

# **Promoting Renewable Electricity Generation through Guaranteed Feed-in Tariffs vs Tradable Certificates: An Ecological Economics Perspective**

**Reinhard Madlener**

Institute for Advanced Studies and Scientific Research Carinthia (IHS Kärnten)  
Domgasse 5, 9010 Klagenfurt, Austria  
Tel. +43-463-592 150; Fax. +43-463-592 150-13; email. madlener@carinthia.ihs.ac.at

**Sigrid Stagl**

Vienna University of Economics and Business Administration (WU Wien)  
Reithlegasse 16/1/4, 1190 Vienna, Austria  
Tel. +43-1-313 36-5859; Fax. +43-1-31336-5835; email. sigrid.stagl@wu-wien.ac.at

## **Abstract**

For a variety of reasons it can be argued that the share of electricity generated from renewable energy sources should be increased. However, many of the new renewable energy technologies cannot yet successfully compete against conventional ones, and therefore support schemes are needed. A common approach, at least within the European Union, is the provision of guaranteed feed-in tariffs. More recently, tradable certificate schemes in connection with certain quota targets have been proposed and debated in-depth. In some countries they are already being implemented. As both guaranteed feed-in tariffs and tradable certificates are primarily justified on purely economic grounds, there is no guarantee that these policy instruments are also favoured from an ecological economics perspective. Based on arguments from co-evolutionary theory, this paper investigates the extent to which these two policy instruments can satisfy ecological and socio-economic criteria as well and enhance a certain degree of diversity of electricity generating technologies. On a conceptual level, some basic design characteristics of tradable electricity certificates and feed-in tariffs that are differentiated according to socio-economic-ecological criteria are introduced.

## **1 Introduction**

The promotion of the use of renewable energy sources (RES) has become a primary concern of many energy policy-makers in the world. Apart from mitigating climate change and local environmental pollution, the increased use of RES offers a chance to stretch the resource base, increase employment levels, foster remote and rural communities, improve the balance of trade, increase the diversity of energy supply, and to support the domestic energy technology manufacturing industries.

In Europe, apart from RD&D spending on yet non-commercial technologies, for a number of years guaranteed feed-in tariffs were the most widely used instrument to directly support electricity generation from renewables. Due to their increasingly distortionary effects with growing market shares of RES, however, tradable renewable electricity certificate schemes have attracted a lot of attention lately (Drillisch 1999, 2000; Kühn et al. 1999; Madlener and Fouquet 1999; Menges 1998) that offer a potential to raise economic efficiency. For obvious reasons, both of these schemes create protected sub-markets for renewable

electricity within the European internal electricity market. Based on co-evolutionary arguments, we will focus on the extent to which these two price-support instruments can satisfy criteria considered important in ecological economics.

It should be noted that the substitution of RES for fossil and/or nuclear fuels is no panacea either. If not based on precautionary and sustainability principles, extensive use of renewable sources for energy may indeed lead to important adverse environmental impacts (Abbasi and Abbasi 2000). Thus, for the identification of truly sustainable electricity production possibilities, detailed sustainability criteria are required that should include indicators like greenhouse gas and pollutant emission, impact on ecosystems, land and material use, noise, visual amenity, employment creation, local value added, etc.

Hence an important issue to discuss in this context is sustainability. For *strong sustainability* to hold – the notion usually adopted by ecological economists (e.g., Gowdy and O'Hara 1997; Noël and O'Connor 1998) – two rules apply with regard to renewable resources. First, the rate of harvest of renewables should be kept below their natural rate of regeneration. Second, the rate of use of non-renewable resources should be less than, or equal to, the rate of technological progress in developing substitutes or the rate of saving through conservation efforts. Hence the basic idea behind the concept of strong sustainability is that the resource stock should be kept constant over time (Pearce and Turner 1990). Obviously, most countries are not following these rules. Therefore, besides reducing energy demand, a shift to an increased use of RES for the production of electricity, under the conditions described above, seems advisable in order to achieve a higher degree of sustainability.

An important issue in our investigation is to identify instruments that tend to favour electricity generation techniques with lower adverse socio-economic-ecological (SEE) impacts, while at the same time ensuring a certain degree of short-term economic efficiency. In principle, we can distinguish between more planning-oriented instruments and more market-oriented instruments. We will see, that for achieving such different goals as SEE quality and economic efficiency, the question is not so much a choice between the two alternatives, but rather the weight given to the one or the other characteristic.

The argumentation followed in this paper is based on evolutionary economic theory, emphasising possible irreversible developments, uncertainty, path-dependence, the institutional context of innovation, and the importance of diversity within a system for long-term existence.

The organisation of the paper is as follows: First we present the theoretical framework underlying our argumentation, followed by an introduction to the (mainly European)

institutional framework related to the promotion of commercially available renewable electricity. Then, the different alternatives of direct price-supporting measures as currently applied in different countries are critically reviewed. In the subsequent section 5, we introduce the basic design of a multi-criteria scheme to evaluate different renewable electricity technologies; the scheme is based on social preferences. In section 6, we investigate instruments that are in line with the planned EC Directive on the promotion of renewable electricity (CEC 1999a) and which can overcome the critique mentioned above. We refer to these as ‘*socio-economic-ecological tradable electricity certificates*’ and ‘*socio-economic-ecological feed-in tariffs*’, respectively. Section 7 concludes.

