The IPTS REPORT

July/97

ISSN 1025-9384

EDITED BY THE INSTITUTE FOR PROSPECTIVE TECHNOLOGICAL STUDIES (IPTS)
AND ISSUED IN COOPERATION WITH THE EUROPEAN S&T OBSERVATORY NETWORK

EUROPEAN COMMISSION
Joint Research Centre

ABOUT THE IPTS REPORT

The IPTS Report was launched in December 1995, on the request and under the auspices of Commissioner Cresson What seemed like a daunting challenge in late 1995, now appears in retrospect as a crucial galvaniser of the IPTS' energies and skills

The Report has published articles in numerous areas, maintaining a rough balance between them, and exploiting interdisciplinarity as far as possible Articles are deemed prospectively relevant if they attempt to explore issues not yet on the policymaker agenda (but projected to be there sooner or later), or underappreciated aspects of issues already on the policymaker's agenda The long drafting and redrafting process, based on a series of interactive consultations with outside experts guarantees, quality control.

The first, and possibly most significant indicator, of success is that the Report is being read The issue 00 (December 1995) had a print run of 2000 copies, in what seemed an optimistic projection at the time. Since then, its circulation has been boosted to 7000 copies Requests for subscriptions have come not only from various parts of Europe but also from the US, Japan, Australia, Latin America, N Africa, etc

The laurels the publication is reaping are rendering it attractive for authors from outside the Commission. We have already published contributions by authors from such renowned institutions as the Dutch TNO, the German VDI, the Italian ENEAand the US Council of Strategic and International Studies.

Moreover, the IPTS formally collaborates on the production of the IPTS Report with a group of prestigious European institutions, with whom the IPTS has formed the European Science and Technology Observatory (ESTO), an important part of the remit of the IPTS. The IPTS Report is the most visible manifestation of this collaboration.

The Report is produced simultaneously in four languages (English, French, German and Spanish) by the IPTS; to these one could add the Italian translation volunteered by ENEA: yet another sign of the Report's increasing visibility. The fact that it is not only available in several languages, but also largely prepared and produced on the Internet World Wide Web, makes it quite an uncommon undertaking

We shall continue to endeavour to find the best way of fulfilling the expectations of our quite diverse readership, avoiding oversimplification, as well as encyclopaedic reviews and the inaccessibility of academic journals The key is to remind ourselves, as well as the readers, that we cannot be all things to all people, that it is important to carve our niche and continue optimally exploring and exploiting it, hoping to illuminate topics under a new, revealing light for the benefit of the readers, in order to prepare them for managing the challenges ahead

Preface

The adaptation of the system of production to changes in society and economic and environmental constraints demands, among other things, that research able to bring about new know-how, products, procedures and services, be developed. In this spirit, the Commission has set up a series of multidisciplinary task-forces with the following aims: defining research priorities in close consultation with the socio-economic actors concerned; strengthening coordination between European, national and private research activities and stimulation of an environment favourable to innovation.

The "Environment - Water" task-force, created along these lines, has undertaken a lengthy consultation with Commission services and the various European actors concerned, such as businesses and other water treatment and distribution utilities, public and private research centres, user sectors at regional and national level, etc. The results of these consultations and analysis, which have been carried out in parallel, have served both to take a fresh look at actions currently in progress and to develop an action plan for European research into water for the years ahead.

The research activities covered by the Fourth Framework Programme have also been reviewed, with the aim of promoting synergies between the scientific, economic and technological domains concerned. The dialogue established between the programme coordinators and other Commission services has underlined the importance of supporting other European water-related policies (for example, agriculture, regional development and international cooperation) in achieving their goals. It has also served to clarify the socio-economic, institutional and political context in which research results should be appraised.

The action plan set out by my services at the start of the current year was presented and discussed during a 'validation' seminar on 19-21 June last year in Baveno (Italy) to which the main participants in the consultation process, other domain *experts, as well as those European organizations usually consulted concerning the direction given to European research, were all invited to attend. This action plan deals with the surveillance and evaluation of the state and development of European fresh-water resources, prevention and treatment of pollution, the fight against chronic shortages in certain regions, water savings which can be achieved in agriculture and industry, and in particular the development of financial and institutional instruments aimed at achieving more rational management of this precious resource. The field covered takes in the completed basic research, industrial and pre-standardization research, the development of measurement systems and decision support tools, technological and management innovations, together with the dissemination of knowledge and know-how. The field is wide, but actions for priority support along various axes have been defined with precision so as best to achieve a concentration of European research activities and so better meet the expectations of citizens and socio-economic actors in terms of use value of the investigation for their activities.*

This action plan, fruit of more than a year of analysis and consultation, is a highly valuable contribution to the detailed definition of the content of the "key action" for the management and quality of water put forward by the Commission for the Fifth Framework Programme. The discussions have got the new framework programme off to a good start and they will continue over the coming months, taking into account in particular the more detailed definition of the key actions, which will be a totally new feature for European research mechanisms.

THE IPTS REPORT
16
JULY 1997

EDITED BY THE INSTITUTE FOR PROSPECTIVE TECHNOLOGICAL STUDIES (IPTS)
And issued in Cooperation with the European S&T Observatory Network

PUBLISHED BY THE EUROPEAN COMMISSION
Joint Research Centre

ISSN: 1025-9384
Catalogue Number: GK-AA-97-006-EN-C

DEPOT LEGAL: SE-1937-95

THE IPTS REPORT
is published in the first week of every month, except for the months of January and August. It is edited in English and is currently available free of charge, in four languages: English, French, German and Spanish.

SUBSCRIPTIONS
For a free subscription to The IPTS Report, or to amend an existing subscription, please write with full details to:

The IPTS Report Secretariat
IPTS, JRC Sevilla
World Trade Center
Isla de la Cartuja
E-41092 Sevilla, Spain
Tel +34-5-44 88 284
Fax· +34-5-44 88 235
E-mail: ipts_secr@jrc.es
Web address. www.jrc.es/iptsreport/subscribe.html

CONTENTS

EDITORIAL

The first article in this issue examines the potential of biotechnology in providing cleaner production technologies in the pulp and paper industry. It suggests that the adoption/promotion of very promising technologies is hampered by both the existing technological regime (the set of established practices, expectations and design principles guiding technological choices), as well as the characteristics of competition in the sector (price-based competition, little value added mature industry). Moreover regulation, if not carefully implemented, may lock-in certain technological trajectories and lock-out others (such as biotechnologies), even if the latter hold promise for better environmental performance in the future.

The second article has as its starting point the agreement of March 1997 reached by EU Ministers of the Environment for a 15% reduction of greenhouse gas emissions by the year 2010, compared to 1990 emission levels. In the longer term, even greater reductions are considered necessary by scientists. Given these exigencies and the difficulty countries have been having in meeting the self-imposed targets of the Montreal protocol, this article suggests that all avenues should be explored, including reduction of energy intensity, acceleration of use of renewable energy sources, as well the potential of carbon dioxide removal (CDR), especially in light of very recent 1996-97 large-scale efforts in CDR (Indonesia, Norway). Clearly, the application of CDR is meaningful only within the framework of programmes promoting and not hindering the effective reduction of CO_2 emissions.

