Prices versus quantities : choosing policies for promoting the development of renewable energy

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Abstract

Now that the risks of climate change have been confirmed and the European States have declared their willingness to pursue ambitious objectives for producing electricity from renewable energy sources, it becomes crucial to take a look at the relative efficiency of the different incentive schemes used. Such schemes 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. Clearly, these instruments are much the same as those used in environmental policies, with similar discussion involved in their choice. 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 authors examine the efficiency of the different incentive schemes for the development of renewable energy sources, both from a theoretical point of view by comparing price-based approaches with quantity-based approaches, and from a practical point of view by looking at concrete examples of how these different instruments have been implemented. 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.

1. 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. These technologies can be substituted for conventional energy sources and limit damage to the environment caused by conventional electricity generation techniques by going further than the inefficient end-of-pipe solutions 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 European Directive on renewable energies (EC, 2001) [1], aimed at facilitating the achievement of the European commitment to reduce greenhouse gas emissions by stepping up development of electricity from RES (RES-E), has made it necessary to further reinforce these incentive schemes.

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.

While considerable progress has been made in several renewable energy technologies, others are still immature or have not reached an adequate level of economic performance. Therefore, they cannot yet compete directly with existing technologies which have benefited for some considerable time from mass production and learning effects. But if the rate of technical change can be maintained, renewables technologies could compete with fossil fuels for grid electricity production .

Ideally, the simplest, most efficient solution for re-establishing fair competition between power generation technologies would be to correct the market imperfections by implementing an optimum environmental tax. This would be an incentive to technological innovation and to changes in consumer behaviour, without making any distinction between solutions (renewables, electricity savings). But, in practice, taxes are faced with the problem of political acceptability and, furthermore, an environmental tax may not be sufficient in itself to stimulate the dynamic learning process required to bring down costs. Thus, by creating incentives for electricity producers to adopt renewable energy technologies, public policies – also referred to as market opening policies - are aimed at stimulating technical change and learning processes that will enable costs to be brought down to an economically competitive level.

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.

In this paper, we shall take up the classic debate concerning the efficiency of environmental policy instruments by analysing the relative efficiency of the three types of instrument designed to stimulate the development of renewable energy sources. First, we examine the justification of policies supporting renewable energies on the basis of the positive externalities

[1] According to the Directive on "green electricity", 22% of the electricity consumed in the European Union in 2010 must be generated from RES, compared with 14% in 1997 (including large hydro).

that they generate and their role in stimulating the learning process. Next, the instruments are characterised in relation to the classic discussion of price-based approaches versus quantity-based approaches. Third, the dynamic and static efficiency of the instruments is analysed in relation to the different criteria that distinguish price-based and quantity-based approaches when real adoption and innovation processes are considered.

The notion of efficiency involves in principle competition between the different technologies such that an optimum contribution is obtained from each, depending on their respective potential and costs. But here we consider that national support policies for renewable energy are implemented in a coherent framework in which specific objectives are allocated to each technology in relation to its cost function[2]. This notion of efficiency is two-fold. On the one hand, it involves trying to minimise overall expenditures in reaching the final objective according to the cost-effectiveness approach, since it is not possible to refer to an environmental damage curve to define the optimum level of reducing environmental externalities (static efficiency). On the other hand it involves producing permanent incentives to cost reductions through technical progress, so that ultimately competitivity will be achieved (dynamic efficiency).

Our analysis of support policies will focus on renewable energy technologies used to generate electricity for the grid and for this purpose we will treat all these technologies as a single technology. 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 might range from R&D support for emerging technologies to information and communication support for those technologies that have already demonstrated their profitability. 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 empirical analysis.

2. Environmental justification of public policies supporting renewable energy

In order to ensure the development of renewable energy technologies, government involvement is essential in the emergence phase so as to protect them from direct competition with conventional technologies. Without such support, market forces alone would result in only limited diffusion of RES in a few market niches. Diffusion would not be sufficient for these technologies to benefit from dynamic learning effects and become competitive with existing technologies.