## **2 Theoretical Framework**

### **2.1 Co-evolution of economy, society and nature**

Explaining the relationship between development and the environment, scientists usually stress how new technologies and science have facilitated the discovery of new resources and access to lower grade resources. In contrast, Gowdy (1994) and Norgaard (1994) emphasise that environments are complex physical and biological systems rather than simply stocks of separate resources. Moreover, they see environmental degradation as a problem of social organisation: “*Correcting the unsustainability of development is not simply a matter of choosing different technologies for intervening in the environment. The mechanisms of perceiving, choosing, and using technologies are embedded in social structures which are themselves products of modern technologies*” (Norgaard 1994:29). For our analysis this means that the development of environmentally less damaging new energy technologies is certainly an important step towards maintaining or improving environmental quality, but an equally difficult question is how the introduction and application of these new technologies is organised.

Economic development is therefore seen as an evolutionary process that results in changes of knowledge, technologies and social organisation over time (Gowdy 1994; Norgaard 1994). As the environment changes, the economy must re-adapt – a co-evolutionary process.

### **2.2 (Co-)Evolutionary principles**

With reference to the entropy law Georgescu-Roegen (1971) provided a powerful metaphor (the famous non-turnable hourglass) as a challenge of the mechanical, reversible and static world of neo-classical economics. The emphasis on qualitative change,

**irreversibility**, indeterminateness and true scarcity produced a radically different picture of economic activity than the common circular diagram where there is no impact on external systems or resources (Gowdy and Mesner 1998). Georgescu-Roegen suggested to view the economy as a one-way flow of low entropy energy and resources going into the economy and leaving as high entropy waste. Entropy in one system can decrease only by taking low entropy from another (see Baumgärtner et al. 1996; Norgaard 1994, for discussions of common misinterpretations by economists). Reliance on energy from fossil/nuclear fuels is an example of such an unsustainable process. At current levels of non-renewable energy use, the substitution of the different types of renewable energy for fossil and/or nuclear fuels and the reduction of energy demand are indispensable prerequisites for sustainability. With reference to the laws of thermodynamics, Georgescu-Roegen emphasised the role of qualitative change in the environment. In this respect, he linked concepts of evolutionary theory, economic theory and the environment into a comprehensive world view of environment and society (Gowdy 1996; Söllner 1997).

Norgaard (1994) frames development as a co-evolution between cultural and environmental systems. Co-evolving systems have parts and relations which change in unforeseeable ways. Important environmental problems like climate change, the reduction of the ozone layer and the loss of biodiversity are characterised by a high degree of **uncertainty** about nature, incidence, and/or timing of possible environmental costs. Uncertainty – the strong variety in Knight’s sense (Knight 1921) – is commonly defined as a situation where the range and the probability distribution of outcomes is not known in advance. The uncertainties considered here are mainly related to the long-term horizon and the socio-economic-ecological interactions that are **complex**<sup>1</sup> and potentially irreversible (Faucheux et al. 1997). Because of uncertainties, complexity of ecosystem functions, and the long time scales involved, environmental norms cannot be set through use of conventional economic valuation methods. And resource allocation cannot be left to markets alone (Funtowicz et al. 1997). In this context monetary evaluation alone and its implicit assumption of substitutability are insufficient. Besides, any attempts to express environmental indicators in several significant digits amounts to a misleading hyper-precision (Funtowicz and Ravetz 1990). The valuation of ecosystem functions requires a methodology which allows for the complexities of the system to become explicitly admitted to the valuation process rather than being implicitly

---

<sup>1</sup> A system is considered *complex* if it cannot be captured by a single perspective. Particularly difficult to explain is the outcome of ‘emergent complex systems’ that are complex systems which possess at least some of the following characteristics: individuality, intentionality, consciousness, foresight, purpose, symbolic representation, and morality; in short, as soon as humans come in (Funtowicz et al. 1997).

considered in 'corrected' market prices (O'Hara 1996). This is why we refer in our analysis (i) to physical units of emission and ecological impact – an array of different units like hectares or tonnes – rather than abatement costs; ; and (ii) allow for a process where decision-makers and stakeholder can judge the social preference of different technologies.

Change in social and ecological systems can take many forms. Since they do not change in a deterministic way, however, evolution seems to be the better reference. For evolution to work there must always be a **variety** of forms from which to select. Under conditions of complexity and uncertainty a diversity of co-evolving systems assures that at least some of them respond favourably to an occasionally harsh environmental surprise as well as to long-term environmental change. In this framework the emphasis shifts from the flow of materials to the flow of values, ways of thinking, technologies, ways of organising people, and natural genetic material. Thus an evolutionary process involving selection cannot be an optimising one, at least not in the strict sense. It requires variety and to some degree it involves ceaseless and systematic error-making as well (Hodgson 1993). This clearly calls not only for fostering a variety of different technologies for the use of renewable resources, but also for supporting different organisational types of energy production. And as many of the electricity generating technologies using RES are still under (continued) development, and a large part of the conventional fuels are still being subsidised (lack of a level playing field), renewables technologies need during the development process a realm which is at least to some degree protected from competition with established technologies.

The question which role past developments have on future developments (i.e., **path-dependence**) is another crucial point in (co-)evolutionary theory. Future development of an economic system is affected by the path it has traced out in the past. The initial conditions are extremely important for the dynamic path. In chaotic models the outcome can change dramatically with a small change in the initial conditions. And these initial conditions change at every moment of time (Hodgson 1993). Pagano (1991) addresses the two-way and cumulative interaction of technology with property rights when saying, “in this context, simple efficiency stories may well lose their meaning. Each outcome is likely to be path dependent and inefficient interactions between property rights and technology are likely to characterise the history of economic systems.” Path-dependence is also related with particular kinds of inflexibility in economic processes. Evolving systems can get locked into given paths of development, excluding a host of other, perhaps more efficient or more desirable possibilities (Hodgson 1993).

