Jan Nill

Instrumentation of Time Strategies for an Ecological Innovation Policy: a New Role for Subsidies?

The Cases of Innovation in Iron Production and Housing in Comparison

Diskussionspapier des IÖW 61/04

Institut für
ökologische
Wirtschaftsforschung
gGmbH

Jan Nill

Instrumentation of Time Strategies for an Ecological Innovation Policy: a New Role for Subsidies?

The Cases of Innovation in Iron Production and Housing in Comparison

IOEW Discussion Paper 61/04

Berlin 2004

Institut für ökologische Wirtschaftsforschung (IÖW) gGmbH
(Institute for Ecological Economy Research)

IÖW Main office
Potsdamer Straße 105
D-10785 Berlin
www.ioew.de

phone +49.(0)30.884 59 40
fax: +49.(0)30.882 54 39
mailbox@ioew.de

SUMMARY

Fostering innovation is often seen as important for policies towards sustainable development. Yet, given the ambitious environmental targets implied by sustainability, it might not be sufficient to stimulate incremental innovations alongside well-established techno-economic trajectories. The SUSTIME research project, on which this paper is based, has developed a time strategic policy framework to respond to these challenges, emphasising the role of (techno-economic) windows of opportunities and timing for an appropriate policy.

Within such a framework, the paper aims at a reappraisal of the role of (innovation-oriented) subsidies therein. It is based on a critical review of the literature, and, in particular, two empirical case studies of low energy housing and iron and steel production technologies. The paper shows that also for new strategies, the temporary use of such an "old" and in the view of recent policy debates also "oldfashioned" policy instrument, may remain important due to its flexibility, direct dynamic incentives and also due to political advantages. Temporal limits or digressive rates are crucial for success and contribute to avoid some of the well known economic and political pitfalls of subsidy-type instruments, too.

ZUSAMMENFASSUNG

Eine wichtiger Aspekt von Nachhaltigkeitspolitiken ist die Förderung von Innovationen. Allerdings dürfte es angesichts der mit Nachhaltigkeit verbundenen anspruchsvollen Umweltziele nicht ausreichen, auf inkrementelle Innovationen im Rahmen etablierter Technologiepfade zu setzen. Das Projekt SUSTIME, auf dem das vorliegende Papier beruht, hat ein zeitstrategisches Politikkonzept entwickelt um dieser Herausforderung zu begegnen. Es betont die Bedeutung (techno-ökonomischer) Zeitfenster sowie des politischen Timings.

Innerhalb eines solchen Rahmens verändert sich auch der Blick auf umweltpolitische Instrumente. Das Papier fokussiert hier auf die mögliche neue Rolle von Subventionen als Element von Zeitstrategien. Es basiert neben einem kritischen Literaturüberblick auf zwei empirischen Fallstudien: Innovationen im Bereich Niedrigstenergiehäuser und im Bereich der Eisenherstellung. Es zeigt dass auch im Rahmen neuer Strategien die zeitlich begrenzte Nutzung eines aus der Perspektive aktueller Politikdebatte eher „altmodischen" Instruments wichtig sein kann. Gründe sind die Flexibilität des Instruments, die dynamischen Anreizwirkungen auf First Mover sowie Vorteile bei der politischen Umsetzbarkeit. Eine Befristung oder degressive Ausgestaltung ist für ihren Erfolg von zentraler Bedeutung. Sie trägt auch dazu bei, einige der bekannten ökonomischen und politischen Nachteile von Subventionen zu begrenzen.

ABOUT THE AUTOR

Dipl. Volkswirt Jan Nill, economist, is research fellow at the department Environmental Economics and Environmental Policy of the Institute for Ecological Economy Research (IÖW). Main research areas: sustainability and innovation policy, ecological industrial restructuring, European integration and the environment.
Contact: Tel. +49-(0)30-884594-28, E-Mail: Jan.Nill@ioew.de.

TABLE OF CONTENTS

1. Introduction

Fostering innovation is often seen as important for policies inducing a transition towards sustainable development. Yet, given the ambitious environmental targets implied by sustainability, often it is not be sufficient to stimulate incremental innovations alongside established technological trajectories. Due to economic and institutional path dependencies, however, such policies aiming at innovations, which change those technological trajectories, are difficult.

A broad collaborative empirical research effort on the topic of fostering environmental innovation processes in Germany has established that a simple incentive-response relation between certain economic instruments and innovative effects does not hold generally, but is context specific (e.g. Klemmer et al. 1999, Jänicke et al. 2000, see also Kemp 2000). The general result is a multi-impulse theory in which the same instruments can have different impacts in different circumstances as well as different instruments may have similar impacts.

From a policy perspective, the scientific task which follows from these results is to further specify relevant contexts. The research project "SUSTIME - Innovation, Time, and Sustainability. Timing Strategies of Environmental Innovation Policy" (Nill and Zundel 2002, Zundel et al. 2003, Erdmann 2004)[1] is based on the hypothesis that time and the dependencies of innovation dynamics on time provide a promising systematic context for environmental innovation policy analysis. It is part of every day's knowledge of entrepreneurs and policy makers that not only the content but also the timing of decisions is crucial. Windows of opportunity play an important role, in particular if the type or consequences of the decision are not only incremental. Nevertheless, striving for generality and simplicity, science has hesitated to transfer this knowledge systematically into theoretical reflections. The paper explores this time-strategic approach and focuses on the question to which extent it sheds new light on the debate on appropriate environmental policy instruments.

Hence in the next section a conceptual framework for the appropriate timing of political transition strategies is presented, which has been developed in the SUSTIME project. In section 3 particular attention is paid to the instrumentation of time strategies that try to prepare and utilise techno-economic windows and the role of subsidies therein. Section four applies the policy framework in a comparative way to two empirical cases: iron and steel production and housing. The last section concludes that time strategies are a promising but politically challenging way to enhance transitions towards sustainability. Time limited subsidies could play an important role if they are conceived as one element of such strategies.

