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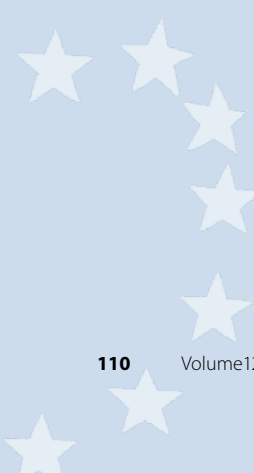
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ABSTRACT

Following a brief review of the rationale for promoting renewable energy sources, this paper compares alternative policies to promote the production of renewable electricity. The focus is on feed-in tariffs (used in Germany, Spain, and France – for instance) and tradable green certificate (TGC) systems (United Kingdom and Italy, for instance). Considering economic theory and practical experience, the criteria for comparing these two alternatives are: cost-effectiveness, environmental effectiveness, and compatibility with market liberalisation. The paper argues that economic theory does not suggest a clear-cut advantage of one instrument over the other and it emphasises that, in any event, the choice of instrument depends on the relative importance attached to these criteria and on cultural factors such as faith – or lack thereof – in markets to help solve environmental problems. In this context, the paper questions the practical usefulness of a European-wide TGC system.

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Pros and cons of alternative policies aimed at promoting renewables

1. Introduction

The promotion of renewables re-started in Europe – and elsewhere in the world – during the first half of the 1990s to align with the objective of reducing greenhouse gas emissions and with energy efficiency policies. This follows an earlier, though temporary, boost in renewables after the oil shocks of the 1970s. Efforts have been directed at developing renewables, in general, and using them for the production of electricity in particular. Specifically, the European Directive 2001/77/C on the promotion of renewable energy sources aims to increase the share of renewables in the energy supply of the EU from 5.6 percent in 2000 to 11.8 percent in 2010. At the same time, the share of renewable energy sources in the production of electricity is targeted to increase from 14 to 21 percent. Moreover, the European Council of March 2007 endorsed a binding target of a 20-percent share of renewable energies in overall EU energy consumption.



Dominique Finon

Reflecting earlier experience with, and limitations of, investment subsidies for renewables, efforts made as from the mid-1990s were initially based on two instruments: feed-in tariffs and tendering systems for long-term contracts at guaranteed prices. Traditional instruments (soft loans, investment grants, tax allowances, tax exemptions, and so on) to encourage the diffusion of near-market innovative technologies complement these two principal instruments. More recently, conventional wisdom seems to suggest that moving towards market-based instruments – such as a green certificate trading scheme – is necessary to reduce the costs of promoting pre-commercial-stage technologies.

In fact, there is the notion of an optimal sequencing of instruments: preferential prices (feed-in tariffs or tendering of contracts at guaranteed prices, for instance) in the early pre-commercial phase of promoting renewables followed by a trading scheme based on green certificate quotas. Moreover, adopting a European-wide system of such quotas is considered a means for minimising the cost of increasing the share of renewables. This is because a trading scheme based on green certificate quotas would shift the development of renewables to those EU member states that are relatively well endowed with renewable energy sources and could thus supply them at low costs.

Against this background, this paper examines the pros and cons of alternative policies to promote renewable energy technologies that have not yet reached commercial maturity. Section 2 briefly reviews the rationale for promoting renewable energy and introduces criteria for comparing alternative policy instruments. Using these criteria, Section 3 shows what economic theory tells us about the pros and cons of alternative policies. Section 4 moves beyond theoretical considerations by offering practical policy lessons. Section 5 concludes.

2. Promoting renewable energy: rationale, instruments, and criteria for assessing alternative instruments

2.1 The rationale for policies in support of renewable energy

Governments traditionally support research and development and demonstration projects in a variety of sectors given well-known market failures in the creation and diffusion of product and

process innovation. To the extent that such market failures arise in the area of renewable energy, too, there is an argument for promoting renewable energy technologies. However, more important in the case of renewables is their contribution to replacing fossil fuels associated with environmental externalities – in particular climate change.¹

Focussing on environmental aspects, it is nonetheless pertinent to ask whether there is a need to promote renewables in situations where economic policies internalise the environmental externalities of polluting energy technologies. In principle, solutions exist that internalise the environmental effects of using fossil fuels and, thus, get round the need for specific instruments in favour of renewables. As for climate-change externalities, these instruments are a tax on CO₂ emissions (with the tax equalling the climate-change externality) or a quota-and-trade system (with the quota on CO₂ emissions set at the socially optimal level). Indeed, a criticism of specific policies in favour of renewables is that the costs of avoiding CO₂ emissions through these policies (€100–€150/t CO₂) exceed by far the estimated social damages of CO₂ emissions (\$20–\$30/t CO₂) (see, for instance, Newbery 2003, and Fischer and Newell 2004).

Imposing a sufficiently high CO₂ tax, which would foster the replacement of fossil fuels with renewables, encounters a variety of difficulties.

But imposing a sufficiently high CO₂ tax (or stringent CO₂ quota), which would foster the replacement of fossil fuels with renewables and technological progress, encounters a variety of difficulties. First, estimating an optimal CO₂ tax or CO₂ quota is surrounded by considerable uncertainties. Second, both instruments – notably when set at the right level – will have visible distributional effects and, thus, encounter problems of acceptability. This is evidenced by the refusal of a European eco-tax at the beginning of the 1990s and the small number of EU member states (Denmark, Sweden, the Netherlands, and Finland) that imposed a significant eco-tax on energy. Third, there is no guarantee that even a high price of CO₂ emissions will trigger more substitution of new clean technologies for fossil fuels than policies directly supporting clean technologies (see, for instance, the literature reviewed in Jaffe *et al.* 2002). This is mainly for two reasons: regulatory uncertainty as to the price of CO₂ (which is liable to follow, for instance, when the period during which the quota applies is too short, as in the EU Emission Trading Scheme) and entry barriers for renewable technologies.

To elaborate on the last point, even when internalising the environmental costs of using fossil fuels, renewable technologies might face entry barriers. For instance, technologies at an early stage of development might be expensive now, but their costs are likely to fall considerably as and when they gain commercial maturity. Kolev and Riess (this volume) discuss the underlying rationale for promoting new renewable technologies in greater detail. Another entry barrier stems from constraints and costs of integrating decentralised, renewable technologies into an existing centralised infrastructure. The cost of integrating renewable electricity into the network (comprising network investment cost, balancing cost for intermittent production, the cost of regulating voltage and frequency, and so on) are indeed among the most important obstacles for developers and producers of renewable electricity. And then, there are constraints of land use by, for instance, renewable power units with landscape impacts and projects that rest on the development of energy crops. Easing these constraints requires specific siting and land planning procedures, and not having such procedures increases the risk for the developers of new technologies.

The arguments presented so far highlight environmental reasons for promoting renewable energy. But replacing fossil fuels with renewables is expected to bring non-environmental benefits, too. For instance, it can be argued that increasing the share of renewables in the energy mix of a country brings diversification benefits and enhances security of supply – an issue that Awerbuch and Yang

¹ For simplicity, we ignore possible environmental effects of renewable energy resources – impacts on the landscape, for instance.

(this volume) address in detail. Furthermore, some governments consider the support for new, clean energy technologies as a means to foster competitive export industries, employment, and regional development.

In sum, the existence of entry barriers suggests a need for renewable energy deployment policies alongside efforts to internalise the environmental costs of using fossil fuels. And the nature of these barriers suggests a need for a successive set of policies rather than a one-for-all second best policy. In addition, there is a variety of non-environmental reasons that could justify instruments in support of renewable energy. Let us then look at possible instruments.

