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The Acceleration of Innovation in Climate Policy

Lessons from Best Practice

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In der Schriftenreihe FFU-Report werden seit 1993 Diskussionspapiere aus dem Forschungsprogramm des FFU veröffentlicht. Ergebnisse sollen so frühzeitig einer interessierten Öffentlichkeit zugänglich gemacht werden. Die Reports durchlaufen einen internen fachlichen Review-Prozess. Die vertretenen Positionen liegen in der Verantwortung der Autoren und spiegeln nicht notwendigerweise die Position des gesamten FFU wider.

Summary

This paper describes eight selected "best practice" cases of the acceleration of technical progress in climate policy. These are cases in which the diffusion of low-carbon technologies has been accelerated by policies, involving not just renewable energies, but also energy efficiency policies (the latter being considered more difficult). The author's objective is to describe the phenomenon and its variants, as well as offering a theoretical interpretation, which focuses on the interplay of three feedback mechanisms subject to demanding targets. Conclusions are then drawn from these sections for an ambitious climate policy that addresses both the acceleration in climate change and the competition for low-carbon technologies in industrial policies.

Contents

1 Introduction

Climate policy is currently shaped at two levels: international policy level and the level of industrial policy and innovation competition for climate-friendly technologies. The highly dynamic competition on the global markets for low-carbon products, processes and services stands in stark contrast to the considerable difficulties at the policy level. The worldwide volume of what we could term the "climate protection industry" has now been estimated at € 3.5 billion (Innovas 2010). Climate-friendly technologies are experiencing unusually dynamic growth and competition for such technologies in industrial policy has not only spread to developed industrial countries, but also emerging markets such as China and India. Competition for leading positions in the global market for these future technologies is currently the most powerful driving force of climate protection. More than that: in some countries, this driving force is causing unexpected acceleration. This means we are not just experiencing the feared acceleration of climate change with all the risks that such change entails. There are also examples of the acceleration of technical conversion to low-carbon technologies being forced at a policy level. In terms of climate policy, this could mean that pioneering countries will first enforce this conversion systematically, then force such conversion on competitors and finally contribute themselves as trendsetters to the rapid global diffusion of climate-friendly technologies and policies (Jänicke 2008, 2010).

In this context, this paper will present eight empirical successful cases in which there has been **acceleration in the speed of diffusion** of climate-friendly technologies. The basic theory of this dynamic will first be discussed in terms of relevant literature, in order to provide an explanatory basis for the approach put forward in this paper. The policy-induced market dynamic obviously has repercussions for the innovation process. However, the dynamics of the feedback mechanisms are much more complex. This will be made clear in an explanatory model for multiple feedback processes. Finally, this paper will address the question of how this dynamic process can be configured within the framework of an effective innovation strategy for climate protection.

Let us first consider some examples of the acceleration of diffusion in the climate sector.

2 Selected examples of the acceleration of technical progress in climate-friendly technologies

The examples of the acceleration of technical progress in climate-friendly technologies presented in this paper are cases in which the measures of an ambitious climate policy have successfully forced the diffusion of a certain low-carbon technology (or group of technologies), thereby triggering an innovation dynamic that makes it possible to make already ambitious climate targets even stricter (see Table 1). The examples were selected from best practice. This is based primarily on acceleration: a diffusion speed for the relevant technology (group) above and beyond the set target, although it also implicitly includes the associated effect on climate protection and the advantages associated with market growth.

Both unfavourable developments and limiting factors are therefore methodically disregarded. An evaluation of the efficiency of the instruments themselves, e.g. the enforced solar power subsidies in Germany and Spain (see Frondel and Ritter 2010), is also not part of this study. Methodical restriction to best practice naturally also excludes cases of political "deceleration" (examples of this being the withdrawal of the photovoltaic subsidies introduced in Japan after the 1973 oil crisis or the ending of wind power subsidies in Denmark after the change in government in 2001, although these successful ideas were resumed after a few years in both cases).

The examples are intended to reflect the range of variations in the presented phenomenon. They do not just involve renewable energies, of which there are now numerous examples of successful promotion. Focus is also placed on increases in energy efficiency that have been forced by policy and often viewed as the difficult part of climate policy. The examples come from highly developed industrial countries such as Germany, Great Britain or Japan, as well as emerging markets such as China and India.

Table 1: Examples of innovation dynamics induced by climate policy

Case study	Country	Market effects	Innovation effects	Political repercussions
Renewable energies	Germany	Rapid diffusion, export success	Secondary innovations (costs, effect-tiveness)	Targets made much more strict
Renewable energies (wind, solar)	Spain	Rapid diffusion, export success	Secondary innovations	Announcement that targets will be exceeded
Wind power	China	Very rapid diffusion, export success	Secondary innovations	Targets made much more strict
Photovoltaic	India	Increased diffusion	Major R&D subsidies	Option of making targets more strict
Building energy efficiency	Germany	Increased diffusion	Major innovations	Acceleration in making targets more strict
Energy efficiency policy	Great Britain	Increased diffusion	Promotion of innovation	Targets made more strict (climate target)
Energy efficiency policy	Ireland	Increased diffusion	Promotion of innovation	More extensive programme
Product energy efficiency (Top Runner)	Japan	Very rapid diffusion, export	Major secondary innovations	Further increase in standards

2.1 The promotion of renewable energies

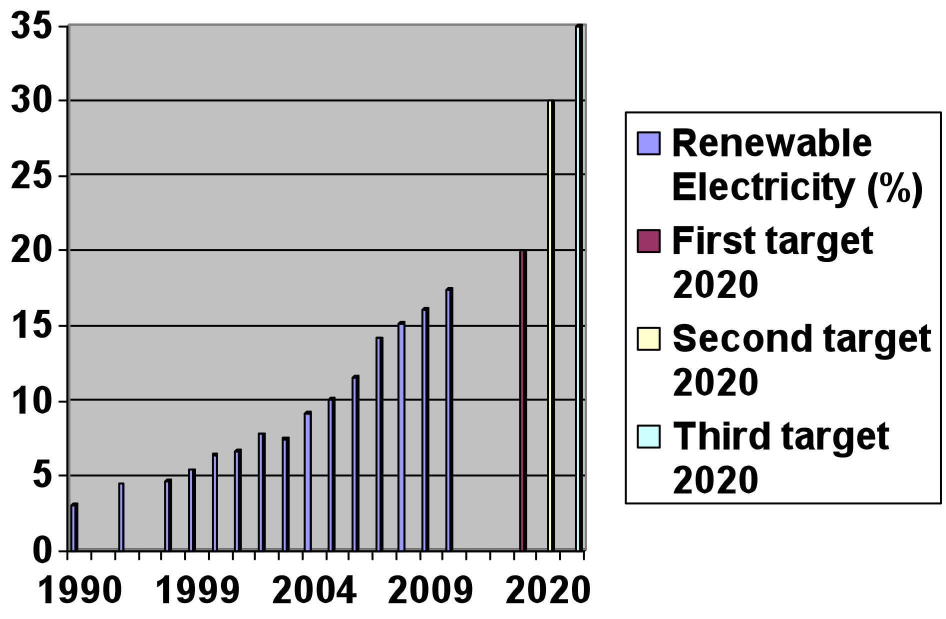
2.1.1 Germany

Next to Great Britain and Denmark, Germany has the strictest climate targets in the EU (if you exclude Luxembourg on the grounds of its cross-border energy dependencies). It has therefore proven to be a major player in this political sector.