The next article highlights the potential of the cluster approach in the context of knowledge intensive innovation. The cluster approach emphasizes the existing strengths in an economy and the importance of interconnections between different economic activities and forms of knowledge. In terms of policy, setting up new clusters from scratch is rife with pitfalls. The emphasis would best be placed on intensifying the use of knowledge in existing clusters, and on creating/facilitating new networks of constructive co-operation in clusters.

The fourth article examines the challenges and opportunities presented by distance learning and the information technologies that are making this possible. The potential as well as the risks implicit in projected developments are highlighted. The article suggests that the new technologies cannot be introduced as an appendix to the existing educational system/process, rather that new didactic approaches and methodologies should be developed, in which these technologies will be embedded.

The final article tackles standardization issues and their environmental dimension. Based on a report commissioned by the German Parliament, it suggests that although the "deregulation" of standard setting in the EU in recent years has had positive repercussions in terms of promoting the establishment of the single European market, its potential for promoting the achievement of environmental goals has not been explored.

Biotechnology

Biotechnology as a Cleaner Production Technology in Pulp and Paper

Chris Tils and Per Sørup

Issue: The uptake of biotechnology is not only of importance in the pulp and paper sector. In general, biotechnology offers process-integrated routes for enhancing industrial environmental performance. Conventional physical, chemical or thermal processes can often employ the use of high temperatures, extreme pH and organic solvents. Biotechnological processes, i.e. biocatalysts, generally work under mild circumstances, are highly selective and use little additional chemicals. So far, this promising potential seems to have been undervalued and the pulp-and-paper sector may be a case in point.

Relevance: Several biotechnologies are emerging or are already available, which can be used for environmental purposes, for example in the pulp and paper sector. The introduction of advanced biotechnology in this sector poses specific problems because of existing technological regimes and other specific sector characteristics. Moreover, regulation could lock new technological developments out of the market, including biotechnological ones.

In this article, we show that biotechnology can play a role in the greening of industry, using the pulp and paper industry as a case-study. Moreover, we discuss barriers and mechanisms which can influence the uptake of biotechnology in this sector. Why is it important to do so? One of the promises of biotechnology was that it could make industrial production clean in an integrated way. Although biotechnology is still believed to be able to play a role in greening, few 'clean' biotechnological processes are actually in use. By studying the causes of this situation, we can learn why promising, cleaner biotechnological options are not adopted. Moreover, we can draw policy-oriented lessons.

To arrive at these lessons, we take the paper production technology as the starting point of our analysis. We describe how and where biotechnologies can have an impact on the production process. Next we analyse which barriers and mechanisms influence the uptake of these technologies. We demonstrate that the likelihood that technology is adopted depends on the way a biotechnology impacts on the current production process. We end the article by sketching policy implications.

Biotechnologies for cleaner paper production

Biotechnologies can tackle environmental pollution of the paper production process in several ways, ranging from end-of-pipe clean-up of effluents to more integrated environmental solutions. We selected four examples from ongoing developments in biotechnology. The point where

Although biotechnology is believed to be able to play a role in the greening of industry, there are relatively few 'clean' biotechnological processes in use

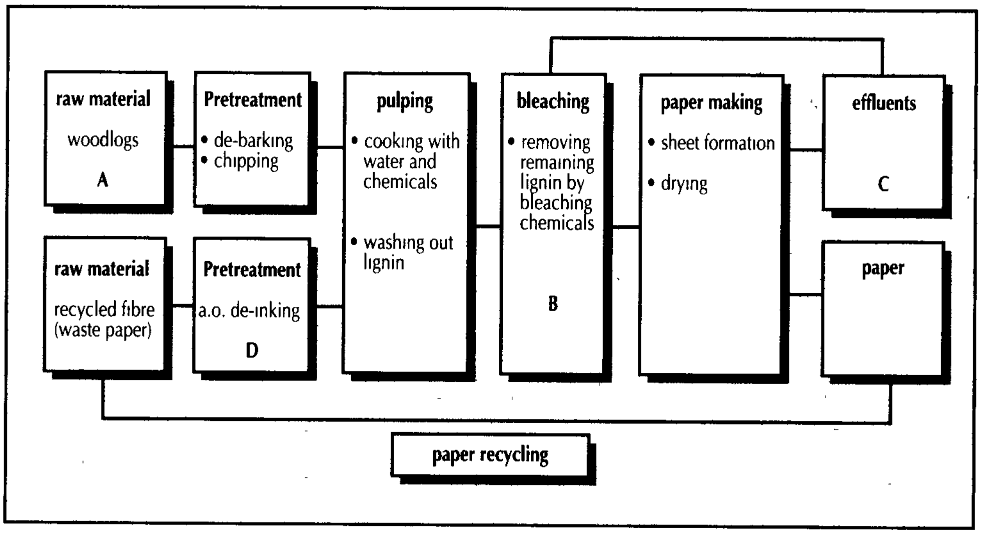
The probability of biotechnology being adopted in an industry is dependent on the impact it has on current production processes the selected technologies impact in the paper production process is indicated in Figure 1, which gives an overview of the production process.

The first emerging technology is related to trees, the most important raw material for paper production. An attempt is made to change their chemical structure by genetic engineering (Figure 1: A). More precisely, research is aimed at structural modifications of lignin, the environmentally pernicious component of wood. The role of the genetic engineering of trees could develop into providing the pulp industry with 'tailor-made fibres'. Genetically modified trees are an example of an integrated technology: by substituting the current raw material, the overall process becomes less polluting. The introduction of tailor-made fibres as raw material offers the possibility of simplifying the current process, possibly by eliminating certain parts of it.

Emerging technologies, such as the genetic engineering of trees, 'bleach boosting', and the de-inking of waste paper by enzymes all offer alternative, greener processes

Biotechnology is becoming established in the bleaching process by 'bleach boosting', an enzymatic pre-treatment (Figure 1: B). By adding enzymes, the structure of wood becomes more accessible for bleaching chemicals and in this way, can significantly reduce the requirements for chlorine or other bleaching chemicals. Enzyme producers expect that in the future, enzymes may be able to replace bleaching chemicals completely. Bleach boosting is an integrated technology, because it reduces the input of bleaching chemicals. An interesting point here is that this integrated technology has very much of an add-on character and incremental features. The core process is not changed; enzymes are (almost literally!) an addition to the current process. This goes against the general notion that integrated, clean technology demands radical innovation, while end-of pipe technology is incremental and add-on. The third biotechnology is the **purification of waste waters** (Figure 1: C) which is applied. The treatment of bleach waste water effluents is a typical example of add-on, end-of-pipe technology. The actual production process of paper is not changed. An extra step is added to the overall process to clean up resulting effluents. Fourth, in the future, biotechnology is expected to play a role in **de-inking of waste paper** by using enzymes (Figure 1: D). One of the necessary pre-treatments for using waste paper as a raw material, is to remove ink from it. De-inking

Figure 1. The pulp and paper process



Paper is made from a pulp of cellulose fibres Wood and recycled paper are the most important sources of these fibres The main purpose of the pulp and paper process is to separate the right (cellulose) fibres, from the unwanted material (such as lignin, which makes paper brown) Pulp and paper production is a highly complex process The figure is a heavily simplified representation processes are major energy consumers and use chemicals. Currently, de-inking involves pulping the paper in highly alkaline solutions. Enzymes, such as cellulases or lipases, will offer an alternative treatment in the future. This alternative does not involve any major changes in the core process of paper making.