2.2 Instruments and their link to the development stage of new technologies

A first fundamental observation is that the choice of policy instrument needs to reflect at what stage the development of a renewable technology is. Considering the sequence of development stages from the R&D phase, to the demonstration phase, pre-commercial phase, and – finally – to the commercial maturity of the technology, the choice and sequence of instruments could be broadly described as follows (Foxon *et al.* 2005): R&D subsidies in the R&D phase; investment grants and public procurement in the demonstration phase; purchase obligations, quotas, or fiscal incentives in the pre-commercial phase; full reliance on the energy price effect of internalising the environmental cost of fossil fuels at the stage of commercial maturity. What this indicates is, in essence, a shift from directly subsidising investment in renewable technologies during the R&D and demonstration phases to subsidising the production of renewable energy in subsequent stages of developing technologies.

The choice of policy instrument needs to reflect the stage of development of the renewable technology.

One reason for this shift is that supporting investment beyond the demonstration phase often leads to productive inefficiencies and is exposed to the risk of stop-and-go policies. Direct investment support is prone to two problems. First, there is limited concern about long-term performance and maintenance. Experience with direct subsidies and tax credits for investment in renewable electricity capacity – largely used in the 1980s, notably in United States – has indeed shown that producers soon neglected maintenance after the capacity went on stream and stopped it at the first operational incident (Sawin 2004). Second, when investment-tax-credit regulation expires, new projects dry up and the industry producing renewable energy equipment tends to collapse. Against this background, the shift from supporting investment to supporting production needs to be carefully designed, taking into account the development phase of a technology.

Let us then focus on the three main instruments in support of the production of renewable energy (rather than direct support of investment in the underlying production capacity): feed-in tariffs, tradable green (i.e., renewable) certificate systems, and tendering systems – all coming ideally after direct investment support has pushed technologies beyond the demonstration phase. These instruments have common characteristics. To begin with, they effectively subsidise renewable energy production over a long period of time (10-15 years), covering the economic lifespan of the equipment. As a result, the return on investment is increased and the pay-back period reduced by rewarding producers for the actual amount of energy produced. All this assumes that the support will indeed be available (and sufficiently high) over the investment lifetime – an issue that will be discussed in more detail in Section 3.

Second, the instruments rest on an obligation to buy renewable energy, green certificates, or both. To be effective, the economic agents mandated to buy must be clearly designated, and mandated buyers are generally the suppliers of electricity. For completeness, it is useful to point out that there may also be voluntary buyers of renewable energy or green certificates. While this contributes to

the promotion of renewable energy, it is bound to be inefficient given the well-known free rider problem.

Third, these instruments do not involve public expenditure. Typically, the higher financial cost of producing renewable energy is passed on to consumers through the electricity price. For European countries, the wholesale price effect of this currently ranges from €1-€3/MWh – which is very little compared to a wholesale price of around €50-€55/MWh in 2006-2007. Although it is true that the instruments do not require public expenditure, it is possible that the costs are shared between energy consumers and tax payers. In the United States and some European countries, for instance, policies existed that combined a purchase obligation (raising energy prices) with a tax credit on the production (lowering tax revenue). The advantage of fully passing on costs to consumers and not making the support of renewables dependent on budgetary decisions is that this provides a more reliable investment framework.

2.3 Criteria for assessing alternative policy instruments

Instruments for fostering renewable energy should aim at achieving a social optimum.

In principle, the choice of instruments for fostering renewable energy needs to rest on the objective of achieving a social optimum, and many dimensions of a social optimum need to be taken into account – notably the estimated value of negative environmental externalities. Given the difficulty of reliably estimating such externalities, there are – in practice – implicit or explicit quantitative ‘renewable’ targets to be achieved over a specific time span, maximum acceptable costs of these instruments, and distributional considerations.

In general, when designing environmental policies in the presence of uncertainty about the costs of environmental damages, one cannot reason simply in terms of cost-benefit analyses or second-best optimal tax policies. Rather, it is more appropriate to conceive policies that achieve a targeted reduction in pollution in a cost-effective manner (Baumol and Oates 1988). This is also true when it comes to designing policies in support of renewable electricity, mainly because of the enormous difficulty of reliably estimating the benefits of such policies, i.e., the economic value of emissions avoided and other benefits of using renewables for electricity generation.

If we thus take the objective of raising the share of renewables to a certain level (without trying to assess the social benefits of meeting this objective), one could think of three criteria to compare alternative policies. First, the criterion of social efficiency – here largely defined as cost-effectiveness. Obviously, one would like to achieve the objective at least cost. A variety of issues need to be considered in this context. Uncertainty and how it influences the cost-effectiveness is one. Another is whether alternative instruments differ in their impact on technology development and, thus, the cost of renewables in the future. Does the instrument incite the deployment of a variety of renewable technologies of different degrees of maturity with a technology-specific design, or does it play by encouraging indistinctly the set of renewable energy technologies? In a perspective of dynamic efficiency, the cost increase resulting from a technology-specific support can be beneficial in a long-term perspective: indeed, it opens the way to large-scale deployment of new technologies before the exhaustion of the resource potential of front-runner technologies in order to avoid an undue cost increase in the transition from front-runner technologies to the next generation of renewable technologies (Neuhoff 2005, Huber, *et al.* 2001). And then, there is the question of how the cost-effectiveness of an instrument might change if it is jointly applied by a group of countries, such as the European Union, rather than by each country individually.

It is worth noting that defining social efficiency in this way leaves open the possibility to examine the distributional effects of alternative policies, notably the rents accruing to producers of renewable

energy located in regions with a natural advantage in using renewables or – more generally – producers generally benefiting from learning effects. In sum, a legitimate government concern is to avoid producers' rents and the cost for consumers to become too high. This means, in particular, that policies must be flexible, including the possibility of revising downward or even terminating the support in light of the progress that renewable technologies make towards becoming commercially competitive without further public support.

The second criterion for assessing alternative policies is environmental effectiveness, which is measured by the additional renewable energy capacity installed due to the policy, taking into account that the support should be set as low as possible to achieve the desired result. The capacity impact of a policy depends on the size of the incentives it offers and on how long investors can count on them. The size of the incentive is determined by the additional remuneration per unit of renewable energy produced. To successfully increase capacity, the additional remuneration must cover all the extra costs and risks of energy production, taking into account that these vary across different technologies. As for how long investors can count on the incentives, two factors are of importance: the long-term predictability of the policy itself and the efficiency of the trilateral relationship between the government, mandated purchasers, and developers/producers of renewable energy (Langniss and Wiser 2003; Finon and Perez 2006). Obviously, producers of and investors in renewable energy production need stable and predictable cashflows, which are heavily influenced by the indirect subsidy offered by alternative policies. All this implies that even when there is a change in policies for future investments, the long-term commitment of the government and the relationship between parties must remain intact for investments already made.

The impact of policies promoting renewables depend on the size of the incentives they offer and on how long investors can count on these incentives.

The third criterion guiding the comparison of alternative policies in support of renewables concerns their conformity with the market regime of the energy sector in question. An instrument to support renewable electricity should be compatible with the market regime of the electricity industry. But this does not mean that an instrument must rely as much as possible on a market mechanism. Rather, the design of a policy in favour of renewables should be coherent with the market principles by not distorting competition.

3. Comparing alternative policies in support of renewables

To work out as clearly as possible how alternative policies in support of renewables score against the criteria introduced in the previous section, this section will concentrate on two key policy alternatives: feed-in tariffs and tradable green certificate (TGC) systems. We will begin with a brief description of these instruments, move on to analysing them in-depth in light of the criteria set above, and then propose an overall assessment.

