068
Average bidding prices		
UK	France	
0.041	0.048	

Source: EC; 1999; NFFO; Eole 2005.

The second factor affecting the attraction of bidding systems is the uncertainty regarding the profitability of submitted projects, for which considerable preparation costs are incurred. The allocation of subsidies after a competitive tendering procedure introduces an element of uncertainty and a new risk⁵, with the unsuccessful bidders remaining fully responsible for the costs of preparing their proposals. Furthermore, the very nature of the bidding system means that profit margins are considerably reduced and expected profitability rates significantly lower than those associated with fixed tariffs. The balance between the risks involved and expected profits is thus clearly to the disadvantage of competitive bidding, making it a less attractive system for investors.

A final factor will influence the feasibility of projects proposed in the context of a bidding system. Certain aspects (environmental impact studies, information programs and public interest, site integration ...), which might appear less important, are given less attention in the project preparation phase. Consequently, in certain regions there may be a strong opposition movement (Brunt, 1998). In comparison, the acceptability of projects is much higher in countries that have feed-in tariffs. In this case, the better profitability conditions offered make it possible to avoid a concentration of projects at the most efficient sites, or the creation of excessively large and controversial wind farms. In this type of incentive system, public preferences can be taken into account through an implicit internalisation of visual externalities. Projects are then more evenly distributed throughout the country. The absence of competition between projects and more favourable purchase prices are

⁵ Under NFFO-5, 408 bids were examined, of which 147 were refused.

factors that have contributed to more geographically balanced development which raises less opposition at the local level.

- Overall cost of supporting renewables

Feed-in tariffs are extremely simple to implement from an administrative point of view. However, they have proved very costly in terms of subsidies, either for clients of electricity utilities or for the State budget, this being the price to pay for the positive impact on the generation of renewable energy. In 1998, the Danish government paid out over 100 million euros in subsidies and this figure was expected to rise still further with the increase in generation capacity, creating an increasingly heavy burden on the public budget (Morthorst, 1999). This type of support policy also requires very high cross-subsidies, estimated at around 200 million euros in Germany in 2000.

A big advantage of bidding systems is that the level of subsidies for renewable electricity generation can be controlled. In this respect, quantity-based approaches have enabled authorities to maintain greater control over public spending through the organisation of successive tendering procedure, progressively revealing the shape of the cost curve. A comparable result could have been obtained with feed-in tariffs, but the system was institutionally rigid, making it impossible to control through the adjustment of feed-in tariffs.

The feed-in tariffs versus competitive bidding debate has forced the former system to make adaptations to take into account overall cost of public support. Feed-in tariffs decreasing in stage with the level of production have been introduced in order to limit the surplus to the producers at generating sites of high quality. These incremental feed-in tariffs ensure a minimum rate of return to producers at generating sites of lower quality while at the same time controlling the rent allowed to producers who benefit from more favourable conditions (Elgreen, 2001). Germany, and more recently France, have now incorporated this device into their support policy.

- Incentives to reduce costs and prices

Insufficient incentives to lower costs is considered to be the principal weakness of feed-in tariffs, while competitive bidding systems have proved to be particularly effective in this respect (Mitchell, 1995; Mitchell, 2000).

The successive tendering procedures under the NFFO (Non-Fossil Fuel Obligation) resulted in regular decreases in the prices awarded to successful bids. The average price for proposals, irrespective of the technology involved, went from 6.7 ceuro/kWh under NFFO-3 (1994) to 4.2 ceuro/kWh under NFFO-5 (1998). This price was only 0.15 ceuro/kWh above the pool reference purchase price for the corresponding period (Kühn et al, 1999). This price reduction bears witness to

the capacity of bidding schemes to enable consumers to benefit from all the opportunities to cut production costs.

At the same time, referring to the theory of interest groups, feed-in tariff systems are much less flexible and revisable than bidding schemes when it comes to limiting rents. There is a fundamental political problem in announcing a drop in government support renewable energy. The decrease in investment costs and the improved performance of certain renewable energy technologies, and wind energy in particular, are only partially reflected in the lower feed-in tariffs observed in Germany. This relative price stability results paradoxically in an increase in the share of subsidies allocated to new projects that benefit from technical progress⁶. To overcome this problem, price reductions must be announced ahead of time, when the device is put in place. With degressive feed-in tariffs that anticipate technical progress, the profits resulting from technical progress can be shared out more equitably by reducing the total cost borne by the community while granting a certain surplus to producers (Elgreen, 2001).

While competitive bidding systems undeniably create greater incentive to lower prices and costs of renewable energies, it should be noted that the price reductions observed are not necessarily related solely to technical change (falling investment costs, improved technical performance, learning experience of operators, search of scale effects...) or to its side effects (fall in cost of credit associated with a different perception of the technological risks, for example) but also to a systematic effort to reduce costs through economies of scale and use of the very best sites available.

- Incentives to innovate

The criterion of the dynamic efficiency of the incentive instruments enables the approach to be extended beyond examining simply the effects of reduced costs over a short period. Consideration can also be given to the possibility of establishing sustainable technical progress. The establishment of such a dynamic process depends in part on the technological learning processes related to the wider diffusion of the technologies, but also on manufacturers' R&D investments and thus on the surpluses that they might be allocated.