This climate policy had several features in its favour. It arose as a subject that reached across all the parties, in which the opposing environmental protection interests and the interests of those in favour of nuclear power converged (Jänicke 2010). The second positive initial feature was that the collapse of the East German heavy industry after reunification led to reductions in CO_2. Thirdly, a feed-in tariff for electricity from renewable energies was introduced early on in 1991, representing a valuable source of information and experience. Another feature was the innovative approach of German climate policy, given further emphasis as "ecological modernisation" in the coalition agreements of the red/green Federal Government in 1998 and 2002.

The unexpected acceleration of the speed of diffusion of renewable energies (and building energy efficiency) was the consequence of extensive measures introduced by the new Federal Government in 1998, a coalition of Social Democrats and the Green Party. There was a significant increase in the existing feed-in tariffs for renewable energies. As a result, the Kyoto target of reducing greenhouse gases by 21% by 2012 was exceeded by 2007 and this surprise effect also made its mark in renewable energies (Figure 1).

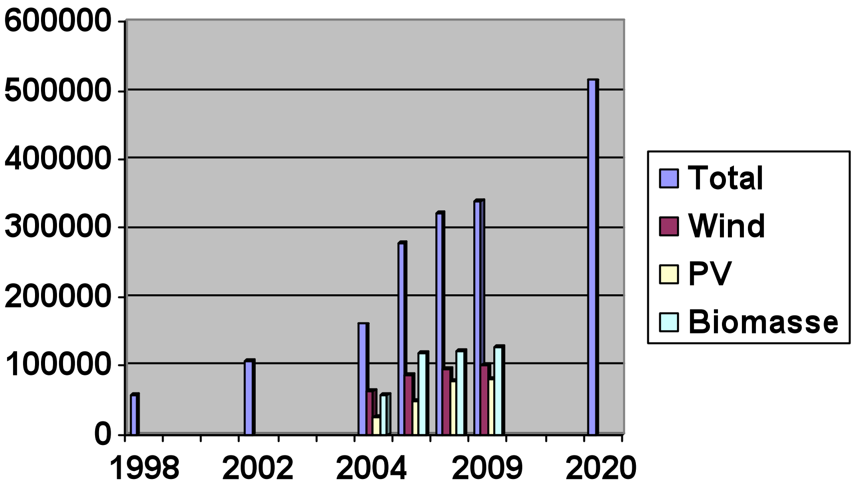
Figure 1: Share of renewable electricity in Germany 1998-2010 and targets for 2020



(Data: Statistisches Bundesamt 2010)

In 2000, the Federal Government was still focusing on the target of increasing the proportion of electricity generated by renewable energies by at least 20% by 2020. The growth effect triggered by this policy made it possible to raise the target in 2009 to at least 30%. A higher target of 35% was specified in the Federal Government energy concept in September 2010 (BMWi and BMU 2010). A figure of 38.6% is officially expected in the 2010 national action plan for renewable energies (Federal Government 2010). The sector itself is predicting 47% for the same year (Renewable Energies Agency 2010). The main reason for this new approach was the particular dynamism in the innovation process, indicated (for example) by the fact that the forced promotion of the new energies after 1998 triggered a sharp increase in new patents in this area. The effectiveness of solar and wind power has been constantly increasing. There have been major reductions in production costs. In 2009, this leading industry on the world market created / secured 340,000 jobs (Figure 2).

Figure 2: Employment in the renewable energy sector 1998-2009 and forecast 2020



(Data: BMU 2010)

2.1.2 Spain

Spain has rapidly become a global player with high growth in renewable energies – particularly wind power and photovoltaics. The dominant instrument of this growth was also an attractive feed-in tariff (Bechberger 2009). Despite a reduction in the feed-in tariff, the set target for solar electricity was reached ahead of schedule in 2007 and far exceeded in the following year. The Spanish government has raised its 20% target for the proportion of power generated by renewable energies in 2020 to an official expectation of 22.7%. The ambitious Spanish EU target of achieving a 40% target for the proportion of electricity generated by renewable energies in 2020 is also likely to be exceeded, according to official forecasts (ENDS Europe 19.4.2010). Around 200,000 jobs have been created in the sector (Bechberger 2009). In April 2010, the Spanish power company Iberdrola announced that it would be building one of the world's largest wind parks in Romania, generating 1,500 MW.

This development of renewable energies in Spain is particularly noteworthy, as it is in stark contrast to its failure in other areas of climate policy: the proportion of greenhouse gases has risen by 52.5% between 1990 and 2007. This means the relatively easy Kyoto target (+ 15%) has been missed by quite some way. Perhaps the most obvious explanation is that, in contrast to Germany, the electricity industry invested early in renewable energies and has since experienced international success on this market (Bechberger 2009). Experience has shown that such a strong player has little interest in energy efficiency as part of end consumption and often opposes measures against such efficiency. Furthermore, the relatively easy Kyoto target was hardly an incentive to make an effort in this area. The low significance of climate policy as a driving force is an indication of the independent *economic* significance of renewable energies in this country.

2.1.3 China

One might think that this dynamism was only possible in highly developed industrial countries, but China as an emerging market also offers some striking examples. The development target for solar power for 2020 has been increased five times. In the wind power sector, China may have started out with European technology, but is now becoming increasingly independent. Setting ambitious development targets, the country has triggered a dynamic in wind power that has almost overwhelmed it. This is perhaps best expressed in this sequence of targets set for 2020 (China's Clean Revolution 2008; REN21 2009; Pellman 2010, and other sources):

- 20 GW was the target in 2004
- 30 GW was planned as the target in the long-term programme for renewable energies in 2007
- 100 GW was formulated as the new target shortly afterwards
- 150 GW was set as the "unofficial" target in 2010.