3.1 Salient features of feed-in tariffs and tradable green certificate systems

To start with feed-in tariffs, their main characteristics are: an obligation to purchase electricity based on renewable energy at a fairly high price – with both obligation and price guaranteed over a long period of time (8 years in Spain, 15 years in France, and 20 years in Germany, for example). The purchase obligation is with the distributors-suppliers in their service areas and it applies to all new renewable power generation units. To promote the development of a diverse set of renewable technologies, feed-in tariffs differ across technologies. They reflect the generating costs of a typical renewable electricity unit (including some risk premium) and are not set on the basis of the

avoided generating cost of the distributor-supplier subject to the purchase obligation. Unless the supply curves for renewable electricity are known, the quantity of renewable electricity production resulting from setting feed-in tariffs is not known *ex ante*.

The recovery of the extra cost of renewable electricity that mandated buyers incur can be organised in three ways: an increase in the price of every kWh sold by the distributors subject to the purchase obligation when such distributors have a legal monopoly as in the former monopoly regime; a compensation between competing distributors-suppliers (given that they are obliged – irrespective of their own sales – to buy all the renewable electricity produced in the area of their distribution networks); or reimbursements financed by a tax on all electricity transmitted via the national grid. In the latter case, the extra cost of renewable electricity is paid by all electricity consumers. An alternative, or complement, to passing on the extra cost to electricity consumers is budgetary support to mandated buyers. Budgetary support could also be given to producers of renewable electricity to limit the level of the feed-in tariffs and, thus, cost for consumers; this could be done either through eco-tax and/or VAT exemption, as in the Netherlands and Denmark, or tax credits on the renewable electricity production – as in the United States.

Turning to tradable green certificate systems, the main features of this instrument are the following. It designates economic agents subjected to a rising renewable, or green, electricity quota (normally, these agents are electricity suppliers or distributors/retailers) and eligible technologies and installations (typically including only new installations and possibly excluding new large hydro plants and waste incineration). Designated agents – suppliers for short – can fulfil their quotas (expressed in percent of each supplier's annual sales of electricity and rising over time) in different ways. They can produce renewable electricity, purchase it under long-term contracts from specialised producers, or purchase green certificates, which originate from suppliers that exceed their quotas or from specialised producers that choose to sell part of their renewable electricity in the market rather than directly under long-term contracts. The quota is complemented by a penalty to be paid in case of non-fulfilment of the quota. But this penalty could be seen as a safety valve rather than a threat to force suppliers to meet their quotas. Rather than fulfilling his quota, a supplier may opt to pay the 'buy-out price' (its name in the UK system) for not meeting the quota, which could in extreme cases represent the full quota. In essence, this buy-out price puts a ceiling on the cost of renewable certificates. A last trait of the TGC design is the reallocation of penalty revenues to the agents who strictly respected their quotas, which is an incentive to respect the quota.

The price of green certificates acts like a premium for the production of renewable electricity.

A number of conceptual differences between feed-in tariffs and TGC systems are worth highlighting. In contrast to feed-in tariffs, TGC systems directly specify the targeted quantity of renewable electricity. This being said, as suppliers can also fulfil their quotas by purchasing renewable electricity or green certificates, TGC systems create competition that encourages the production of renewable electricity at least cost. Another difference is that TGC systems do not impose a contractual arrangement on price and quantity between producers and buyers of renewable electricity and green certificates. The remuneration for producing renewable electricity essentially has two components. One is the price of electricity as determined in the electricity market where renewable electricity is sold. The other is the price of certificates as determined in the market for green certificates. Thus, the price of green certificates acts like a premium for the production of renewable electricity. Finally, as the renewable electricity quota for a country as whole is allocated in an equitable way to competing suppliers, there is no need for a specific financing mechanism to compensate suppliers for the extra cost of fulfilling their quotas. This facilitates the acceptance of this type of support for renewables by electricity regulators and large users of electricity – both always eager to limit the cost of promoting renewables.

3.2 Cost-effectiveness

3.2.1 Static and dynamic cost-effectiveness – a closed-economy perspective

As in other areas of environmental policy, price-based instruments (here: feed-in tariffs) and quantity-based instruments (here: TGC systems) lead to similar results if the cost of renewable electricity is known with certainty, transaction costs are zero, and no dynamic learning effects are considered. In these circumstances, setting a feed-in tariff at level p will result in an overall quantity of renewable electricity q and, conversely, fixing that quantity upfront under a TGC system will result in a price p for renewable electricity.² In other words, with perfect information and zero transaction cost, whether the government fixes the price – as in the case of feed-in tariffs – or the quantity, as in the case of TGC systems, makes no difference. Moreover, it does not matter whether or not the price or quantity is the same for all technologies.

However, it is equally well known that when information is incomplete and when the shape of cost curves is uncertain, price-based and quantity-based instruments lead to different results (see Cropper and Oates 1992 and Weitzman 1974). In fact, depending on the shape of cost curves for renewable electricity, feed-in tariffs may be better than TGC systems – and *vice versa*. Another important issue here is whether the total cost of producing renewable electricity turns out to be higher or lower compared to the level anticipated when choosing between feed-in tariffs and TGC systems.

Let us illustrate all this with the help of Figure 1. If marginal costs are known with certainty, as represented by MC in Figure 1, setting a feed-in tariff P will result in an output of renewable electricity Q . Given this tariff and quantity, consumers pay for renewable electricity an amount indicated by the area $OQXP$. This amount can be broken down into a part covering actual production costs ($OQXW$) and a part representing producers' surplus (WXP). With certainty, a TGC system leads to the same outcome.

Consider now the situation where, contrary to expectations at the time when deciding either in favour of feed-in tariffs or a TGC system, the marginal cost curve turns out to be MC' rather than MC . In case a feed-in tariff is the policy instrument, renewable electricity production turns out to be Q' , the cost for consumers is $OQ'YP$, and producers' surplus increases to WYP . Depending on the size of the difference between expected and actual costs, the impact on output and the cost for consumers can be substantial. In case a TGC system is the instrument, output reaches the expected level Q , the price of renewable electricity is P' , cost for consumers is $OQZP'$, and producers' surplus is WZP' . All in all, when the marginal cost of renewable electricity turns out to be lower than expected by policy makers, feed-in tariffs deliver a higher output at the pre-determined price P whereas a TGC system delivers the targeted output at a lower price.

Further insights can be gained when we compare both instruments for the same output level, notably Q , that is, the output explicitly or implicitly targeted by both instruments. As Figure 1 indicates, for this output, consumers would save an amount equal to $P'ZXP$ if the instrument is a TGC system and not a feed-in tariff. It is worth noting that what consumers pay less in the case of a TGC system comes fully at the expense of the producers' surplus. The conclusion so far is that when the cost of producing renewable electricity turns out to be lower than expected, the TGC system is more

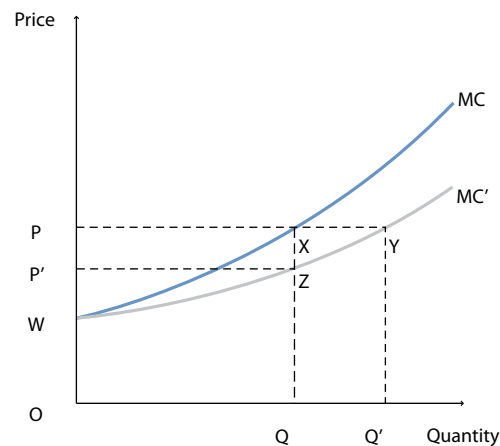
When information is incomplete and when renewable electricity costs are uncertain, price-based and quantity-based instruments lead to different results.

² It is useful to note that in equilibrium and under perfect information, the feed-in tariff is equal to the shadow price of the quantity objective of the TGC system, which is equal to the sum of the price of green certificates and the price of conventional electricity.

cost-effective than a feed-in tariff and it limits the risk of an excessively high output and burden on consumers.

