Price-based versus quantity-based approaches for stimulating the development of renewable electricity: new insights in an old debate

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1. Introduction

The general awareness that has been growing over the past 20 years of the threats to the environment, recently strengthened by the confirmation of the risk of climate change [1] has led to a significant reawakening of interest in renewable energy, owing to the environmental advantages that they represent in comparison to conventional energy sources. This interest motivated the application on 27 October 2001 of the European directive on the promotion of electricity from renewable sources (RES-E) [2]. In addition to introducing certification for green energy and measures aimed at creating equitable conditions and facilitating the penetration of renewable energy into the domestic energy market, the directive specified that an aim of the European Union would be to double the share of renewable energy in gross energy consumption, with the target being to reach 12% by 2010. At national level, this ambition means that each of the member states will have significant production targets to reach by 2010.

In this new context, the support that the public authorities have been giving to renewable energy sources over the past 10 years or so assumes a new dimension. The various incentives offered in the past, which fluctuated with oil prices, now need to be reinforced in order for the above targets to be reached within the timescale set. The cost of the public policies that this implies will no doubt increase, and the effectiveness of the various types of incentive used will thus become a question of crucial importance. Indeed, faced with the deployment of green energy production required by the European Commission (22% of gross electricity consumption by 2010 as against 13.9% in 1997), it will be a vital concern to achieve these goals at the lowest possible cost.

To help clarify matters, this article contains a comparative analysis of the relative efficiency of the instruments used to promote renewable electricity [3], first from a static point of view and then using more dynamic criteria. First, we examine the justification of policies supporting renewable energies on the basis of both the internalisation of externalities in electricity production and their role in stimulating the learning process in relation to still immature renewable technologies. Next, the instruments are characterised in relation to the classic discussion of environmental policy that considers price-based approaches versus quantity-based approaches. Third, we look at the cost of these policies for the community and more specifically at the sharing of surplus and the repercussions this has on the tendency of producers to innovate.

2. Environmental justification and features of public policies supporting renewable energy

The obstacle facing renewable energies in the domestic electricity market is twofold. First of all, the wholesale price gives a very imperfect idea of the real cost of electricity production. As it does not take into account the cost of pollution control inherent in the use of fossil fuels, it prevents the environmental benefits of renewable energies from being considered at their true value, and thus removes any comparative advantage they may have. Second, as these technologies are still immature, they cannot enter into direct competition on the market with conventional technologies. Now, without the stage of widespread dissemination needed for the technological learning process to occur properly, these technologies cannot aim to be competitive. Public intervention may therefore be justified in theory in two ways: internalisation of the environmental externalities and stimulation of technological change.

2.1 Absence of internalisation of environmental externalities

The main advantage of renewable over conventional energy 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 RES-E cannot be assured spontaneously by the market. The liberalisation of the electricity market, seen as the possibility offered to customers of expressing their preferences and thus their willingness to pay for

[1] Intergovernmental group of experts on climate change, 2000: Special report on emission scenarios, summarised for decision-makers.

[2] Directive 2001/77/CE of the European Parliament and Council dated 27 September 2001.

[3] The thermal use of renewable energies will not be dealt with here even though they offer potential for development that is at least as high as that for electricity. Pending a European directive similar to that for electricity production, the issue of heat production from renewable energy sources is distinctly different and would need to be discussed in a separate article.

this environmental good, may appear to be a partial response to this problem of appropriation. But, as can be seen from experience in Europe, the problem of free-riding remains [4][5]. Individual choices do not fully reflect the real value that the public may place on preserving the environment by generating green energy and therefore cannot replace public assistance.

Moreover, the advantages offered by RES-E cannot be viewed simply in terms of reducing greenhouse-gas emissions. Indeed, as they are purely domestic, they may make a significant contribution to improving the reliability and diversity of energy supplies. Today, the European Union relies on energy imports to cover 50% of its consumption; this figure could reach 70% by 2020 [6]. With the international energy scene dominated by uncertainty regarding the physical availability of raw materials and the geopolitical stability of the major producing regions, the development of green electricity production would help to slow down the rate of growth of this dependence to a great extent.

Lastly, the undeniably local character of green electricity production would make it by definition a significant source of job creation at local level. Hence this is an important aspect of regional development when considering greater economic and social cohesion among the regions.

2.2 Stimulating technological change

A real appreciation of these advantages by the market and the re-establishment of equitable conditions for competition between fossil fuels and renewable energy sources will still not guarantee the creation of a dynamic process of renewable energy diffusion that is consistent with the collective objective of preserving the environment. Renewable energies, which like any new technology have to compete with established technologies, remain in an unfavourable position. 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 [7][8]. 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 [9]. 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: 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 [10] and at the same time helps expand the range of techniques that can contribute to environment preservation.

2.3 Fixing aims: a cost/efficiency approach

The public support for RES-E is therefore justified initially as a temporary compensation for the negative externalities that they avoid. As long as energy taxes do not represent the marginal cost of the damage caused by using fossil fuels, this support aims to re-establish a balance in the conditions of competition between technologies to the benefit of the least polluting. State intervention is justified by the existence of shortcomings in the market with the aim of "*inciting economic agents to adopt patterns of behaviour that are more in line with the public interest than those which they would adopt without such action"* [11].