The unexpected development dynamic has therefore led to constantly higher targets for 2020. In 2009, China built wind power plants with a capacity of 25 GW, expanded this year by 13 GW (CleanEdge 2010). This high growth led to discussions about a more far-reaching development target of 150 GW for the same date. According to the Chinese Renewable Energy Industries Association, it may be possible to exceed even this target (Global Wind Energy Council 3. 2. 2009). However, given annual growth rates of over 100%, it is unsurprising that the Chinese government is aiming to limit this extensive growth.

There are now around 70 Chinese manufacturers achieving some success on the global market (REN21 10-2009). China's significant research and development efforts are supporting the secondary innovation process and economies of scale when it comes to renewable energies (similar technological success is also being achieved in the further development of flue gas desulphurisation technology in China).

2.1.4 India

After the EU, USA and China, India has installed the most wind power plants. The largest manufacturer, Suzlon, has a world market share of 6% (2009). Since 2009, the country has also been pursuing an ambitious solar strategy with a dynamic approach that is worthy of note here. Experiences had been gathered earlier with a programme promoting electricity generated from renewable energies in locations with no power connections (Remote Villages Electrification Program). This brought electricity to thousands of small towns. It was also supported by Indian solar power providers. The government is attempting to combat technological deficiencies by promoting research and development. India established a special Ministry of New and Renewable Energy at an early stage. After the government raised its target for the development of renewable energies in general, it announced an ambitious programme at the end of 2009, aimed at generating at least 20 GW of domestic solar power for 2022. Amongst other things, 20 million solar lighting systems are to be installed in rural regions in the target year of 2022. The tools for this programme are a mixture of binding feed-in tariff regulations and subsidies. The Indian "Solar Mission" is part of a climate policy package that also includes energy savings of 19,000 MW (almost 100 Mt. CO_2), which will be made via tradeable "Energy Saving Certificates" amongst other initiatives (Ministry of Power 2009).

What makes the Indian photovoltaic plans passed by the Cabinet so interesting is not just the systematic development of the country's own industry, which is intended to make India a "global leader in solar energy" (Government of India 2009). For the first time, plans will include possible acceleration through positive learning effects: "The ambitious target for 2022 of 20,000 MW or more will be dependent on the 'learning' of the first two phases". The government will be focusing on competitive costs, innovations and the development of production capacities. "(A)fter taking into account the experience of the initial years, capacity will be aggressively ramped up to create conditions for up scaled and competitive solar energy" (Government of India 2009).

2.2 Energy efficiency policy

Are the successful renewable energies on which innovation research has been based so far a lucky special case in climate policy that is not representative of the situation as a whole? Isn't the promotion of energy efficiency, which is progressing much slower in the EU (for example), more difficult in principle? Isn't “green growth" much easier to achieve than the corresponding reductions required? Perhaps so, but nevertheless, without wishing to deny the varying levels of difficulty faced in environmental policies, there are still areas of common ground: the examples of energy efficiency policies below indicate that the positive feedback mechanisms of an ambitious climate policy can also apply here. The common denominator is a climate strategy based on technology that establishes and develops markets for energy-efficient innovative products. These products range from economical electrical equipment to building technology to contracting.

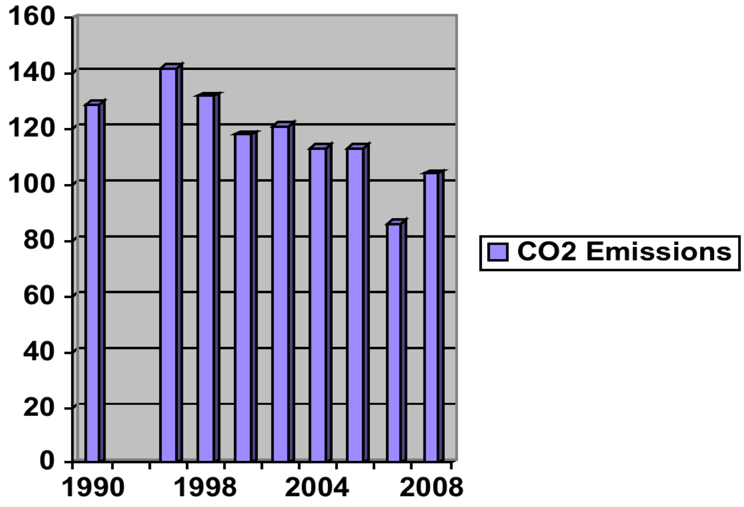
2.2.1 Germany

In Germany, energy saving and CO_2 reduction in *buildings* is an example of the acceleration of the diffusion process linked to environmental policy and technology. This is evident in the change in public discourse, amongst other things. While conversation focused on partial reduction of energy consumption in 1998, discussions 10 years later turned to the political promotion of positive energy houses – i.e. buildings that could contribute to power generation themselves. At the end of this dynamic learning process, the President of the main association of the German construction industry said in March 2008 that the construction sector played a "key role in climate protection" (press release 12-08 by the association).

Standards for energy consumption in new builds began to be made stricter in 1984 and this was continued in 1995, but it was in 2002 that the pace of this tightening of regulations really picked up speed. A further reduction in consumption was agreed in 2007 and 2009, accompanied by the announcement of further tightening of regulations in 2012. This standard would correspond to a saving of more than 80% in comparison to 1984. In terms of climate policy, there have also been important additional measures that affect existing buildings, particularly the eco-tax passed in 1999.There have also been subsidy measures for energy-based building renovations. For example, € 6 billion in subsidies were invested in the CO_2 building renovation programme between 2006 and 2009. According to the Ministry of Construction, this triggered investments of € 30 billion and secured or created 290,000 jobs (BMVBS 2010). Overall, climate-friendly investments in the building sector made up a tenth of all investments in Germany in 2005, reaching € 40 billion. Based on the additional climate protction measures of the "Meseberg Programme", this sum was revised as an estimate of € 54 billion (BMU and UBA 2009). Growth in this area affects a wide range of products, from insulation materials to heating systems. The number of heat pumps in production alone rose sixfold between 2003 and 2008 (BWP 2009).

The change is evident (amongst other things) from its effects on CO_2 emissions, which had been rising before. Between 1996 and 2008, they fell by around 40 Mt. (Figure 3). This partial success in climate policy corresponded to the aforementioned economic success. However, it only came to public attention in the context of the climate change warnings issued by the IPCC (2007). The decision to make minimum energy requirements stricter for new builds was taken in the same year.