The results are reversed, however, when the marginal costs of producing renewable electricity prove to be higher than anticipated (in Figure 1 the marginal cost curve would lie above MC). With a feed-in tariff, a smaller-than-expected amount of renewable electricity will be produced at the pre-determined feed-in tariff. With a TGC system, the targeted quantity will be generated, but at a higher price than expected – and higher costs for consumers. What is more, the producers' surplus under a TGC system will be larger than the surplus under a feed-in tariff. In sum, when reality shows that assumptions about the cost of producing renewable electricity were too optimistic, a price-based instrument (i.e., feed-in tariffs) will be more cost-effective than a quantity-based instrument (i.e., TGC systems). In this situation, feed-in tariffs set a ceiling for the marginal cost of each renewable technology; conversely, a TGC system – while directly controlling output – leaves the setting of prices to the workings of the system, possibly resulting in surprisingly high prices.

Figure 1. Cost-effectiveness and cost for consumers: feed-in tariffs vs. tradable quotas with lower-than-expected marginal costs of producing renewable electricity



Hybrid solutions, combining price-based elements with quantity-based elements, can limit the costs for consumers.

Both types of instruments can limit the costs for consumers through hybrid solutions, which combine price-based elements with quantity-based elements (Roberts and Spence 1976). To illustrate, as mentioned above, TGC systems usually include the option that electricity suppliers pay a penalty instead of (fully) meeting their quotas. This option provides a safety valve in case renewable electricity turns out to be much more expensive than anticipated. In the price-based approach, two approaches are developed. Under the first, successive downward adjustments to the feed-in tariffs can be made at certain intervals if marginal costs turn out to be lower than anticipated. Under the second approach, downward adjustments of prices for new capacities are programmed upfront, reflecting – among other things – anticipated cost declines due to learning and experience effects, technical progress, and the increasing use of renewable resources.

Reflecting the possibility of overestimating marginal costs and, equally important, successive future cost declines, feed-in tariffs are often considered less suited than TGC systems to let market forces play their role in controlling the cost for consumers. While producers of renewable electricity can, and probably will, exert competitive pressure on the producers of equipment used for generating renewable electricity, any decline in the cost of equipment will boost the profits of producers – as long as the level of feed-in tariffs remains unchanged for new capacity. By contrast, TGC systems have the potential to encourage *ex ante* competition not only between equipment producers, but

also between renewable electricity producers. The main reason for this is that obligated suppliers have a keen interest in minimising the cost of complying with their quotas.

However, all this does not mean that we can necessarily expect TGC systems to deliver renewable electricity at lower cost for consumers than feed-in tariffs. This is because TGC systems come with far more uncertainties than feed-in tariffs, and this higher degree of uncertainty affects the relationship between obligated suppliers, producers, and financiers. Ultimately, this results in higher risk premiums that suppliers, producers, and financiers take into account when embarking on renewable electricity projects, thereby raising the cost of such projects.

One should not necessarily expect a tradable green certificates system to deliver renewable electricity at lower cost than feed-in tariffs.

To illustrate this point, let us look at the revenue characteristics of a renewable electricity project under each of the two instruments. In the case of feed-in tariffs, revenues are fairly certain given that there is a guaranteed price at which production can be fed into the network. In the case of TGC systems, revenues depend on the uncertain market price of electricity and the uncertain price of green certificates: electricity-price risk combines with green-certificate-price risk. To the extent that some suppliers do not fulfil their quotas and pay a penalty instead, there is an additional source of revenue for suppliers that meet their quotas because total penalties paid are allocated *ex post* to them. But this source of revenue is uncertain too.

When the production of renewable electricity is difficult to schedule – as in the case of wind energy, for instance – the electricity-price risk is exacerbated by uncertainties concerning balancing costs, which – in TGC systems – are entirely borne by producers of renewable electricity. In TGC systems, the generation of renewable electricity needs to observe all electricity market rules, including those pertaining to the balancing market mechanism that aims at ensuring the reliability of the whole power system (Mitchell *et al.* 2004). By contrast, under feed-in tariffs, renewable power plants do not need to supply a certain load profile and the balancing costs fall on obligated suppliers.

Revenue risk also arises from uncertainty as to how the quota will increase over time and, in particular, at which level it will not be raised any further. When the quota approaches its ultimate level, investment in additional renewable electricity generating capacity may create an oversupply of green certificates and, thus, a drop in their price. This adds to the risk of renewable energy projects in a TGC system and, thus, their costs.

Both instruments considered here also differ in their exposure to political and regulatory risks. In general, the impact of regulatory changes is more difficult to anticipate under a TGC system than under a system of feed-in tariffs. For instance, although it is clear that a decrease in the penalty for not observing quotas will reduce the price of green certificates and, hence, the amount of penalties that can be passed on to complying suppliers, the size of this effect is difficult to anticipate. This creates uncertainty as to the overall profitability of investment in renewable electricity projects. Moreover, in a feed-in tariff system it is easier than in a TGC system to insulate existing renewable projects from the effects of changes in rules governing the system. For instance, although a cut in feed-in tariffs could apply, in principle, to both new and existing projects, the latter are usually protected by appropriate legal or institutional arrangements.³ Things are different in a TGC system. For instance, broadening the scope of eligible technologies (e.g., making wood co-firing eligible) and changing the way technologies are certified (i.e., the quantity of certificates associated to a

³ For instance, in Germany, where feed-in tariffs are backed by two successive laws (EFL law of 1990 and EEG law of April 2000 – amended in 2004), legal and constitutional principles effectively protect investors from the regulatory change (Langniss and Wiser 2003). In France, developers of renewable electricity under feed-in tariffs are less well protected because the implementation of such tariffs is a matter of decree and not of law (decree of the 6.12.2000).

technique) could increase abruptly the number of certificates. The ensuing drop in the price of green certificates will adversely affect the profitability of existing renewable projects, with investors having no legal protection against this form of partly alienating the value of 'green' capacity installed in the hope that the regulatory framework remains unchanged.

The considerable uncertainties surrounding renewable projects in TGC systems has two main consequences. First, other things being equal, the relatively high risk will make finance for renewable electricity more costly than it would be under feed-in tariffs, thereby increasing the cost of renewable electricity. Empirical support for this hypothesis will be provided in Section 4, where we look at the experience with alternative policy instruments.

The second consequence of TGC systems is that they tend to reduce competition among producers of renewable electricity. In addition, there are built-in tendencies that undermine competition in the market for green certificates, thereby distorting the price signal that this market is expected to send. To see why, consider first that the risks and transaction costs associated with supplying renewable electricity under a TGC system will encourage large, independent suppliers to become part of vertically integrated electricity companies, or – alternatively – buy electricity and trade green certificates under long-term contracts. Indeed, long-term contractual arrangements rather than spot transactions on the market of green certificates and/or vertical integration could become necessary to buttress the profitability of renewable electricity projects and thus ensure their financing.⁴ All this implies that only the small obligated suppliers with changing loads will make permanent use of the certificates market, implying limited competition and liquidity in that market. This creates an opportunity for large obligated suppliers – though not really relying on the certificate markets – to exert market power to increase certificate prices and thus the cost of renewable electricity to consumers.

Let us now move beyond static aspects of cost-effectiveness and briefly consider it from a dynamic efficiency viewpoint. The main point to develop here is that the relatively large producers' surplus generated by feed-in tariffs (thereby making this instrument not look particularly cost-effective from a static viewpoint) is the very means of fostering technological progress and, thus, cheaper renewable electricity over time. In terms of Figure 1, the hypothesis is that feed-in tariffs lead to a faster rightward shift of the marginal cost curve over time than a TGC system would .

There are three channels through which feed-in tariffs encourage technological progress. First a generous producers' surplus spurs the deployment of renewable technologies which, in turn, gives rise to learning and experience effects that lower marginal production cost.

A generous producer surplus allows greater research and development efforts by equipment manufacturers.

