Regulatory and Institutional Innovation for the Promotion of Renewable Energy Use

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Abstract. In this paper we study regulatory and institutional innovations required for an accelerated market diffusion of new renewable energy technologies. The main focus is on the situation in Europe. The paper argues that the existence of incentive-based promotion schemes is just one of several of the necessary conditions that must be fulfilled in order to allow renewables to penetrate the energy system in the politically desired intensity. The main conclusion drawn from the analysis is that in order to successfully initiate and perpetuate the market diffusion of renewables, in most cases it will be useful to identify and tackle the most important latent drivers and obstacles involved jointly and in a systemic and actor-oriented approach.

Introduction

New renewable energy technologies (RETs) are an important element for the long term transition towards a more sustainable energy system, and a more sustainable society and economy. Over the last decade, despite a still very low average contribution to overall energy supply in most countries (which at the global scale still relies to 80% on fossil fuels today; UNDP/UNDESA/WEC 2000), several of these technologies have experienced double-digit growth rates in market diffusion in some European countries (e.g. Kaltschmitt et al. 2002; Johnson & Jacobsson 2000), and making substantial progress along the learning curve (e.g. Isoard & Soria 2000; Nitsch, 1999; Neij 1997).

The diffusion of many new renewable energy technologies has begun in the 1980s or 1990s, starting with the use of methane from landfills and waste water treatment plants, the passive and active use of thermal solar energy, the re-vitalisation of small hydro power, the first automation of wood-fired boilers and ovens, as well as with bio-diesel and ethanol from biomass as vehicle fuels. In terms of capacity installed, wind power and solar collector systems have been particularly successful in some European countries and in Asia in the 1990s and received much attention; they can, therefore, serve as models for the increased utilization of other RETs. Especially wind power presently exhibits an enormous growth potential, as most of the material problems concerning the rotor which were most crucial in the past century (Heymann 1996) have been solved by now. This was an important precondition for a successful scaling-up of capacity, so that today learning effects and economies of scale and scope are becoming major drivers (Gipe 1995; Isoard & Soria 2001; Johnson & Jacobsson 2001), also with regard to exports (Jochem et al. 2002).

Energy policy-makers and the related administrative bodies often focus their efforts primarily on R&D funding and the provision of financial incentives for the investment or operation of RETs (e.g. capital and/or operating & maintenance cost subsidies).The many additional factors that are potentially relevant for the diffusion of innovative RETs and for the various actors supporting the diffusion process are typically much less well understood and considered in policy design.

Incentive-based regulatory promotion schemes, typically in the form of guaranteed feed-in tariff systems, quota-based tradable certificate systems, and bidding systems, have been intensively studied in recent years (e.g. Madlener & Drillisch 2002; Menanteau et al. 2001; Espey 2001; Morthorst 2000; among many others) and are meanwhile in place in most of the EU Member Countries. They are presently considered as key to increase the market penetration of renewables, as foreseen, for example, in the

- 1997 EC White Paper "Energy for the Future" (CEC 1997), which calls for a doubling of the share of renewables from 6 to 12% in overall gross inland energy consumption by 2010, and the recently signed
- EU Directive 2001/77/EC on the promotion of electricity from renewables (CEC 2001), which contains indicative target shares for renewables for each of the EC member countries until 2010.

Both documents clearly signal the willingness of the European Union and its member states to set and pursue ambitious steps to raise the contribution made by RETs in the energy supply system. Given the political challenges implied by these targets (and related sub-targets and efforts), and the momentum created at various levels, it becomes crucial to study the effectiveness both of existing and planned future policies and of the institutional frameworks in the EU and its Member Countries in influencing the speed of diffusion of particular renewable energy technologies.