The context within which a firm operates is crucial for its success. To a large extent the context is influenced by institutions, which comprise the type and level of social culture, the level of technical and general education, and the material and institutional supports for entrepreneurial activity (Hodgson 1988). Even the characteristics selected depend on the overall environment, because payoffs are dependent on the nature of the industry as a whole. Thus 'natural selection' does not necessarily favour the more efficient units, i.e., always the optimum or near-optimum outcomes. This puts markets and their potential to produce efficient results in perspective. Hodgson (1993) concludes from these findings from evolutionary economics that *"such circumstances may constitute a pretext for some kind of intervention in the economy, because there is no guarantee that efficient firms will actually be selected in a competitive evolutionary process"* (p.209). In energy markets, where positive and negative externalities, uncertain consequences, and a high degree of irreversibility prevail, this clearly calls for deliberate intervention of policy-makers both for the use of renewable sources and for a more sustainable use of energy sources.

### **2.3 Interdependency of goals**

In addition to the goals of just distribution of income, efficient allocation of resources and high societal stability, Daly (1977, 1992) added the dimension of scale of economic activity. From co-evolutionary ideas it follows that policies and instruments aimed at containing scale have important effects on intragenerational distribution, on the allocative efficiency of markets, and on economic stability – i.e. the goals are interdependent (Stewen 1998). For example, more efficient use of resources will reduce the throughput and therefore the required scale, as fewer inputs are necessary for the same output (the net effect being determined by the size of the "rebound effect"). Therefore, electricity shall be generated, distributed, and used in the most efficient manner possible. On the other hand, the reduction of scale may be a requirement for the efficient functioning of markets. Once fossil fuels become scarce, efficient production of goods and services will be hindered, unless production structures are adapted gradually on time. This is necessary as due to market imperfections (externalities, unequal market power, lack of certain information etc.) we cannot in general count on market prices to express adequate signals of scarcity in good time. Since future generations are different people, this is not merely a matter of allocation, but also of distribution. As an example, renewable electricity generating technologies might not always constitute the most cost-efficient options for reducing greenhouse gas emissions. However, we may want to start from the assumption that there are, in addition to greenhouse gas

mitigation goals, other reasons for a government or a society which can justify the direct support and use of renewable energies (Kühn et al. 1999).

One step further, it can be concluded from the fact that co-evolving natural and social systems are way too complex, so that identifying an optimal technology mix for sustainable development is not possible. This is the first argument for supporting a variety of technologies. The second argument was based on path-dependence. Under conditions of uncertainty in combination with a learning process and high investments necessary to develop working alternative technologies, it appears recommendable to develop an array of technologies available for future provision of a crucial input factor like energy.

Our principal criteria applied in assessing policy instruments enhancing the generation of electricity from RES are therefore:

- increasing short-term economic efficiency;
- reducing the environmental impact (in physical terms); and
- developing a variety of technologies.

As a next step, we will introduce the institutional framework for the increased use and promotion of renewable electricity, primarily from a European perspective.

### **3 Institutional Framework**

In line with the need for common rules in the European internal market for electricity, as stipulated in the EU-Directive 96/92/EC (CEC 1997a), the European Commission aims at harmonising the different support schemes for renewables in order to reduce market distortions and trade limitations. Article 8(3) of the Directive permits Member States to require renewable electricity preference in dispatching. Moreover, an accelerated penetration of RES for electricity generation is recognised as a major potential area for action to meet the commitments made both under the Kyoto Protocol and the targets set in the EC White Paper on renewables (CEC 1997b). Particularly, the White Paper states that RES still make an unacceptably low contribution to the Community's energy balance, as compared to the technical potential available, and suggests a doubling of the share of RES in the EU overall gross inland energy consumption from 6 to 12 percent by 2010.

In the Commission's 1998 draft Directive on access of electricity from renewable energy sources to the internal market in electricity (CEC 1998) it was stipulated that the share of electricity generated from renewable sources should be at least 5% by the end of 2005. Moreover, it was suggested to allow direct price control schemes only until 2005 and to promote both competition between different RES and international trade of regenerative electricity. In this version also standardised certification was favoured.

In April 1999, the European Commission presented a Working Paper (CEC 1999b) in which the advantages and disadvantages of different support mechanisms were discussed. Its main objective apparently was to serve as a basis for further discussions. Moreover, it signalled more flexibility regarding transitory regimes from non-competitive fixed price to competitive market-based schemes.

The latest EC draft Directive of November 1999 on the promotion of electricity from RES in the internal electricity market (CEC 1999a) is in many respects more vague than the 1998 version and repeatedly emphasises the importance of the subsidiarity principle. The only obligation for member states in this draft is to set and meet national targets for the domestic future consumption of electricity from RES: “*Member states where the share of electricity from RES which receive direct price support exceed 5% of the domestic electricity consumption may limit the access to produces from member states which have equally reached their 5% threshold*” (CEC 1999a). Access to direct price support schemes must be granted also to non-domestic producers no later than 10 years after the entry into force of the Directive. In order to avoid massive feed-in from non-domestic producers, feed-in tariffs must by then have approached the level of support schemes in other countries. In addition, this draft Directive also contains a prioritisation of electricity from RES in terms of access to transmission network in case of congestion problems. The Commission wants these measures to be seen as “*an inter-linked package aimed at developing, in due course, a true and effective single market for RES, and providing a real and significant boost to this sector*” (CEC 1999a).

Outside Europe, the U.S. Renewables Portfolio Standard (RPS) has been conceived by the American Wind Energy Association (AWEA) in the mid-1990s as a market-based concept for the promotion of renewable electricity. At least seven U.S. states have already announced firm plans to introduce some form of RPS, and several others are currently discussing an introduction. Moreover, the U.S. Clean Energy Act 1999 includes an RPS to increase renewable electricity sources gradually to 20 percent by 2020. The bill also aims to increase competition among renewable sources to bring their prices down faster. In Australia, the intention of the government is to phase in an obligation on the wholesale buyers of electricity by 2001 to acquire an increasing number of renewable electricity certificates, as part of an attempt to raise the share of renewable electricity from 10.5% in 1996/7 to 12.5% in 2010 and to provide certainty to industry (Greenhouse Energy Group 1999, AGO 1999).