Second, a generous surplus allows greater research and development efforts by equipment manufacturers. This is because a high surplus and attractive feed-in tariffs allow electricity producers to offer equipment manufacturers better prices than they could under the more competitive TGC instrument. In fact, the experience of German, Danish and Spanish producers of wind energy equipment indicates the favourable impact that feed-in tariffs can have on the development of nascent technologies. That said, this favourable impact and, thus, the advantage of feed-in tariffs weakens once a performing international industry emerges.

⁴ In the United Kingdom, since the implementation of the Renewable Obligation Certificates (ROC) system in mid-2002, most of the investments have been carried out by subsidiary companies of the five large suppliers, and a minor part of the investment has been undertaken by independent producers protected by long-term contracts with a minimum contractual timespan of 13 years. This has also been observed in Texas where, despite the possibility to exchange certificates, all the distributors-suppliers who carry the obligation have negotiated bilateral, long-term contracts (10 to 25 years) to reach their quotas of renewable electricity (Langniss and Wiser 2003).

Third, compared to the TGC instrument, feed-in tariffs are easier to design with technology-specific tariffs so that electricity producers do not only select the most mature renewable technologies, but also promising technologies that are at an earlier stage of technological and commercial maturity. Some authors argue that market-based incentives of TGC systems stimulate risk-taking and innovation too (see Egenhofer 2005, for example). Although true, the stimulus to innovation is unlikely to match that of feed-in tariffs, which allow firms to adopt innovative technologies while being sure of a reasonable stream of revenues.

Overall, there is good reason to believe that feed-in tariffs are better than TGC systems in fostering technological progress. Somewhat paradoxically, supporters of TGC systems argue that if technology-specific investment grants for projects based on second-ranked technologies complement TGC systems, their drawback in fostering technological progress will be mitigated. Alternatively, it is sometimes proposed to create technology-specific TGC systems; however, instead of one big and possibly efficient market for exchanging certificates, there would then be a number of different – but smaller – exchanges.

We will now broaden the analysis by examining the cost-effectiveness of feed-in tariffs and TGC systems in a European policy context.

3.2.2 Cost-effectiveness – a European perspective

An alleged advantage of a TGC system over feed-in tariffs is that it would – if applied at the European level – foster a cost-effective development of renewables across the EU. The underlying economic logic is a straightforward extension of the one underpinning the case for TGC system at the national level. As argued above, at the national level, a firm subject to a renewable electricity quota can meet its obligation by producing renewable electricity, purchasing it (directly from other firms, or indirectly from the green certificates market), or a combination of the two. Applied to the EU – where each member state will have to observe its quota – this would mean that a country with comparatively high costs of renewable electricity buys renewable certificates from other countries for as long as its marginal cost of producing renewable electricity exceeds the sum of the certificate price and the market price of electricity. And *vice versa*: a country with low costs of producing renewable electricity produces such electricity in excess of its quota, earns green certificates for this excess, and sells them in the certificates market – all this making sense as long as its marginal cost of producing renewable electricity is lower than the sum of the certificate price and the market price of electricity. In equilibrium, supposing a common price of electricity across EU member states, there would be least-cost production of the targeted amount of renewable electricity, a common price of green certificates, and the same long-run marginal cost of producing renewable electricity in all member states.

An alleged advantage of an EU-wide tradable green certificates system over feed-in tariffs is that it would foster a cost-effective development of renewables across the EU.

Notwithstanding the useful role a European-wide TGC system could play, in principle, in efficiently achieving renewable electricity targets, it must be emphasised that for such a system to be fully effective, two conditions must hold: first, there must be an integrated European electricity market and, second, the national institutional and regulatory frameworks supporting the green certificates market must be harmonised. In fact, establishing such a system in a situation where these conditions are not fulfilled could lead to considerable inefficiencies. The remainder of this sub-section explains why.

To start with the need for an integrated electricity market, note that in equilibrium, the certificate price is the difference between the marginal cost of renewable electricity and the market price of electricity (see Box 1). Consider now a situation where EU certificate markets are fully integrated but electricity markets are not. There will then be a common price of certificates, but different electricity

prices. It follows that the marginal costs of renewable electricity differ across EU countries – contrary to what would happen in the idealised world of fully integrated electricity markets. Moreover, there will be undue rents to producers of renewable electricity in countries with higher electricity price.

This being said, introducing a common TGC system in Europe in lieu of national TGC systems could nonetheless lead to a more efficient allocation of renewable electricity production across Europe. For instance, with perfectly integrated certificates markets, but imperfectly integrated electricity

Box 1. The benefits of a European TGC system in imperfect market conditions

Considering a tradable green certificate (TGC) system, the purpose of this Box is to set out the equilibrium relationship between the market price of electricity, the price of green – or renewable – certificates, and the marginal costs of producing renewable – or green – electricity. We will illustrate this relationship by considering three cases, involving two countries.

A key observation to make upfront is that renewable electricity is a joint product, comprising two sub-products: ‘normal’ electricity (i.e., electricity as consumed, comprising renewable electricity and electricity from polluting plants) and – assuming that renewable technologies replace polluting ones – better environmental quality (which results from establishing property rights on the environment). The price of green certificates is linked to the marginal cost of renewable electricity and the market price of electricity. An important corollary is that the sub-products are sold on independent markets (the green certificates market and the electricity market), which have different structures and demand functions.

Case 1 – each country has its own TGC system

In equilibrium, the relationship between the market price of electricity (P_E), the price of green certificates (P_C), and the marginal costs of producing renewable electricity (MC_R) is:

$$P_C^A = MC_R^A - P_E^A$$

$$P_C^B = MC_R^B - P_E^B$$

The first equation shows this relationship for country *A* and the second equation for country *B*. Let us assume that both countries produce the same amount of renewable electricity, but that country *B* produces at lower marginal cost than country *A* ($MC_R^B < MC_R^A$). In these circumstances, both countries could achieve the same overall amount of renewable electricity at lower costs if country *B* increased its production and if country *A* reduced its production. Assuming upward-sloping marginal cost curves, no further efficiency gains can be made once marginal cost are the same in each country.

Case 2 – countries introduce a common TGC system

Variant 1: perfect integration of certificate markets and of electricity markets

If both countries move to a common TGC system and succeed in establishing a fully integrated electricity market, the price of certificates and the price of electricity will be the same in both countries, that is, $P_C^A = P_C^B$ and $P_E^A = P_E^B$. It follows that, in equilibrium, marginal costs are also the

markets, the production of renewable electricity could fall in countries with initially high marginal cost of renewable electricity and it could increase in countries with low marginal costs. But the opposite could happen, too, as set out in detail in Box 1, when a common TGC system would reduce rather than increase the cost-effectiveness of producing renewable electricity. The risk of this happening is high if countries with costly renewable resources have high electricity prices and countries with low-cost renewable resources have low electricity prices.

same in both countries, which – in turn – implies that renewable electricity production has risen in country *B* and fallen in country *A*. In these circumstances, a common TGC system results in an optimal allocation of renewable electricity production across countries.

Variant 2: perfect integration of certificate markets, but imperfect integration of electricity markets

Things are different when the certificate markets are fully integrated ($P_C^A = P_C^B$) – which is a reasonable assumption as certificates are tradable financial assets – but the electricity markets are not ($P_E^A \neq P_E^B$) – because of physical constraints to exchange electricity between countries, for instance. In these circumstances, marginal costs of producing renewable electricity are not equalised across countries ($MC_R^B \neq MC_R^A$) and, thus, a common TGC system does not lead to an optimal allocation of renewable electricity production across countries. Whether or not the ensuing allocation of renewable electricity is better than the one under separate TGC systems depends on the constellation of P_C^A, P_C^B, P_E^A and P_E^B before establishing a common TGC system. In principle, three outcomes are possible.