Recently, several researchers have made attempts to design system-based analytical frameworks to address the diffusion of renewable energy technologies (e.g. Fuchs & Arentsen 2002; Painuly 2001; Jacobsson & Johnson 2000; Loiter & Norberg-Bohm 1999; Roos et al. 1999). The goal of this rather exploratory paper is to add to this body of literature by studying the diffusion of innovation process in a broader interdisciplinary context of actors, their networks, and institutional

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settings, applying the concepts of barriers and latent drivers. Based on this analysis, policy instruments and measures of involved actors are discussed in their ability to stimulate technological progress and further market penetration of renewable energy technologies.

Particularly, we address the regulatory and institutional innovations needed for an increased diffusion of RETs by focusing on six aspects: (a) cost reduction potentials of new RETs; (b) know-how of the actors involved (e.g. investors, planners, architects, bankers, installers); (c) risk perception, lack of experience; (d) legal framework conditions; (e) technology competition; and (f) resistance of existing market players. We discuss these aspects by choosing illustrative examples for selected RETs in EU Member Countries, which can help to better understand the problems, possible remedies, and chances incurred.

The remainder of the paper is organised as follows: we will first shed some light on the role of barriers and latent drivers for the diffusion of renewable energy technologies. Second, we introduce factors influencing the diffusion rate of innovations from the diffusion theory literature. Third, for the six aspects (a)-(f) mentioned above, we analyse the policy actions needed to induce regulatory and institutional innovations, giving particular attention to actor- and network-related policy instruments that can help to foster the diffusion of RETs, followed by the conclusions drawn from the analysis.

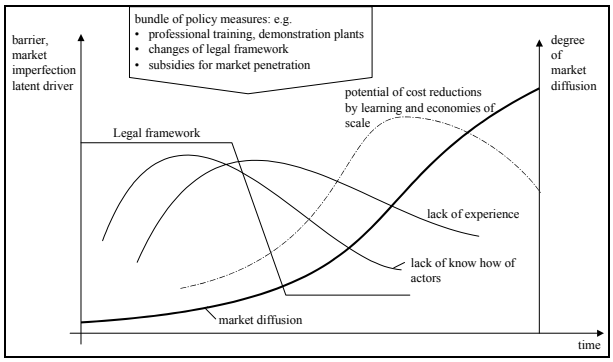
Barriers and latent drivers

The diffusion of RETs crucially depends on existing barriers and (latent) drivers. *Barriers* include market, network and institutional failures, such as

- lack of technological knowledge and market survey of relevant actors (e.g. installers, planners, architects, potential investors) and their professional associations;
- lack of financial flexibility of small businesses, newly founded companies, and home owners, as RETs are typically considerably more capital-intensive, compared to traditional energy conversion technologies;
- legal and administrative obstacles; such as regional construction ordinances, traditional decision making or distrust of officials of local or regional authorities against new technologies;
- price distortions (external costs of traditional heat and electricity generating systems not taken into account, such as environmental pollution along the energy chain, uncovered risks of major accidents etc.), or
- market power abuse of early entrants for the case of grid-based energies, such as large or local electricity, gas or district heat utilities, e.g. by offering very low feed-in tariffs or by asking for extremely high safety and measurement investments at the interconnection point, and/or high prices for remaining energy deliveries or maintenance power.

For a further discussion of barriers for the long-term integration of RETs in Europe see for example Hohmeyer et al. (1998: esp. Chapters 4 and 5). Most important here is the observation that several of the mentioned barriers exist simultaneously, forming a complex which may have to be alleviated by a bundle of synchronised parallel policy measures (see Figure 1 and 2). Figure 1 illustrates this aspect of timing as a crucial factor faced by policy-makers trying to reduce barriers, and to activate latent drivers for an accelerated market diffusion of renewable energy technologies.