From a theoretical standpoint, government support can be justified as a way of correcting negative externalities resulting from the use of fossil fuels and of achieving dynamic efficiency by stimulating technical change.

2.1. Absence of internalisation of environmental externalities

[2] The marginal cost of developing the potential of a particular technology.

The main advantage of renewable energies over conventional energy generation is that they contribute to the preservation of public goods, namely clean air and climate stability. Because of the non-excludable and non-rival characteristics of these public goods, private actors are not prepared to invest in something which everyone can acquire free of charge. In such conditions, the diffusion of renewable energies cannot be assured spontaneously by the market.

The liberalisation of the electricity market may appear to be a partial response to this problem of appropriation by enabling consumers who want to pay for this environmental good to purchase green electricity directly from a supplier. This solution, already tested in a number of countries (Germany, United States, Netherlands, etc.), can provide insight into the preferences of consumers and their willingness to pay for RES-E[3]. Although green electricity seems to attract an increasing number of supporters in certain countries, most consumers are not prepared to pay a higher price for a public good which everyone will be able to benefit from; the problem of free-riding remains a very real one (Batley, 2001; Wiser et al, 1997; Mirabel et al., 2001). Experience has shown that the proportion of green electricity purchasers is low, around 2 to 3%, except in cases where there are strong incentives in the form of tax exemptions for electricity consumers (Wusthangen, 2001)[4]. In fact, individual choices do not fully reflect the real value that the public may place on preserving the environment by generating RES-E.

This market failure could be solved by the introduction of regulations on fossil fuel emissions which would encourage greater use of renewable energy sources. If we assume that the cost of environmental damage can be estimated, the problem could also be solved by the introduction of a Pigouvian tax which would re-establish competitive equilibrium between technologies to the greater benefit of less polluting ones (Pigou, 1932). But, given the political problems related to the introduction of such a tax, the negative externalities stemming from the consumption of fossil fuel energy are reflected only imperfectly in energy prices[5]. The public support given to the generation of renewable energies is thus justified if looked upon as temporary compensation for the avoidance of negative externalities. Logically, this support should end once taxes applied to the different energy forms start to reflect the marginal cost of the damage caused by fossil fuel use[6].

However, it is difficult to estimate the cost of the damage avoided or the value of the public goods preserved, in terms of air quality or climate change, by using renewable energy. Since certain parameters are difficult to observe, reference cannot be made to an optimum level of emission reductions and thus renewable or non-carbon energy generation in a series of energy policy measures. In fact, renewable energy policy objectives have been defined without reference to an explicit "carbon value". Consequently, the problem has to be approached resolutely in terms of cost-effectiveness, where the objectives to be attained are defined in a discretionary manner by policy-makers on the basis of available scientific data but without sound economic rationale. The use of economic instruments such as taxes or permits

[3] Another type of scheme currently being tried out in Switzerland allows individuals to bid to buy the right to use electricity generated from planned solar equipment

[4] In the Netherlands in 2001, 8% of consumers opted to buy green electricity, but with a tax incentive of 0.06 Euros/kWh.

[5] So far, only a few countries (notably the Netherlands and Denmark) have imposed special taxes, for example on CO2 emissions.

[6] Energy dependency could also be considered a negative non-environmental externality, partially reflected in fiscal measures applied to energy products.

nevertheless guarantees that the defined objective will be reached at the lowest cost (Baumol and Oates, 1971).

2.2. Stimulating technical change

The creation of conditions for competition between fossil fuel and renewable energy sources which reflect all private and social costs will still not guarantee the creation of a dynamic process of renewable energy diffusion consistent with the collective objective of preserving the local and global environment. Renewable energies, which like any new technology have to compete with established technologies, remain in an unfavourable position. When they arrive on the market, they have not reached their optimum performance in terms of cost and reliability. Optimum performance will be achieved gradually as a result of the process of learning by using or learning by doing (Arrow, K., 1962; Dosi G., 1988). In other words, it is not because a particular technology is efficient that it is adopted, but rather because it is adopted that it will become efficient (Arthur, 1989). Incentive systems are therefore required so that renewable energy technologies can be adopted beyond narrow market niches and progress on their learning curves.