---

1 Project co-ordination: Prof. Stefan Zundel, University of Applied Sciences Lausitz; other scientific partners: TU Berlin, IÖW, MERIT Maastricht) within the RIW research programme on "Frameworks for Innovations towards Sustainability" funded by the German ministry of research and education (www.riw-netzwerk.de).

2. A time strategic conceptual framework for innovation policy[2]

2.1 A dynamic evolutionary economic approach

Modern evolutionary economics depicts the creation and implementation of innovations as an unsteady process. Phases of radical change of technological paradigms alternate with phases of incremental improvement of given technologies (Dosi 1982). Technological paradigms create patterns for further technological progress, therefore characterising technological development as potentially path dependent. The initial conditions of technological progress build a framework for further incremental development.

Periodically such paradigms tend to be exhausted and novel technological solutions emerge. In phases during which a particular paradigm dominates, alternative technological solutions have little chance of market success. Economies of scale and scope, spill over effects within networks, regulatory frameworks, which are often specified only for a given technology, discriminating others, create support for the dominant technology and impede alternative technologies. For actors of the dominant trajectory, a change of technology would imply considerable sunk costs, depending also on the phase of the investment cycle. Hence technologies with serious impacts on environment can be locked in to some extent and it is difficult to change the path of technological development in favour of (non-incremental) innovations with positive ecological effects.

During times of change, i.e. a critical phase of technological competition in which the old paradigm becomes unstable due to external factors or internal problems and competitive new solutions are available, opportunities for a transition towards environmentally more sound technologies are better, at least if they are appropriately supported by environmental innovation policy. Such instable phases can be conceptualised as "time windows of opportunity" (David 1987, Erdmann 1993). We define a techno-economic window of opportunity or *time window* as an instable phase of (market oriented) technological competition in which actors such as firms or policy actors have a greater opportunity to change the direction of trajectories in a significant way than during stable phases.

It is useful to distinguish two types of technological competition: *"old/new" competition* between an incumbent technology on a well established trajectory and new technologies (such as modelled e.g. by Reichel, 1998). The driving factors have been described above, and in the case of environmental innovation policy, this is the overall framework of a transition. But also "*new/new*" *competition* between new technologies (such as emphasised in the models of Arthur, e.g. 1989) can be important in such instable phases and contribute to the shaping of techno-economic windows, in particular if increasing returns to adoption occur, caused by network effects, economies of scale and scope and technology specific learning effects. In such a situation, a new technology's success does not only depend on its economic and technical features. Even if considered better from a more general point of view, other new technologies can succeed if there are first movers on the market stage. A small lead or contingent events self-enforced by increasing returns can bring about completely different directions of development of the techno-economic system in question.

---

2 This section is largely based on Zundel et al. (2004), in which the framework is presented in more detail.

What makes the distinction between stable and instable phases of techno-economic systems interesting from a political point of view is that the success conditions for policies, which attempt to alter the direction of development paths, change over time. Techno-economic windows provide an opportunity for a more effective or lower cost environmental innovation policy and make thus transitions towards more sustainable technologies easier. A time-strategic approach to environmental innovation policy designed for a change or a transition of the given path of technological development should make use of that.

Traditional economic wisdom restricts interference by policy into markets to framework setting activities, because markets are believed to be a superior allocation mechanism. Also from an evolutionary economic point of view, markets are often assumed to function more effectively than politics (for a survey on the evolutionary literature see Nill 2004). By interfering with technological competition a time strategic approach seems to contradict this assumption to some extent. It is based on the assumption that in fact also framework policies have a technology content which is important to consider for sustainability transitions. If path dependency is empirically relevant and if the path in question is not sustainable, a lack of political support for alternative solutions in stable phases of the techno-economic system will in fact favour established solutions. Moreover, a lack of differentiation in political support of alternative solutions in unstable phases can bring about a new dominance of a particular technology before the potential of alternatives can truly be tested.

For political time strategies building on these dynamics, however, also the success conditions in the political system are important: First, the system cannot be completely separated from society. In democratic societies policy reacts – as it should – to public interests. On the other hand, the political system is not completely free in adapting public interests; it has its own institutional and social momentums. These mechanisms operate like a filter and influence whether and to what extent external impulses are picked up by political actors and are transformed in political concepts and actions. In particular in old/new competition, also (attempts of) institutional and political stabilisation of the old path by the incumbents have to be systematically taken into account. Here it makes a difference if the path changing innovations can easily be driven or adopted by established firms or whether they are disruptive for the established actors because they involve discontinuities in competencies, organisation and markets (Christensen 1997). In the latter case, a strong incentive arises for political bargaining instead of R&D in order to prevent a transition. The political system can then be inert and impede external impulses for change. In such cases, the political system also has to move in an unstable phase for making a transition possible, a political window of opportunity is necessary (Nill 2002).

2.2 A taxonomy of time strategies

Time strategies should reflect the specific conditions and dynamics in the techno-economic system. The following taxonomy, which has been developed in the SUSTIME project, uses the idea of a sequence, beginning with an old path and the discovery that this path is not sustainable. The sequence ends when a transition is completed and market forces are reinforced. This idea is closely related to the concept of transition management (Kemp and Rotmans 2004), but we investigate different situations in more detail here. The following table gives an overview about possible states depending on time:

Table 1: Taxonomy of techno-economic dynamics and related policy targets

	Status of the techno-economic system	**Kind of competition**	**Quality of alternatives**	**Policy strategy and targets**
1	Stable	None	Only theoretical alternatives exist	Demonstration of technical feasibility
2	(still) stable	(New/new) old/new foreseeable	Promising solutions	**"Window preparation"** Diversity and development
2a	*Stable (but social pressure for quick path change)*	*(New/new)*	*Promising solutions*	***"Window creation":*** *Enabling of transition and avoiding of rush selection*
3	Unstable (window)	Old/new + new/new	At least one solution is competitive	**"Window utilisation":** Making transition easier and avoiding rush selection
3a	*Unstable (window)*	*Dominant old/new*	*Only one alternative solution is competitive, others are only promising solutions for the future*	***"Window utilisation"*** *Making transition easier*
3b	*Unstable (window)*	*Dominant new/new*	*Multiple alternative solutions are competitive*	***"Window utilisation"*** *avoiding rush selection*
4	Stable	None	Transition is completed	Reviving selection function

Source: adapted from Zundel et al. (2004)

With respect to the corresponding policy strategies, we can assign the following names to the possible states of a techno-economic system described above:

- *Window preparation*: 2
- *Window creation*: 2a. This state is characterised by a stable phase of the techno-economic system and a political attempt forcing the system to a transition, e.g. by making alternatives competitive (dominant old/new case), or by the political determination of a new ecological functional requirement which opens a new/new competition.
- *Window utilisation*: 3, 3a, 3b

In the following we focus on the constellations 2 and 3, i.e. policies for window preparation and window utilisation.

2.3 Policies for window preparation

The phase of window preparation is characterised by a *stable* old path, but there is at least one *promising new solution*. The main targets for policies which *prepare* the emergence of future techno-economic windows for a transition are creating diversity by improving search and development processes and stimulating firms to develop at least one competitive solution, for example by organising learning curves.

Government should make best use of market forces; here this involves mainly searching for new promising solutions and developing new solutions until they become competitive to some extent. For window preparing policies expectation management is important. Weak signals such as long-term targets also play a role. Mechanisms may e.g. include the creation of niches for or the support of new alternatives, such as argued in the concept of strategic niche management (see Kemp et al. 1998). Also economic instruments may play an important role. If budget is limited or if strong increasing returns are involved, a trade off between development of a particular promising solution and diversity is possible. Additionally, we must keep in mind that environmental policy requirements can also hinder window emergence, e.g. delay investment cycles (retrofitting), thereby increasing sunk costs especially if end-of pipe treatment is involved. In this case a transition is obstructed by environmental policy itself.

Political-economic constraints are probably of less importance - except if the policies are expected by relevant actors of the dominant path to be in fact window-creating policies. However, the result may be rather a restriction of feasible instruments than of the policies as such: While policies with direct negative impact on dominant path actors are difficult to achieve, policies which rather support new alternatives should remain feasible - also the influence of new path actors may help here.

2.4 Policies for window utilisation

If at least one alternative solution becomes competitive to some extent, the situation may be generally characterised by the following features: the old path is *unstable* or at least a techno-economic window can be anticipated, and there is competition between different new solutions. At least one of the new solutions is *competitive* in principle. In short, we face a combination of *new/new* competition and *old/new* competition. Fundamentally a transition is now possible and the government's target is to facilitate this transition, for example by abandoning discriminating mechanisms for the new solution.

For examining appropriate policies which *take advantage of* or *utilise* such a techno-economic window for a transition that has emerged or will emerge in the techno-economic realm, it is helpful to first regard two sub cases separately, namely dominant old/new and dominant new/new competition, before looking at the general, but not always relevant, old/new/new case. If one takes the specific background of time strategies, namely increasing returns, serious, it should be rarely the case that the *utilisation* of old/new and new/new windows has to be dealt with simultaneously, i.e. that in both sub-constellations the dynamics are highly unstable. Usually, such windows should rather emerge in sequences (old/new (promise of solution) - new/new – old/new (if old is not ruled out politically)), thus often only one of the two types is actually time critical.

For policies, which *utilise* techno-economic windows of the *old/new* type (case *3a*) sometimes a relatively small and perhaps even temporary political impulse is sufficient. The main political task is to grasp the situation and have flexible and well dosable instruments available to deal with the dynamics. However, in this situation window utilisation usually tends to imply selection. Due to the different dynamics of old and new technologies, it is difficult to manage a fair and result-open old/new competition; nor is this usually the environmental aim.

However, the utilisation of such a window by policy is supposed to be subject to political-economic constraints only under particular conditions. The criterion proposed is a *disruptive impact* of window utilisation on actors of the old path. This may be the case if it implies

(a) a probable decision of the technological competition (and not only the ensuring of window openness), and

(b) this decision would have a significantly negative impact on politically important economic actors, for example due to competence- or cost-based constraints to utilise the techno-economic window successfully themselves.

Due to these (expected) disruptive effects, the result often is a blocking of the political system so that a political opportunity to utilise the techno-economic window is supposed to be tied to other change facilitating conditions in the political or social system, for example political windows (Nill 2002).

Sometimes the necessity of a transition is clear due to internal limits of the old path. As a result, new/new dynamics come to the forefront (case *3b*). For policies, which *take advantage of* or *utilise* these new/new techno-economic windows, "utilise" can also mean "keep the window open" for a sufficiently long time. Political responsibility is also high here: environmental policy may act as the "small historical event" within the selection environment important for the increasing returns models, e.g. biases competition. This may reinforce or even lock-in first mover advantages. Under some conditions, it may be necessary to extend the duration of the techno-economic window by means of political intervention (David 1987) in order to ensure that political discrimination of ecologically superior better solutions does not occur.

In some cases of phase 3 the situation is more complicated than in 3a or 3b: besides the competitive solution there are other solutions that are merely promising and have not yet attained competitiveness. The development of their potential can be strongly impeded by simply following the target of transition. If some new solutions can use network effects and early economies of scale, they can gain an advantage, and cannot be overtaken by other promising solutions with a possibly greater potential. In other words, in this case there is a trade-off between diversity and facilitating transition. In this situation the government must keep the window open by suppressing the selection function of markets until the most promising solutions have developed their potential. If this is too costly or not feasible and the old/new window can only be used by the more advanced technologies, a lock-in of new solutions must be avoided at least, e.g. through reservation of niches etc. This is not easy for political reasons, the promoters of the available solution might press to secure their future market.