Figure 1. Timing and intensity of barriers and of latent drivers as challenges for a policy to accelerate market diffusion of renewable energy technologies



Source: own illustration

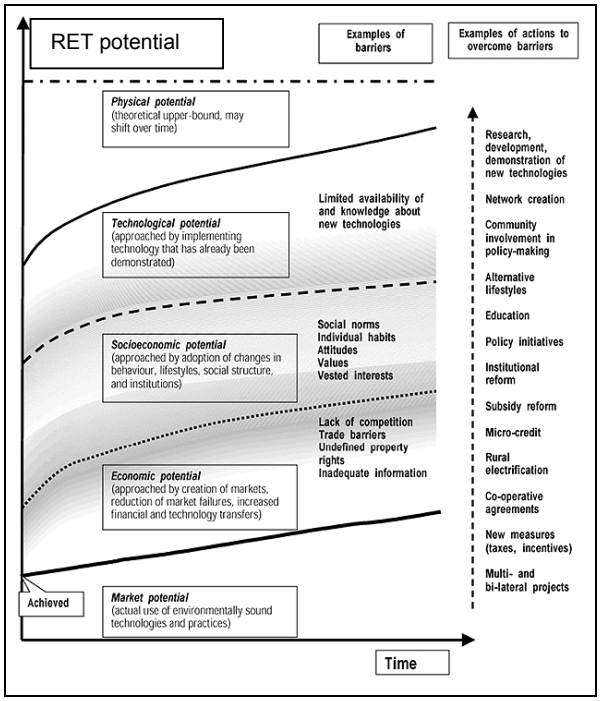
Figure 2, taken from the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC 2001) and adapted for RETs, provides some examples of barriers at the various RET potential levels, together with examples of measures to overcome these barriers. In our opinion, this kind of graphical representation can provide highly useful hints for interdisciplinary and systematic discussions on which and how certain barriers can hinder the exploitation of the various RET potentials over time and how they can be successfully tackled.

There has been much attention to barriers and market imperfections in the last two decades, representing a rather mechanistic concept of innovation and technology diffusion. So far, however, rather little attention has been dedicated to *latent drivers* being able to promote the diffusion of renewables (Jochem et al. 2000; Rennings 2000); such drivers may include the

- cost reduction potentials gained by learning effects and economies of scale and scope (both in equipment manufacturing and use),
- readiness of associations of technology suppliers, installers, contracting companies and energy users to undertake marketing, professional training and procurement programmes, possibly additionally supported by environmental groups or home savings banks, or the
- internalisation of the externalities of fossil fuel use, accepted maybe even voluntarily by some investors in the residential, business or public sector, creating a policy climate in administration and policy-making that allows to develop the accep-

tance of a gradual introduction of energy taxes, emission certificates, or specific regulations or boundary conditions for the diffusion of renewables in a liberalised energy market.

Figure 2. Barriers and different potential levels renewable energy utilization



Source: adapted from IPCC (2001), Fig. 5.1

Factors influencing the rate of diffusion of innovations

The term 'diffusion of innovation' refers to the process by which an innovation is communicated through certain channels over time among the members of a social system (see Rogers 1995: Ch.1; Dosi 1982). In diffusion theory, one may distinguish between the following factors that influence the rate of diffusion of innovations (Rogers 1995: Ch.6):

- Perceived attributes (relative advantage, compatibility, complexity, trialability, observability);
- Type of innovation decision (optional, collective, authoritative);
- Communication channel/s used;
- Nature of social system;
- Extent of change agents' efforts.

Given the large range of influencing factors, RET technologies, applications, and types of adopters, it is obvious that there is no such thing as a simple recipe for the successful promotion of RET diffusion. Besides, in the past especially change agents have often overemphasized adoption *per se*, neglecting possible undesirable consequences of innovation diffusions, which calls for a considerate, careful, and sufficiently foreward-looking approach.