Other barriers related to the technical and economic characteristics of renewable energies stand in the way of their diffusion: their capital-intensive profile, the need to mobilise mass production effects rather than scale effects because of their size limitations, and, in certain cases, their failure to generate energy on a continuous basis. The new actors in the liberalised electricity markets tend to favour the least capital intensive generation technologies with non random energy supply , while the technological culture of established electric utilities tends to favour large systems. RES-E do not therefore present the same value for a market actor as does, for example, a gas turbine which can generate power continuously. This type of competition between electricity generating techniques constitutes sufficient justification for providing public support for new energy technologies: it stimulates a dynamic process which will reveal their ultimate performance (Foray, 1996), and at the same time helps expand the range of techniques that can contribute to global environment preservation.

3. Choice of instruments to foster the development of RES-E: an environmental policy issue

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.

3.1. Price-based or quantity-based approach:

In addition to research and development (R&D)[7], support schemes fall into three main categories that are either price-based or quantity-based in their approach:

[7] RD&D programmes, as well as investment subsidies, were the first methods introduced to improve performance and stimulate the diffusion of renewable energies. They are still used today for the most immature technologies. But, for those technologies which are now nearly competitive, more specific instruments are used which aim at integrating renewable energies in the electricity generation market.

- feed-in tariffs, used in particular in Denmark, Germany, Spain and Italy, which constitute the oldest and most widely used support system;
- bidding processes such as those used in the United Kingdom and in France until 2000. This type of scheme is based on a fixed amount of renewable energy to be generated nationally;
- tradable green certificates schemes, where electricity suppliers are obliged to produce or distribute a certain quota of renewable energy. This type of scheme is already used, or soon will be used, in several countries (Netherlands, Denmark, Sweden, Italy and United Kingdom) on more or less experimental basis, but could eventually be extended to all European countries.

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). It 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} x 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) [8]. 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).

(Fig 1 goes here)

[8] In Germany, the feed-in tariffs for wind energy is 90 % of the weighted average tariff, and in Denmark the tariff is fixed at 85% of the domestic tariff supplemented by the reimbursement of the carbon tax (see Table 2). The extra cost compared with the wholesale market price is borne by the company, which passes it on in its electricity rates (Germany, Italy), or is assumed by the State (Denmark).

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 producers. 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.

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 2). 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 then 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[9].

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).

(Fig 2 goes here)

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. In liberalised markets, green certificates concern essentially distributors-retailers or, as in Italy, electricity producers[10]; but consumers can also be directly

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[9] When it was first introduced, the English competitive bidding system (NFFO) awarded the price proposed by the marginal project to all producers (one bid price). It was thus producers who benefited from the differential profit. This was not applied in the subsequent system.

[10] Italy is planning to introduce a green certificates market in 2002, with an initial renewables quota of 2 %.

involved in the trading system[11]. Operators then have the possibility of generating the required amount of electricity themselves, purchasing through long term contracts from a specialised renewable energy generator, or purchasing certificates for specific amounts of green electricity from other operators (Berry, T. et al, 2001; Voogt, M. et al. 2000).

Certificates are issued by renewable electricity generators who benefit from generating renewable electricity in two different ways: by selling it on the network at the market price, and by selling certificates on the green certificates market.

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 todevelop renewable energy sources and thus have different marginal production cost curves[12], 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.

Take the example of two distributors A and B who are assigned production objectives O_A and O_B(Fig.3). To reach the objective O_A , distributor A, who has poorer quality resources, will incur a higher marginal production cost MC_A. The possibility of trading certificates enables him to limit his production to PR_A, and purchase certificates at the equilibrium price p to reach the target amount O_A. For his part, producer B increases his production to PR_B and sells his surplus certificates on the market at price p. The introduction of certificates results in a reduction in the cost of achieving the overall objective ($Q = O_A + O_B$), shown by the shaded areas, compared with a situation without flexibility mechanisms where the operators are subject to the constraints O_A and O_B.