First, the allocation of renewable electricity production between the two countries moves in the right direction, but falls short of reaching its optimum. With $MC_R^B < MC_R^A$ before creating a common system, this means that production and marginal costs increase (fall) in *B* (*A*) – but MC_R^B remains smaller than MC_R^A .

Second, the allocation of renewable electricity production between the two countries moves in the right direction, but exceeds its optimum. In other words, production and marginal costs increase (fall) in *B* (*A*) beyond the optimal level, resulting in $MC_R^B > MC_R^A$. This outcome could be less, equally, or more efficient than the situation before introducing a common TGC system.

Third, the allocation of renewable electricity production between the two countries moves in the wrong direction: country *B*, which produces renewable electricity at lower marginal costs than country *A* before the creation of a common TGC system, reduces its renewable output while country *A* raises its output. As a result, the positive difference between MC_R^A and MC_R^B becomes even greater. This outcome is clearly less efficient than the situation before introducing a common TGC system.

In sum, without fully integrated European electricity markets, a common TGC system does not ensure an optimal allocation of renewable electricity production across countries. The reasoning sketched here for given capacities to generate renewable electricity applies, too, to investments in additional capacity: investments in additional renewable power capacity might not take place where it is cheapest.

What are then the chances for a well-integrated EU-wide electricity market? While some EU governments and the European Commission continue to aim at creating such a market, a truly functioning EU-wide market with common electricity prices is very unlikely to materialise. A more realistic scenario is the emergence of smaller regional markets, each possibly comprising a number of EU countries. For instance, the markets of the Nordic countries are fairly integrated, and there are indications of interaction between continental European markets (France, Germany, Austria, Belgium, and the Netherlands) during large periods of the year. Efforts – led by the Commission, regulators, and transmission system operators – to harmonise access to national grids and trans-border interconnections will improve this nascent integration (European Commission 2005). Although true, because of limited interconnection capacities between markets, it is unlikely – neither over the short nor medium term – that the so-called electric peninsulas (i.e., Italy, Iberic countries, Nordic countries, the United Kingdom, and Greece) will be integrated in a pan-European market.⁵ In the long run, electricity prices could possibly converge even if the physical separation of markets endures thanks to the convergence of technology mixes across countries that will happen with the replacement of existing generating capacity. However, differences in technology mix will persist because of differences between countries in, for instance, coal policies, hydro resources, and acceptance of nuclear technology.

A necessary condition for an effective common tradable green certificates system is that EU members harmonise all rules governing the system.

A second condition for an effective common TGC system is that EU members harmonise all rules governing the system (eligible technologies, type and duration of the certificate, certificate exchange rules, and so on).⁶ In addition, they must harmonise – or abolish – all other instruments in support of renewable electricity (tax credits, investment grants, preferential indirect taxation, and so on). Obviously, a country that maintains such instruments creates an artificial cost advantage for its producers, thereby distorting competition between projects at the European level and preventing an efficient allocation of new investment in renewable energy.

Advocates of an EU-wide TGC system appear to minimise the distortion that could arise if these two conditions are not met and/or the intrinsic difficulties of harmonising the rules of the game and of integrating Europe's electricity markets. It should also be pointed out that the economic advantage of a common TGC could be reached through a burden sharing agreement among member states. Based on the estimated potential of renewable resources in each member state, members' obligations (that is, a targeted percentage of renewable electricity in national electricity production) could be set to approximate an equalisation of marginal costs. Indeed, this is the philosophy of the 2001 Directive, which proposes voluntary objectives for developing renewable electricity – objectives defined on the basis of experts' studies on the renewable resources potential of each EU member state (see European Commission 1996, for instance). Adopting renewable electricity targets for each member state aligned with its specific renewable resource potential seems to be more promising than an EU-wide TGC system. Under such an arrangement, member states would be free to choose the instrument (feed-in tariffs, national TGC system, or competitive tendering) to achieve their national targets.

⁵ In normal years, wholesale prices in the 'electric peninsulas' without capacity surplus (Spain and Italy) have amounted to €60/MWh and more, which is considerably above prices in 'continental markets', the Nordic market, and the UK market (around €30-€50/MWh) – where surplus of capacity has remained. Without increasing trans-border transmission capacity, these differences will continue to persist.

⁶ Although evident, it merits repeating that renewable electricity production existing prior to the possible introduction of a common TGC system must be excluded from the certificates system to avoid the transfer of rents from one country to another without there being any investment in new renewable capacity.

3.3 Environmental effectiveness

The environmental effectiveness of an instrument is measured by its success in stimulating investment in renewable power generating capacity and electricity production from this capacity. A variety of factors influence investment and production, notably the level of support and its reliability and predictability. As far as reliability and predictability are concerned, an important aspect is the vulnerability of an instrument to external shocks and changes in the political balance of power after elections. Obviously, the higher the level of support and the more reliable and predictable investment revenues, the greater the impact on investment and production will be. But there is also a trade-off in the sense that with relatively low revenue reliability and predictability, expected revenues need to be high to induce investment. Bearing this in mind, let us consider now both instruments.

The environmental effectiveness of an instrument is measured by its success in stimulating investment in renewable power generating capacity and electricity production from this capacity.

Feed-in tariffs have a good chance to be environmentally effective if they grant sufficient financial support for a long enough time span while minimising transaction costs of producers in their relation with the obligated purchasers of renewable electricity. Indeed, such transaction costs are normally minimal as there is no need to establish any contract between producers and purchasers, except for agreements on technical conventions governing the secondary duties of producers (maximum annual production covered by the tariff, conditions of connection, technical tuning, and so on). Provided feed-in tariffs are sufficiently high and guaranteed for the whole economic life of the investment, potential producers should have no difficulty in sourcing finance for their projects. In sum, although feed-in tariffs do not directly target the quantity of renewable electricity production but its price, they can be expected to perform well in terms of environmental effectiveness without being more costly than TGC systems.

In principle, one would expect TGC systems to be more effective than feed-in tariffs in increasing investment in and production of renewable electricity – after all, this instrument directly targets the quantity of renewable electricity. However, real-world TGC systems are in fact hybrid instruments, controlling quantity and price. This is because they allow suppliers to pay a penalty rather than fulfilling their quota. Obviously, too low a penalty – for instance one very close to the electricity generating cost of the marginal project needed to respect the general quota – would induce mandated suppliers to pay the penalty for part of their quota rather than to comply with them. In these circumstances, investment in new renewable capacity might not be considered attractive and, as a result, although fixed *a priori*, the quantitative target might be missed.

The UK experience clearly shows how too low a penalty – the buy-out price – makes suppliers decide to disrespect their quotas. In 2003 and 2004, the buy-out price was €43/MWh. The market price for electricity ranged between €30/MWh and €45/MWh. The lower end of this range together with the buy-out price suggest a reference price of renewable electricity of €73/MWh – compared to a long-run marginal cost of wind energy of €90/MWh. In these circumstances, many suppliers decided to pay the penalty for part of their obligation rather than observe their quota. More specifically, in 2002-04, between 41 percent and 45 percent of the overall quota was ‘met’ by penalty payments. In 2004, the buy-out price was raised to €47/MWh, reducing the gap between the targeted quota and what was actually achieved in 2005 to 31 percent.

All in all, meeting an increasing target for renewable electricity with a TGC system presents intrinsic difficulties. The challenge is to adequately raise the quota, which influences the certificate price, and the penalty that is meant to cap the cost for consumers. In other words, the aim of limiting cost for consumers makes it difficult to achieve ambitious renewable energy targets. And experience so far

suggests that feed-in tariffs have been more successful than TGC systems in spurring the production of renewable electricity.

3.4 Conformity with the underlying market regime

Over recent years, EU member states have been liberalising their electricity sectors – albeit at different speeds and to different degrees. This raises the question of how alternative instruments for promoting renewables conform to a market regime that might be characterised by a vertical separation of network business, the abolishment of regional monopolies, and – in general – by more competition.