3. Instrumentation of time strategies: the role of subsidies

3.1 A new, time-strategic perspective on instrument choice

From a dynamic point of view, it must be emphasised that the usual treatment of instruments in economic textbooks is misleading to some degree. In a dynamic context also framework instruments such as taxes or tradable permits have a “technological content” depending on the time of implementation. If a given techno-economic system is in a stable phase and there are no promising solutions, these instruments mainly induce an improvement of dominant technologies. This contributes to explain why empirical findings on the impact of taxes and tradable permits on the stimulation of research and development of new solutions are not very convincing (Kemp 2000). If the system is unstable, even a moderate impulse may give the system’s development a new direction. Hence timing, design and dosage of instruments may be more important than the question of choice of instrument. The vivid debates also on the implementation procedures of economic instruments such as taxes and emission trading are a case in point. This confirms some aspects of the multi-impulse-hypothesis, but puts them in a systematic context: The dynamic efficiency or innovation impact of policy instruments is a function of techno-economic dynamics in time. This implies a change of perspective: from "regulation to innovation" towards "innovation to regulation". A precondition for appropriate time strategies is the identification of the relevant features of techno-economic dynamics (as described in table 1 above) and the adaptation of instruments to these.

Moreover, a time strategic analysis of policy instruments involves the following aspects:

- Instruments should contribute to keep a balance between clear signals pointing to a transition and adjustment flexibility to new developments

- Instruments should be techno-economically and politically feasible and accepted by society

Both aspects lead to the conclusion that often a combination of general framework instruments and specific temporary impulses is most appropriate. For the latter, a set of additional, process-oriented criteria is important:

- Is it possible to design the instrument according to the techno-economic dynamics and to time its beginning and finish of implementation appropriately?

- Is it possible to treat different solutions unequal?

- Is it suitable to the political system so that a quick and flexible implementation is possible?

Given these criteria, appropriately designed subsidies can be an attractive policy instrument within a time strategy for environmental innovation policy.

3.2 A reappraisal of the debate on subsidies as innovation policy instrument

Especially in the economic literature, subsidies[3] have a bad image. They contradict the polluter-pays-principle, are expensive, politically difficult to remove and there is the danger of windfall profits. The neoclassical theoretical literature states that the innovation impact of subsidies is lower than that of taxes or tradable permits (e.g. Milliman and Prince 1989). The more recent, empirically underpinned literature is less categorical. Kemp (2000) emphasizes the importance as well as the limits of subsidies as instrument. R&D subsidies may be important for variety creation if uncertainty prevails as well as if a technology switch is costly and no market exists. In his view, investment subsidies are more problematic, and the empirical success is limited, albeit there are counter examples if they are managed appropriately. In their broad collection of empirical studies, Klemmer et al. (1999) discover a bigger impact of subsidies than assumed in advance. They highlight the role subsidies may play for the first market introduction of an innovation. This study is also a first attempt to relate the impact of instrument to innovation phases. But Klemmer et al. (1999) rather focus on individual decisions of innovators (invention, market introduction, diffusion) than on the dynamics of techno-economic and political systems. From the latter perspective, the potential role of subsidies - as well as their limitations - emerges even more clearly.

3.3 Subsidies as an element of window preparation strategies

At first glance, two different strategies for window preparation are conceivable. Either a strategy based on a general framework-changing instrument like environmental taxes as main element, which destabilises the old path and improves the economic perspectives of new paths. Or, in particular when product or system innovations are aimed at, strategic niche management (e.g. Kemp et al. 1998), which cares systematically for the development of different alternatives by securing niches for experimentation. In both approaches, however, subsidies will often play an important role. It is a well-established empirical result that at least regarding to path changing innovations, the innovative effects of taxes are limited (Kemp 2000, Linscheidt 2000). Hence there is at least a complementary role for R&D subsidies. This holds in particular when more radical and hence more risky and often also more costly solutions are striven for. Moreover, subsidies for pilot demonstration projects or demand creating investment subsidies are an important instrument to provide for niches.

The advantage of subsidies is the easy targeting and the possibility to treat different solutions in a differentiated manner. To reach the goal of window preparation, a digressive or temporary way of implementation is crucial, as for example in the German Renewable Energies Act. Moreover, they have at least two important political advantages. A successful demonstration of feasibility of a new solution paves the way for a more stringent regulation, a historically well-known dynamic pattern of the interplay of process innovation and regulation in Germany. Second, from a political economy perspective, they are more easily implemented than more general instruments like taxes if established actors are supposed to fear the new path to be disruptive. While policies with direct negative impact on dominant path actors are difficult to achieve, policies that rather support new alternatives should remain feasible - also

3 The term of subsidies is used here in its economic meaning of a positive support instrument. This does not necessarily need to take the form of a subsidy in its judicial meaning as financial instrument of the State.

the influence of new path actors may help here. Hence, implementation may be feasible without the need for a political window of opportunity.

3.4 Subsidies as an element of window utilisation strategies

It is useful to regard the two sub cases of window utilisation, 3a and 3b (see table 1) separately. In the case of prevailing old/new competition, and if no economic instrument such as taxes or permits is already in place, a time limited environmental standard, which destabilises the old path, or temporary investment subsidies may be instruments of choice. For both instruments, however, institutional limits are important to consider (see cases below). Taxes and tradable permits are also well or even better suited, because they allow for flexibility in the firm decisions to make the technological transition, but difficult to dose and to implement quickly.

In the case of dominant new/new competition, taxes or tradable permits are well suited to let the new/new competition play in an innovation-enhancing way. However, there is the danger that promising solutions which are still on a higher point of the learning curve are locked-out, especially if there are no big and resourceful actors behind this path. In such situations, subsidies could play an important additional role to keep technological competition and thus the techno-economic window open or at least to secure a niche for future solutions. As a general instrument, however, they are too costly. If a regulatory standard is the main instrument chosen, so-called innovation waivers are a possible advantageous element of implementation. They allow the regulated party to delay compliance if an innovation with an improved performance is installed instead of the minimum standard (e.g. Ashford et al. 1985).