From the point of view of strict economic logic, compensating for negative externalities appears to be justified as long as the sum of the benefits that it offers is higher than the sum of the costs that it imposes (this is the cost/benefit principle). However, it is debatable whether a reliable, unquestionable value can be determined for externalities. The difficulty lies in estimating the value of the public good that is preserved by the development of RES. Given the problems that occur in observing certain parameters, it is impossible to refer to an optimum level of renewable energy production. Consequently, one is forced to adopt a strict cost/efficiency approach in which the target is defined exogenously by political decision-makers on the basis of available scientific information, but without any economic rationalisation.

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[4] BATLEY, S.L, COLBOURNE, D., FLEMING, P.D, URWIN, P., 2001, Citizen versus consumer : challenges in the UK green power market, *Energy Policy*, 29 (6), pp. 479-487.

[5] WISER, R., PICKLE, S., 1997, *Green marketing, renewables, and free riders : increasing customer demand for a public good*, Ernest Orlando Lawrence Berkeley National Laboratory.

[6] European Commission, 2000, *Vers une stratégie européenne de sécurité d'approvisionnement énergétique*, Livre Vert, COM (2000) 769 final.

[7] ARROW, K., 1962, The economic implications of learning by doing, *Review of Economic Studies*, 29.

[8] DOSI, G., 1988, The nature of the innovative process. In DOSI, G ; FREEMAN, C. et al. (ed.), *Technical change and economic theory*, London.

[9] ARTHUR, W.B., 1989, Competing technologies : increasing returns and lock-in by historical events, *Economic Journal*, 99 (1).

10 FORAY, D., Diversité, sélection et standardisation: les nouveaux modes de gestion du changement technique, *Revue d'Economie Industrielle*, (75), 1996, pp.257-274.

[11] BONTEMPS, P ; ROTILLON, G., 1998, *Economie de l'environnement*, La découverte, Paris.

It is in this cost/efficiency approach that the aims fixed by the European Commission – however indicative – represent a considerable advance in the development of RES-E, as they define the level of effort to be provided by the member States. It is also in this perspective that we shall compare the efficiency of the instruments available to the public authorities to throw some light on discussions concerning the amounts of money allocated to deploying renewable energies.

3. The price-quantity issue applied to incentive instruments for renewable energy

An examination of the policies implemented in Europe over the past 20 years to stimulate the development of RES shows that the instruments used all bear a strong resemblance to the instruments of environmental policy to which they can be assimilated. In particular, they raise the same questions from the point of view of the classical debate between price-based and quantity-based approaches [12].

3.1 How instruments to promote green electricity work

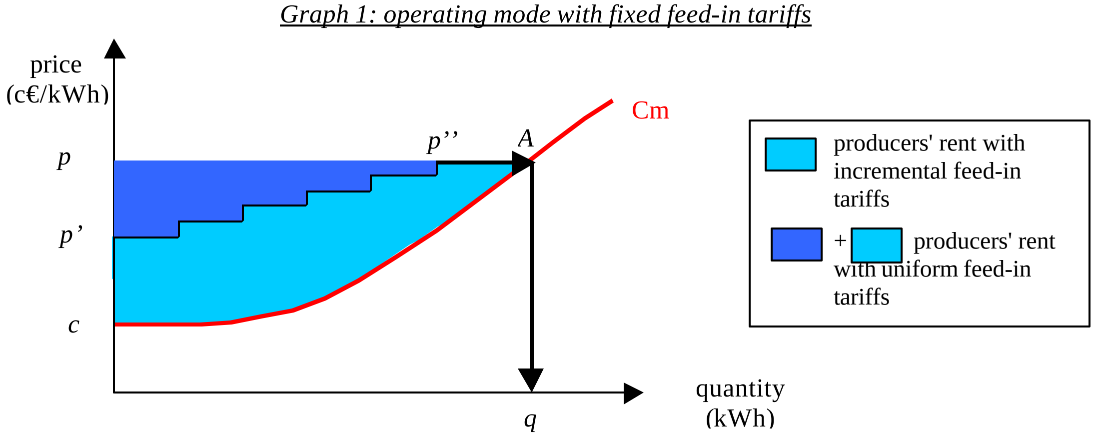
Public funding for research and development and subsidies to encourage investment were initiated 25 year ago and have long been the main measures used within the European Union for promoting RES. They are still directed at the least mature areas of technology, but in the case of those that are nearly competitive from the economic standpoint, more specific instruments are now used with the aim of introducing RES into the electricity market. Support schemes fall into three main categories that are either price-based or quantity-based in their approach:

- fixed feed-in tariffs, used in particular in Denmark, Germany, Spain, and France since 2001, which constitute the oldest and most widely used incentive 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 or final consumers are obliged to produce or buy a certain quota of renewable energy. This type of scheme is used in a few countries (Netherlands, Denmark, Belgium) on an experimental basis, but could eventually be extended to most member States (Italy, United Kingdom, Austria, Sweden).

❑ ***Fixed feed-in tariffs***

The guaranteed 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 thus works in the same way as a pollution tax does for firms that pollute. In practice, producers are encouraged to exploit all available generating sites until the marginal cost of producing RES-E equals the proposed feed-in tariff p (cf. graph below). The amount generated then corresponds to q. q may be estimated a priori if the marginal cost curve for RES-E is known, which is not generally the case (cf below) .

<u>*Graph 1: operating mode with fixed feed-in tariffs*</u>



In the simplest case of a uniform feed-in tariff, all producers whose marginal cost is lower than the fixed feed-in tariff benefit from the tariff p. The differential rent [13] thus granted to producers is therefore represented by the area (cAp) between the marginal cost curve (Cm) and the feed-in tariff p.