## **4 Direct Price-Influencing Instruments in the European Union**

### **4.1 Guaranteed feed-in tariff schemes**

Guaranteed feed-in tariffs may be seen as subsidies on generated output, at least for the part that exceeds the market price of electricity. They imply that utilities are subject to a purchase obligation for electricity produced from certain renewable energy technologies and have to pay a certain guaranteed (minimum) tariff per kWh of electricity supplied. Typically, the renewable sources and technologies covered, and the tariffs to be offered, are specified in great detail.

Guaranteed feed-in tariff schemes as in Austria, Denmark and Germany have proven to be very effective in promoting the deployment of particular RES (especially in Denmark and Germany in the case of wind power), and cause relatively minor regulatory and administrative costs. However, due to the purchase obligation, a major disadvantage is that they tend to discriminate against those electric utility companies that happen to operate in regions with large RES potentials. As a consequence, the obligation can lead to potentially large distortionary effects among competing utilities. Another major disadvantage of guaranteed (or fixed) feed-in tariffs lies in the fact that they often do not provide enough incentives for investors to drive down costs by means of technological innovation and/or improvement of operations. Also, it is very difficult to find (and regularly adjust) an optimal tariff level for each of the renewable energy technologies included in the scheme that avoids excessive profit margins, enhances at least some degree of economic efficiency, and promotes all technologies in the way and to the extent desired. Finally, with such a price-driven instrument the achievement of a particular quantity target cannot be safeguarded.

With regard to enhancing static and dynamic economic efficiency the new renewable energy law (EEG 1999, 2000) that passed the German parliament recently is worth mentioning. Particularly, it should help to double the share of electricity generated from RES from 5 to 10% by 2010 and to enable an economically viable production for a variety of renewable energy technologies. An interesting feature of the planned new regulation is an annual reduction of the guaranteed feed-in tariffs for certain technologies after 2002 (biomass 1%, wind 1.5%, photovoltaics 5%),<sup>2</sup> in order to reflect technological progress.

In sum, in the case of guaranteed feed-in tariffs it is basically in the hands of the policy-maker (and their skills and motivations) to allow for at least some degree of economic efficiency (i.e., by reducing the tariffs over time according to the expected/desired

---

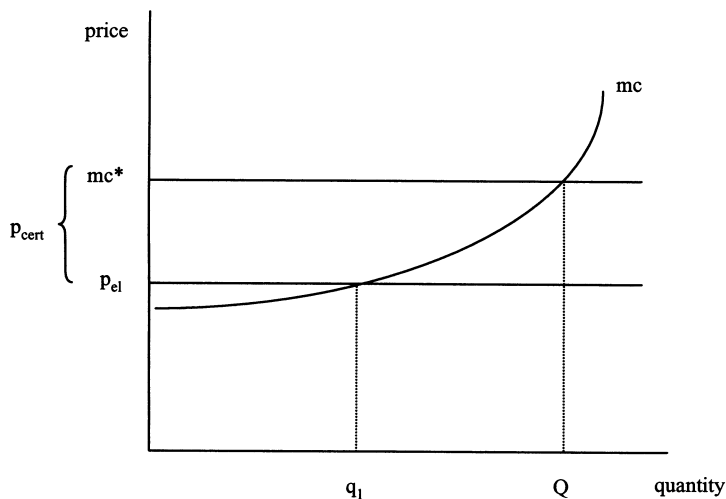
<sup>2</sup> For the other renewable energy technologies included the cost reduction potentials are considered to be quite exhausted and accounted for by the rate of inflation only.

technological progress), to steer the diversity of technologies employed (i.e., by widening or narrowing the range of eligible renewable energy technologies), and to have an influence on the environmental impact (i.e., by under-/oversubsidising certain technologies). A disadvantage is that the achievement of certain quantity targets cannot be safeguarded.

#### 4.2 Tradable renewable electricity certificates

Under a tradable renewable electricity certificate system, electricity from RES is sold just like conventional electricity at market prices (market for kWh). The additional costs incurred in producing renewable electricity are covered by the sale of certificates (market for certificates). These are demanded by the electricity suppliers (or alternatively the consumers) who are required to purchase a certain amount of certificates from producers of electricity from RES according to a quota, or fixed percentage, of their total annual electricity sales (or consumption in the alternative case). The principal idea of a tradable renewable electricity certificate system is to sell the environmentally beneficial characteristics of using renewables separately from the electricity itself. The total price achieved by producers of electricity from RES is composed of the normal electricity price and the price for the certificates. Figure 1 illustrates the basic idea.

Figure 1: Tradable certificates – costs, price and quantity



Without supportive instruments electricity from RES would be produced only up to point  $q_1$ .  $Q$  denotes the target quantity of electricity produced from RES (i.e., the quota) and  $p_{el}$  the price of conventionally produced electricity. The price of the certificates,  $p_{cert}$ , is equal to the difference between  $mc^*$  and  $p_{el}$ . Thus, it depends on the supply of electricity from RES: the lower the supply the higher the certificate price, which corresponds to an incentive to increase supply.

The main advantage of a tradable certificate scheme is that it enhances static and dynamic economic efficiency. Low-cost producers will be able to produce and sell their certificates first. The market determines which renewable plants to build, where, and for what price. This leads to the positive effect that regionally operating distribution companies are no longer restricted by the resources availability and technical possibilities in their own region. For obvious reasons, a weakness is that low-cost (and maybe low-promising) options might push higher-cost more-promising options (like offshore wind) out of the market (Kühn et al. 1999; see also Schaeffer et al. 1999).