Taken together, temporary subsidies as an instrument which supports first-movers can play an important role in window utilisation strategies, in particular if other economic instruments are not available or if the most promising solutions are in different stages of technological development.

4. Empirical application: a comparison of two cases

In the following, the policy framework presented is applied to two empirical cases and the window preparation and utilisation strategies are compared. The chosen cases, iron and steel production and low energy housing, share some similarities but also differ in important respects so that a comparative analysis is instructive. In both cases, the old technological paradigm is confronted with environmental problems and new promising technical solutions emerge. Hence, techno-economic windows are anticipated by at least some actors. Another similarity is that both cases are not "high tech", thus the pace of technical change is rather slow. The first case represents a technologically radical innovation of a capital-intensive process situated in a market with substantial entry barriers. Moreover, in this case supra-national dynamics and competition play an important role. The second case rather deals with a functional or system innovation of a capital-intensive product supplied by markets with low entry barriers. One implication is that in the first case time strategies before window realisation, i.e. window preparation strategies, are of paramount importance while in the second case appropriate window utilisation policies are the key challenge. The focus of the presentation is on old/new competition.

4.1 The case of iron and steel production

Steel production is one of the most energy and environment consuming industrial activities. Today two production routes based on different technologies dominate steel making. The still dominant *coke oven - blast furnace - basic oxygen furnace route* and the originally by and large complementary *scrap - electric arc furnace route*. The first route takes place in so-called integrated steel mills at a quite high production scale while the latter is typical for so-called minimills, which work on a much lower scale. In the last years the iron making stage as well as the stage subsequent to crude steel production have seen important invention and partly also innovation processes. An important example is smelting reduction technology (SRT), a technologically radical new process of iron making which skips the coke oven stage and substitutes for the blast furnace. SRT is one of the very important energy efficiency increasing process technologies in industry; it is expected to reduce specific energy consumption by more than 20 per cent and CO_2 emissions by 15% (and other emissions even to a higher degree) (Worrell et al. 1997). This is a typical case of competition between an *old* and a *new*, environmentally beneficial, technology. Luiten (2001) puts forward the hypothesis that SRT is locked-out from commercialisation in integrated steel mills by the dominance of the old blast furnace route of iron making (for a detailed analysis see Luiten 2001 and Nill 2003).

Theoretical alternatives to the conventional, very capital-intensive ironmaking stage such as directly reduced iron or smelting reduction technology have been already known since the 1950s, serious research efforts, however, only started in the middle of the 1970s. A main driver introducing dynamics into these R&D processes since the middle of the 1980s was the anticipation of a window of opportunity for innovation in the sense of market introduction due to the replacement necessity of obsolete coke ovens and blast furnaces in integrated steel mills (ISM). For example, in the Netherlands as well as in Japan, important replacement necessities of coke ovens or even blast furnaces (in Japan up to 40 per cent of the installed capacity) were anticipated for 2000 to 2005 (Hogan 1994, Moors 2000). SRT being a quite radical process change requiring large amount of process automatisation and training (Worrell et al. 1997), a long time horizon was important. In this research competition, globally ten different SRT trajectories were pursued by different networks (Luiten 2001). The technological preferences for a particular smelting reduction process were mainly related to earlier R&D experiences. At the end of the 1980s and the beginning of the 1990s relevant prototypes emerged and the construction of small pilot plants of several SRT types was the next step envisaged.

However, the dominant trajectory did not stand still. The existing capital stock was being continuously improved and upgraded and thus its lifetime extended so that the need to replace the existing coke ovens became less pressing. One impulse for this was environmental regulation. Moreover, the incremental innovation of direct pulverised coal injection in the blast furnace, combined with the increasing availability of coke imports, reduced the need for coke production (EC 2001, 319). And finally, cleaner coke ovens were developed. All in all, the cost advantages of SRT became smaller and smaller and some producers reinvested into the traditional route, thus losing interests in alternatives (Luiten 2001). As a consequence, the anticipated window did not materialize (yet).

One result was that only in the Netherlands and in Japan integrated producers seriously pursued possible market introduction and thus the anticipation of a techno-economic window stabilised. The technical processes being patented and published in the mid nineties, and pilot plants being put into place, now the step to a demonstration plant was on the agenda. Due to the investment scale, and costs as well as the risk involved, this step in effect proved to be already a very time critical stage, because it would be only taken if a serious success chance for market introduction were perceived. The Dutch example nicely illustrates this point: Including the pilot plant Hoogovens had invested up to this point 6.5 million US $ into SRT development (Moors 2000, 244). From 1996 on Hoogovens planned for its SRT technology a demonstration plant of industrial scale, i.e. 700.000 tons a year. The costs were estimated at 125 million US $, which is above the costs of an *isolated* replacement of a blast furnace which is reported to cost 100 Mio US $ (Hogan 1994, 186).

Finally, the techno-economic window did not materialise yet, although the Dutch government wanted to support the facility (see below). Due to the overall economic situation and other investment priorities, Hoogovens first postponed and two years later, in 1999, stopped the development (Moors 2000). Also in Japan a demonstration plant was not build up to now. Probably, market introduction of SRT in integrated mills will at least be postponed for five to ten years. In the meantime, there is a certain probability that SRT will be introduced in minimills, substituting hot iron for scrap in the electric arc furnace route. Some attempts are on the way, but it is not clear if the critical investment amount hurdle, which is beyond usual investment capacities of minimill producers, will be successfully taken. One first generation SRT, COREX, however, which is less promising from an environment perspective and of which the use is only possible in newly built steel mills, has successfully exploited a local niche and diffuses now in some emerging countries[4].