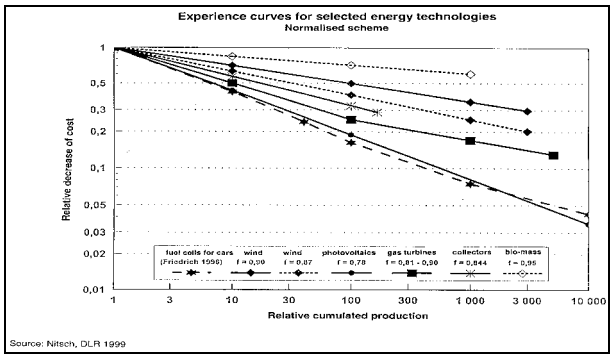
Regulatory and institutional innovations needed and policy actions recommended

In this section we discuss, for the six selected aspects mentioned earlier, problems and solutions in the context of RET diffusion, and the public policy action needed to foster regulatory and institutional innovation for the promotion of RETs.

(a) Cost reduction potentials of new RETs

Experience, e.g. gained from the wind power industry, has taught that a promising RET strategy seems to be the following (Haier 1998): Start with small production levels and relatively high R&D costs per unit produced. Second, increase conversion efficiencies, material efficiencies, and labour productivities. Third, scale up product capacities. Fourth, exploit cost degression potentials by economies of scale (automated production) and scope (system integration), which can be expected to be significant (see Figure 3).

Figure 3. Experience curves for selected energy technologies



Source: Nitsch (1999)

☞ Feed-in laws for electricity fed into the grid, like in Germany, Spain and France, demonstrate the necessity that policy-makers establish stable boundary conditions for the creation of an investor-friendly climate in the market for new renewable energy technologies and services, so that the cost reduction potentials can actually be successfully exploited.

(b) Know-how of actors

New technologies and the related know-how have to be absorbed by all relevant actors involved:

- new groups of investors (e.g. home-owners, farmers, new SMEs) need information and education;
- change agents (e.g. traditional planners, architects) need professional training and education;
- traditional installers need to know how to integrate new systems and how to deal with the new professional environment (work on roofs, at farms, etc.);
- new and traditional finance bodies (e.g. development companies, venture capital financiers, contractors) are in need for technical consulting services.

Depending on the stage of the adoption process and the type of potential adopter(s) involved, *word-of-mouth information* (close to the decision) or *mass*

communication channels (first information, raising awareness) are more appropriate (see Rogers 1995) for a successful diffusion of innovations.

☞ Therefore, policy-makers should carefully think about the most appropriate communication channels, and put their emphasis on group-specific information, professional training, changes in education, and technical consulting for finance market actors (e.g. banks). An interesting example for a successful training project in sustainable energy technologies provides the VOCATIONES project within the Leonardo da Vinci programme of the European Union undertaken in Romania (Fara et al. 2002).

(c) Risk perception, lack of experience

Many RETs are linked to some kind of supply- and/or demand-side disadvantage of intermittent production. Modern control technologies and intelligent system combinations can alleviate this problem, but back-up capacities for electricity and/or heat supply in times of low production output may still be required.

Another risk factor is the often to a large extent still unknown performance of the technology involved, e.g.

- operational performance under unfavourable conditions; (e.g. off shore wind turbine parks);
- health and safety aspects (e.g. occupational accidents);
- uncertainty about market size and price developments, often aggravated through unstable boundary conditions of energy policies;
- unknown costs of maintenance;
- risks from starting too big / neglect of scaling up (e.g. the German 3 MW wind turbine GROWIAN failed mainly because some components still had severe weaknesses, while at the same time smaller Danish wind turbines had already proven their reliability in practical use; Gipe 1995; Heymann 1996; Johnson & Jacobsson 2001).

Finally, also the risk perception both of the public and of funding institutions are crucial (Johns & Bouillé 2002; Wohlgemuth & Madlener 2000).

☞ Policy-makers should therefore take into account that renewable energy policies may have a strong influence on the risk premiums asked for by investors, creating repercussions on the financing structure of renewables projects. A much better understanding on how policy design may affect project development and financing processes is needed, and financial assistance programmes for the promotion of RETs need to be predictable and stable over some time in order to support the attraction and confidence of investors and intermediaries in the new market.