The question remains why it is so important to know how the described biotechnologies impact the current paper production process. One could simply argue that the technologies that have environmental benefits just have to be developed and implemented. However, in the coming sections we demonstrate that a number of factors could influence the development of biotechnology in the pulp and paper industry. Moreover we show that the likelihood of biotechnology being implemented depends on the way it impacts the current production process.

Technological regimes and the adoption of biotechnology

The way firms choose their technology depends very much on what the 'technicians' of the firm believe is feasible. In the pulp and paper sector also, technicians tend to have a set of basic design principles which guide technological choices. We call this phenomenon a 'technological regime'. A technological regime can lead to a kind of blindness to alternative technological solutions, making it very difficult for those alternatives to enter the technological arena. In the case of the pulp and paper industry, the technologies used have a long history. The foundations of modern paper-making are based on technologies stemming from the end of the 19th and the first half of the 20th century. Of course, innovation is still taking place, but the basic process (pulping bleaching paper-making) is still the same. Furthermore the technological regime of the paper production process has not changed much. It is based on the fact that wood consists of wanted fibres (cellulose) and unwanted material (i.e. lignin). The process design is aimed at separating the wanted and unwanted materials, thus solving the problems which unwanted materials like lignin entail and do this as effectively as possible.

What could this general notion of technological regimes mean for the uptake of the described biotechnologies? The idea that **genetically modified trees** can provide a source of 'tailor-made fibre' does not necessarily fit into the current technological regime. There are two differences. First, the very aim of developing tailor-made fibres is different: the aim is (eventually) to design fibres which avoid the problems caused by unwanted materials (like lignin) to date. Second, the expectation that this can lead to simpler processes also goes against the trend in pulp and paper making, which is adding increasing process steps for improving the process. Bearing these two differences in mind, one could even imagine that a new technological regime could emerge out of this development, although this is highly speculative. It is much more likely that the new raw material is used as an incremental innovation: simply by adding small quantities of it, the overall features of the raw material feed is improved.

On the other hand, **bleach boosting, purification of waste bleach waters and de-inking of waste paper by enzymes** seem to fit into the current regime of paper making. Bleach boosting improves the performance (in terms of cost and environment) of current bleaching processes by adding a small step to the current process. The fact that it is already becoming established underlines its compatibility with current practice. Purification of waste water also fits into the current paper making regime, because it leaves the current production process unchanged. The same goes for using enzymes for de-inking waste paper.

Technological regimes, or the basic and often long-established set of design principles governing technological choices in an industry, can create resistance to alternative solutions

Additional necessary investments in environmental technology may be unpopular in industries with strong price-based competition

Investments in environmental technology are mostly made in incremental, add-on innovations, as opposed to ones with more far-reaching implications which could lead to the redesign of processes

Sector characteristics and the adoption of biotechnology

Apart from technological regimes, specific characteristics of the pulp and paper sector also influence the adoption of biotechnology. Knowledge of how biotechnology pervades mature sectors, such as pulp and paper, is largely absent. However, we can suggest certain factors which influence, positively or negatively, the uptake of biotechnology.

First of all, the fact that the pulp and paper sector uses a biological raw material is an advantage for the development of biotechnological options in the sector. Biological, organic raw materials are suitable for biological conversions. On the other hand, working with a natural material also can raise a barrier: the natural heterogeneity of wood makes it difficult to use scientific methodologies to solve technological problems. The natural variation in physical characteristics of wood complicates the creation and diffusion of generally applicable or even codified knowledge. How this relates to biotechnology, which is strongly science-based, remains an open question. However, it's interesting to note that the possibility of genetically modified trees also opens up possibilities of a more uniform raw material.

Another factor is the economics of the sector. In literature on environmental innovation, it is often assumed that pollution prevention provides economic benefits by savings on, for example, energy and materials. However, in the pulp and paper sector, this is not automatically the case. Competition in the sector is based on price and economies of scale and the added value of products generally is low. This leads to a situation where additional necessary investments in environmental technology can simply entail extra costs. Thus, it is extremely important whether there are any economic benefits to be expected from new technologies. What does this mean for the described biotechnologies? Technologies like bleach boosting and enzymatic de-inking can provide an economic plus. In the case of bleach boosting, there are savings on the input of bleaching chemicals, and in the case of de-inking possibly on chemicals and energy. In the case of genetically modified trees it is much harder to speculate on the economic side of the technology, because it might on the one hand cause process simplifications, possibly leading to lower costs. On the other hand it might raise the costs of the raw material, which presently constitute 45-65% of the final price of pulp and paper.

The specific innovation pattern of the pulp and paper sector (see Box 1) can also influence the way biotechnology can be adopted. Investments in environmental technology are mostly made in incremental, add-on solutions. This leads to an increasing complexity of the production system and it is widely acknowledged that this will lead to greater difficulties for implementing radical, integrated environmental innovation. This means that incremental, add-on innovations, such as bleach boosting, are more likely to be adopted than the ones with potentially more far-reaching implications, like massive use of genetically modified trees as a new raw material which could lead to the redesign of processes. The supplier dominance which plays an important role for chemistry also sheds a light on possible adoption processes of biotechnology in the sector. The way in which the chemical sector takes up biotechnology could become a factor in the adoption process, unless biotechnology firms become an important source of innovation for the sector.

Environmental policy and the adoption of biotechnology

Besides technological regimes and sector characteristics, regulation can also be decisive in the innovative and technological developments of

Box 1. Innovation in the pulp and paper sector

The pulp and paper industry is a large-scale, capital intensive industry with competition on price, a low research intensity, a mature manufacturing technology and economies of scale. In the innovation literature, it is stressed that innovation in industries with these characteristics is largely an incremental process. Another feature of innovation in the pulp and paper sector is that technological inputs originate mainly from outside the industry. Successful firms see suppliers of materials and equipment as the most important **sources of innovation**. Since chemistry is one of the major constituents of paper-making technology, it is widely recognised that significant contributions to paper product development in the future will come from the chemical side of paper making.