(Fig.3 goes here)

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 (mc_A and mc_B). Under the green certificate system, specific objectives (O_A and O_B) can be assigned to all the operators while at the same time minimising the overall cost of reaching the production target through equalisation of the marginal production costs.

It is worth noting that, in this same situation, a competitive bidding scheme concerning the amount $O_A + O_B$ would give the same result. The feed-in tariff system would also result in efficient allocation of the amounts produced by the distributors, but not necessarily the total

[11] In the proposed Danish green certificate market, consumers will be obliged to include a certain amount of renewable-based electricity in their consumption. The liability will lie with the distributors, who every year will have to justify the purchase of a proportion of renewable electricity for their customers. The renewables quota is set at 20% for 2003 whereas the proportion of renewable electricity consumed in Denmark was 10% in 2000 !

[12] In the case of wind energy, for example, it is clear that a distributor situated in a coastal area will benefit from more favourable wind resources and consequently lower production costs than a distributor located inland.

amount sought, given the lack of information on the shape of the marginal production cost curves.

3.2. 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. It is therefore equivalent to introduce a tax t resulting in an overall quantity of pollutants Q_m, or to sell rights corresponding to the same quantity Q_m, the equilibrium price then becoming established at the level of the tax t . 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.

However, price-based and quantity-based approaches are not equivalent in situation where information is incomplete and where there is uncertainty (Cropper and Oates, 1992). Thus, when the depollution cost curves are not known, the tax provides a certain control over the cost of measures to be used. By placing a ceiling on the marginal cost, the price-based approach introduces a limit on the pollution control measures to be used by eliminating options which are too costly. 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, and if new scientific information justifies limitation of the authorised levels, this can be achieved by limiting the number of permits in circulation; permit prices will adjust accordingly. In a price-based approach, successive adjustments should be made to the tax level in order to achieve the targeted pollution reductions.

The symmetry between the price-based and quantity-based approaches is thus not total. One or the other may be preferred depending on the depollution cost curve and the damage curve (Weitzman, 1974). In the present case of policies to address the problem of climate change through stimulating renewable energy sources, if we suppose that the objective is determined in reference to a curve of avoided damage, a very simplified analysis reveals that the quantity-based approach is preferable when the slope of the marginal cost curve is gentle. In fact, a price-based approach would, if the cost curve were incorrectly estimated, give a quantitative result that would be well off target. Inversely, when the cost curve is steep, a price-based approach should be adopted since the effect on the volume of electricity generated is relatively small and the result closer to the target[13].

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 flat[14] it can be seen that a slight variation in the feed-in tariff proposed leads to substantial increase in the quantities produced (Fig.4), 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

[13] This result must of course be adjusted to take into account the damage curve, as shown by Weitzman.

[14] 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.

have made it possible to maintain indirect control over prices and to anticipate the level of subsidies.

(Fig.4 goes here)

3.3. Differences in dynamic efficiency: the impact on technical change

Theoretical analysis of the impact of the different environmental policy instruments on technical change generally leads to the conclusion that economic instruments are more efficient than regulatory mechanisms (Jaffe et al, 1999). In fact, while technical progress enables firms to reduce the cost of complying with regulations, these regulations provide no incentive for firms to make improvements beyond the standards imposed.[15] Taxes and permits are more effective in promoting technical change in that they enable companies to reduce their pollution control costs and save on taxes or on the purchase of permits.

In the present case, 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, the effects of learning on costs being related to cumulated production. 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.

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. 5). With such a hypothesis, where prices remain constant, the community benefits from the increased generation of RES-E and producers keep the surplus created by technical change (area O'XY).

(Fig.5 goes here)

[15] Firms are even less inclined to go further than the standards imposed since they may fear a ratchet effect on the part of public authorities eager to reinforce a standard that has already been exceeded.