(d) Legal framework conditions

Adequate legal framework conditions are an important prerequisite for a successful penetration of new RETs (e.g. building codes, planning procedures, financial support schemes, fair grid access, break-up of technological "lock-in" situations by allowing for the formation of niche markets).

Sometimes, especially in the course of market liberalisation, adaptations to the legal framework have been lagging behind in order to conserve existing structures as long as possible (such as in France in the case of the electricity market opening), or they bear more inertia for a transparent and fair grid use pricing than others (an example is the negotiated third-party-access regulation in Germany, as compared to the regulated TPA in all other EU member countries).

A second important aspect is the credibility and continuity of renewable energy promotion targets. The European White Paper COM(97)599 (CEC 1997), the Campaign for Action (CEC 1999), the Directive for the promotion of renewables (CEC 2001), and other important documents at the European level have been able to send consistent and strong signals in this direction.

Similarly, the Renewable Energy Act in Germany (EEG 2000), despite its turbulent birth, has maintained an active and rather stable market environment, and currently serves as a model for many other European countries. In contrast, renewable energy promotion in Austria has been very heterogeneous across the nine federal provinces, and has been subject to frequent and not always predictable adaptations in recent years, and is only currently in the process of being streamlined in a Renewable Energy Act (Ökostromgesetz 2002).

Finally, changes in governments, such as recently experienced in Denmark, can lead to sudden changes in policy; such changes are less likely if policies are based on parliamentary (and ideally unanimous) consent among the political parties and/or enshrined in laws.

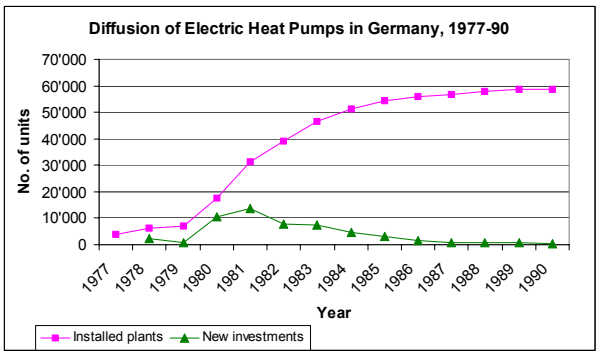
☞ Hence policy-makers should make better use of the virtues of credible policy announcements that improve the investment climate and overall RET market attraction ("announcement effect").

(e) Technology competition with traditional technologies and partially among other new RETs

New RETs may pose a challenge and a threat to traditional technologies that can lead to significant (and often unanticipated) further improvements of the latter. An example provides the diffusion of electric heat pumps in Germany in the early 1980s, which induced technical progress in burners, condensing boilers, control techniques, and insulation of boilers, which in turn significantly slowed down the penetration of heat pumps throughout the 1980s and early 1990s (see Figure 4).

In two seminal articles, Arthur (1989) and David (1986) have shown that technologies being less efficient than others may nonetheless become "locked-in" over time, mainly because of increasing returns that accrue from positive network externalities. Ways to escape such lock-in situations, which currently constitute a major barrier for new RETs, include crises in an existing technology (e.g. nuclear accidents), re-regulation, radical innovation changes in lifestyle and taste, and the emergence of niche markets (e.g. Cowan & Hultén 1996; Islas 1997; Menanteau 2000; Unruh 2000, 2002).

Figure 4. Diffusion of electric heat pumps in Germany, 1977-1990



Source: FhG-ISI

In this context it is worth mentioning that the escape out of a technological lock-in situation does not necessarily imply the creation of another lock-in, as it may also lead to an increase in diversity due to a further segmentation of the range of product/technology applications. The simultaneous spread of condensing boilers, heat pumps and solar thermal collector systems in many European countries in this decade may illustrate this increased diversity. In order to ameliorate technological lock-in, it is important to continuously eliminate existing market entry barriers. Quota-based tradable green certificate (TGC) schemes, for example, aim to achieve dynamic efficiency by fostering the market entry of new players.