---

4 Seen on a global scale, this process contains also interesting aspects of new/new competition. For more details, which go beyond the scope of the present paper, see Nill (2003).

4.2 The case of housing

In Germany, conventional housings have been gradually improved towards a kind of low energy standard, now defined by the energy saving ordinance of 2002 (about 70-110 kwh per m^2a end energy for heating purposes). But in parallel, at the innovation frontier much larger steps are in sight. Technical concepts such as solar housing, zero heat energy housing or plus energy housing can be mentioned. But in particular passive housing emerged as a potential new paradigm, enabling much lower energy consumption for heating at a reasonable cost, while also some more incremental innovations were boosted (for more details see Haum and Nill 2004).

Technologically, a passive house is a system innovation or functional innovation, a combination of technologies which reduce the end energy use for heating purposes to less than 15 kwh per m^2a and hence make the omission of conventional heating systems feasible. To achieve this, a combination of strong thermal insulation, an utilisation of passive solar gains by solar-oriented windows and internal savings, a special type of three-layer windows and a ventilation system with heat recuperation which provides for the necessary rest of energy are used (Feist 1996). The innovation concept of passive housing was developed in the late 1980s in Swedish-German collaboration. The feasibility was shown on the basis of new computer simulation programmes. A prototype was constructed 1991 in Darmstadt-Kranichstein. The main actors were outsiders to the construction industry, and strongly motivated by environmental concerns. The main component innovations required were integrated planning approaches by architects and better insulated three-layer windows.

To a certain extent, passive housing can be described as a disruptive innovation (Christensen, 1997), because at least in the beginnings, the environmentally motivated lead users accepted a reduced product performance. Since 1995, some further passive houses were constructed and an innovation network of researchers, architects and small firms evolved who made a boost of component innovations of windows and integrated ventilation and heat recuperation systems. At the end of 1998, there have been some 120 passive house flats. In 1999 there was a first boost of the new trajectory. Policy reacted and supported the new solution (see below). The investment cost difference has been reduced to about 15 per cent. The number of houses increased markedly, the necessary window technology became commercially available and important technical problems had been solved. Expectations rose that there could be a techno-economic window for successful competition with conventional housing, mainly based on three pillars: cost reduction due to the omission of the conventional heating system, learning and scale effects in component development, and raising energy prices. A market analysis concluded that up to 2010 a market share of 11 to 23 per cent could be reached (Witt and Leuchtner 1999). Incumbent actors such as constructors of prefabricated houses and component suppliers began to react to the dynamics and to offer passive houses as part of their portfolio, while still perceiving the passive house as a niche. At the same time, they explored more incremental steps of optimising conventional low energy housing towards “three litre houses” (30 kwh per m^2a), keeping the conventional heating systems.

Until today, these dynamics have resulted in quality improvements and a rising market share. As of end of 2002, there were more than 2500 passive house accommodation units. The market share, however, is still well below one per cent of new housing. There have not yet been significant further cost reductions. The price of passive houses is still about 10 to 15 per cent higher than in conventional houses, and slightly higher than in three-litre houses (Schulze-Darup 2002). The cost saving potential is estimated at nearly 50 per cent for windows and about 30 per cent for ventilation and recuperation units. Recently, some policies that could be termed window utilising are visible, but their effects remain to be seen (see below).

4.3 The empirical role of subsidies in time strategies - window preparation

In the iron and steel case, governments were substantially involved in window preparation, though their activity alone was not sufficient for window emergence. Luiten (2001, 186) estimates that about 25-30 per cent of the total expenditure for SRT development, up to now between 600 and 700 million US $, was provided by governments. In most industrial countries general R&D efforts in the steel industry were supported by governments; in the European Community of Coal and Steel financed by a levy on steel prices. In the SRT case, it played a supplementary but sometimes rather substantial role. In the Netherlands, the European subsidies were at the beginning of the 1990s complemented with a covenant in the framework of the National Environmental Policy Plan. The base metal industry agreed to increase its energy efficiency between 1989 and 2000 by 20 per cent. In turn, no economic instruments such as an energy tax were considered. The political feasibility was no problem, because the political system was open and the techno-economic actors proactive. The efficiency increase, however, was feasible with incremental improvements. Concerning the impact of subsidies on innovation, Luiten (2001, 191) concludes that in most cases, the support led to additional research while its impact concerning an acceleration of the development is less clear.

In the middle of the 1990s, a very time critical stage of window preparation was reached, in which again subsidies played an important role. In 1997, the Dutch government announced the so-called CO_2 Reduction plan that involved substantial budgets. The integrated steel producer Hoogovens applied for government support of a demonstration facility. The latter awarded 30 million US $ which was about 25% of total expenditures. Hoogovens wanted to provide the same amount but failed to find another investor for the remaining 60 millions. Hoogovens, however, was not willing to invest more, given the rather high risk of the project. Thus in 1999, the firm formally announced a development stop (Luiten 2001, 196). That in fact the window preparation policies did not result in the commercialisation of the new technology did not lie in the hand of policy but seems to be a reasonable element of contingency, leaving market actors the last decision about the outcome of the competition.

There was no political window necessary, because the proposed policy, i.e. a subsidy scheme, was an established instrument and the Dutch political system is well known for its strategic capabilities (e.g. Nill et al. 2002, 23-31). And the expected effects were incremental because the change of technologies, even if radical in terms of processes, is not disruptive, but indeed competence enhancing for the main economic actor concerned. So there is not too much stickiness towards the old path and an adaptation to the new solution is feasible. Moreover, there were some, however not binding restrictions at the European level, i.e. the Coal and steel subsidy framework to avoid unfair competition. The intended subsidy had to be approved by the European Commission, which was done with the (questionable) argument that the demonstration project would be far from market commercialisation. In general, there is no example that an iron making demonstration plant failed due to lack of political support. Almost everywhere where a window preparation seemed promising, governments were ready to support the projects, even with substantial amounts of money.