As a matter of principle, a tradable green certificates system seems to readily conform with liberalised electricity markets.

As a matter of principle, TGC systems seems to readily conform with liberalised electricity markets – for a variety of reasons. First, TGC systems do not distort competition between suppliers. This is because the ability of a supplier to meet his quota obligation does not depend on whether or not additional renewable electricity can be produced at reasonable cost in his supply area. The obligation can be met by purchasing green certificates, which can be bought at a market price from any plant generating renewable electricity. Second, as long as the renewable electricity quota is the same for all competing suppliers, they all carry the same cost for supplying renewable electricity quota and there is, thus, no need for a specific financing mechanism. Third, as explained in Box 1, the value of the ‘greenness’ of renewable electricity is linked to the market price of electricity, given that producers of green electricity receive the electricity price and the certificate price.

By contrast, with feed-in tariffs, the production of renewable electricity is not governed by market forces given the obligation to purchase at a fixed price. But there is a way to strengthen the role of market forces – a solution applied in Spain: to define a price premium that is added to the wholesale electricity price. Each year, this premium is calculated on the basis of the cost of renewable electricity and the average wholesale electricity price during the preceding year. This solution links the revenue (per kWh) of renewable electricity producers to the market price of electricity.

Feed-in tariffs could distort competition when there is clear-cut unbundling between distribution (a physical network activity) and supply (a commercial activity) – a model the European Commission tries to promote – by imposing unequal obligations on competing suppliers. To avoid distorting competition, it is necessary to entrust an agency with the responsibility for buying renewable electricity at guaranteed tariffs because suppliers are no longer regional monopolists. This agency then needs to auction the renewable electricity it has bought, or reallocate it to suppliers in proportion to their market shares.

However, making feed-in tariffs compatible with liberalised electricity markets does not really pose problems in countries where the activities of local, regional, or national incumbent operators have been ‘unbundled’ only moderately (e.g., when only the accounting of distribution and supply activities has been unbundled). And then, the spatially prescribed obligation to purchase renewable electricity raises few problems when incumbents remain dominant suppliers with *de facto* captive customers – as it is the case in France, Germany, Spain, Ireland, and Portugal where feed-in tariffs are in place. However, to ensure conformity with market principles it is necessary that the incumbents subject to the purchase obligation are compensated in a transparent and fair way from a fund financed by a special tax on every transported kWh. In sum, there is considerable scope for making feed-in tariffs compatible with a liberalised electricity market regime.

3.5 Which instrument is preferable?

Overall, economic reasoning does not suggest a clear-cut advantage of feed-in tariffs over TGC systems – and *vice versa*. Each system has its strengths and weaknesses.

Feed-in tariffs promise greater environmental effectiveness and they are relatively easy to design so that they foster the development of a diverse set of renewable technologies. They can also be fairly cost-effective – at the national level and in the European policy context – provided they account reasonably well for countries' underlying renewable resource potential, cost differences across technologies, cost differences when a given technology is used in different locations, and anticipated cost decreases because of technological progress. Tariffs that take these factors into account help limit producers' rents and, thus, costs to consumers. In line with expected technological progress, they can also be phased out as and when technologies have matured or targeted capacities have been installed. This constitutes now the reference design for feed-in tariffs. But, admittedly, feed-in tariffs could result in too much renewable capacity in certain technologies and they could be too costly if there is no timely adaptation and eventual phasing out of tariffs.

TGC systems make good use of market forces with a view to minimising the cost of meeting renewable electricity targets. Almost by design, there is no risk that this instrument inadvertently leads to excessive investment in renewable capacity. If the targeted amount of renewable electricity is set at too high a level – relative to underlying marginal cost curves, that is – buy-out prices offer a safety valve that caps the cost for consumers. All in all, the use of market forces and the setting of quantitative targets in combination with buy-out prices all promote a cost-effective supply of renewable electricity. This being said, potential investors in renewable electricity might perceive the stream of revenue resulting from their investment as too uncertain. This tends to stifle investment in renewable capacity, increase financing cost, or both. In addition, large transaction costs might offset the downward pressure on cost resulting from competition. What is more, competition itself might not develop as hoped for if producers and suppliers strive for vertical integration or long-term contracts with a view to limiting risks and reducing transactions costs. A further drawback of TGC systems is that they effectively concentrate their support on the least costly technological solution and, thus, they do not stimulate technological diversification. To mitigate this shortcoming, there could be complementary support mechanisms, such as tax credits and investment grants for promising, though less advanced, technologies. However, this would lessen the beneficial impact of competition – one of the presumed strengths of TGC systems.

Having compared the economics of feed-in tariffs and TGC systems and concluded that neither outperforms the other on theoretical grounds, it needs to be pointed that the choice of instrument is largely political in any case. It reflects the preferences of governments and citizens, notably preferences pertaining to environmentalism and the respective role of the state and free markets in an economy. With faith in markets and a strong preference for controlling costs, governments are likely to choose market-based instruments, such as TGC systems. Conversely, with less of a free-market culture and a strong preference for attaining quantitative environmental goals, the choice is more likely to be in favour of feed-in tariffs.

Besides economic reasoning and political considerations, guidance in choosing instruments for promoting renewable electricity should also come from good – or bad – practice. A point we address next.

Economic reasoning does not suggest a clear-cut advantage of feed-in tariffs over a tradable green certificates system – and vice versa. Each system has its strengths and weaknesses.

4. Lesson from the application of alternative policy instruments

The experience of EU member states with promoting renewable electricity production is now sufficiently documented to draw some lessons on how various instruments have worked in practice. Insights follow from experience with designing and applying various policy instruments and from what they have achieved in meeting policy objectives. As before, we will concentrate on feed-in tariffs and TGC systems.

One lesson is that the influence of a particular instrument cannot be isolated from other factors that foster, or hinder, the development of a country's renewable electricity resources.⁷

Key obstacles to developing renewable electricity generation include fragmented planning procedures and local acceptability problems.

Specifically, how successful an instrument is depends as much on the level of support it provides as on the planning procedures and rules that govern the recovery of balancing costs and the cost of connecting renewable power plants to the network. To illustrate, although France adopted in 2000 feed-in tariffs as generous and predictable as those in Germany, investment in renewable generating capacity and its performance fall well short of what has been achieved in Germany (e.g., in 2005, installed wind energy capacity amounted to 530 MW in France and 15,000 MW in Germany). Key obstacles to developing renewable electricity generation in France include fragmented planning procedures and local acceptability problems. There is thus no doubt that effective planning procedures and network integration rules can help reduce project costs and risks and they must therefore be an integral part of a successful renewable energy policy. But like the support for renewable energy in general, they reflect the political backing of the underlying renewable technology. In addition, they reflect social preferences for global environmental protection and energy security, on the one hand, and local environmental concerns on the other.

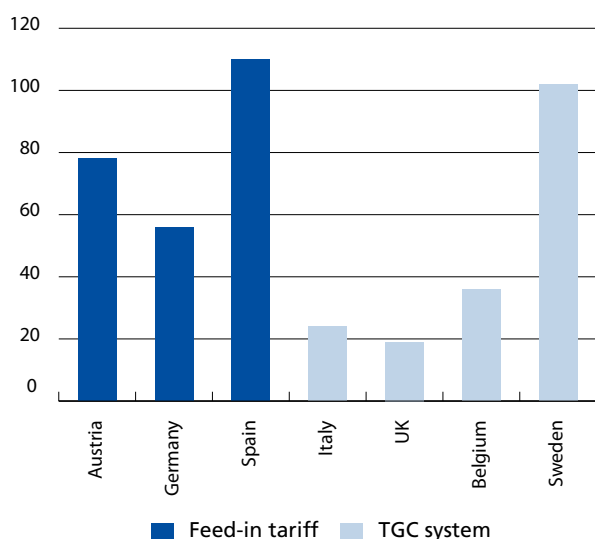
Another lesson is that differences in the stability and predictability of the support for renewable electricity largely explain why some European countries were more successful in increasing the share of renewable electricity than others. Let us take the case of onshore wind, so far the most successful renewable electricity technology.