☞ Consequently, in order not to grossly overestimate RET potentials, it is important that both policy-makers and market players calculate the market and innovation potentials for RETs also on the basis of the remaining potentials of the traditional and of the potentials of other competing RET technologies. Moreover, lock-in situations should be avoided by creating an open market environment.

(f) Resistance of existing market players and formation of new players

• *Actors*

The transition to a different energy supply system with a new technology mix requires the existence of strong actors, or groups of actors, who push innovative energy technologies forward and help to change regulations and institutions (Edquist 1997). *Prime movers*, such as multinational enterprises or networks of smaller actors, are key actors. In contrast to small single or non-organised actors, they have the potency to raise large-scale funding, to invest substantially (e.g. in R&D and marketing), to raise public and political awareness, and to diffuse new technologies (Johnson & Jacobsson 2000: 636) to a critical mass level where their further penetration becomes self-propelled (in the innovation diffusion literature a market penetration of between 10-25% of the saturation level is often considered sufficient; cf. Rogers 1995: Ch.8).

Installers, planners, architects and other important actors may not recommend systems they are not very familiar with. A good example is the diffusion of solar thermal heating systems in Austria, which was launched by DIY groups and only later adopted by commercial actors (Ornetzeder 2001). Similarly, modern and often automated small-scale biomass heating systems suffered from the fact that installers preferred to install oil- and natural-gas-fired heating systems with which they were much more acquainted, and from unjustified image problems (e.g. regarding operating comfort, reliability, greenhouse gas and pollutant emission levels).

Another group of actors that has seen the diffusion of RETs mainly as a threat are transmission and grid operators (Isoard & Soria 2001: 631). They have often tried to hinder the feed-in of electricity from (renewable and non-renewable) distributed generation plants by charging excessive grid-use tariffs or by asking for expensive safety and measurement investments.

• *Networks of actors and institutions*

Existing energy market players often have strong and long-established associations that resist change. In some countries, such as Germany, industrial associations continue to play an important political role (e.g. in the set-up of the agreement of negotiated access of small generators and related grid-use tariffs).

Likewise, it is important for renewable energy actors to form associations (e.g. many national wind power associations are very powerful and influencial in lobbying). However, associations for different renewable energy technologies do not always manage to effectively co-operate against competing non-renewable energy technologies, and tend to only lobby for their own technology (instead of simultaneously lobbying for complementary RETs and efficient energy use as well in order to achieve a greater overall impact on the transition of the energy system towards more sustainability).

☞ Consequently, the requested structures for a successful and actor- and network-related promotion policy for the diffusion of new RETs comprise

- political support by members of parliament, administration, and others (e.g. for setting appropriate boundary conditions in the liberalised energy markets);
- powerful associations that are initiated and subsequently supported either by proponents (such as EUROSOLAR) or technology producers and/or adopters (e.g. German Association Biogas, German Federal Association of Wind Power, European Renewable Energies Federation – Eref, among many others);
- legitimisation and support by consumer associations (information, consulting, joint procurement initiatives);
- promotion of R&D networks (e.g. by means of EC research funding) and competence centres (e.g. RENET-Austria in Guessing for energy from biomass; European Joint Study Centres);
- professional training of supply-side actors, such as planners, architects, installers, bankers (e.g. by involving them in the set-up and running of pilot and/or demonstration plants);

- education of the demand-side actors (potential adopters), and more generally the public.

Conclusions

In this paper we have studied regulatory and institutional innovations that help to foster the diffusion of renewable energy technologies.

The transition to an energy system that is more reliant on renewable energy sources implies a higher diversity of supply. It rests upon the simultaneous dismantling of barriers and activation of latent drivers, and in particular the existence of powerful actors, the establishing of institutions and well-designed networks, and the build-up of competence.

Finally, the analysis has shown that the long-term transition to sustainable energy systems needs a holistic policy strategy, i.e.