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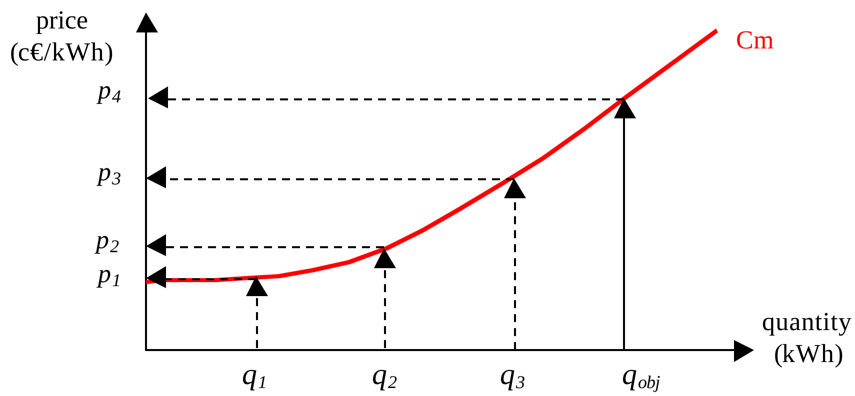
[12] COURNEDE, B., GASTALDO, S., 2000, *Combinaison des instruments prix et quantités dans le cas de l’effet de serre*, Journées AFSE, Marseille, France.
[13] In energy economics, differential rent is used conventionally to designate income derived from least-cost oil resources in comparison with marginal resources. Marginal resources are defined as the most expensive ones exploited to satisfy demand at a given moment (CHEVALIER, J.M., BARBET, P., BENZONI, L., *Economie de l’Energie*, Presses de la Fondation Nationale des Sciences Politiques & Dalloz).

To ensure a minimum rate of return to producers at generating sites of lower quality (hydraulic, solar and wind energy may be concerned) while at the same time controlling the rent allowed to producers who benefit from more favourable conditions, it is possible to define a feed-in tariff decreasing in stages with the level of production. Carefully defined instruments can thus combine the aims of regional development (avoiding a concentration of installations at the most profitable sites) with economic efficiency (encouraging the most productive investment). Introducing an incremental feed-in tariff *p'* can thus help to limit the differential rent to the area (*p'p''Ac*) situated between marginal cost curve and the increments resulting from the tariff [14].

- ***Competitive bidding processes***

In the case of competitive bidding processes, the regulating authority defines a reserved market for a given amount of RES-E. Electric utilities are then obliged to purchase the electricity from the selected power producers. Competition-based bidding systems were used in the United Kingdom under the Non-Fossil Fuel Obligation (NFFO) in force from 1991 to 2000, which concerned different renewable energy technologies, and in France with the Eole 2005 programme set up in 1996 and abandoned in 2000, which concerned only 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.

Graph 2: operating mode with competitive bidding



Via successive bidding procedures, the competitive bidding process shows the shape of the marginal cost curve (cf. graph 2). To reach the objective set (q_{obj}), the quantities q_1, q_2, q_3, and then q_{obj} are successively put up for auction and offered at the maximum prices p_1, p_2, p_3 and p_4. In this situation, therefore, producers do not receive any differential rent.

- ***Green certificates***

In this type of scheme, a fixed quota of electricity sold by suppliers on the market (supplier-distributors, electricity generators or consumers) must be generated from RES [15]. Operators then have the possibility of generating the required amount of electricity themselves, purchasing it in the long term from a specialised renewable energy generator, or purchasing certificates for specific amounts of green electricity from other operators [16]. 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. Since operators do not all benefit from the same opportunities to use renewable energy sources and thus have different marginal production cost curves [17], 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.

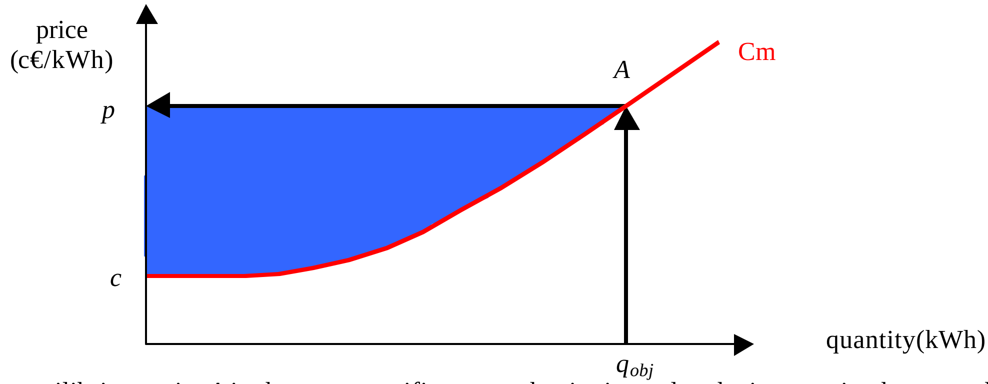
[14] For a detailed discussion of the mechanism of incremental guaranteed feed-in tariffs, cf. ElGreen Project, 2001, *Action Plan for a Green European Electricity Market*, European Communities, pp. 24-25.

[15] This obligation concerns suppliers in the United Kingdom and producers in Italy.