Feed-in tariffs and pay-as-bid tendering schemes differ in terms of how the surplus resulting from technical change is shared out. In the first case, it is producers-investors and manufacturers who benefit from the entire surplus resulting from lower costs, if the feed-in tariffs are not adjusted in step with technical change. In the case of competitive bidding, producers must pass on cost savings to

taxpayers or consumers. This distribution of the surplus has two consequences:

- The technological learning effects have been much greater for manufacturers in countries that have opted for feed-in tariffs because of the strong growth in generating capacities. Remember that the three leading countries in Europe, stimulated by feed-in tariffs, installed 20 times more generating capacity in 2000 than the countries operating competitive bidding schemes.
- The reduced margins inherent in the bidding system have limited the R&D investment capability of manufacturers and their suppliers. Consequently, in interdependent economies operating different support mechanisms, the reduction in costs observed for wind power generating systems with bidding systems is helped by the technical progress made by manufacturers in countries where support policies are more favourable. In these countries, since firms are allowed to benefit from the differential profit, feed-in tariff schemes have enabled manufacturers to invest more heavily in R&D and to consolidate their industrial base⁷.

Green certificates: a new quantity-based approach compatible with the liberalisation of the electricity market

Despite their apparent effectiveness in stimulating the development of renewable energies, feed-in tariffs could be replaced over the next few years by a system of green certificates. The reason for such a possible change is two-fold:

- the rapid growth in production and the corresponding increase in RES-E subsidies,
- the liberalisation of the electricity sector in Europe. The cost of supporting renewables, when unequally shared, distorts the competition between suppliers, a situation which is incompatible with the opening up of the European market desired by the Commission.

Feed-in tariffs could develop in such a way that they do not distort competition and so that all consumers contribute to supporting renewable energies. In 2000, Germany set up a system of sharing the cost of supporting renewable energies among the electric utilities. Nevertheless, green certificates, designed to allow compatibility of incentive frameworks with the opening up to competition, are more adapted to the new types of

⁶ New legislation in Germany – EEG law, Spring 2000- and in France – wind energy tariff decrees, Autumn 2000- provides a first response to this problem (cf. infra).

⁷ In 1998, Germany, Denmark and Spain were home to eight of the ten biggest wind turbine manufacturers in the world. On the other hand, in the United Kingdom, the government has not reached its goal of developing a competitive renewable energy industry.

electricity market (Voogt et al, 2000; Wohlgemuth, N., 1999).

- The contribution of green certificates

Through the system of green certificates, renewable energy generation is becoming, to a certain extent, an integral part of the electricity market, instead of being separate as in the case of other incentive schemes. Green certificates are attributed to RES-E generators who exploit the power they generate in two different ways: by selling the electricity at the wholesale market price, and by selling certificates to operators who have a particular quota to meet. Support mechanisms for renewable energy development are then no longer unrelated to electricity price changes, as was the case with competitive bidding schemes and feed-in tariffs. The total price per renewable kWh, which is equal to the wholesale market price plus the price of the green certificate per kWh, should in theory correspond to the full cost of the marginal unit to be installed during the growth period of green electricity. Conversely the green certificate price at one time would be established as the difference between this marginal cost during the development phase and the wholesale market price.

Under the system of green certificates, RES-E generation objectives can be imposed on electricity distributors/retailers with an aim of achieving overall allocation efficiency when they have access to different resources. Green certificate trading in fact makes it possible to use the least costly energy sources, for a single technology (coastal regions before inland areas) and for several competitive technologies (wind power before photovoltaic). But this advantage may become a disadvantage, from a dynamic point of view, since it tends to prevent investment in promising - but insufficiently developed - technologies. This type of system is of particular interest in an international context where trading possibilities are greater than at a purely national level, in particular where the electricity market is small or where one operator supplies virtually the entire national territory, as in France.

Such a system should thus be of particular interest in Europe with the introduction of the European Directive on green electricity defining national objectives for RES-E generation for 2010. The Directive assigns differentiated objectives to Member States in order to take into account existing potential and the efforts already made. However, since the marginal production cost curves for each country are not known, this allocation may not be the most efficient way of sharing the burden⁸. Through the system of tradable certificates,

⁸ For example, Germany, which has been given the objective of increasing RES-E consumption from 2.4 % in 1997 to 10.3% in 2010 and where wind energy potential is limited and already widely exploited, may have to make a greater effort than Ireland, whose target is to increase green electricity consumption from

priority could be given to using the least-cost resources, so that the overall target will be reached in the most economic way.

The theoretical interest of certificates must not however mask the problems associated with the organisation of certificate exchanges. For a green certificate market to work, new functions must be guaranteed - certification of RES-E producers, trade register, accounting and auditing, with penalties imposed in the event of failure to respect obligations - all of which lead to high administration costs. So as not to place too much initial pressure on the price of certificates, the quotas imposed must be moderate at first then increase gradually in step with development possibilities.