- the simultaneous activation of latent drivers and a reduction/elimination of existing barriers;
- adequate boundary conditions in liberalised markets, clear and continuous signals of prices and objectives (e.g. cost reductions);
- clear information about cost and emission reduction potentials of traditional technical alternatives;
- well-informed and well-educated investors, planners, installers, maintenance staff etc.
- strong associations of technology producers and users for quick collection and exchange of experience, quality control, information and professional training, marketing and lobbying (build-up of competence).

References

Arthur, W.B. (1989), Competing technologies: Increasing returns and lock-in by historical events, *Economic Journal*, 99(1), 116-131.

CEC (1997), Energy for the Future: Renewable Sources of Energy. White Paper for a Community Strategy and Action Plan, COM(97)599 final as of 26 November 1997, Brussels: Commission of the European Communities.

CEC(1999), Energy for the Future: Renewable Energy Sources, Campaign for Take-Off, DGXVII, Commission Services Paper SEC(1999) 504, Brussels, 9 April 1999.

CEC (2001), Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market, OJ L 283/33, 27 October 2001, Brussels: Commission of the European Communities.

Cowan, R.; Hultén, S. (1996), Escaping Lock-In: The Case of the Electric Vehicle, *Technological Forecasting and Social Change*, 53: 61-79.

David, P.A. (1986), Clio and the Economics of QUERTY, *American Economic Review*, 75(2): 332-227.

Dosi, G. (1982), Technological paradigms and technological trajectories. A suggested interpretation of the determinants and directions of technical change, *Research Policy*, 11: 147-162.

Edquist, C. (1997), *Systems of Innovation: Technologies, Institutions and Organizations*. London: Pinter.

EEG (2000), Gesetz für den Vorrang Erneuerbarer Energien (Erneuerbare-Energien-Gesetz – EEG), Bundesgesetzbaltt Jg. 2000 Teil I Nr. 13, Bonn, 31 March 2000.

Espey, S. (2001), Renewables portfolio standard: a means for trade with electricity from renewable energy sources?, *Energy Policy*, 29(7), 557-566.

Fara, L.; C. Gutierrez; S. Fara (2002), Leonardo da Vinci Project Results Concerning Training in Sustainable Energy Technologies, *Proceedings of the World Renewable Energy Conference VII*, Cologne, 29 June – 5 July 2002.

Fuchs, D.A.; Arentsen, M.J. (2002), Green electricity in the market place, *Energy Policy*, 30(6): 525-538.

Gipe, P. (1995), *Wind energy comes of age*, John Wiley & Sons, New York.

Haier, S. (1998), Grid-Integration of Energy Conversion Systems, New York: John Wiley.

Heymann, M. (1996), Lost hopes and opportunities. The history of the use of wind power 1890-1990 (in German) Munich: Deutsches Museum.

Hohmeyer, O.; Bräuer, W.; Groscurth, H.-M. (1998), Bottlenecks and Obstacles – Success Stories and Measures, in: The LTI-Research Group (ed.), *Long-Term Integration of Renewable Energy Sources into the European Energy System*, Heidelberg/New York: Physica-Verlag.

IPCC (2001), Climate Change 2001: Mitigation. In: B. Metz, O. Davidson, R. Swart and J. Pan (eds.), Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge/UK: Cambridge University Press.

Islas, J. (1997), Getting round the lock-in in electricity generating systems: the example of the gas turbine, *Research Policy*, 26(1): 49-66.

Isoard, S.; Soria, A. (2001), Technical change dynamics: evidence from emerging renewable energy technologies, *Energy Economics*, 23(6): 619-636.

Johnson, A.; Jacobsson, S. (2000), The diffusion of renewable energy technology: an analytical framework and key issues for research, *Energy Policy*, 28(9): 625-640.

Jochem, E., Madlener, R., Mannsbart, W. (2002), Renewable Energy Technology Diffusion: Prospects of the German and Swiss Industry in the World Markets, *Proceedings of the World Renewable Energy Congress VII*, Cologne, 29 June – 5 July 2002.