There are several examples of existing tradable renewable electricity schemes. In 1996 (with revisions in 1998) the “Green Label” system was introduced in the Netherlands and has received much attention since then. Based on a trading market combined with a voluntary commitment by Dutch utility companies to reach a set renewable energy target, the system has so far produced mixed results, partly due to the lack of binding targets until the end of 1999. Although the instrument implementation time elapsed has not yet been sufficient for a detailed analysis, the Dutch experience shows (i) that the government needs to set clear intermediate and long-term targets (policy predictability); (ii) that green certificates should be valid for more than one period (flexibility to allow for “banking” and “borrowing” of certificates); and (iii) that internationalisation is necessary to enhance the stability and liquidity of the market (cf. Spaccarotella 2000).

Other countries who have introduced, or are about to introduce, tradable renewable electricity certificates comprise a number of U.S. states (1998), Denmark (starting 2001), Italy (starting 2002), and the U.K. (expected for 2001). Specific plans exist in the Flemish part of Belgium and in Australia (Drillisch 1999). Besides, a Renewable Energy Certificates System (RECS; cf. [www.recs.org](http://www.recs.org)) was initiated in the Netherlands, Denmark and the U.K. with the aim to stimulate an internationally harmonised market for renewable energy certificates. Participants from Austria, Belgium, France, Germany and Italy have joined in the meantime, and many other countries have shown interest. In contrast to most other systems that mainly focus on the promotion of near-market technologies, the RECS also includes large-hydro power.

Overall, conventional tradable renewable certificate schemes tend to favour low cost technologies, a problem that can only be partly ameliorated by introducing technology bands of (almost) equally competitive technologies. The major aim is to increase economic efficiency, whereas diversity of supply and a reduction of the environmental impacts is rather difficult to achieve, as this depends on how many of the technologies can successfully

compete in the market, and whether or not the lowest-cost technologies are in fact those with the least environmental impact, respectively.

### **4.3 Bidding or tender-based systems**

Bidding or tender-based systems feature elements both of feed-in tariff systems (guaranteed prices) and tradable certificate systems (competition, quota targets), and have been introduced in the United Kingdom, in France, and in Ireland. Generators compete on price for contracts to supply renewable electricity within a certain limited capacity quota. Usually the bids are invited by different 'bands' of technology. Bids received are ranked by the authority in charge in order of price. The cheapest bids in each technology band are accepted in preference. The marginal bid is therefore most expensive and sets the final price paid for the whole band (cf. Mitchell 1995, 1999).

The most widely studied scheme is the British Non-Fossil Fuel Obligation (NFFO) system that has been successful in lowering prices of electricity generated from renewable energy sources, indicating that economic efficiency was increased. More mature technologies and a reduced perception of risk (which lowers cost of finance) have contributed to this success. However, their impact on the total amount of green electricity generated was limited. Also, the costs of preparing bids to NFFO are relatively high, which tends to promote larger companies as the main bidders instead of small and local ones (Kühn et al. 1999). Finally, evaluating the bids is a relatively cumbersome and bureaucratic process (Grubb and Vigotti 1997).

Potential investors in a bidding system are also faced with several uncertainties. First, the chance of winning a bid is rather low. Second, planning permission problems and local resistance against the construction of electricity generation plants from RES have made realisation impossible in several cases. Third, for every NFFO-round it is unclear which share of the total funds will be available for renewable technologies (Mitchell 1995, 1999).

Summing up, bidding or tender-based systems have helped to increase economic efficiency. Similarly to the case of the guaranteed feed-in tariffs, the diversity of supply allowed is primarily determined by the policy-maker, with the only (more theoretical) difference that if a technology is economically very unattractive, it might still be included in a tariff scheme, whereas it can probably not successfully compete in a bidding scheme. In terms of environmental impacts, the comment made for tradable certificates applies: higher economic efficiency of a particular technology does not necessarily correspond with larger environmental benefits.

## 5 Criteria Weighting and Social Preferences

Irrespective of which instrument one applies, physical differences in resource intensity (e.g., emissions, land use) and options for future generations are usually ill-represented in deregulated markets. Without accompanying measures, there is a danger that many of the biogeophysical and socio-economic criteria considered important in ecological economics are neglected in such support schemes that are, more often than not, primarily based on (short-term) economic considerations.

Therefore, in this section we focus on how to take into account the differences in the biogeophysical and socio-economic (i.e., what we want to refer to as ‘socio-economic-ecological’ or ‘SEE’ in this paper) impacts of the different technologies and at the same time to provide a sufficient incentive for investors to drive down costs by improvement of operation. In order to distinguish different electricity generation technologies by their SEE impact, the options must be compared by a number of quality criteria, which in many cases can be measured with a number of indicators using data collected by statistical offices and science labs or simulations calculated by environmental scientists.

Table 1 provides an illustrative example on how such a criteria matrix could look like. For each of the criteria mentioned, an evaluation (e.g., on a scale from 1 to 10) would have to be found for each of the renewable energy technologies considered. Note that short-term economic efficiency criteria are excluded, as these are already implicit in the support mechanisms described. Adverse (e.g., pollutant emission) and benign (e.g., employment creation) will have to be aggregated in such a way that they do not cancel each other. This can to some degree be achieved by the definition of minimum values for individual criteria. (In terms of notation, a ‘high SEE impact’ stands for a relatively less desirable technology and ‘low SEE impact’ for a relatively more desirable technology).

The numbers in the following table given for “renewable energy technology 1” are purely fictitious and are only meant to serve illustrative purposes.