Figure 3: CO_2 emission of households in Germany 1990-2008



(Data: BMU 2010)

The 2010 energy concept put forward by the Federal Government now intends to further tighten the regulations: by 2020, all *new* builds are to be "climate-neutral". By 2050, "all buildings should be almost entirely climate-neutral". The renewal rate should rise from 1% to 2%. By 2020, heating requirements should drop by 20%. The aforementioned building renovation programme is to be continued accordingly (BMWi and BMU 2010). However, for the moment subsidies have been reduced for house renovations, due to budget restrictions.

2.2.2 Great Britain

The acceleration of technical conversion to climate-friendly energy technologies has also been forced at a policy level in other EU countries. Great Britain, the second European leader in climate policy, has a climate policy advantage similar to Germany – the generation of electricity from coal was phased out early on for political reasons by former Prime Minister Margaret Thatcher. This took a little of the shock value away from ambitious climate targets. Since then, the country has far exceeded its relatively high Kyoto target for the reduction of greenhouse gases (minus 12.5% by 2012). A reduction of over 20% is expected for 2010.

Great Britain was the first industrial country to set a legally binding reduction target of "at least 26%" for 2020 (80% for 2050) in the 2008 Climate Change Act. In May 2009, the target was increased to 34%. In January 2010, the Environmental Audit Committee of the House of Commons recommended an even stricter climate target "beyond the commitments we have already made". Instead of the previous target of reducing greenhouse gases by 34% by 2020, the Government is to aim for a 42% reduction (House of Commons 2010).

In addition to the increased use of gas, British success has mainly been achieved in energy efficiency. Great Britain's aim was to improve energy efficiency by 9% by 2016. A figure of 18% is now expected. All new builds are expected to be "zero-carbon" in Great Britain by the same year (Ecofys et al. 2006; OECD 2009). The measures implemented include the successful Energy Efficiency Commitment, which requires the energy industry to implement measures to encourage private customers to save energy. More than half the savings have come from heat insulation measures. Another effect of this policy was the rapid market success of economical electrical equipment.

The British successes in increasing energy efficiency are of interest here, as they stand in stark contrast to the development of renewable energies, which was only addressed as a more significant topic in 2010.

2.2.3 Ireland

Ireland is also a remarkable example of an accelerating climate policy: in addition to the target of a 40% proportion of "green" electricity for 2020, it has also set an ambitious target of 20% energy savings by 2020. Ireland has managed to become the country with the most extensive energy savings in the OECD. Energy intensity has been reduced annually by 3.4% between 1990 and 2007, far above the OECD average of 1.5% (OECD 2009: 77). The energy strategy has helped efficient technologies become a success on the market, particularly in the industrial and buildings sectors. The "Sustainable Energy Authority of Ireland" (SEAI), founded in 2002, has played a major role. According to government estimates, Ireland's efficiency target for 2016 within the EU framework will be significantly exceeded, as in Great Britain. The 2007 energy action plan, which has already proved successful, was made even stricter in 2009. This was linked in part to the participation of a green party in the government. The SEAI "Strategic Plan 2010-2015" is an interesting example of enforced modernisation in the whole energy sector on the basis of successes in the energy efficiency sub-sector. The energy efficiency policy is to be continued – including the involvement of the energy sector and "energy service companies" – and should save € 25 billion in the buildings sector alone.

The 25-year vision of an entirely "green" electricity supply and electricity exporting on this basis is now being formulated for renewable energies too. One of the major players here is Siemens Ireland (ENDS Europe 29.3. 2010). The programme has a clear approach in terms of industrial policy: the energy policy is intended to increase competitiveness, reduce costs, boost employment and make Ireland a "globally recognised centre of expertise" (SEAI 2010). It remains to be seen whether Ireland's acute financial problems will dampen the country's ambitions when it comes to climate policy.

2.2.4 Japan

The example of the Japanese "Top Runner" programme is well known, classifying the most energy-efficient top model in a product category as the benchmark for a binding standard. The motto "Developing the world’s best energy-efficient appliances" also demonstrates real ambition in terms of industrial policy (ECCJ 2008). Most of the 21 regulated products (there are now 23) have reached the top standard ahead of schedule or exceeded it, leading to the definition of a new Top Runner standard each time. According to Nordqvist, this has led to a *cycle of standard setting – compliance period – evaluation and revision – and renewed standard setting* (Nordqvist 2006). For example, computers were meant to be consuming 83% less electricity on average by 2005. This target was reached already in 2001. A second standard was set for 2007. Again the expected reduction of 69% has been surpassed (minus 81%). Now a third standard for 2011 was set with an expected reduction of 78% (METI 2010). The more modest target for cars for 2010 (minus 23%) had already been reached five years earlier. Furthermore, a new standard was defined with the aim of further savings of 29% (ECCJ 2008). The Top Runner programme is generally considered to be highly successful. It promoted competitiveness for the corresponding products. Despite fears, it has not resulted in higher production costs.

3 Theoretical interpretation

The following interpretation of the listed examples is from the bottom up and seeks explanations for the phenomenon of accelerated technical change in the climate sector. Such a process is widely used in scientific policy advice. It differs from the – predominantly mono-disciplinary – examination of set theories in academia. Given the relative novelty of the phenomenon and the political relevance of the subject, a certain level of openness in the explanation seems justifiable.

Before going into an explanatory approach, the special nature of environmental innovations needs to be addressed. In this case, we are not just talking about a specific *technology-based policy* – a climate policy relying on marketable technical solutions. It is also based on technical innovations to a great extent and these innovations display significant special features. This special nature of the innovations is a major factor in the shaping of the phenomenon of stricter climate policy measures linked to environmental policy and technology, which is under discussion here.

3.1 The special nature of innovations in environmental and climate protection

Nowhere are innovations as often under discussion as when it comes to environmental and climate policy. And for good reasons. Environmental innovations in general, and climate-related innovations in particular, have particularly special features in comparison to other innovations. Firstly, they are a prerequisite for long-term industrial growth, as they require an ever-increasing level of protection against ecological damage; this requirement alone makes ongoing innovation necessary. Secondly, as global industrialism is increasingly unable to rely on cheap raw materials, there is pressure to increase resource efficiency; this again means that ongoing innovation is required. The market-compliant technical answers to both problems are the creation of environmental innovations and ongoing ecological modernisation (Jänicke 1984, 2008; Jänicke and Jacob 2007). This leads to the third special feature of ecological innovations: more than most technical innovations, environmental innovations have both, a globale and a future market potential. The fourth special feature is that eco-efficient innovations that also save on resources make a positive contribution to productivity. These four reasons explain why there has been no general competition that would be to the detriment of the environment (“race to the bottom”) and why developments have actually mainly been the exact opposite (Vogel 1995; Hettige et al. 1996; Jänicke 1998a; Wheeler 2001; Holzinger 2007). Fifthly, however, environmental innovations are also characterised by the fact that they are largely dependent on political support in terms of market failure (Johnstone 2007; Ernst & Young 2006; see Jänicke 1978, 2008). Although the market is constantly yielding technical innovations, including those in the environmental sector, this is hardly enough on its own to generate the acceleration dynamic described in this paper.