Recently, environmental concerns have become one of the most important **drivers of innovation** in the sector. Bleaching is conceived as the process with the most environmental impact. The trend in current technological developments in the bleaching process is away from elemental chlorine bleaching in the direction of total chrine-free bleaching and ozone and peroxide bleaching. Another important environmental issue is the still increasing role of recycled paper. Recycling can serve as a trigger for innovation, because several types of technology are needed to make recycling less energy-consumptive and more cost-effective.

a sector. One of the basic rules for innovation-friendly regulation, is to focus on environmental performance, not on technologies. Regulation which focuses on specific technologies may discourage innovation. An important question is how technological choices in the pulp and paper sector are influenced by European environmental regulation, the most important being the EU packaging directive (60% of paper production goes to packaging) and the directive on Integrated Pollution Prevention and Control (IPPC).

The packaging directive requires that between 25% and 45% by weight of the packaging materials contained in packaging waste will be recycled. This is a typical example of regulation which focuses on environmental performance. It is clear that these requirements give a direct stimulus to innovation in paper recycling technology. After all, they guarantee a market potential for new recycling technology. The fact that enzymatic de-inking technology is developed will probably also be influenced by this mechanism. It is clear that the environment will benefit from these innovations. But there is also another side of the coin. Recent Life Cycle Analysis in the field of the pulp and paper industry revealed that recycling today is beneficial to our environment but that this might not be the case in the future. It might well be possible to improve the paper production process to the point where its environmental burden becomes less than that of recycling. And improving the environmental performance of the process is exactly where biotechnology can contribute. Recycling might even become a barrier to entrance to new (bio)technologies that are aimed at improving the primary production, because the guaranteed recycling market gives recycling technology a competitive advantage.

The IPPC directive requires the application of Best Available Technologies (BAT) for industrial installations with the purpose of integrated pollution control. BATs have to be proven, meaning presently applicable under

Environmental regulation may discourage innovation if it is not sufficiently flexible and forward-looking

The setting of BAT standards must be careful in order to avoid a lock-in effect on technology

Policy can stimulate radical change for 'mature' industry by setting technical requirements or performance standards

industrial conditions. Currently, a document on standards for BATs is under preparation for the pulp and paper sector. How can this regulation impact innovation in the sector and the uptake of biotechnologies? Firstly, we should note that the first aim of the IPPC directive is to protect the environment, not so much to innovate. That also becomes clear from the fact that the standards are based on proven technologies. However, it should be noted that the BAT is changing with time in the light of technical advances. Competent authorities must monitor or be informed of such progress.

The directive will certainly cause technological change in the sector. More precisely, technological followers will upgrade their technology to the level of the leaders. It is obvious the environment will benefit from this. However, this boost for the more massive diffusion of **proven** technology does not mean necessarily that **new** technology is developed and exactly this point causes debate. On the one hand, the upgrading process can lead to an extra stimulus to the technological leaders to invest in even further-reaching innovations than their competitors. On the other hand, the setting of BAT standards must be careful in order to avoid a **lock-in** effect on technology. Capital equipment in the sector has as lifetime of ten-twenty years. From this point of view, investments made in a technology today can not be made in developing new even better technologies for the future. So investments of today could lock in the technologies for the future to come.

How does the BAT concept relate to the described biotechnologies? Established technologies such as bleach boosting can become a part of a BAT. This will provide a stimulus to their further uptake. A totally different situation goes for a development like genetically modified trees. This technology can provide a new **raw material,** while the IPPC directive is more oriented to industrial processes. The BAT selection and updating process must avoid these pitfalls to avoid limiting innovation.

Policy implications

The first question logically arising from the described barriers and mechanisms is: If there are so many barriers to introducing these technologies in the mature pulp and paper sector, is it then worth investing (environmental) policy efforts into trying to do so? The innovation literature provides a direction for an answer. It suggests that policy can provide a stimulus towards 'de-maturity' of a sector, for example, by setting technical requirements or demand performance standards that favour radical change. In this way, (environmental) policy can stimulate developments towards more investments in innovation. So there is a good case for using environmental policy to provoke innovation in the sector.

What form should such policy take? It should on the one hand, of course, make the sector more environmentally friendly and on the other, not 'block' interesting innovations. This article demonstrated that recent environmental legislation has positive effects on the environment and also impacts on future technological developments. However the effects of regulation on innovation are sometimes uncertain and under debate.

This still leaves us with the general question of how to stimulate the overall innovation of a sector, above the level of compliance with environmental regulation. The probable answer should be found in integrating innovation in environmental policy. The approach followed in this article provides us with a suggestion as to how to do so, as we explain below.

The starting point of our analysis is the production technology of a specific sector and the way new emerging and available technologies impact on it. This choice provides us with a detailed insight to how different technological developments are subject to regulations and other mechanisms that influence the uptake of the technology. Two examples: the bleach boosting technology matches the technological regime, can provide a cost advantage, and can in principle be stimulated by BAT standards. Genetically modified trees do not necessarily match the current technological regime, the economic effects are unclear, and they may or may not be subject to the BAT standard. This detailed, **sector-specific** information can thus provide insight into the innovation effects of regulation. Using this insight in the process of designing environmental regulation is a prerequisite for strengthening the beneficial effect of environmental policy on innovation, also for greening purposes of biotechnology.

Keywords
biotechnology, environment, policy, innovation, pulp and paper industry

References

- Abernathy, W. and Clark, K. *Innovation: Mapping the Winds of Creative Destruction.* Research Policy, vol.14, no.1, 1985.
- Auttio, E., Dietrichs, E., Führer, K. and Smith, K. *Innovation activities in Pulp, Paper and Paper products in Europe.* Draft Report to the European Commission, DGXIII, Innovation Programme. EIMS project 94/112. Luxembourg, 1997.
- CEPI - Confederation of European Paper Industries. *Annual Statistics,* 1995.
- Eriksson, K. *Biotechnology: three approaches to reduce the environmental impact of the pulp and paper industry.* Sci. Progress Oxford, p.175-189, 1991.
- European Commission. *IPPC directive.* Directive 96/61/EG, 1996.
- European Commission *Packaging Directive.* Directive 94/62/EC, 1994.
- HMIP. *The making of paper pulp by chemical methods.* London, HMSO, 1995.
- Kemp, R. *Technology and the transition to environmental stability: The problem of technological regime shifts.* Futures, Vol.26, nr.10, p.1023-1046, 1994.
- Landis Gabel, H., Weaver, P.M., Bloemhof-Ruwaard, J., and Van Wassenhove, L. *Life Cycle Analysis and the policy options: the case of the European Pulp and Paper Industry.* Business Strategy and the Environment. Vol.5, p.156-167, 1996.
- Norberg-Bohm, V. and Rossi, M. *The power of incrementalism: Environmentally induced technological change in pulp and paper bleaching in the US.* Paper presented at the Greening of Industry Conference, Heidelberg Germany, 1996.
- Novo Nordisk. http://www.novo.dk/
- Porter, M. and Van der Linde, K. *Green and competitive: Ending the stalemate.* Welford and Starkey. Business and the Environment. Earthscan, London, 1996.
- Rosenberg, J. *Exploring the black box: technology, economics, and history.* Cambridge University Press, 1994.