Table 1. Criteria influencing ecological impact and their relative importance (illustrative)

CRITERIA	RENEWABLE ENERGY TECHNOLOGIES			
	RET 1	RET 2	...	RET N
<b>BIOGEOPHYSICAL DIMENSION</b>				
<b>Inputs needed for production</b>				
▪ Land resources	6	...		
▪ Water resources	3	...		
▪ Materials requirements (e.g., scarce and/or heavy materials)	2	...		
▪ Indirect energy requirements	3	...		
<b>Potential consequences of production</b>				
▪ Impact on natural biota, habitats and wildlife	2	...		
▪ Environmental risks (e.g., groundwater contamination)	3	...		
▪ Noise	5	...		
▪ Visual intrusion	4	...		
▪ Impact on microclimate	2	...		
▪ Impact on soil productivity	2	...		
▪ Resettlements	2	...		
<b>Potential consequences in energy conversion and use</b>				
▪ Air pollution (e.g., SO <sub>x</sub> , NO <sub>x</sub> , CO <sub>2</sub> , VOC, particulates)	3	...		
▪ Organic emissions (e.g., dioxin hydrocarbons, toxic irritants, carcinogenic compounds)	1	...		
▪ Generation of solid wastes (e.g., bottom ash)	1	...		
▪ Water pollution	1	...		
▪ Pressure on land and water resources	2	...		
▪ Other hazards (e.g., accidental fires, exposure to toxic chemicals)	2	...		
<b>SOCIO-ECONOMIC DIMENSION</b>				
▪ Employment creation	8	...		
▪ Occupational hazards	3	...		
▪ Impact on local poverty	2	...		
▪ Household income disparity	3	...		
▪ Democratic control over markets	1	...		
▪ Safety of power supply	4	...		
▪ Impact on balance of trade	6	...		
▪ Long-term economic viability	2	...		
▪ Local value added	3	...		

Note: In our example, the scale ranges from 1 to 10, where 1 stands for the least impact and 10 for the maximum impact.

However, in this setting two problems arise: First, the consequences of a number of environmental impacts are characterised by uncertainty. This requires that more importance is given to the process of decision-making than under conditions of certainty (Faucheux et al. 1997; Funtowicz and Ravetz 1994; O'Hara 1996). Second, it will be rather the rule than the exception that a certain technology is superior to others with regard to one criteria, but inferior to one or several others. The importance given to one criteria compared to another (weights) cannot be derived scientifically, but is a question of social preferences. How can we know about the desirability of the different technologies? To find out about social preferences, the relevant actors must be asked. Interviews with decision-makers (authorities) and stakeholders (e.g., groups of people affected by energy decisions) can be undertaken. This technique is commonly applied in multi-criteria decision aid (MCDA). While in most cases interviews are made with individuals, an increase of group decision-aid applications can be observed (e.g., Georgopoulou et al. 1998; Karni et al. 1992) and appears suitable for the given context.

For the choice of the MCDA method, it should be noted that not only the ranking of the technologies, but also the extent of preference is of interest for the design of instruments. Therefore, a method must be chosen which allows for cardinal (e.g., Analytical Hierarchy Process – AHP), not only ordinal ranking (e.g., outranking). The former methods, however, are based on strong assumptions.

The outcome of such a procedure would be an indicator of SEE impact for each renewable energy technology which can then be applied in 'SEE feed-in tariffs' as well as in 'SEE tradable electricity certificates', respectively.

## **6 Two Alternative Instruments Derived from Socio-Economic-Ecological Goals**

In this section we want to describe how the 'traditional' direct price-support mechanisms described in section 4 could be modified in order to redress the existing imbalance towards short-term economic performance goals in direction of a more balanced approach of simultaneously targeting SEE criteria (as set out in table 1). While it is a challenging task to determine the different degrees of socio-economic-ecological impact of the various technologies, we consider the mere reference to economic and, say, emissions criteria as insufficient (such an attempt was made, for example, by Drillisch 1999, who suggested to regulate the number of certificates issued by CO<sub>2</sub> equivalents).

For reasons of space, we will restrict ourselves to guaranteed feed-in tariffs and tradable certificates. However, the arguments made can be extended to bidding or tender-based systems in an analogous way.

## **6.1 SEE-differentiated tradable electricity certificates**

To avoid the important drawback of tradable electricity certificate schemes that they tend to reduce technological diversity by cornering higher-cost options, at least two options can be thought of: (i) to introduce technology bands in order to provide for a certain degree of technological diversity; or (ii) to vary the number of certificates issued according to the SEE impact of the technology in question.

### ***Introduction of technology bands***

If tradable renewable electricity certificates are not only understood as means of reflecting external costs and benefits, but also as mechanisms for supporting the commercialisation of emerging technologies and a certain (additional) diversity of supply, separate bands would be needed for different renewable energy technologies. This way crowding out of at least some of the more expensive and/or less developed technologies could be avoided (Grubb and Vigotti 1997). While maintaining the least-cost mechanism inherent in such systems, a problem with this approach is that the liquidity of the certificates market diminishes, as instead of one single certificate traded in one single certificate market there would be separate certificates for electricity generated from biomass, wind, (solid/liquid/gaseous) biomass, solar-thermal, photovoltaics, etc. Eventually it is a political decision which technologies are allowed to compete with each other in the various technology bands, but in principle it can be thought of that relatively more expensive but SEE-friendly technologies are included (whereas without banding these would not be able to compete successfully), thereby not only increasing the diversity of supply as a function of the number of bands allowed for, but also decreasing the adverse overall impacts of the energy system on the economy, society, and nature.