This acceleration is also necessary in terms of policy standards, as the dynamics of global environmental problems mean that the ecological innovation process needs to be highly effective. The concept of the "Green New Deal", based on state intervention to resolve crises, has become relevant in this context.

The acceleration of climate change has made the question of the political forcing of technical change more important. In this regard, it has also become clear that these are more than normal innovations that the market can bring about on its own (such as increasing the efficiency of coal-fired power plants). An appropriately ambitious innovation strategy can be configured as follows: 1. It can aim towards radical innovations far beyond the rebound effects triggered by the complete separation of the problem variables from economic growth. 2. It can increase the level of diffusion. Technical solutions that are restricted to niche markets or the OECD area alone are unsuitable for climate policy. 3. It can increase the speed of diffusion, i.e. the annual diffusion rate in a country. The feared acceleration of global warming (IPCC 2007) makes the acceleration of conversion to low-carbon technologies a central topic for discussion.

3.2 Research approaches

At this point, it is crucial to mention economic literature, which focuses on the significance of market successes and economies of scale. The interplay of market success and secondary innovations when it comes to manufacturing costs and product quality is also a major factor in this subject area. It has already been examined, using the German policy that promotes renewable energies as an example (Jacobsson and Lauber 2006; see Mez 2007). The dynamic development in renewable energies is also the subject of theoretical interpretation in a Japanese study of PV. Watanabe et al. have described the interaction of technical innovation cycles with market cycles as "virtuous cycle" (Watanabe et al. 2010). However, the picture is only fully complete once the "policy cycle" – from "agenda setting" to the evaluation of policy outcomes – is included, having been a key category in policy analysis since Sabatier (Sabatier 1999). It is obviously this interaction of three cycles that characterises the dynamics of innovation processes induced by environmental and climate policy (see below). Competition in industrial policy for climate-friendly technologies is shaped by these multiple dynamics and strengthens it at the same time.

For a long time, economists have neglected the role of the state and politics when it comes to environmental innovations or have seen political regulation as more of a detrimental factor for innovations. However, there have been empirical studies on the significance of state regulations in relation to the creation of environmental innovations since the 1980s (Ashford et al. 1985). Later, both Wallace and, above all, Porter have taken steps in this direction (Porter and van der Linde 1995; Wallace 1995; see also Hemmelskamp 2000; Frohwein 2005; Jacob 2005; Ekins and Venn 2006; Reid and Miedzinski 2008). More recent examinations focus on different instruments that look at the entire innovation cycle: from invention to market introduction (innovation) to market penetration (diffusion) (see Hemmelskamp et. al. 2000: 135-138; Jänicke and Lindemann 2010). Driesen (2010) in a remarkable approach proposed a new type of environmental law which generally stimulates eco-innovation.

Now, however, the listed examples demonstrate a *situational improvement in opportunities for policy action*. This is a familiar subject in policy analysis. In "multiple-stream theory", the convergence of (a) discussed problems, (b) discussed solutions and (c) political opportunities is taken as a situational opportunity for action (Kingdon 1995; Zahariadis 1999; Jänicke 1998). Zundel et al. (2003) have elaborated on discontinuities in the innovation process and the significance of the policy "window of opportunity" from an economic point of view. Fortunate circumstances or points in time are highly significant in climate policy. This applies particularly to the year 2007, with the convergence of (a) new information on climate change (IPCC 2007), (b) competition in industrial policy for climate-friendly technologies and (c) the G8 Heiligendamm resolutions. This is helpful when it comes to understanding the background of the examples, but there is more to them than this. They are situational opportunities for policy action that can offer chances for market success on one hand and new technical potential in the innovation process on the other hand – as a result of an ambitious, technology-based climate strategy.

Literature on environmental policy capacity for action is also relevant to the subject under discussion (OECD 1995; Jänicke and Weidner 1998; Dalal-Clayton and Bass 2002). Policy capacity for action can be generally defined in negative terms as the limit beyond which the success of any measures cannot be expected. Lack of knowledge, lack of financial resources, an incompetent state apparatus, a weak national innovation system (OECD 1999) or a generally insufficient level of development are just some of the factors involved here. In addition to the general negative definition, there are positive additional specific capacities for action that are relevant here, including the capacity to achieve set targets. Prittwitz has used the example of the tightening of smog regulations to illustrate the positive effects of a developed capacity for action on policy ambitions (Prittwitz 1990). The capacity of a state can be well-developed in general, but be limited in terms of strict regulations on climate protection. The subject may be blocked by dominant energy interests up to and including the media (as in the USA). There may be a lack of technical experience or domestic suppliers.

The question of capacity for action is vital, because it fundamentally determines how realistic climate targets can be. This will be discussed in more detail in the next section.

3.3 The significance of climate targets

The successful cases of ecological modernisation presented here can naturally be contrasted with negative experiences in many countries and sectors. It is hardly surprising to find such deficits in countries that have only set undemanding targets or none at all. In policy analysis, targets are only useful as explanatory aids when combined with actors and implementation concepts. However, the lack of target specifications or the undemanding nature of such targets in relation to the innovation process can also be seen as an important indicator. Within the EU-15, countries with weak Kyoto targets for greenhouse gas reduction by 2012 also tend to be "unremarkable" in terms of innovation behaviour. This is hardly astonishing. However, what is remarkable is that countries with weak climate targets also tend to fail to achieve them. There are numerous countries with "weak" targets for greenhouse gases in the Kyoto process. These targets range from zero growth up to the permitted rise in emissions of up to 27% (Portugal). Measurements of emissions up to 2007 have clearly shown: all the countries that deviate significantly from the Kyoto Protocol path also had undemanding targets. What is more: those weak targets were largely missed. The USA had no target at all for 2012; USA emissions rose by almost 17% (in comparison to 1990). Overall, this could be referred to as an *underchallenged syndrome* (Jänicke 2010). This concept is particularly relevant in cases where there had been capacity for action for a more ambitious policy at an earlier stage. This applies not only to the USA, but also Japan – both countries having played a pioneering role in environmental policy at an international level in the 1970s.