[16] VOOGT, M., BOOTS, M.G., SCHAEFFER, G.J. and MARTENS, J.W., 2000, Renewable electricity in a liberalised market: the concept of green certificates, *Energy and Environment*, 11 (1).

[17] In the case of wind energy, for example, it is obvious that a distributor situated near to a coastal area will have greater resources, enabling him to achieve lower production costs than a producer situated inland.

<u>*Graph 3: operating method with green certificates*</u>



The equilibrium point *A* in the green certificates market is situated at the intersection between the demand curve, defined by the quota q_{obj}, and supply, represented by the marginal cost curve (Cm). The quota q_{obj} is thus represented on the green certificates market by the equilibrium price *p* [18]. The differential rent allocated to producers is thus equal to the area (*cAp*), as in the case of uniform feed-in tariffs.

3.2 The consequences of uncertainty on marginal cost curves

In the case of energy production, when all the necessary information is available, price-based and quantity-based schemes produce very similar results. It is therefore equivalent to introduce a feed-in tariff *p* resulting in an overall quantity of production *q*, or to fix a quota q_{obj} corresponding to the same quantity *q*, the equilibrium price (in the green certificates market) or marginal price (in the case of bidding processes) then becoming established at the level of the fixed feed-in tariff *p*. The administrative authority can fix the "price" in the case of the fixed feed-in tariffs, or the "quantity" in the case of green certificates or competitive bidding, so as to reach the same green electricity production target.

However, price-based and quantity-based approaches are not equivalent in situations where information is incomplete and where there is uncertainty [19]. When the cost curves are not known, neither of these approaches can give an idea a priori of the overall cost of green electricity production sought. However, guaranteed feed-in tariffs offer a certain way of controlling the cost of the measures to be implemented, as, by setting a ceiling for the marginal cost, guaranteed prices eliminate options that are too costly. Conversely, the quantity-based approach by definition offers direct control over the target level of production, whereas successive adjustments to the feed-in tariffs (particularly downwards, which is rarely acceptable politically) would have to be made to achieve the desired level of production.

The symmetry between the price-based and quantity-based approaches is thus not total, and one or the other may be preferred depending on the respective shape of the production cost curves [20]. If it is assumed that the RES curves are relatively flat in the present situation [21], it can be seen that a slight variation in the proposed feed-in price will have major repercussions in terms of the quantities produced. As the overall cost of achieving an objective *q* is given by the product $p \times q$, an overestimated fixed feed-in price will result in a significant increase in RES-E production and a large quantity of public subsidies. In contrast, the quantity-based approach will help to limit this risk as fixing a quota or organising successive competitive bids is a way of ensuring total control over quantities and hence indirectly over the volume of public subsidies. This apparently obvious result can, however, explain the paradox that fixed feed-in tariffs in the field of RES are criticised as being too costly.

3.3 Empirical analysis: the supremacy of fixed feed-in tariffs

A number of renewable energy technologies have benefited to varying degrees from the 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 at the present state of development, should be able to provide most of the extra renewable energy required to reach the objectives set by the European Commission. An examination of the results obtained by the various member states as a consequence of the incentives they have offered appears to underline the fact that fixed feed-in tariffs are

[18] A green electricity producer can sell his production on the wholesale market and green certificates market. The price of the green certificate itself is thus obtained by deducting the wholesale price from the marginal cost of production.

[19] CROPPER, M.L., OATES, W.E., 1992, Environmental Economics: a survey, *Journal of Economic Literature*, vol XXX, pp 675-740.

[20] WEITZMAN, M.L., 1974, Prices versus Quantities, *The Review of Economic Studies*, 41 (4), pp 477-491.

[21] The shape of the cost curves is not precisely known. However, the latest studies consider that they are flat and predictable with a high level of probability (ElGreen project, 2001, *Action Plan for a Green European Electricity Market*, European Communities).

better than competitive bidding procedures [22]. The efficiency of these instruments will now be examined in terms of stimulating RES-E, industrial impacts and project acceptability.

- ***Stimulation of RES-E***

The two systems exhibit radically different characteristics in terms of future profitability, risks and transaction costs. The fixed 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: these three countries alone accounted for over 90% of additional installed capacity in Europe in 1999. Total installed wind capacity in Germany, Denmark and Spain reached 7717 MW at the end of 1999, while it did not exceed 500 MW in UK and France.

This result can be partly explained by the high price level proposed in the fixed feed-in tariff systems (7-9 c€/kWh) while the competitive bidding systems led to significantly lower prices (4-5 c€/kWh): all else being equal, it is perfectly logical that higher feed-in tariffs should correspond to greater quantities of RES-E. The difference between the proposed prices do not explain, however, the huge observed differences between the installed capacity. 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 option for investors.

The second factor affecting the attraction of bidding systems is the uncertainty regarding the profitability of submitted projects. The fact that bidding procedures take place at irregular and particularly unscheduled intervals has also created a climate of instability that works to the disadvantage of operators, in contrast to fixed tariff systems.

Lastly, the high transaction costs incurred by the bidding procedures (for project formulation and monitoring, obtaining building permits, etc.) have undeniably been an obstacle to the development of RES-E, as the size of the installations is necessarily limited, making it difficult for them to be profitable during the contract period.

- ***Industrial impacts***

At the industrial level, the impact also differs between countries that have set up guaranteed tariffs and those that use competitive bidding schemes. In 2000, 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.