- Utterback, J. *Mastering the Dynamics of Innovation: How companies can seize opportunities in the face of technological change.* Harvard Business School Press, Boston, 1994.
- Viikari, L. *Use of biotechnology in the pulp and paper industry.* Comett course. VTT Biotechnology and Food Research, Finland, 1994.

About the authors

Chris Tils is a Senior Researcher Fellow at the IPTS. He is responsible for the activities involved in the IPTS project 'Modern Biotechnology and the Greening of Industry', which forms part of the Institute's activities in environmental issues. A food engineer by training, he worked for the Rathenau Institute, the Dutch office of Technology Assessment, in the fields of biotechnology and health care His main research interest is the relation between policy and environmental innovation.

Per Sørup is a Principal Scientific Officer at the IPTS He is responsible for the Institute's environmental activities From 1990-1993, he was responsible for the Socio-Economic Environmental Research programme of DGXII. He holds a Masters degree in chemistry and a Ph.D. in biochemical immunology from the University of Copenhagen His main areas of interest include the greening of industry, innovation and foresight.

Acknowledgements

Jaakko Pöyry Oy

Leena Paavilainen, Vice President R&D Fibre Technology

VTT, Finland

Liisa Viikari, Research Professor Biotechnology

METLA, Finland

Elena Kopylova, Research Co-ordinator "World Forests, Society and Environment"

IPTS, Spain

Petra Hedström, Chris Hendriks, Stephane Isoard, Don Litten, Ineke Malsch

Contacts

Chris Tils, IPTS,

tel: +34 5 44 88 229, fax: + 34 5 44 88 279, e-mail: chris.tils@jrc.es

Per Sørup, IPTS

tel: +34 5 44 88 320, fax: + 34 5 44 88 235, e-mail: per.sorup@jrc.es

Towards Meeting CO_2 Emission Targets: The Role of Carbon Dioxide Removal

C. A. Hendricks and W.C. Turkenburg

Issue: Some industrial sectors have already taken the initiative and begun implementing carbon dioxide removal technologies. Since September 1996, oil companies in Norway have been injecting recovered carbon dioxide into an aquifer. In Indonesia, there are plans to inject carbon dioxide into deep aquifers. The total amount projected to be injected approaches one year of carbon dioxide emissions of the EU.

Relevance: While the relation between high emission rates of greenhouse gases and the risk of a climatic change becomes more and more evident, the global anthropogenic emissions of greenhouse gases rise further. To abate the risk of a climatic change sufficiently, it has been recommended that the emission of carbon dioxide, the main greenhouse gas, should at least be halved by the end of the next century. This requires the development and implementation of a sustainable energy system. In this context, technologies to recover and store carbon dioxide could be explored.

Introduction

One of the main environmental challenges today is the avoidance of (a possible) anthropogenically-induced climate change causing severe damage to human health and welfare, and to ecosystems. According to the Intergovernmental Panel on Climate Change (IPCC), a scientific panel established by the United Nations Environmental Programme and the World Meteorological Organisation, the conviction of a relation of increased atmospheric greenhouse gas concentrations and the risk of a climate change is growing. In July 1996, Ministers attending the second Conference of Parties in Geneva affirmed the scientific basis for action on climatic change and stressed the need to accelerate talks on how to strengthen the United Nations Convention on Climate Change.

As a result of this ongoing awareness, an agreement was reached in March 1997 at a meeting of the Ministers of the Environment of the EU on a 15% reduction of greenhouse gas emissions by the year 2010 with reference to the 1990 level. The proposed reduction objective will be subject to agreement during the third Conference of Parties in Kyoto in December 1997. In this meeting, a protocol or other legal instrument should be adopted containing stronger commitments by developed countries to the abatement of greenhouse gas emissions for the post-2000 period.

To achieve a situation that prevents dangerous anthropogenic interference with the atmosphere, it has been recommended that before the year 2100, the concentration of carbon dioxide, the main greenhouse gas in the

Increased awareness of the threats of anthropogenically-induced climatic changes is leading to calls for the reduction of greenhouse emissions atmosphere, should be stabilized at a level below 500 ppm (parts per million), but preferably below 450 ppm. To achieve stabilization at 450 ppm, the global emission of carbon dioxide should be reduced from the current level of 6 GtC (Gigatonnes) per year, to a level below 3 GtC per year by the end of the next century. Moreover, cumulative emissions should be limited to 700-1100 GtC, which is 800-1100 GtC less than the emissions under "business-as-usual" conditions. In article 3.1 of the United Nations Framework Convention of Climate Change (UN-FCCC), it is agreed that the developed countries should take the lead in combating climate change. Consequently, it can be argued that a global reduction of 50% probably implies a reduction in the industrialised world of at least 80%.

In a strategy to reduce greenhouse gas emissions, various options are applicable. But to reduce emissions substantially and sufficiently, considerable efforts should be made, taking into account **all** options that can be applied in a sustainable way. One of the options which has received only little attention up to now is Carbon Dioxide Removal (CDR). This technique recovers carbon dioxide from an energy conversion process and subsequently keeps it out of the atmosphere, for instance by storing it underground. Nowadays, the best studied option is the recovery from power plants, and from natural gas recovery processes, but good opportunities also exist in industrial processes and, in the longer term, in the transport sector.

The potential for Carbon Dioxide Removal in the reduction of greenhouse gas emissions has not yet been fully explored

The technology development of CDR is currently at different stages with regard to recovery, transport and storage. Carbon dioxide recovery has already been practised on a small scale, mainly for use in the oil recovery industry and food industry. For large-scale applications, a considerable potential exists to improve the various concepts and schemes to recover carbon dioxide. From a technical point of view, transport by pipeline and storage by injection deep underground are relatively easy to implement. In the USA already over 600 kilometre of large-scale pipeline is in use for pumping carbon dioxide. In the oil and gas industry, considerable experience has also been obtained in the underground storage of gases. To develop CDR, a number of governments are currently planning demonstration projects for the recovery and storage of carbon dioxide. In the Climate Technology Initiative, initiated by the OECD countries during the first Conference of Parties, Japan and the United States in particular emphasised a stronger role for CDR.

In this article we discuss whether or not CDR could play an important role in the emission reduction of carbon dioxide. Beside the technical availability, this will depend on the availability of other suitable emission reduction measures such as energy efficiency improvement and the use of renewable energy sources. The application of CDR should also be in line with the pursuit of sustainability. The latter means that CDR must fulfil the following criteria:

- have enough potential to deliver a substantial contribution to the reduction of carbon dioxide emissions during longer periods of time;
- be economically affordable;
- be efficient in using energy and materials;
- be environmentally sound;
- be socially acceptable.