However, the reverse argument – namely, that countries with highly ambitious environmental or climate targets are systematically better – is simply not true. At the beginning of the 1990s, a fair few industrial countries deliberately implemented incredibly strict climate targets in a "vacuum". As Tews and Binder (2006) have shown, "unrealistically" high targets mostly led to a "downward" revision as soon as it came to actually implementing them. In fact, they were often simply ignored. One example is the German CO_2 target in 1990, which required a 25-30% reduction for 2005. It had been all but forgotten by the target year. Other countries followed the German example: Denmark, Austria, Luxembourg, Australia and New Zealand intended to reduce harmful CO_2 emissions by 20% by 2005. The Netherlands defined a reduction target of 20-25% (in comparison with 1989/90) for all greenhouse gases for 2000 in its much-celebrated environmental plan. None of these targets were reached – they were all abandoned as soon as it came to their implementation (see Table 2).

Table 2: Countries with ambitious climate targets that were abandoned

Country	Climate target (CO_2)	Period
Netherlands (1991)	- 20-25% (greenhouse gases)	1989/90-2000
Denmark (1990)	- 20%	1988-2005
Germany (1990)	- 25-30%	1987-2005
Austria (1990)	- 20 %	1988-2005
Luxembourg (1990)	- 20 %	1990-2005
Australia (1990)	- 20 % (greenhouse gases)	1988-2005
New Zealand (1990)	- 20 %	1990-2005

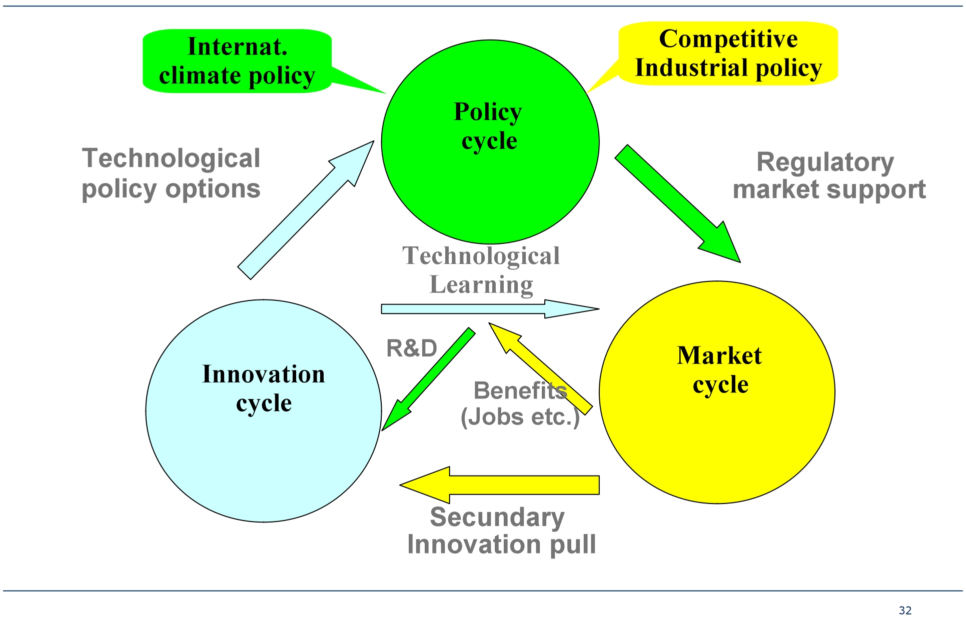
(Source: Tews and Binder 2006)

The logical conclusion is therefore: *ambitious target specifications that are too much of a challenge for a country's capacity tend to be abandoned or neglected. Weak targets also offer no incentive for innovations.* The optimum case lies between the two extremes, whereby *the country's capacity for action is used in full, but not overloaded*. This is most likely to occur where climate *targets are based on the best available technology and there are existing domestic suppliers for this technology. These suppliers are also important partners for the new policy*

3.4 The triple cycle of innovation

At the heart of the subject under discussion here lies the interaction between three processes: firstly, policy influence on market development; secondly, the effects of the induced market dynamic on the development of innovations, and thirdly, the repercussions of the market and innovation dynamic on the policy process (Figure 4). These three areas have an intrinsic logic, which is interestingly also reflected in the fact that their dynamic is presented as a cycle (Watanabe et al.2000). Since Sabatier (1999), the *policy cycle* has been defined in stages: agenda setting – target and policy formulation – decision – implementation – result. The final evaluation of the result usually leads to the setting of a new agenda. In addition to product development, investments and the final offer by a company, the *market cycle* involves demand, competition, price development and, above all, the induced demand for innovations that improve product quality and reduce manufacturing costs. This affects the third cycle, the *innovation cycle*. It comprises invention and development until the product is ready for the market, market introduction, the actual innovation, and finally the diffusion of the product that, if successful, will provide new incentives for innovations. The markets for climate-friendly low-carbon technologies are usually organised markets. They are "policy-driven" (Ernst & Young 2006), usually with a mix of climate policy and industrial policy motives. In essence, an ambitious climate strategy in the sense of Section 3.1 is a government strategy. Its successes can trigger positive feedback for the policy. Policy can also promote the innovation process directly. It can provide fundamental support for new technology via the provision of targeted R&D resources. Above all, targeted state R&D resources can support the secondary market-driven innovation process, which improves the quality and manufacturing costs of climate-friendly technology in competition. Ambitious government target specifications can also offer a stimulating long-term perspective for the process. Policy therefore controls market and innovation processes, and both can result in positive feedback for the policy: in addition to the intended effect on the climate, market success for low-carbon technologies also has a positive effect on employment and supplier interests, which backs up the policy. The innovation process supported by the market and state creates additional action options for a technology-based policy. More effective photovoltaic systems or efficiency technologies could justify more ambitious climate targets in practice and market success encourages the political acceptance of this.

Figure 4: Policy acceleration: The triple cycle of innovation



Overall, the three cycles work in such a way that they boost each other and enable each other to experience positive feedback. As cycles, they tend to carry the process forward to a higher level. The amendment of laws at the end of a policy cycle is a typical process here.

The innovation dynamic presented here is naturally subject to *international framework conditions:* the policy process is subject to this influence in two ways. National governments are influenced to a greater or lesser degree by global climate policy. Furthermore, a large number of governments are also subject to the conditions of innovation competition for low-carbon technologies, based on industrial policy. National suppliers in this sector are also usually exposed to international competition and the domestic markets are influenced by this combination. Even the national innovation system is not free from international influences and is often subject to competition amongst research suppliers.