### ***Issuance of certificates by socio-economic-ecological impact***

The major difference between electricity from RES and electricity produced from conventional sources is the intrinsic lesser SEE impact which, however, differs from technology to technology. From an ecological economics point of view, it is therefore desirable to distinguish the technologies by their SEE impact. Technologies with a high SEE impact are subsidised to a lesser extent than technologies with a low SEE impact. Analogous to the method suggested by Drillisch (1999) this can be achieved by emitting different numbers of certificates depending on the SEE impact of a particular technology. The major advantage of this method is, as compared to one based on technology bands, that only one

market for certificates and only one quota is needed. Hence liquidity of the certificates market will be much higher, while achieving the same diversification and SEE effect.

## **6.2 SEE-differentiated feed-in tariffs**

In the case of guaranteed feed-in tariffs, schemes are usually driven by certain economic motives (avoidance of excessive profits without choking the introduction of the technologies desired) and political considerations (diversity of supply, promotion of some local industry, etc.). In principle, it is straightforward to adjust an existing tariff scheme according to more SEE-driven criteria simply by adjusting the evaluation factors. Because the socio-economic-ecologically most preferable energy technology will in general not be the most economic technology, however, political acceptance may in many cases be much more difficult to realise. Besides, due to the uncertainty inherent in the assessment of certain criteria, the need for readjustments may be higher than under unicriterial feed-in tariff systems, which may significantly increase investors' planning uncertainties and the regulatory and administrative costs.

The main critique put forward against guaranteed feed-in tariffs, however, cannot be eliminated by designing an socio-economic-ecologically more justified scheme: the lack of static and dynamic economic efficiency and that the achievement of certain quantity targets cannot be safeguarded. Nonetheless, it can be avoided that technologies with highly adverse SEE impacts receive unjustifiably high guaranteed prices.

## **7 Conclusions**

This paper focused on the ecological economics' perspective of promoting the use of electricity from renewable sources by means of fixed feed-in tariffs or tradable renewable electricity certificates, i.e. direct price-supporting mechanisms. Starting from the strengths and weaknesses of these two instruments, we have started to elaborate how they need to be adjusted in order to satisfy criteria that are considered important in ecological economics and co-evolutionary theory.

While the introduction of ecological impact factors in the design of instruments will allow to achieve better environmental quality and provide incentives to lower short-term costs with both instruments investigated here, some differences remain. By the use of 'ecologically differentiated feed-in tariffs' it will be easier to ensure the maintenance of diversity of technologies. By use of 'ecologically differentiated tradable electricity permits' instead, the achievement of a certain quota of electricity generated from RES can be guaranteed.

We find that a differentiation of support by ecological impact may strongly increase gains that can be achieved from using such instruments. The choice between the instruments will then depend on whether the maintenance of diverse technologies or the guarantee of a particular quota achievement is considered more important.

## References

- Abbasi, S. A., & Abbasi, N. (2000). The likely adverse environmental impacts of renewable energy sources, *Applied Energy*, 65, 121-144.
- AGO (1999). 2%: A boost for the renewable energy industry - A positive greenhouse outcome. The Australian Greenhouse Office. ([www.greenhouse.gov.au/markets/2percent\\_ren/fs\\_boost.html#renewable](http://www.greenhouse.gov.au/markets/2percent_ren/fs_boost.html#renewable))
- Baumgärtner, S., Faber, M., Manstetten, R., & Proops, J. (1996). The Use of the Entropy Concept in Ecological Economics, In Faber, M., Manstetten, R., Proops, J. (Eds.), *Ecological Economics: concepts and methods* (pp. 115-135), Cheltenham: Edward Elgar.
- CEC (1997a). Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity, Official Journal No. L027/20, 30 January.
- CEC (1997b). Energy for the Future: Renewable Sources of Energy. White Paper for a Community Strategy and Action Plan, Brussels: Commission of the European Communities, COM(97)599 final, 26 November.
- CEC (1998). Draft Proposal for a Directive of the European Parliament and of the Council on access of electricity from renewable energy sources to the internal market in electricity. Brussels: Commission of the European Communities, 13 October.
- CEC (1999a). Proposal for a Directive of the European Parliament and of the Council on the promotion of electricity from renewable energy sources in the internal electricity market. Brussels: Commission of the European Communities, 23 November.
- CEC (1999b). Working Paper of the European Commission. Electricity from renewable sources and the internal electricity market. Brussels: Commission of the European Communities, March.
- Daly, H. E. (1977). *Steady-State Economics: The Economics of Biophysical Equilibrium and Moral Growth*. San Francisco: W. H. Freeman.
- Daly, H. E. (1992). Allocation, distribution, and scale: towards an economics that is efficient, just, and sustainable. *Ecological Economics*, 6, 185-193.
- Drillisch, J. (1999). Quotenregelung für regenerative Stromerzeugung. *Zeitschrift für Energiewirtschaft*, No. 4, 251-274.
- Drillisch, J. (2000). Renewable Portfolio Standard and Certificates-Trading on the Dutch Electricity Market, *International Journal of Global Energy Issues*, 14 (forthcoming).
- EEG (1999). Entwurf eines Gesetzes zur Förderung der Stromerzeugung aus erneuerbaren Energieträgern in das öffentliche Netz (Erneuerbare-Energien-Gesetz – EEG), Berlin BT-Drucksache 14/2341, 13 December 1999.