- ***Project acceptability***

A last factor affects project feasibility in the context of competitive bidding systems. Certain aspects that are apparently less essential, such as impact studies, informing and consulting local people, integrating the works into the site, etc. are paid less attention during the project formulation phase. As a result, strong opposition movements have grown up in certain regions, particularly in the north of England. In contrast, projects are much more acceptable in countries that practice guaranteed tariffs since the better profitability rates that they offer mean that projects are not concentrated in the best sites, where the construction of extremely large numbers of wind turbines is difficult to accept.

Comparatively speaking, feed-in tariffs have an undeniable advantage in relation to these three criteria. However, it should be stressed that the objectives initially set by the governments that opted for competitive bidding systems were much less ambitious at the outset than those of the German, Danish and Spanish governments. The difference between the results obtained with competitive bidding and fixed feed-in prices is thus due in part to the fact that the implicit aims in the two cases were extremely different. But it can also be explained by the more incentive nature of feed-in tariffs, which are more predictable and provide producers with a higher rent. In this respect, in the absence of any technological progress (cf. table 1), green certificates are no different from uniform fixed feed-in tariffs, which enable producers to benefit from the entire differential rent. Conversely, competitive bidding systems completely eliminate differential rents to the benefit of consumers, but do not offer the same results in terms of installed capacity. Incremental feed-in tariffs may be considered as an intermediate option that keeps the incentive character of the price-based approach while at the same time limiting the differential rent received by producers, thereby lightening the financial burden borne by the community.

4. Cost to the community and stimulation of technological progress: the question of surplus sharing

The second justification for public RES-E incentive policies is that they stimulate technological change, none of RES-E technologies being yet sufficiently mature to compete on the electricity market. By analysing the distribution of surplus (defined as the sum of all rents), the approach can be extended beyond simply its ability to stimulate lower costs over a short period, to include the possibility of creating lasting technological progress. The introduction of such a process depends partly on the investment made by constructors in research and development, which leads to certain

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[22] Experience with green certificates is still limited, and therefore cannot be included in this empirical analysis.

improvements, but also on the technological learning processes connected with wider dissemination. Here again, different types of support will have different effects depending on whether incentives are offered for innovation (research and development) or dissemination (widespread adoption of the innovation) [23].

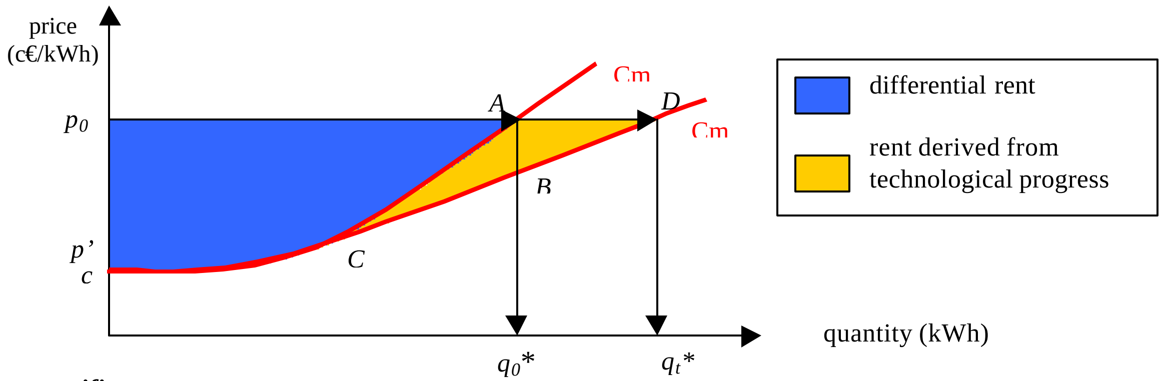
4.1 Graphic analysis

Whatever system of incentives is adopted, technological progress will produce a downward shift in the marginal cost of production curve. The marginal cost of achieving a given goal is lower following innovation. All else being equal, the effect will be to increase the surplus obtained by producers but, depending on the type of incentive used, the surplus created in this way will not be shared in the same manner.

- ***Uniform guaranteed feed-in tariffs***

The consequence of price-based incentives is that the quantity of green electricity produced increases from q_0* to q_t*: for the same tariff level, producers can now exploit sites that were not economically profitable before the innovation (cf. graph 4). This instrument gives producers the entire benefit of the rent derived from technological progress (i.e. the area *ADBC*) [24]. In this case, therefore, technological progress results in an unscheduled increase in the quantities produced and in the producers' surplus. It is represented by the area (cDp_0).