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'[16]

The three instruments produce different results in terms of how the surplus is distributed. 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.

4. 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. Wind energy, and to a lesser extent biomass technologies, should be able to provide most of the extra renewable energy required to reach the objectives set by the European Commission[17].

Wind power technology is not efficient enough, however, for its development to take place spontaneously, as long as the negative externalities resulting from conventional energy sources are not internalised. It is thus essential for support policies to be maintained and even reinforced if the ambitious targets announced in certain countries are to be achieved. Given the greater efforts required to achieve these more ambitious goals, the question of the efficiency of the incentive measures and their cost can no longer be ignored.

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.

[16] Similarly, some of the surplus is kept by producers in a bidding system when prices are determined with reference to the marginal project ("single bid price").
[17] In France, it is estimated that sources used to increase RES-E generation to comply with the European Directive will be divided as follows: photovoltaic (1%), geothermal (2%), small hydro (9%), biomass (13%) and wind (75%) (*Systèmes Solaires* - n°141, 2001).

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.

4.1. The comparative efficiency of feed-in tariffs and bidding systems

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

Stimulation of electricity generation from renewable sources: 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)[18]. 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 period[19]. 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 goes here)

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

[18] Less is known about the Spanish system than the German and Danish systems, which are well documented. With 2235 MW of installed wind capacity at the beginning of 2001, Spain has announced strong growth rates over the last four years and is now in third position in Europe. The incentives framework gives producers the choice between a feed-in tariff for each kWh produced (0.066 euro in 1998, then 0.063 in 1999), or a variable price calculated on the basis of the market price plus a premium per kWh produced (0.031 euro in 1998, then 0.029 in 1999). The aim of the Electricity Law of November 1997 is for renewable energy consumption to reach 12% of primary energy consumption by 2010, essentially through the use of feed-in tariff schemes. This target would seem to be attainable.

[19] 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.

power in the present phase, a virtual doubling of the marginal cost leading to a significant increase in associated capacities.

(Table 2 goes here)

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 risk[20], 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[21]. 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). This has been the case in the north of England. 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. For example, in Germany, most of the potential is concentrated in the North Sea, yet only 53% of the wind energy projects are installed there[22]. The absence of competition between projects and more favourable purchase prices are 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

[20] Under NFFO-5, 408 bids were examined, of which 147 were refused.
[21] Return on investment is on average of the order of 10 to 15% in the case of feed-in tariffs and 8 to 12% for competitive bidding (P. E. Martin, Observ'ER, personal contact).
[22] New Energy, An almost magical year for the German industry, n°1 Feb 2002.

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 to take into account technical progress.

The feed-in tariffs versus competitive bidding debate has forced the former system to make adaptations to take into account technical progress. Technical progress and the lowering of RES-E generating costs can be anticipated by introducing a system of degressive tariffs (Elgreen 2001), whereby the public authorities can announce in advance the lower tariffs for future projects. The profits allocated to producers and which are the result of technical progress can then be reduced while preserving the stability of the incentive framework. Germany, and more recently France, have now incorporated this device into their support policy.

Finally, while a policy of feed-in tariffs seems to offer the best conditions to producers eager to make progress on the renewables learning curve, the public support required by this type of incentive constitutes a fairly heavy burden for the communities concerned. On the other hand, competitive bidding schemes, even though they make it possible to control overall costs, have not been able to stimulate technical progress in the local equipment construction industry.

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 (cf. Table 3). This relative price stability results paradoxically in an increase in the share of subsidies allocated to new projects that benefit from technical progress[23]. 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.

[23] 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).

(Table 3 goes here)

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 base[24].

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

[24] 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. The premature opening up of the market to competition has had an eviction effect on inexperienced British manufacturers to the advantage of Danish manufacturers who, better prepared by a much larger national market, have supplied Britain with most of its wind energy generating equipment (Hemmelskamp, 1998).