The main risk in this type of system is the volatility of the certificate price and its negative effects on investors, which happens if the market is limited and lacking liquidity due to a small number of participants (Morthorst, 2000). On the supply side, a supplier wishing to enter the market must be able to anticipate future prices and make his project "bankable" in order to secure a loan to enable him to invest in new production capacity. The creation of a futures market with long term contracts would be a way of limiting certificate price volatility caused by meteorological factors and estimating the future profitability of projects. On the demand side, borrowing or banking mechanisms are other possible ways of limiting price fluctuations that might result from overly strict limits on the validity of certificates.

- Expected efficiency of certificate system

The system of tradable green certificates is similar to the quantity-based mechanisms examined earlier but differs from a bidding system in that each operator is assigned quantitative objectives. The concrete performance of green certificate trading cannot be assessed on the basis of experience, since such mechanisms have so far been introduced only in some countries. Nevertheless, a number of potential advantages can be mentioned.

- Stimulation of new RES-E generation capacity. Environmental policy objectives can be easily defined in quantitative terms, allowing a steady progression from a known initial situation by introducing increasingly more ambitious quotas. Anyway, the possibility of anticipating future prices, along with sufficiently profitable price levels, are essential conditions if such projects are to remain attractive to investors. A futures market could enable this difficulty to be overcome if the market is sufficiently liquid. With the growth dictated by an evolving quota system, market prices will in principle be

1.1% in 1997 to 11.7% in 2010 and which has abundant wind energy resources.

sufficiently profitable because of the increasing demand for certificates.

- Incentive to lower costs. The creation of a green certificates market provides a double incentive to lower costs. First, the electricity produced by RES installations is sold on the grid at the market price, which tends to be falling due to deregulation and increased competition. Second, producers of renewable electricity are under the constant pressure of competition because of the green certificate market. This pressure creates incentives for potential investors not only to control the cost of equipment but also to control operating costs once the equipment is installed.

Conclusion

In ideal theoretical situations, price-based and quantity-based approaches are seen as comparable methods for achieving RES-E targets. But this symmetry is no longer applicable when uncertainty is taken into account. As a consequence, different criteria should be considered when evaluating the efficiency of such incentives, and in particular the question of stimulating technical change:

- Policy cost control. It is clear that the quantity-based approach is the more effective in controlling the cost of government incentive policies: by inviting tenders for successive quotas it is possible to maintain direct control over installed capacities and indirect control over the marginal production cost and thus over the cost for the community. Similar control is also maintained through the quotas imposed on electricity suppliers under green certificate schemes. Conversely, in feed-in tariff systems, RES-E production cannot be anticipated with any precision because of the uncertainty regarding cost curves. It would of course be theoretically possible to adjust prices according to the response of producers, but in a neutral environment. In practice, this type of control would be difficult to implement for political and institutional reasons, making it difficult to adjust quantities and thereby control the cost for the community.
- Installed capacities. In terms of installed capacity, price-based approaches have given far better results than quantity-based approaches. In theory, there should be no such difference, since bidding prices established at the same level as feed-in tariffs should logically give rise to comparable installed capacities. The difference can be explained by the attraction of fixed prices, which project developers see as ensuring a safe investment with better predictability and a stable incentives framework, as well as by the lower transaction costs for each project.

- Stimulation of technical change. The incentive to reduce costs is much stronger in the competitive bidding system, since competing producers must reflect lower costs in prices in order to win subsidies. In a system of feed-in tariffs, there is less incentive to lower costs, since drops in production costs have not systematically been reflected in the feed-in tariffs (Germany until 2000). However, it is possible, as demonstrated by the new incentive policy in France, to provide for a gradual reduction in feed-in tariffs to take into account the progress made in renewable technologies.

Other dynamic factors also play a role. First, greater new installed capacity allows cost reductions through technological learning on the part of national manufacturers. Second, feed-in tariffs enable manufacturers to invest more heavily in R&D and to consolidate their industrial base. This is evidenced by the fact that Denmark, Germany and Spain are the world leaders in wind turbine production.

- Other public policy objectives. Finally, while competitive bidding systems in theory allow the introduction of many selection criteria to take into account objectives concerning land development or minimisation of the pressure exerted on the best sites, it can be seen that such objectives have been better achieved in countries operating feed-in tariff systems. Moreover, these objectives are not incompatible with feed-in tariff mechanisms, as shown by the German and French systems in which adjustable tariffs have been introduced to encourage the development of wind power projects on supposedly less attractive sites.

The greater efficiency of feed-in tariff mechanisms in helping countries to achieve renewable energy development targets is confirmed by the gradual disappearance of competitive bidding systems in the wake of low project implementation rates. But the price/quantity issue is by no means settled. The potential advantages of a quota-based green certificate trading system are prompting an increasing number of countries to use such schemes to meet ambitious goals for new energy generating capacity in a cost-effective way. Compared with other instruments, green certificate trading provides the best opportunity for distributing an overall objective in the most efficient way among several technologies and for organising renewable energy development on the scale of several countries. But given the limited experience with green certificate markets, and as long as uncertainties persist concerning market operation and the creation of a framework that is considered stable by investors, its real efficiency has still to be proven.

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