Graph 4: guaranteed feed-in tariffs and rent derived from technological progress

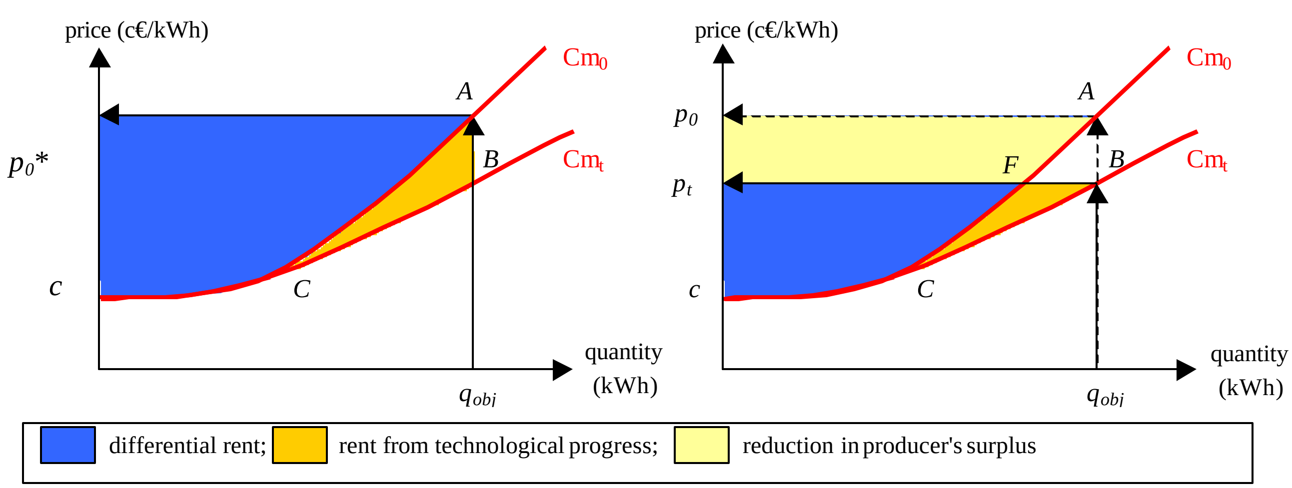


- ***Green certificates***

In the case of green certificates, technological progress is taken into account automatically as the price of the certificate is set at level p_t without the regulator having to intervene (cf. graph 5). The rent derived from technological progress and granted to producers is thus equal to the area (*CBF*) and the mechanical lowering of prices under the effect of innovation allows the community to save an amount equal to the area (p_tFap_0). The total producers' surplus is thus equal to the area between the new marginal cost curve Cm_t and the new price p_t, (cBp_t). With a quantity-based instrument governed by market mechanisms, technological progress will thus reduce the rent allocated to producers and consequently cost less for the community.

Graph 5: green certificate markets and rent derived from technological progress

5.a in situation 0 | 5.b in situation t



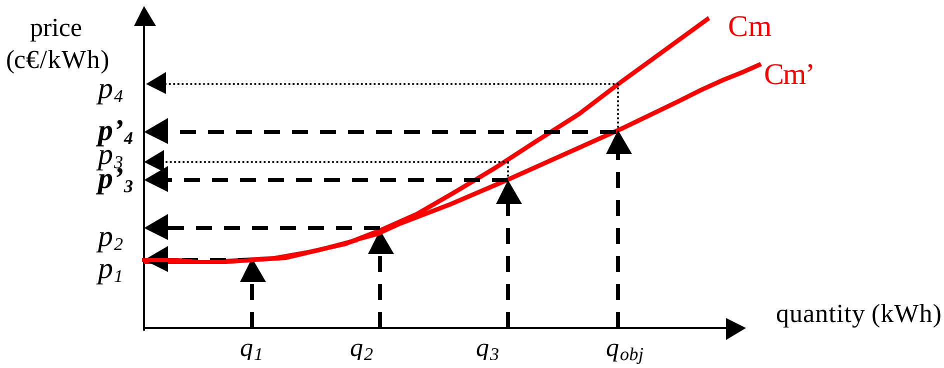
[23] MILLIMAN, S.R., PRINCE, R., 1989, Firm incentives to promote technological change in pollution control, *Journal of Environmental Economics and Management*, 17, pp 247-265

[24] The rent derived from technological progress is defined as the increase in the producer's surplus connected with maintenance of the previous incentive framework whereas new and more effective technologies are available.

- ❑ ***Competitive bidding***

As in the static situation (cf. above), the procedure involving successive calls for bids means that competitive bidding can also follow the marginal cost curve without any intervention by the regulator (cf. graph 6). The maximum prices p'_3 and p'_4 automatically replace the maximum prices p_3 and p_4 in the bids received from producers replying to invitations q_3 and q_{obj}, thus cancelling the entire rent derived from technological progress allocated to them [25].

Graph 6: competitive bidding and rent derived from technological progress



- ❑ ***Introduction of Decreasing feed-in tariffs***

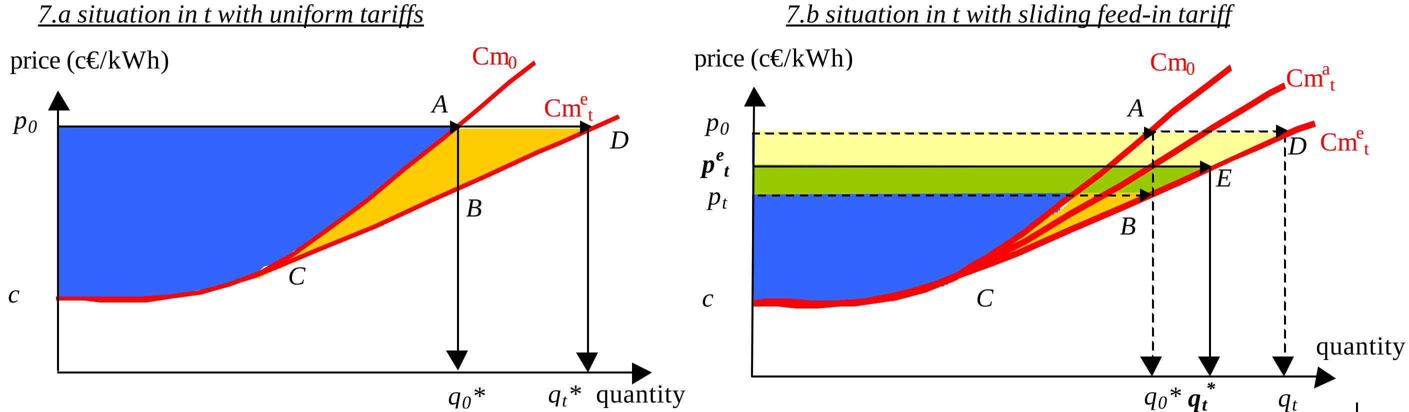
The fixed tariff versus competitive bidding debate has emphasised a number of imperfections and in particular obliged price-based systems to evolve so that technological progress is taken into account more fully.