Below, we will briefly describe the carbon dioxide emission reduction options in terms of their potential impact on the carbon dioxide emissions in the next century. Subsequently, we will have a closer look at the possible role of CDR following the given criteria for sustainability.

Options to reduce carbon dioxide emissions

Figure 1 gives an overview of the potential contributions of carbon dioxide emission reduction options. This overview is based on a variety of published assessment studies [Turkenburg, 1995]. A short description of some of the options is presented.

An important option to prevent the emission of carbon dioxide is a strong **reduction of the energy intensity** of the economy, largely by improving the efficiency of energy and material consumption. A potential improvement of 75% towards the middle of the next century exists. Realisation of this potential could prevent the emission of 600 GtC compared to a 'business-as-usual' reference case (see Figure 1), corresponding to an emission reduction of 600 GtC. However, obtaining a 300 GtC reduction will already be a major challenge.

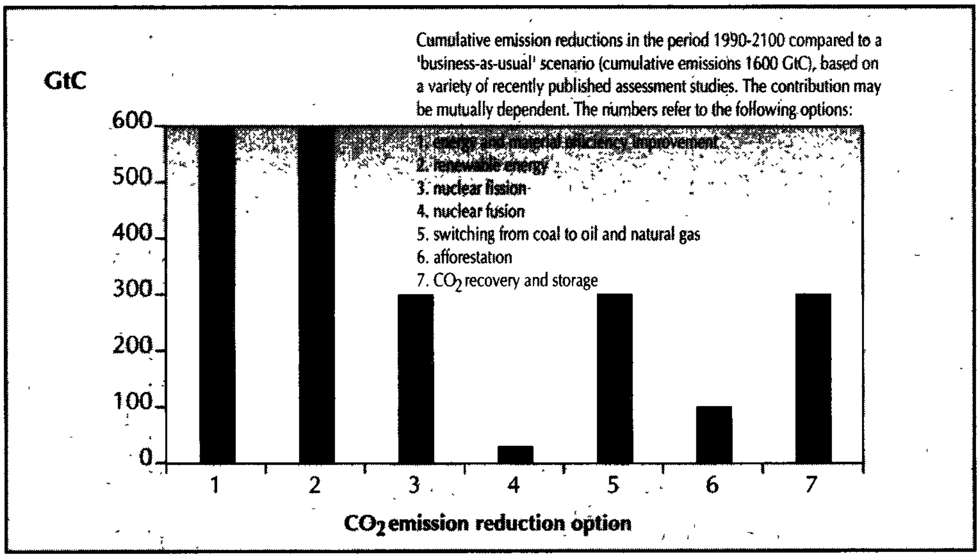
A second important option is the accelerated use of **renewable energy sources.** The potential of these sources is huge and their future looks promising. Amongst others, studies from the World Bank and the World Energy Council estimated that renewable energy sources could meet more than half our energy needs by the middle of the next century, although it may take twenty years from now before massive application can be achieved in competitive way. Similar views have more recently been presented by Shell.

Fuel shift to less carbon-containing fuels is another option that can play an important role in reducing carbon dioxide emissions. A cumulative emission reduction by fuel switching of 300 GtC might be feasible if, instead of coal, an additional amount of, for example, 10,000 EJ of oil and 20,000 EJ of natural gas were recovered and utilised. Whether this can be achieved is not yet known.

Nuclear energy could, in principle, play an important role in the reduction of carbon dioxide emissions. To substantially reduce the cumulative carbon dioxide emission by 2100 for instance, to the order of 300 GtC, the generating capacity

Improved energy efficiency and the use of renewable energy sources may significantly reduce CO_2 emissions

Figure 1. Potential contribution of options to reduce cumulative carbon dioxide emissions in the period 1990-2100 compared to a business-as-usual scenario with a cumulative emission of 1600 GtC. The shaded area indicates the uncertainty in the estimations. Note that the figures are mutually dependent



Studies indicate that the storage of CO_2 in underground and undersea depositories is a viable solution

should increase by factor 10. As a result, half the electricity demand could be supplied by nuclear energy by the year 2100. It is unsure, however, whether such a development will take place. Nuclear energy faces a number of problems: safety of installations, high costs, lifespan and waste disposal, risk of proliferation and lack of public support.

We can conclude, in principle, that a number of options can be developed and applied to prevent emissions of carbon dioxide. But we must recognise that it is uncertain whether these options can be developed in time and whether they can be applied at the required level. In the interim to developing these options, Carbon Dioxide Removal could play an important role. Moreover, CDR is the only greenhouse gas mitigation option that may allow continuing large-scale use of fossil fuels.

Carbon Dioxide Removal: In pursuit of sustainability

Potential of carbon dioxide reduction by CDR

The emission mitigation potential of CDR may be limited by the potential to use the carbon dioxide and by the space available to store it safely and securely. Table 1 presents an overview of storage potentials as discussed in the literature.

The potential to utilise recovered carbon dioxide as a commodity is interesting but small. An option, the potential of which is not yet included in the table, might be the use of carbon dioxide for enhanced gas recovery from deep coal beds. The carbon dioxide is used to push the methane out of coal layers. It is argued that for each recovered methane molecule, two molecules of carbon dioxide will be absorbed. Preliminary studies indicate that in the Netherlands, there is a potential to recover 7500 billion cubic metres of natural gas in this way. This would imply a storage potential of 4 GtC in the Netherlands alone.

The potential to store carbon dioxide in depleted oil and natural gas fields is much larger. Estimates range from 130 to 500 GtC, depending on the amount of oil and gas recoverable. The estimated potential for disposal in aquifers ranges from about 90 GtC to over 1000 GtC. A recent comprehensive study for the Joule II programme estimates a storage capacity of 220 GtC for the EU and Norway. The study also concludes that underground disposal is a perfectly feasible method of storing very large quantities of carbon dioxide. The carbon dioxide could most probably be retained for millions of years.

The ocean is also a large potential repository for carbon dioxide; it already contains nearly 40,000 GtC. Eventually the ocean absorbs over 85% of the carbon dioxide released to the atmosphere. Discharging carbon dioxide directly into the ocean would accelerate the ongoing, but slow, natural process. The high storage estimation is based on a limitation of the maximal accepted increase of the acidity of the ocean water: a pH (acidity) change of 0.2.

Based on these options, recent analyses of the IPPC Working Group on Energy Supply Mitigation Options suggest that CDR could prevent the emission of at least 300 GtC.