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, financed either from public funds, as in Denmark, or by local or regional electricity utilities that are obliged to purchase electricity generated by RES-E producers situated in their supply area, as in the case of Germany. In this case, the burden of financing renewables is not distributed equitably among the electricity consumers who are the first to benefit from this energy.

- the liberalisation of the electricity sector in Europe, which has enabled an increasing number of consumers (industry, large firms in the tertiary sector, even domestic consumers in certain countries) to obtain their electricity from the supplier of their choice. The cost of supporting renewables, which is unequally shared, distorts the competition between suppliers, a situation which is incompatible with the opening up of the European market desired by the Commission. It is no longer possible for a utility that is obliged to buy the renewable electricity generated in its country to pass on its extra costs to the eligible consumers. So if additional costs are only passed on to non-eligible consumers, problems of equity inevitably arise.

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 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, from a dynamic point of view, become a disadvantage, 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[25]. This 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 burden [26]. Through the system of tradable certificates, priority could be given to using the least-cost resources, so that the overall target will be reached in the most economic way. In this type of scenario, national support mechanisms must be harmonised in order to avoid unfair competition in the certificate market place. In fact, if complementary incentive mechanisms are maintained by some Member States, the price of certificates in these countries will be at an artificially lower level and the burden will be shared neither efficiently nor equitably.

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.

The creation of floor prices and ceiling prices for certificates is also seen as a way of ensuring that certificate prices remain within acceptable limits for investors and buyers (Fristrup, 2000). The floor price mechanism is based on the purchase of green certificates by a regulator at a price agreed upon if supply is too plentiful. A ceiling price may be needed because of the risk of a relative shortage of certificates. The same regulator would be responsible for selling certificates to purchasers at a guaranteed price if the market price went above this ceiling price. The same result would be achieved by imposing a tax on certificate purchasers who had not fulfilled their quotas. The money collected would then be redistributed to producers-sellers of certificates through a reverse bidding system. Thus, purchasers of certificates would

[25] See note 1.
[26] 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 1.1% in 1997 to 11.7% in 2010 and which has abundant wind energy resources.

be certain of achieving their RES-E quota at a marginal price equal to or below this ceiling price.

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 the Netherlands and Denmark. 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. It may be noted that, as already indicated, use of the market-based certificate system introduces an element of instability compared with bidding schemes, this instability being related to the volatility of certificate prices (cf. supra). Unlike feed-in tariffs, paying RES-E producers with green certificates could lead to a lack of market anticipation which might impede the development of these new technologies. The possibility of anticipating future prices, along with sufficiently profitable price levels, are essential conditions if such projects are to remain attractive to investors. Nevertheless, a futures market could enable this difficulty to be overcome if the market is sufficiently liquid. Furthermore, with the growth dictated by an evolving quota system, market prices will in principle be 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.

5. 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 and when we consider the relative efficiency of these instruments in stimulating sustainable technical change. The discussion aroused in each country by reforms to renewable energy development incentive policies clearly illustrates the need to consider different criteria 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, since 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 therefore 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). 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 renewables 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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Figures