The principle of a decreasing feed-in tariff involves anticipating technological progress (cf. graph 7) and hence the shift in the marginal cost curve. On the new cost curve (Cm^e_t), the tariff needed to obtain the quantity q_0* is no longer p_0, but p_t. However, the regulator does not know for certain how technology will develop, and he must therefore fix a feed-in tariff on the basis of an anticipated technological progress (Cm^a_t). If the observed cost curve (Cm^e_t) differs from the anticipated cost curve (Cm^a_t), the quantity produced will be $\mathbf{q_t^*}$.

A comparison between graphs 7a and 7b shows that the decreasing price mechanism enables the area ($p_0DE\mathbf{p^e_t}$) to be saved by consumers in contrast to a uniform feed-in tariff that grants the surplus cDp_0 to producers. In this way it is possible to limit but not entirely eliminate the rent derived from technological progress allocated to producers. Ultimately, the total surplus from which producers benefit corresponds to the area ($cE\mathbf{p^e_t}$). It is higher than the producers' surplus allocated in the context of a green certificate market (cBp_t) if the regulator responsible for sliding guaranteed feed-in tariffs has anticipated less technological progress than is actually observed (the same is true for the quantity of green electricity production, which reaches the level $\mathbf{q_t^*}$.). Nevertheless, this system ensures a more equitable distribution of the rent derived from technological progress, as it reduces the overall cost for the community while at the same time giving a surplus to innovative producers.

Graph 7: the contribution of sliding feed-in tariffs

7.a situation in t with uniform tariffs — *7.b situation in t with sliding feed-in tariff*



Legend : Cm_0= marginal cost curve at 0; Cm^e_t= effective marginal cost curve at t; Cm^a_t= anticipated marginal cost curve
$q_0*_{(reps.\ t)}$= optimum production at 0 (resp. t); $\mathbf{q_t}$= production at t without sliding mechanism.
$p_{0(resp.\ t)}$= optimal fixed feed-in tariff at 0 (resp. t); $\mathbf{p^e_t}$= effective feed-in tariff at t.
[blue] differential rent; [orange] rent from technological progress; [yellow] gain (cf. text),
[green] surplus allocated to producers owing to wrong estimate of real technological progress.

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[25] Depending on the shape of the marginal cost curves and the rate of technological progress, the average bidding prices for successive tenders may even fall (cf. NFFO 3 to 5, OFGEM, 1998, *Fifth renewables order for England and Wales*).

Table 1: Summary of differential rents and total surpluses according to support instrument

	Differential rent (static)	Total surplus (dynamic)
Competitive bidding	None	None
Green certificates market	Maximum (cAp)	Low (cBp_t)
Uniform guaranteed feed-in tariff	Maximum (cAp)	Maximum (cDp_0)
Incremental guaranteed feed-in tariff	Low ($p'p''Ac$)	-
Sliding guaranteed feed-in tariff	-	Average (cEp^e_t)

Where promoting technological progress is concerned, this analysis shows that a distinction can be made between stimulating innovation and encouraging its dissemination. Making producers compete with one another through competitive bids forces them to adopt the most efficient technologies in order to be awarded contracts. However, as this involves restricting their profit margins (by eliminating the differential rent derived from technological progress), they have difficulty in initiating the innovation process by investing in R&D. With guaranteed feed-in rates, the maximum surplus is allocated to producers, so that they are better placed to develop new technologies even though this will cost the community more. None of these extreme solutions is really satisfactory. This is especially true of constant uniform or incremental feed-in tariffs, which award the benefits of technological progress only to producers. From this point of view, sliding rates and green certificates are the most attractive options as they do not entirely eliminate the surplus derived from technological progress as bidding processes do, while at the same time they enable consumers to benefit from the improved performance levels due to technological progress (table 1).

4.2 The question of surplus sharing: considerations for empirical analysis

Available empirical data are insufficient for performing a detailed analysis of surplus-sharing between producers and consumers and its consequences in terms of technological progress [22]. However, an examination of the incentive systems implemented in various European countries seems to confirm the initial results obtained by a theoretical analysis. Competitive bidding processes have encouraged producers to adopt available new technologies in order to remain competitive, but they have not enabled them to present well-structured industrial supplies and invest major resources in R&D. Conversely, industrial supplies have developed considerably through the encouragement of guaranteed feed-in tariffs, though this has cost the community very much more.

- ***Overall cost of supporting renewable energy sources***

The policy of guaranteed feed-in tariffs has proved to be very costly in terms of public subsidies. This is the direct result of its positive effect on RES-E. Subsidies paid in 1998 by the Danish government represented more than 100 million euros and it seemed likely that this amount would continue to grow owing to the regular increase in capacity, creating an increasingly great burden on the State budget [26]. This policy also requires costly cross-subsidies that could be estimated at around 200 million euros in Germany in 2000.