The diagram shown in Figure 4 refers indirectly to three typical innovation policy pitfalls that can be classified as follows:

1. Policy oblivion: It is mainly neo-classical economists who tend to neglect the role of the state and policy or even ignore this role as a disruptive factor. Although this may well be justifiable in the case of some innovations, environmental innovations are characterised by the fact that they are dependent on policy (see Section 3.1). In climate protection, performance requirements for the innovation process are so high that active state involvement is essential. This involvement does not mean bureaucratic state intervention, but rather a widespread, exertion of influence weighed up beforehand – and this is precisely the state of most policy consulting today (see SRU 2004: 525ff.).

2. Innovation oblivion: The opposite is the case here – radical climate politicians tend to focus on massive promotion of the required better technology, without offering any basis for this process in the innovation system. In the case of the Germany promotion of renewable energies, such innovation oblivion could well have slowed the drop in prices for "green" electricity and made success less likely for German suppliers on the global market. However, the actual German climate policy after 1998 has triggered a boom in new patents for this technology and the infrastructure for corresponding innovation promotion does indeed exist.

3. Market oblivion: This pitfall mainly exists amongst research politicians. Too much is expected from one-sided R&D promotion. The pull of a high market dynamic is underestimated here. Usually forced by policy, this market dynamic – as a technology pull – is a decisive factor for the multiple innovation process under examination here.

3.5 On the governance of climate policy acceleration

The aforementioned examples of "best practice" in climate protection suggest that there are political conclusions to be drawn here. In the light of the presented cases and the phenomenon of multiple positive feedback mechanisms, can a more ambitious climate policy be justified, at least for countries with sufficient capacity? The quoted example of Indian solar power promotion represents an interesting attempt by a government to move in this direction.

The following generalisations seem possible (with all due reservations):

- In addition to prior experience and the existence of suitable providers, the prerequisite for such processes is the existence of a government R&D research environment that supports the secondary innovation process (also in China and India).
- The decisive factor is then the definition of calculable climate targets at the limits of the capacity that is technically feasible for a country. As shown, the targets need to be *ambitious* and *realistic*. The calculability of the targets is based on the programme of implementation and its foreseeable effects.
- If the targets are implemented successfully and therefore effectively boost market growth for climate-friendly technologies, this results not only in economies of scale but also *secondary innovations*: new processes that reduce manufacturing costs (e.g. the drop in costs for photovoltaics in Germany and Spain) and product innovations, e.g. those that improve the energy efficiency of a product (as is the case with wind power in Germany and China).
- Market success not only generates jobs, but also interest from new suppliers, which further legitimises the ambitious policy measures and often pushes them aside. This tends to broaden the policy conditions for action and increase the level of policy aspirations. In the end, climate targets that were once the subject of dispute are often widely accepted. More far-reaching targets can even be accepted (according to Infratest Dimap, 62% of German citizens surveyed at the end of 2009 stated that an ambitious climate policy is an advantage *for the economy*).
- The effects of international competition also play a part here: competitors from other countries can further develop the successful technology and offer these developments themselves on the global market. This gives rise to a situation in which the progress of a pioneering country is only held back by the need for constantly new innovations. This means international industrial policy competition can also accelerate the triple cycle (Figure 4).

4 Conclusion: Save the climate who can

The positive feedback process phenomenon that can be triggered by an ambitious climate policy, as described in this paper, is extremely significant in terms of current climate policy. Even if innovation strategies are naturally exposed to a relatively open framework of action, certain generalisations are possible and allow political conclusions to be drawn. Climate policy is intrinsically linked to the pioneers. And pioneers have mostly advantages. In terms of *climate policy*, this justifies unilateral, unconditional ambitious policies, albeit only in countries that possess the necessary capacity to act. The examples presented here indicate the wide scope of these countries.

However, there are also sufficient plausible arguments in favour of the enforcement of pioneering policies by those who are capable of doing so when it comes to *industrial policy*. A country with a set target level is only a pioneer for a certain period of time. Part of the innovation process is the take-up of innovations by competitors, who then further develop those innovations and offer them on international markets. It is this innovation competition that characterises climate-friendly, low-carbon technologies. Top runner positions and "first mover advantages" (Porter) are therefore to be considered in dynamic terms: they are only held back over time by the need for more ambitious targets.

Bibliography

Agentur für Erneuerbare Energien (2010): Erneuerbare Energien 2020. Potenzialatlas Deutschland. Berlin.

Ashford, N. A./Ayres, C./Stone, R. F. (1985): Using Regulation to Change the Market for Innovation, in: Harvard Environmental Law Review Vol. 2, No. 9, 419-466.

Bechberger, M. (2009): Erneuerbare Energien in Spanien. Erfolgsbedingungen und Restriktionen, Stuttgart: Ibidem-Verlag.

BMWi/BMU: Energiekonzept (Entwurf). 7. September 2010.

BMU/UBA (2008): Innovationsdynamik und Wettbewerbsfähigkeit Deutschlands in grünen Zukunftsmärkten, Berlin.

BMU/UBA (2009): Umweltwirtschaftsbericht 2009, Berlin.

Bundesregierung (2010): Nationaler Aktionsplan für erneuerbare Energien gemäß der Richtlinie 2009/28/EG sowie der Entscheidung K(2009) der Kommission vom 30. 6. 2009 (Entwurf).

CleanEdge (2010): Clean Energy Trends 2010 (www.cleanedge.com/reports/pdf/Trends2010pdf).

Dalal-Clayton, B./Bass, St. (2002): Sustainable Development Strategies, London: Earthscan.

ECCJ (The Energy Conservation Center, Japan) (2008): Top Runner Program, revised edition, Tokyo.

Driesen, D. M. (2010): An Environmental Competition Statute, in: Flournoy, A.C./Driesen, D.M. (Eds.): Beyond Environmental Law: Policy Proposals for a Better Environmental Future, Cambridge: Cambridge University Press.

Ekins, P./Venn, A. (2006): Assessing Innovation Dynamics Induced by Environmental Policy, London: Policy Studies Institute.

Ernst & Young (2006): Eco-industry, its size, employment, perspectives and barriers to growth in an enlarged EU, European Commission: DG ENV.

Frohwein, T. (2005): Der Einfluss umweltpolitischer Regulierung auf Innovationen, in: Hansjürgens, B./Nordbeck, R. (eds.): Chemikalienregulierung und Innovationen zur nachhaltigen Wirtschaften, Heidelberg, 17-44.