- EEG (2000). Gesetz für den Vorrang Erneuerbarer Energien (Erneuerbare-Energien-Gesetz – EEG) sowie zur Änderung des Energiewirtschaftsgesetzes und des Mineralölgesetzes, Berlin BT-Drucksache 14/2776. (<http://dip.bundestag.de/parfors/parfors.htm>)
- Faucheux, S., Froger, G., & Munda, G. (1997). Toward an Integration of Uncertainty, Irreversibility, and Complexity in Environmental Decision Making. In J. C. J. M. v. d. Bergh & J. v. d. Straaten (Eds.), *Economy and ecosystems in change: analytical and historical approaches* (pp. 50-74). Cheltenham, UK/Lyme, NH: Edward Elgar.
- Funtowicz, S. O., & Ravetz, J. (1990). *Uncertainty and Quality in Science for Policy*. Dordrecht: Kluwer.
- Funtowicz, S., O'Connor, M., & Ravetz, J. (1997). Emergent Complexity and Ecological Economics. In J. C. J. M. v. d. Bergh & J. v. d. Straaten (Eds.), *Economy and ecosystems in change: analytical and historical approaches* (pp. 75-95). Cheltenham, UK ; Lyme, NH: Edward Elgar.
- Georgescu-Roegen, N. (1971). *The entropy law and the economic process*. Cambridge, Mass.: Harvard University Press.
- Georgopoulou, E., Sarafidis, Y., & Diakoulaki, D. (1998). Design and implementation of a group DSS for sustaining renewable energies exploitation. *European Journal of Operational Research*, 109, 483-500.
- Gould, S. J. (1987). The Panda's Thumb of Technology. *Natural History*, 1, 14-23.
- Gowdy, J. M. (1994). *Coevolutionary economics: the economy, society, and the environment*. Boston: Kluwer Academic Publishers.
- Gowdy, J. M. (1996). Sustainability as a Concept of Social Science: Economic Concepts of Sustainability (pp. 39). Frankfurt: Institut für Sozial-Ökologische Forschung.
- Gowdy, J. M., & O'Hara, S. U. (1997). Weak Sustainability and Viable Technology. *Ecological Economics*, 22, 239-47.
- Gowdy, J., & Mesner, S. (1998). The Evolution of Georgescu-Roegen's Bioeconomics. *Review of Social Economics*, 56, 136-56.
- Greenhouse Energy Group (1999). Implementation planning for mandatory targets for the uptake of renewable energy in power supplies (pp. 105). ([www.greenhouse.gov.au/](http://www.greenhouse.gov.au/))
- Grubb, M. & Vigotti, R. (1997). *Renewable Energy Strategies for Europe: Vol. II: Electricity Systems and Primary Electricity Sources*. London: Royal Institute of Economic Affairs/Earthscan.
- Hodgson, G. M. (1988). Markets as Institutions. In G. M. Hodgson (Ed.), *Economics and institutions: a manifesto for a modern institutional economics* (pp. 173-194). Cambridge, UK.
- Hodgson, G. M. (1993). *Economics and evolution: bringing life back into economics*. Ann Arbor: University of Michigan Press.
- Karni, R., Feigin, P., & Breiner, A. (1992). Multicriterion issues in energy policy making. *European Journal of Operational Research*, 56, 30-40.
- Knight, F. (1921). *Risk, Uncertainty, and Profit*. Houghton Mifflin: Boston.
- Kühn, I., Schaeffer, G. J., Voogt, M., & Crookall-Fallon, C. (1999). Renewable Electricity and Liberalising Markets (REALM) - Working Group III: National Incentive Schemes and How to Improve Them.

- Madlener, R. & Fouquet, R. (1999). Markets for Tradable Renewable Electricity Certificates: Dutch Experience and British Prospects, BIEE Conference “*A New Era for Energy? Price Signals, Industry Structure and Environment*”, St. John’s College, Oxford, 20/21 Sept 1999.
- Menges, R. (1998). Staatlich garantierte Preise oder regenerativer Quotenhandel? Elemente eines Fördermodells für die erneuerbaren Energien in Deutschland (Federally guaranteed prices or renewable quota trading? Elements of a subsidisation model for renewable energies in Germany), *Energiewirtschaftliche Tagesfragen*, 48(11), 687-693.
- Mitchell, C. (1995). The renewables NFFO. A review. *Energy Policy*, 23, 1077-1092.
- Mitchell, C. (1999). Renewable Energy in the UK – the beginning of a new era, BIEE Conference “*A New Era for Energy? Price Signals, Industry Structure and Environment*”, St. John’s College, Oxford, 20/21 Sept 1999.
- Noël, J.-F., & O'Connor, M. (1998). Strong Sustainability and Critical Natural Capital. In S. Faucheux & M. O'Connor (Eds.), *Valuation for Sustainable Development - Methods and Policy Indicators* (pp. 75-97). Cheltenham, UK/Northampton, MA: Edward Elgar.
- Norgaard, R. B. (1994). *Development betrayed: the end of progress and a coevolutionary revisioning of the future*. London/New York: Routledge.
- O'Hara, S. U. (1996). Discursive ethics in ecosystems valuation and environmental policy. *Ecological Economics*, 16, 95-107.
- Pagano, U. (1991). Property rights, asset specification, and the division of labor under alternative capitalist relations. *Cambridge Journal of Economics*, 15, 315-342.
- Pearce, D., & Turner, K. R. (1990). *Economics of Natural Resources and the Environment*. New York: Harvester Wheatsheaf.
- Schaeffer, G. J., Boots, M. G., Martens, J. W., & Voogt, M. H. (1999). Tradable green certificates. A new market-based incentive scheme for renewable energy: introduction and analysis (pp. 39): Energieonderzoek Centrum Nederland (ECN).
- Söllner, F. (1997). A reexamination of the role of thermodynamics for environmental economics. *Ecological Economics*, 22, 175-201.
- Spaccarotella, N. (2000). Energy: Trading on green - Denmark wants to pave the way for the creation of a pan-European trading market for 'green certificates', *Utility Europe* (p. 15).
- Stewen, M. (1998). The interdependence of allocation, distribution, scale and stability - A comment on Herman E. Daly's vision of an economics that is efficient, just and sustainable. *Ecological Economics*, 27, 119-130.