In the case of bidding systems, the possibility of controlling the public subsidies allocated to RES-E is a major advantage. In this respect, a quantity-based approach enables public expenditure to be controlled more efficiently by organising incremental increases, progressively revealing the shape of the cost curve. A comparable result could have been obtained with guaranteed feed-in tariffs but the system was rigid from the institutional standpoint, making it difficult to control its progress by adjusting guaranteed prices in accordance with technological progress. Introducing sliding rates now means that price changes can be announced from the outset (cf. below).

- ***Distribution of surplus and innovation stakes***

Fixed feed-in tariffs and pay-as-bid tendering schemes differ in terms of how the surplus resulting from technological change is shared out. In the first case, it is producers-investors and manufacturers who benefit from lower costs, if prices are not adjusted in step with technological change, while in the second case, producers pass on cost savings to taxpayers or consumers. But the very slight impact made by quantity-based incentive mechanisms on renewable energy generation limits the learning effects of local manufacturers in the countries concerned. Remember that the three leading countries in Europe, stimulated by fixed feed-in tariffs, installed 20 times more generating capacity in 2000 than the countries operating competitive bidding schemes.

In terms of R&D programs, the reduced margins inherent in the bidding system limit the budgets of manufacturers and their suppliers. Consequently, in interdependent economies operating different support mechanisms, the reduction in costs observed for wind 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

[26] MORTHORST, P.E., 1999, Danish renewable energy and a green certificate market, Conference paper *Design of energy markets and environment*, Copenhagen.

allowed to benefit from the differential rent, feed-in tariffs make it possible for manufacturers to invest more heavily in R&D and to consolidate their industrial base.

Lastly, while the policy of fixed feed-in tariffs seems to offer better conditions for producers wishing to progress on the learning curve with regard to renewable technologies, it needs to be supported by the public authorities and this is quite costly for the community. Conversely, bidding processes have not triggered long-term improvements in technology in spite of their efficient control of overall costs.

5 Conclusion

In terms of installed capacity, much better results have been obtained with price-based approaches than with quantity-based approaches. In theory, this difference should not exist, as bidding prices set at the same level as fixed prices should logically lead to comparable installed capacities. The difference can be explained by the strong incentive effect of fixed prices, which make existing incentive systems more stable and more predictable in the eyes of investors. On the other hand, the system of fixed feed-in tariffs makes it difficult to anticipate the level of RES-E production owing to uncertainties relating to the cost curves, and thus limits the extent to which the cost of incentive policies can be controlled. From this point of view, quantity-based approaches are more efficient as bidding for successive quotas provides an indirect way of controlling overall costs.

Fixed-price and pay-as-bid systems lead to two situations that differ in the way the differential rent is distributed. In the case of fixed feed-in tariffs or green certificates it is the producers who benefit entirely, whereas in pay-as-bid systems no rent is given to them. Similarly, the surplus resulting from technological progress is distributed solely to the benefit of producers in the case of fixed price systems and solely to the benefit of consumers in pay-as-bid systems. European experience in supporting wind energy shows that, in the first case, conditions are more favourable for the development of new technologies but at a high cost to the community, whereas in the second the lower margins for producers raise questions concerning ongoing technological changes. Between these two extremes, sliding fixed feed-in tariffs that make allowance for improved performance levels and green certificates are incentive systems that distribute surpluses more equitably between producers and consumers and are thus of obvious interest in supporting the development of new energy technologies without the entire cost burden falling on the consumer.

The potential advantages offered by green certificate trading systems based on fixed quotas are encouraging a number of countries to introduce them in order to achieve high installation targets in an economically efficient way. Greater control over quantities, competition among producers and the incentive to lower costs are among the main reasons for adopting green certificates. This system also has an advantage over the others in terms of efficiency of allocation. This advantage, which is based on the exploitation of differences in marginal costs, can be usefully applied at European level to reach the targets fixed by the European Directive at the least cost for the community [27]. However, as long as uncertainties remain, especially concerning the operation of the markets and the creation of a framework that investors consider stable, its actual efficiency remains to be proven.

Lastly, any comparison between the various instruments must take into account the actual conditions of application of incentive policies that apply not just to one technology but to multiple RES technologies. The ability of a single instrument to support technologies that have reached different levels of maturity may be an attractive way of avoiding the need to define specific incentive frameworks. In the case of bidding processes, specific invitations to tender are essential to avoid competition that would marginalise emerging technologies. In contrast, it would appear to be difficult to create several green certificate markets depending on the technology used. There could be competition between technologies on the green certificates market provided that rules are introduced to make certificates equivalent, according to the technology used, so as to leave room for the development of new technologies. In the case of the European certificates market, this means coordinating the support policies of the member States and defining common priorities in the field of technological development. Without question, the simplest solution is that of fixed feed-in tariffs, which enables them to be modified in accordance with economic performance and the rate of progress of each technology.

This theoretical discussion of the search for a more equitable distribution of the surplus resulting from public incentive policies between producers and the community reflects the public authorities' concern to support the development of RES-E while at the same time improving public welfare. Comparing the efficiency of price-based and quantity-based systems is thus a way of helping to improve the manner in which they are supported rather than of backing the partisans of one system or the other.

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[27] REBUS (Renewable Energy Burden Sharing), 2001, *Effects of burden sharing and certificate trade on the renewable electricity market in Europe*, Energy Research Centre of the Netherlands, ECN