Energy and cost penalties of CDR

For the recovery and storage of carbon dioxide, energy is required. Extraction from flue gases is a relatively energy-intensive process. Applied in a power plant, an additional 20 to 40% of primary energy is required for the recovery, depending on the type of power plant and the method used. The cost lies typically between 100

Table 1. Low and high estimated potential of carbon dioxide utilization and storage options (Turkenburg, 1997)

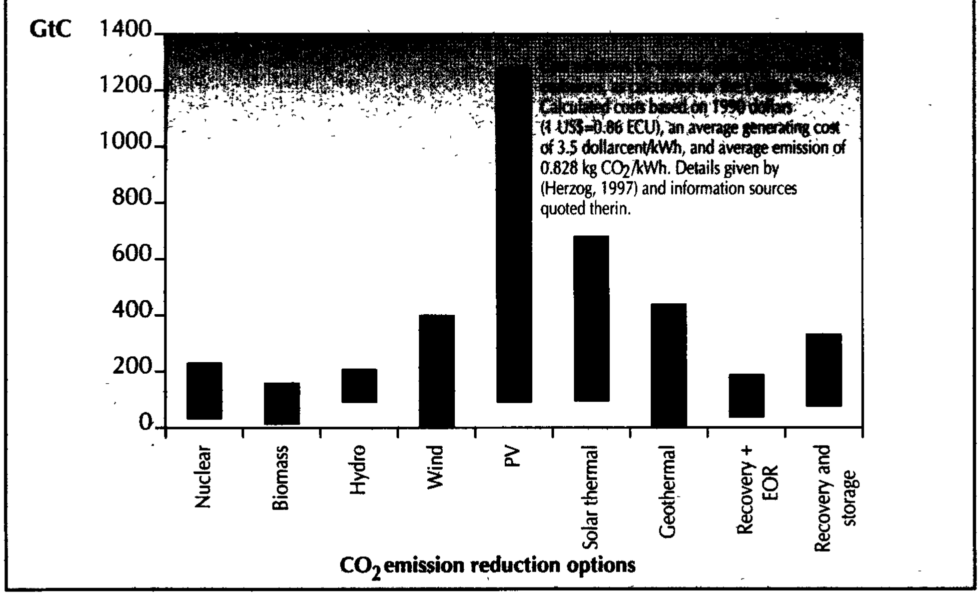
[redacted]			
Exhausted gas wells	90	400	GtC
[redacted]			
Saline aquifers	90	>1000	GtC
[redacted]			

1. Mainly for the use of Enhanced Oil Recovery. Minor contribution for the production of chemicals.

and 250 ECU/tC avoided. Recovery systems that often require less energy decarbonize the fuels before utilizing them. A frequently suggested scheme is the development of an Integrated Coal Gasifier Combined Cycle power plant integrated with CDR. In this way, energy penalties are significantly reduced to less than 15%. The costs are reduced to less than 100 ECU/tC avoided.

CDR can also be applied to large industrial processes. Depending on the processes involved, this can be implemented at relatively low costs (eg. ammonia industry, iron and steel industry and refineries). Application of CDR in industries without large carbon-rich gas flows may be more difficult to realise at a reasonable cost. In this case, other solutions should be found, for example, the decentralized use of hydrogen as produced from centralized decarbonized fossil fuels. For comparison, Figure 2 gives a cost range of various carbon dioxide mitigation options. It should be emphasised that the cost figures are a reflection of various studies which are not independently assessed. The cost data depend strongly on local circumstances.

Figure 2. Indicated cost of carbon dioxide mitigation for various options [Herzog, 1996]



Energy

Current R&D efforts are focused on minimizing the energy and cost penalties of CDR in respect of recovery, transportation and storage

Risks of possible carbon dioxide releases are qualified as unlikely, although more research into environmental effects is required

Currently, R&D efforts are focused on minimizing the energy and cost penalties of CDR. This includes not only research to improve absorbents to decrease the energy requirement of the scrubbing process, but also the development of totally new concepts. One interesting option under investigation is the combustion of carbon-containing fuels in gas turbines in the absence of nitrogen. The resulting flue gas is then essentially carbon dioxide. The combined application of CDR and fuel cells in power production could also, in principle, decrease the energy and cost penalties substantially. When fuel cells are applied in car vehicles, CDR combined with the production of hydrogen from natural gas could become one of the most attractive mitigation options. In the event that recovered carbon dioxide is used for enhanced natural gas recovery, the hydrogen production costs might increase fractionally as compared to the case without carbon dioxide sequestration.

After recovery, the carbon dioxide has to be transported and stored, which adds to the removal costs. Pipeline transportation costs of carbon dioxide are 3-10 ECU/tC (tonne/carbon) per 100 km, depending on size and capacity of the pipeline. The costs of underground storage may vary typically from 4-10 ECU/tC. Stored in the ocean, the costs are more uncertain and may rise to 25 ECU/tC.

Environmental aspects and safety

To allow CDR to play a major role, special attention should be paid to the reliability, safety and environmental consequences of carbon dioxide storage. Could large amount of carbon dioxide escape in a short time, threatening life of humans as occurred in 1986 from Lake Nyos in a volcanic region in Africa, where more than 1700 people were killed? Given the experience acquired in underground storage of gases, most probably not. Experts have qualified the danger of a catastrophic release of carbon dioxide as a highly unlikely event. Nevertheless, due attention should be paid to advanced planning, adequate maintenance and the application of materials. The risk would be reduced even further if storage took place offshore. Other implications of underground carbon dioxide storage to be investigated are the dissolution of host rock, the sterilisation of mineral sources and the effects on ground water.

In the case of carbon dioxide storage in the deep ocean, the main impact would be on non-swimming marine organisms (e.g. zooplankton, bacteria and benthos), especially in the release area, although available data suggest that mortality associated with pH change might be minimal if the injection is properly designed to disperse the carbon dioxide as it dissolves. Nevertheless, apart from safety risks, much more should be known about the impact on marine life and the retention time of the carbon dioxide in sea water.

Social acceptance: The case of the Netherlands

In the period 1993-1995, people in the Netherlands were asked for their opinions, attitudes and preferences regarding electricity supply and the greenhouse problem. According to the results, those questioned preferred a combination of three options to balance future demand and supply of electricity by the year 2010: further energy saving, power production with natural gas and power production from coal combined with carbon dioxide removal. Significantly less priority was given to a second, more intensified package of saving measures, nuclear energy or the use of coal without CDR. In another study among decision-makers in the business sector, CDR was less preferred than 'renewables' or 'more intense energy savings' but more favoured than 'nuclear energy' and 'fuel switch'.

These studies indicate that at present in the Netherlands, CDR is perceived as an acceptable option. Whether this remains the case in the future will probably depend primarily on (the perception of) the environmental and safety aspects of carbon dioxide storage and the results of initial policies to stimulate the efficient use of energy and the application of renewable energy sources.

CDR may be a viable option to reduce carbon dioxide emission, with costs ranging from 4-200 ECU per t/C avoided and a potential of at least 300 GtC. Studies indicate that storage underground may have a limited environmental effect. Impact by storage in the ocean is much more uncertain. There is still considerable scope for improving the performance of CDR, but this will require considerable effort in the field of research, development and demonstration.