Figure 2 shows, for a selected number of EU countries, the annual average per capita output (in kWh) produced by new wind energy installations in 2000-04. The results come from Ragwitz *et al.* (2006). In analysing the efficiency of various support mechanisms for renewable electricity, they have estimated expected revenues to new producers of onshore wind energy and the induced renewable electricity production in Austria, Germany, and Spain – all offering feed-in tariffs – and in Belgium, Italy, Sweden, and the United Kingdom – countries with TGC systems. Using the level of output to measure the environmental effectiveness of the underlying policy, it is fair to say that countries with feed-in tariffs (Austria, Germany, and Spain) performed better than countries with TGC systems – the exception being Sweden. But in the Swedish case, results follow from the specificity of this country's TGC system, which was only adopted in 2003 (replacing a system that offered large tax credits and investment subsidies) and includes existing installations in the portfolio of eligible technologies. Austria, Germany, and Spain applied feed-in tariffs in 1998-2005. Combined with low administrative barriers, this stimulated a strong and continuous growth in wind energy. By contrast, in the United Kingdom, Italy, Belgium and Sweden, the change from a

⁷ An abundant literature discusses the causal links between the diffusion of renewable electricity and variations in the design and strength of policy instruments. Examples include Reiche and Becherger (2004), Reiche (2005), Meyer (2003), and van Dijk *et al.* (2003).

tendering system or feed-in tariffs to a TGC system created much uncertainty during the transition period. Moreover, one can consider the findings summarised in Figure 2 as evidence for the hypothesis that TGC systems do not create an environment secure enough to invest in renewable electricity generation.

Figure 2. Annual average wind energy output per capita (in kWh) of onshore units installed in 2000-2004



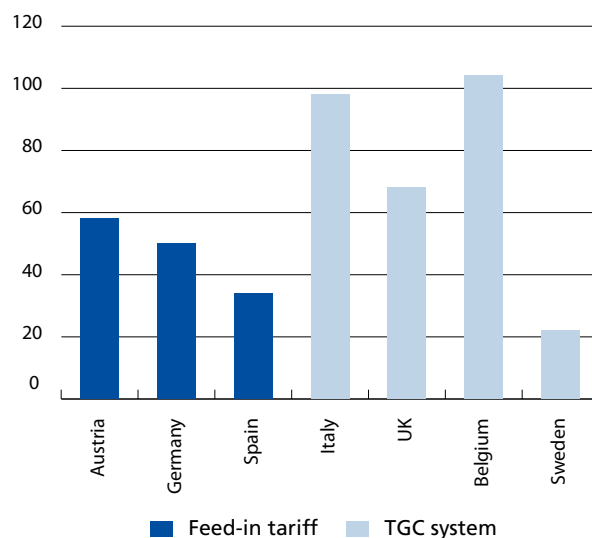
Source: Ragwitz *et al.* (2006)

Feed-in tariffs are often presumed to offer more generous support for renewable electricity than TGC systems, and this – rather than the predictability of the support – could explain their greater environmental effectiveness. But as we have argued in Section 3, from the perspective of potential producers and investors, TGC systems are surrounded by considerable uncertainties, and one consequence of this could be that the revenue required to induce investment in renewables is higher under TGC systems than under feed-in tariffs. Empirical support for this hypothesis comes from Butler and Neuhoff (2004). They show that the remuneration of wind energy is higher under the UK TGC system than under the German feed-in tariffs, which are often portrayed as excessively generous. More specifically, they show that the remuneration of wind energy ranges from around €77/MWh to €100/MWh in the British mechanism, which compares to a figure of €70/MWh under Germany’s feed-in tariffs. Similar evidence comes from Ragwitz *et al.* (2006), who have estimated expected revenues to new producers of onshore wind energy. The estimates – pictured in Figure 3 – show that expected revenues are much higher in the group of countries using the TGC systems than in those relying on feed-in tariffs.⁸ All in all, a fair conclusion is that feed-in tariffs, in practice, do not offer exceptionally high revenues to producers and that reliability and predictability of the policy and investment environment is key for successfully developing the market for renewable electricity.

From the perspective of potential producers and investors, a tradable green certificates system is surrounded by considerable uncertainties.

⁸ This being said, the difference could probably decrease in the future as and when institutional experience with the relatively new instrument of TGC systems accumulates. But even if this were to happen, it would not reduce the risk premium associated with the production of renewable electricity under TGC systems.

Figure 3. Expected revenues (€/MWh) of onshore wind energy: feed-in tariffs vs. tradable green certificate (TGC) system



Source: Ragwitz *et al.* (2006)

Notes: Estimates reflect levelised expected revenues.⁹

The third and final lesson is that governments often offer complementary investment support (soft loans, tax allowances, and so on) – in addition to feed-in tariffs or TGC systems, for example. The need for such additional support scheme seems to be higher in the case of TGC systems, in particular when the objective is to foster not only the technologically and commercially most advanced renewable option but also those lagging behind.

In designing policies to promote renewables, policy makers need to be aware of the complexity of the innovation process driving renewable electricity technologies.

In conclusion, given the experience gained with competing instruments to promote renewable electricity, it may not come as a surprise that erstwhile strong supporters of TGC systems have become more cautious, as evidenced by the evolving position of the European Commission in the debate (European Commission 2005). Policy makers need to be aware, and increasingly are, of the complexity of the innovation process driving renewable electricity technologies. Once they have decided on the instrument, they must be aware of the necessity to clearly signal that the support mechanism will remain in place long enough to ensure an acceptable return to the producers of renewable electricity.

5. Conclusion

Economic reasoning does not provide an unambiguous answer to the question which of the two instruments – feed-in tariffs or TGC systems – is best for promoting renewable electricity. One reason is that there is a range of criteria for assessing the pros and cons of alternative policies, and while one instrument might be strong when measured against one criterion, it might be weak when measured against others. There are then possible trade-offs to consider – such as a trade-off

⁹ The expected levelised revenues were calculated for 2004. Calculations are based on the effective support conditions in each country. Tax exemptions and soft loans are also taken into account in estimating revenues. For countries with TGC systems, certificate prices of 2004 have been extrapolated for the entire active period of the support system for a new equipment. The low estimate for Sweden results from the specificity of the Swedish TGC system, which includes existing installations in the portfolio of eligible technologies.

between good performance of an instrument in terms of cost-effectiveness and possibly less-than-satisfactory performance with respect to environmental effectiveness.

Needless to say that such trade-offs become more relevant when moving from the principles of a particular instrument to its practical application. But it is also true that each of the two instruments examined in this paper could be designed so that its weaknesses are mitigated without compromising its strength too much. This being said, experience with the two instruments in various countries seems to suggest that, in practice, feed-in tariffs are easier to adapt to real-world situations than TGC systems – a finding that holds when considering a common European approach to promoting renewable electricity. What is more, feed-in tariffs seem to offer greater success than TGC systems in providing a predictable revenue planning horizon, boosting investment in renewables, and fostering technological diversification. If society values this more than minimising cost to electricity consumers, feed-in tariffs are a good choice. Conversely, if society considers cost minimisation under market pressures the norm in public policies, TGC systems might be the route to follow. That said, in practice, TGC systems imply a less reliable investment environment, which raises risk premiums and thus capital costs, thereby making cost for consumers higher than what simplified theoretical reasoning suggests.

Feed-in tariffs and tradable green certificate systems could be designed so that their weaknesses are mitigated without compromising their strengths too much.

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