In the case of low energy housing in Germany, regulation and subsidies are the dominant policy instruments. The innovative effects of regulatory policies are usually limited. This is particularly true for building regulation in Germany, where rather the opposite causal chain, i.e. from innovation with a large time lag to regulation, can be observed (Lehr 2000). The first commercial passive houses were sometimes supported at the State level. After the success of the first niche was visible, policy reacted by redirecting an existing premium loan programme for new private housings from low energy housing to passive housing, what can be called a window preparing policy. It supported more than 300 houses in 1999 and more than 500 houses in 2000 and thus supported stabilisation and expansion of the niche. In 2001 the performance standards have been changed from end energy to primary energy use, creating more favourable conditions for the integration of renewable energy heating systems. Since then, also the more incremental new option of three-litre housing is backed, albeit with less favourable interest rate conditions. It is worth mentioning that since 1999 in the framework of the so-called ecological tax reform also the tax on gas and heating oil has been raised to some extent. Expert interviews, however, accord more importance to the subsidies than the tax changes, what is in line with a recent survey of empirical studies (OECD 2003). In effects there were some elements of an unintended niche management present, mainly carried out by the administrative part of the political system, which was open to the innovation dynamics.

Hence in both cases, subsidies were in fact the main instrument for political window preparation strategies - as far as such strategies have been in place at all. In the iron and steel case, only in the Netherlands there was a kind of gradual transition strategy; this is not yet the case in low energy housing in Germany, albeit some first political attempts are observable.

4.4 The empirical role of subsidies in time strategies - window utilisation

In the case of new ironmaking technologies, in integrated steel mills in industrialised countries up to now no window utilisation occurred, the worsening economic dynamics working against reinvestment. However, one could argue that the Dutch climate protection programme contained already some element of de facto window utilisation, given the decisive role of a successful demonstration project. The use of subsidies as proper window utilisation instrument, however, is restricted by European state aid policies in the iron and steel sector. The planned European emission trading system is a chance to revive technological competition in this field - but only if it is appropriately designed and keeps an emission reduction incentive. In fact, by licensing initial emissions levels for free and not setting strict standards, it does not work as window preparing instrument in itself. Hence a so-called innovation reserve - a de facto subsidy which provides similar opportunities to newcomers - is indeed a necessary complement from a time strategic perspective.

In the case of low energy housing, in October 2002 the re-elected red-green German government stated the ambition to utilise the emerging techno-economic window and to create an incentive programme for 30.000 passive houses. Originally it was intended as capital subsidy, reflecting the well-established result that this constitutes a better incentive than a premium loan programme (OECD 2003). Due to budget constraints and administrative problems of creating a new scheme, it has been implemented only to a limited extent, by the way of changing the financial conditions of the premium loan scheme in May 2003. The incentive is now better than before, but with some State schemes being reduced at the same time and another capital subsidy being stopped, the effects remain to be seen.

What is observable is a clear effect of the subsidy offer also for less energy efficient houses, which were reintroduced following demands of construction industry. In 2002 more than 1500 approved houses of the less ambitious standard doubled the 700 accommodation units of passive house standard or equivalent technology. There may be a ratio to do so for environmental reasons, i.e. to achieve an old/new substitution, as long as it leads to additional well performing houses. From a time strategic perspective, however, it is a questionable window-utilising policy, because it may also lead to a replacement of more ambitious new solutions, and hence their dynamic economies are supposed to be lower.

A credible transition strategy is still missing - with regard to the strength of the impulse as well as to time limitations of the instruments. Moreover, in the decentralised housing market, the critical phase of competition is diffusion beyond a niche, and for this subsidies are a quite expensive instrument, while framework instruments like energy taxes would influence the old and new path at the same time. However, for the latter no political window can be discerned.

5. Conclusion

Time strategies are a promising way to conceptualise policies, which use techno-economic dynamics as leverage for a transition towards sustainability. They often combine a long-term framework with specific impulses. Within such a framework, also traditional instruments such as subsidies play a transformed but important role. Put differently, a time strategic policy framework may well explain why subsidies are still used a lot more in real life policies than advised by conventional theoretical considerations. They allow for the political support of first movers and are often easier to implement than other instruments. Nevertheless, the analysis pointed also to some limits of this instruments and highlights that they can only be successful as an element of a broader transition strategy or time-strategic framework.

A time strategic environmental innovation policy is demanding in terms of the abilities of political and administrative actors to manage dynamic processes. The set of abilities required include monitoring to identify possible techno-economic windows, evaluating technological potentials, balancing credible transition goals and a flexible time schedule, developing a proper design of instruments and a willingness to learn. Nevertheless, the empirical cases show at least that it seems to be possible not only for economic but also for political actors to discern techno-economic windows. Also political capabilities to react to these dynamics are observable, albeit considerable improvements can be envisaged. And if the hypothesis holds that it is almost impossible to have environmental policy without effect on technology choice in a path dependent world, the solution cannot be to refrain from political interventions but to more closely examine how to improve political capabilities for an environmental innovation policy as well as its time-strategic instrumentation.

6. References

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

Ashford, N., C. Ayers, R.F. Stone (1985): Using regulation to change the market for innovation. Harvard Environmental Law Review, Vol. 9, 419-466.

Christensen, C. (1997): The Innovator's dilemma: When New Technologies Cause Great Firms to Fail, Boston: Harvard Business School Press.

David, P.A. (1987): Some new standards for the economics of standardization in the information age. In: Dasgupta, P. and P. Stoneman (eds.): Economic policy and technological performance. Cambridge, 206-239.

Dosi, G. (1982): Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change. Research Policy, Vol. 11, 147-162.

EC - European Commission (2001): Integrated Pollution Prevention and Control (IPPC). Best Available Techniques Reference Document on the Production of Iron and Steel. Seville: IPTS.