Jochem, E. Sathaye, J. Bonille, D., eds (2000), Society, Behaviour, and climate change Mitigation, Dordrecht/ Boston: Kluwer Academic Publishers.

Johns, J.; Bouillé, A. (2002). The Role of Private Equity in the New Renewable Energy Technology Sector, *Proceedings of the World Renewable Energy Conference VII*, Cologne, 29 June – 5 July 2002, Amsterdam/New York: Pergamon Press.

Johnson, A.; Jacobsson, S. (2001), The Emergence of a Growth Industry: A Comparative Analysis of the German, Dutch and Swedish Wind Turbine Industries. Forthcoming in: Metcalfe, S. and Cantner, U. (eds): Transformation and Development: Schumpeterian Perspectives (provisional title), Heidelberg: Physica/Springer.

Kaltschmitt, M.; Merten, D.; Falkenberg, D. (2002), Regenerative Energien (in German), *BWK*, 54(4): 66-74.

Loiter, J.M.; Norberg-Bohm, V. (1999), Technology policy and renewable energy: public roles in the development of new energy technologies, *Energy Policy*, 27(2): 85-97.

Madlener, R.; Drillisch, J. (2002), Tradable Certificate Schemes for Single Renewable Electricity Technologies: The Case of Small-Scale Hydro Power Promotion in Austria, Proceedings of the 25th Annual IAEE International Conference "Innovation and Maturity in Energy Markets: Experience and Prospects", Aberdeen, 26-29 June 2002.

Menanteau, P. (2000), Learning from Variety and Competition Between Technological Options for Generating Photovoltaic Electricity, *Technological Forecasting and Social Change*, 63(1): 63-80.

Menanteau, P.; Finon, D.; Lamy, M.-L. (2001), Prices versus quantities: Environmental policies for promoting the development of renewable energy, Cahier de Recherche No. 25, Institut d'Economie et de Politique de l'Energie (IEPE), Grenoble, May.

Morthorst, P.E. (2000), The development of a green certificate market, *Energy Policy*, 28(15), 1085-1094.

Neij, L. (1997), Use of experience curves to analyse the prospects for diffusion and adoption of renewable energy technology, *Energy Policy*, 23(13): 1099-1107.

Nitsch, J. (1999), personal communication.

Ornetzeder, M. (2001), Old Technology and Social Innovations. Inside the Austrian Success Story on Solar Water Heaters, *Technology Analysis & Strategic Management*, 13(1): 105-115.

Ökostromgesetz (2002), Austrian Renewable Electricity Act, Vienna (forthcoming).

Painuly, J.P. (2001), Barriers to renewable energy penetration: a framework for analysis, *Renewable Energy*, 24(1): 73-89.

Rennings, K. (2000), Redefining innovation – eco-innovation research and the contribution from ecological economics, *Ecological Economics*, 32(2): 319-332.

Rogers, E. M. (1995), *Diffusion of Innovations*, 4th Ed., New York: The Free Press.

Roos, A.; Graham, R.L.; Hektor, B.; Rakos, C. (1999), Critical factors to bioenergy implementation, *Biomass and Bioenergy*, 17(2): 113-126.

Unruh, G.C. (2000), Understanding carbon lock-in, *Energy Policy*, 28(12): 817-830.

Unruh, G.C. (2002), Escaping carbon lock-in, *Energy Policy*, 30(4): 317-325.

UNDP/UNDESA/WEC (2000), *World Energy Assessment. Energy and the Challenge of Sustainability*. New York: United Nations Development Programme / United Nations Department of Economic and Social Affairs / World Energy Council.

Wohlgemuth, N.; Madlener, R. (2000), Financial Support of Renewable Energy Systems: Investment vs. Operating Cost Subsidies, *Proceedings of the NAEE Conference "Towards an Integrated European Energy Market"*, Bergen/Norway, 31 Aug - 2 Sep 2000.