Frondel, M./Ritter, N. (2010): Deutschlands Art der Förderung erneuerbarer Energien: Nicht zur Nachahmung empfohlen, Zeitschrift für Umweltpolitik und Umweltrecht, 3/2010, 261-283.

Government of India (2010): Jawaharlal Nehru National Solar Mission – Toward Building Solar India (www.indiaenvironmentportal.org.in).

Hemmelskamp, J./Rennings, K./Leone, F. (eds.)(2000): Innovation-oriented Environmental Regulation – Theoretical Approaches and Empirical Analysis, Heidelberg-New York.

Hettige, M./Huq, M./Pragal, S./Wheeler, D. (1996): Determinants of Pollution Abatement in Developing Countries: Evidence from Southeast Asia, in: World Development, Vol. 24, No. 12, 1891-1904.

Holzinger, K. (2007): Races to the Bottom" oder "Races to the top"? Regulierungswettbewerb im Umweltschutz, in: Jacob, K./Biermann, F./Busch, P.-O./Feindt, P.H. (eds.): Politik und Umwelt. PVS Sonderheft 39, 177-199.

House of Commons/Env. Audit Committee (2010): Carbon Budgets. Third Report of Session 2009-10, London : The Stationary Office Limited, 11. Jan. 2010

IPCC (2007): Climate Change 2007 – The Physical Science Basis (Fourth Assessment Report), Cambrigde, New York: Cambridge University Press.

Jacob, K. et al. (2005): Lead Markets for Environmental Innovations, Heidelberg, New York: Physica-Verlag.

Jacobsson, St./Lauber, V.: The Politics and Policy of Energy System Transformation: Explaining the German Diffusion of Renewable Energy Technology, Energy Policy No. 34 (2006), 256-76.

Jänicke, M./Jacob, K. (eds.)(2007): Environmental Governance in Global Perspective – New Approaches to Ecological Modernisation. 2nd ed. Berlin: FFU.

Jänicke, M./Lindemann, St. (2010): Governing Environmental Innovations, Environmental Politics, Vol. 19, No.1, 127-141.

Jänicke, M. (1978): Umweltpolitik- Beiträge zur Politologie des Umweltschutzes, Einleitung, Opladen: UTB.

Jänicke, M. (1984): Umweltpolitische Prävention als ökologische Modernisierung und Strukturpolitik, IIUG discussion paper 84-1, Wissenschaftszentrum

Jänicke, M. (1998): The Political System's Capacity for Environmental Policy, in: Jänicke, M./Weidner, H. (eds.): National Environmental Policies – A Comparative Study of Capacity-Building, Berlin: Springer, 1-24.

Jänicke, M. (1998a): Umweltpolitik: Global am Ende oder am Ende Global? In: Beck, U. (ed.): Perspektiven der Weltgesellschaft, Frankfurt/M.: Suhrkamp, 332-344.

Jänicke, M. (2008): Megatrend Umweltinnovation, München: Oekom.

Jänicke, M. (2010): Die Akzeleration von technischem Fortschritt in der Klimapolitik – Lehren aus Erfolgsfällen, Zeitschrift für Umweltpolitik und Umweltrecht, Vol. 33, No. 4, 367-389.

METI (2010): Top Runner Program, revised edition, Tokyo: Ministry for Econmy, Trade and Industry.

Mez, L. (ed.)(2007): Green Power Markets: Support Schemes, Case Studies and Perspectives, Brentwood, Essex.

Ministry of Power (2010): National Mission on Enhanced Energy Efficiency to be Implemented from the 1st of April. Press Release December 14, 2009.

Nordqvist, J. (2006): Evaluation of Japan's Top Runner Programme, July 2006 (Framework of the AID-EE Project (ms).

OECD (1999): Managing National Innovation Systems, Paris: OECD.

OECD (2005): Developing Environmental Capacity, Paris: OECD.

OECD (2009): Implementing Energy Efficiency Policies: Are IEA Member Countries on Track? Paris.

Pellman, T. (2010): The Challenges Ahead in 2010, in: China Clean Energy Network 6. 1. 2010.

Porter, M. E./van der Linde, C. (1995): Green and Competitive: Ending the Stalemate. Harvard Business Review, September–October, 120–134.

Prittwitz, V. v. (1990): Das Katastrophenparadox – Elemente einer Theorie der Umweltpolitik, Opladen: Leske + Budrich.

Reid, A./Miedzinski, M. (2008): Eco-Innovation. Final Report for Sectoral Innovation Watch (www.technopolis-group.com).

REN21 (2009): Background Paper: Chinese Renewables Status Report, October 2009 (www.ren21.net/news/news38.asp).

REN21 (2010): Renewables 2010 Global Status Report, Paris (www.ren21.net/globalstatus-report/g2010).

Sabatier, P.A. (ed.)(1999): Theories of the Policy Process, Boulder: Westview Press.

SEAI (Sustainable Energy Authority of Ireland) (2010): Strategic Plan 2010-2015. Dublin.

Tews, K. und M. Binder (2006): Converging Objectives - Diverging Result? National Goal Formulation and Goal Achievement in Climate Change Policies. In: Jänicke, M./Jakob, K. [eds.]: Environmental Governance in Global Perspective, Berlin: Freie Universität Berlin, 97-122.

Vogel, D. (1995): Trading Up. Consumer and Environmental Regulation in the Global Economy, Cambridge, Mass: Harvard University Press.

Wallace, D. (1995): Environmental Policy and Industrial Innovation – Strategies in Europe, the USA and Japan, London: Earthscan.

Watanabe, Ch./Wakabayashi, K./Miyazawa, T. (2000): Industrial Dynamism and the Creation of a "Virtous Cycle" between R&D, Market Growth and Price Reduction. The Case of Photovoltaic Power Generation (PV) Development in Japan, Technovation 20, 299-312.

Wheeler, D. (2001): Racing to the Bottom? Journal of Environment and Development, Vol. 10, No. 3, 225-245.

Zahariadis, N. (1999): Ambiguity, Time, and Multiple Streams, in: Sabatier, P. A. (ed.): Theories of the Policy Process, Boulder: Westview Press.

Zundel, St./Erdmann, G./Nill, J./Sartorius, Ch./Weiner, D. (2003): Zeitstrategien ökologischer Innovationspolitik – der Forschungsansatz, in: Horbach, J./Huber, J./Schulz, Th. (eds.): Nachhaltigkeit und Innovation, München.