Erdmann, G. (1993): Elemente einer evolutorischen Innovationstheorie. Tübingen: Mohr-Siebeck.

Erdmann, G. (2004): Innovation, Time and Sustainability. In: Hemmelskamp, J. and K.M. Weber (eds.): Towards environmental innovation systems. Heidelberg and New York: Physica (forthcoming).

Feist, W. (1996): Grundlagen der Gestaltung von Passivhäusern. Darmstadt: Verlag Das Beispiel.

Haum, R. and J. Nill (2004): Zeitstrategien ökologischer Innovationspolitik bei Wohngebäuden. Berlin: Institute for Ecological Economy Research.

Hogan, W.T. (1994): Steel in the 21th Century. Competition Forges a New World Order. New York et al: Lexington Books.

Jänicke, M., J. Blazejczak, D. Edler and J. Hemmelskamp (2000): Environmental Policy and Innovation: an International Comparison of Policy Frameworks and Innovation Effects. In: Hemmelskamp, J., K. Rennings and F. Leone (eds.): Innovation-oriented Environmental Regulation. Theoretical Approaches and Empirical Analysis, Heidelberg: Physica, 125-152.

Kemp, R. (2000): Technology and Environmental Policy: Innovation Effects of Past Policies and Suggestions for Improvement. In: OECD (ed.): Innovation and the Environment, Paris: OECD, 35-61.

Kemp, R. and J. Rotmans (2004): The Management of the Co-Evolution of Technical, Environmental and Social Systems. In: Hemmelskamp, J. and K.M. Weber (eds.): Towards environmental innovation systems. Heidelberg and New York: Physica (forthcoming).

Kemp, R., J. Schot and R. Hoogma (1998): Regime Shifts to Sustainability through Processes of Niche Formation: The Approach of Strategic Niche Management. Technology Analysis & Strategic Management 10 (2), 175-195.

Klemmer, P., U. Lehr and K. Löbbe (1999): Environmental Innovation. Incentives and Barriers. Berlin: Analytica.

Lehr, U. (2000): The Example of the Thermal Insulation in Germany. In: Hemmelskamp, J., K. Rennings and F. Leone (eds.): Innovation-oriented Environmental Regulation, Heidelberg and New York: Physica, 221-233.

Linscheidt, B. (ed., 2000): Umweltinnovationen durch Abgaben. Die Wirkung von Preisimpulsen im institutionellen Handlungsrahmen privater und öffentlicher Akteure. Berlin: Analytica.

Luiten, E. (2001): Beyond Energy Efficiency. Actors, networks and government intervention in the development of industrial process technologies. Utrecht: Universiteit Utrecht.

Milliman, R.S. and R. Prince (1989): Firm incentives to promote technological change in pollution control. Journal of Environmental Economics and Management, 17, 245-265.

Moors, E.H.M. (2000): Metal Making in Motion. Technology Choices for Sustainable Metals Production. Delft: Delft University Press.

Nill, J. (2002): Wann benötigt Umwelt(innovations)politik politische Zeitfenster? Zur Fruchtbarkeit und Anwendbarkeit von Kingdons "policy window"-Konzept. Discussion Paper No. 54/02 of the Institute for Ecological Economy Research, Berlin.

Nill, J. (2003): Technological Competition, Time, and Windows of Opportunity – the Case of Iron and Steel Production Technologies. Discussion Paper No. 58/03 of the Institute for Ecological Economy Research, Berlin.

Nill, J. (2004): Ökologische Innovationspolitik aus evolutorischer Perspektive. Discussion Paper Series of the Department of Economics of Kassel University, Kassel.

Nill, J., I. Einacker, T. Korbun, R. Nordbeck and A. Peine (2002): Nachhaltigkeitsstrategien. Publication Series No. 158/01 of the Institute for Ecological Economy Research, Berlin.

Nill, J. and S. Zundel (2002): Die Rolle von Vielfalt für Zeitstrategien ökologischer Innovationspolitik. In: Spehl, H. and M. Held (eds.): Vom Wert der Vielfalt. Diversität in Ökonomie und Ökologie, ZAU special issue No. 13/2001, Berlin: Analytica, 148-157.

OECD - Organisation for Economic Co-operation and Development (2003): Environmentally Sustainable Buildings: Challenges and Policies, Paris: OECD.

Reichel, M. (1998): Markteinführung von erneuerbaren Energien. Lock-out-Effekte und innovationspolitische Konsequenzen für die elektrische Wind- und Solarenergienutzung. Wiesbaden: Deutscher Universitätsverlag.

Schulze-Darup, B. (2002): Energieeffiziente Wohngebäude: Einfamilienhäuser mit Zukunft, Köln: TÜV-Verlag.

Witt, J. and J. Leuchtner (1999): Passivhäuser: Nischenprodukt oder Zukunftsmarkt? Eine Marktpotentialstudie. In: Tagungsband 3. Passivhaus-Tagung, Darmstadt: Passive House Institute.

Worrell, E., J.-W. Bode, J. de Beer (1997): Energy Efficient Technologies in Industry. The ATLAS Project. Department of Science, Technology & Society, Utrecht University, Report No. 97001.

Zundel, S., G. Erdmann, J. Nill, C. Sartorius and D. Weiner (2003): Innovation, Zeit und Nachhaltigkeit - Zeitstrategien ökologischer Innovationspolitik – der Forschungsansatz. In: Horbach, J., J. Huber and T. Schulz (eds.): Nachhaltigkeit und Innovation. Rahmenbedingungen für Umweltinnovationen. München: oekom, 55-88.

Zundel, S., G. Erdmann, R. Kemp, J. Nill and C. Sartorius (2004): Towards a New Model of Ecological Innovation Policy. In: Zundel, S. and C. Sartorius (eds.): Time Strategies for Innovation Policy towards Sustainability. Cheltenham: Edward Elgar (forthcoming).