Fig.1: Feed-in tariffs

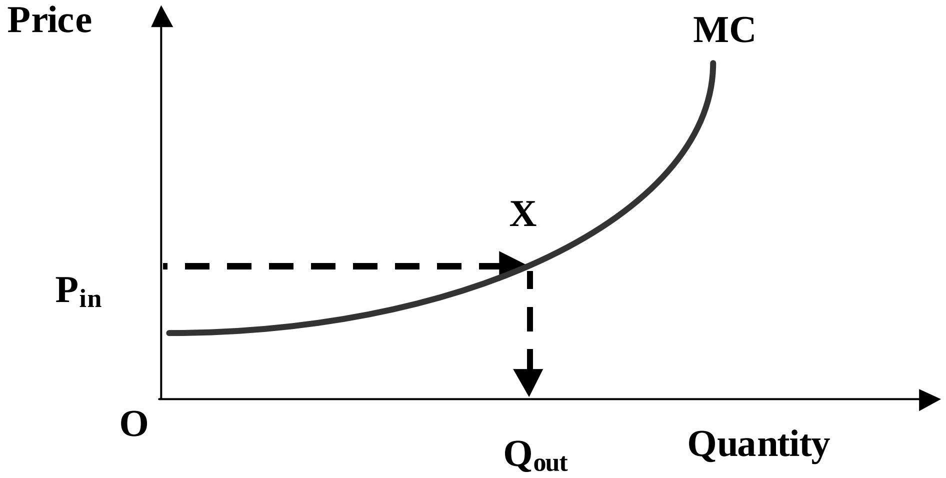


Fig. 2: Competitive bidding system

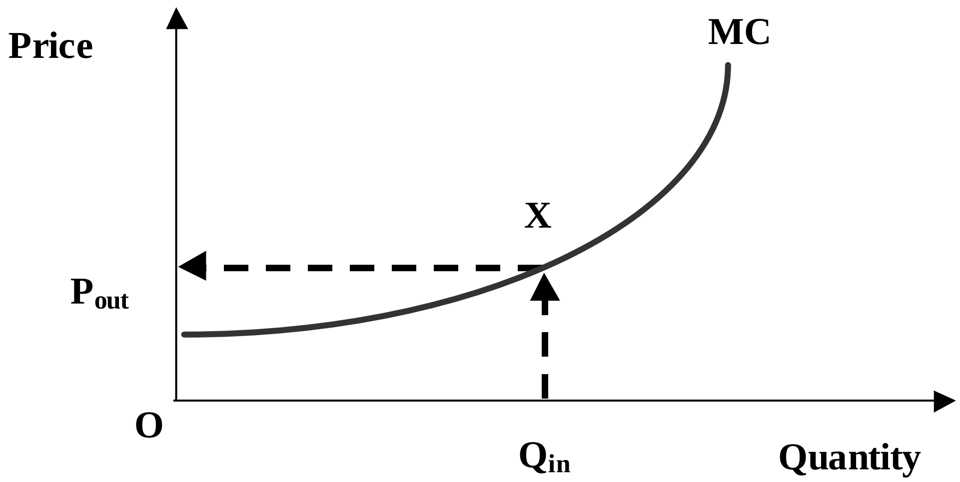


Fig. 3: Operation of green certificates market

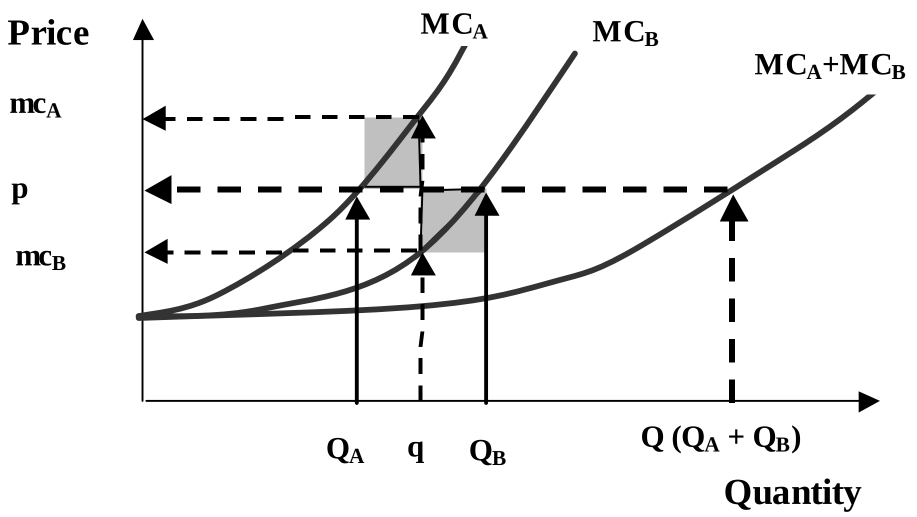


Fig. 4: Prices and quantities in situation of uncertainty

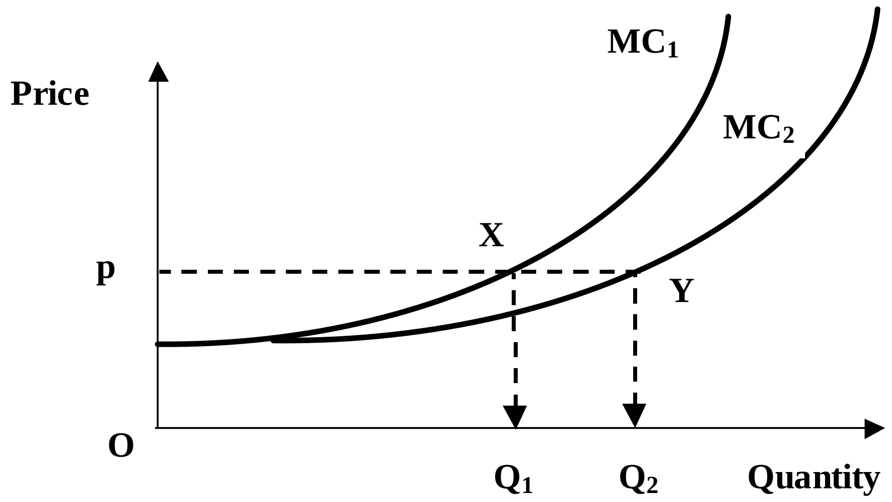
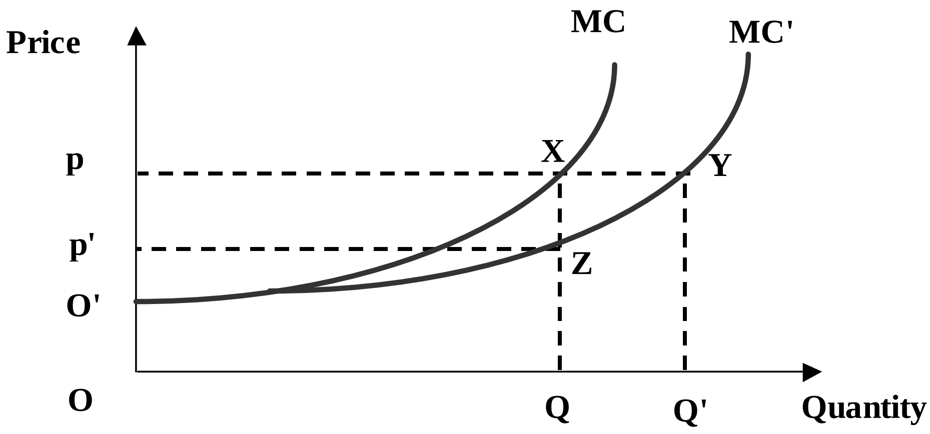


Fig. 5: Impact of guaranteed tariffs on technical change



Tables

Table 1: Impact of incentive schemes on the installed wind power capacity in Europe

Incentives	**Country**	**Installed capacity In MW (end 2000)**	**Additional capacity MW (in 2000)**
Feed-in tariffs	Germany Spain Denmark	6113 2402 2297	1668 872 555
	TOTAL	**10812**	**3095**
Bidding systems	United Kingdom Ireland France	409 118 79	53 45 56
	TOTAL	**606**	**154**

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

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

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

Source: EC; 1999; NFFO; Eole 2005.

Table 3: Changes in prices per kWh of wind energy

		1993	**1994**	**1995**	**1996**	**1997**	**1998**
Germany	pfennig /kWh	16.57	16.93	17.28	17.21	17.15	16.79
UK	pence /kWh	n.d	4.43	n.d	n.d	3.56	2.88
Germany	euros 99/kWh	0.091	0.091	0.091	0.089	0.089	0.086
UK	euros 99/kWh	n.d	0.076	n.d	n.d	0.057	0.045

Sources: for Germany (EC, 1999) and for UK, *Fifth renewables order for England and Wales*, OFGEM, September 1998.