Current Carbon Dioxide Removal activities

The largest research programme on carbon dioxide removal belongs to Japan. Japan's interest in this area is twofold - first a genuine concern for the global environment, but also an interest to develop commercial technologies which they can market world-wide. Since 1990, the Japanese government has spent 300 million ECU. Compared with this, the effort in United States and Europe is very moderate, with a considerably lower level of expenditure. Recently, in a White Paper, experts from the Massachusetts Institute of Technology (MIT) recommended an increase in the US budget of an average of 40 million ECU per year over the next five years. During recent years, experimental practise in CDR has been developing in several countries. In Japan, two main electricity companies are developing improved carbon dioxide recovery processes. Attention is being paid to storage of carbon dioxide in the deep ocean and plans for underground storage have been announced. A demonstration project on underground storage has recently been proposed in the Netherlands, where one million tonnes of carbon dioxide per year will be injected into deep aquifers. The intended carbon dioxide stems from a large hydrogen production plant. The plant emits large streams of concentrated carbon dioxide, which can be recovered at very little cost. The total cost of the project (mainly due to the compression and storage required) is estimated at 60 MECU.

In September 1996, the first 'commercial' CDR project began in Norway. A consortium of four oil companies injects 1 million tonnes of carbon dioxide per year into a one km deep aquifer beneath the Sleipner West offshore field. The carbon dioxide is separated from a CO_2-rich natural gas recovered from the Sleipner East natural gas field.

The Norwegian pioneer project may soon have a successor. Exxon and Pertamina have been awarded the license by the Indonesian government to explore the Natuna gas field, one of the largest in the world. The reservoir contains six trillion ($6x10^{12}$) m^3 gas, including carbon dioxide, which comprises 71% of the total gas present. To use this natural gas, the carbon dioxide must be recovered. Normally, the recovered carbon dioxide is released into the atmosphere. In this case, however, the recovered carbon dioxide will be compressed, transported and injected into two aquifers at a distance of 35 and 75 km from the gas field respectively. One million tonnes of carbon dioxide will be injected per day and the total amount to be injected would equal the current annual carbon dioxide emission of the EU. The reported cost of the carbon dioxide recovery and storage is 17 billion ECU ($17x10^9$ ECU), nearly half the 36 billion ECU project cost.

Surveys in the Netherlands indicate that CDR is perceived as an acceptable option

Japan and Norway emerge as the pioneer countries in CDR development, with Indonesia planning future CDR activities

About the authors
Chris Hendriks holds a PhD in 'Carbon Dioxide Removal from Coal-fired Power Plants' from Utrecht University He has worked as an Adviser for institutes, utilities, the Dutch government, and the European Commission on energy and environment-related topics. Within the IPTS his main areas of interest are: 'Best Available Techniques' (BATs) in the framework of supporting activities for DGXI"s "Integrated Pollution Prevention and Control (IPPC) Directive', and an international study on the 'Assessment of Policy Instruments for Efficient Ozone Abatement Strategies in Europe'.

According to Exxon, the state of the project is advanced and its implementation depends only on the signing of the natural gas sales contract.

At present, no direct financial incentive exists to implement CDR as a part of operational management. Although Norway applies a carbon tax of about 50 ECU per tonne of CO_2 released, this is not applied to carbon dioxide releases from non-combustion processes. A reason for the proactive approach to CDR may be that the Norwegian oil industry fears amplified legislation in respect of this kind of emission. Although in the Indonesian case the argument to incorporate the relatively costly carbon dioxide removal process is not officially communicated, it may be driven by a request on the part of the Indonesian government in the fear of a large future burden of carbon dioxide emissions, in light of future CO_2-related negotiations. Nevertheless, the Norwegian and the Indonesian CDR projects may create a precedent for future hydrocarbon recovery activities.

Conclusions

Fossil fuels account for 85% of today's energy supply. It is unlikely that this can be reduced drastically in a short period without serious economic damage. Therefore, to lower carbon dioxide emissions to a sustainable level, a long-term reduction strategy must be developed, taking into account the use of fossil fuels. To this end, a broad-based research programme is required to explore a diverse spectrum of options valid for multiple time frames. Carbon Dioxide Removal can be, and may have to be, one of the elements in such a strategy. First analyses indicate that Carbon Dioxide Removal can be applied within the pursuit of sustainability development. The application of Carbon Dioxide Removal is only meaningful when it is embedded in a policy that focuses on the development of energy sources and technologies producing little or no carbon dioxide; it should not prohibit this development.

Before Carbon Dioxide Removal can be implemented on a large scale, further research and demonstration should be undertaken to investigate its feasibility, and to bring down energy and cost penalties. Special attention should be paid to the environmental and safety aspects of carbon dioxide storage.

The IPTS REPORT

July/97 16

SUBSCRIPTIONS

The IPTS Report is published 10 times a year in English, French, German and Spanish. For a free subscription to the IPTS Report, or to amend an existing subscription, please post or fax the subscription form below, or send full contact details to the e-mail address shown, or see the IPTS Report page on the World Wide Web.

The IPTS Report Secretariat,
IPTS, JRC Sevilla,
World Trade Centre, Isla de la Cartuja, E-41092 Sevilla, Spain.
Tel: +34-5-44 88 284 - **Fax: +34-5-44 88 235**
E-mail: ipts_secr@jrc.es/Web address: www.jrc.es/iptsreport/subscribe.html

Name: ______________________ **Surname:** ______________________

Title: ______________________

Company: ______________________

Address: ______________________

Post-code: ______________________ **Country:** ______________________

Telephone: ______________________ **Fax:** ______________________

E-mail: ______________________

Please indicate which language version you wish to receive:

❑ English ❑ German

❑ French ❑ Spanish

Keywords

Carbon dioxide removal, sustainable energy supply, carbon dioxide emission reduction, carbon dioxide storage, climate change

References

- Herzog, H., Drake, E. and Adams, E. *CO_2 Capture, Reuse, and Storage Technologies for Mitigating Global Climate Change,* A White Paper, Massachusetts Institute of Technology, Boston, United States, 1997.
- Holloway, S. (ed.), *The Underground Disposal of Carbon Dioxide,* EC-Joule II programme, British Geological Survey, Nottingham, United Kingdom, 1996.
- Turkenburg, W.C. *Energy demand and Supply Options to Mitigate Greenhouse Gas Emissions,* in: Zwerver, S. et al. (eds.), *Climate Change Research: Evaluation and Policy Implications,* Elsevier Science B.V., Amsterdam, 1995.
- Turkenburg, W.C. *Sustainable Development, Climate Change, and Carbon Dioxide Removal (CDR),* Energy Conversion and Management, vol.38 (suppl.) p.53-512, 1997.

Acknowledgements

The authors are grateful for the comments made by the following people:
B. **van Engelenburg** (VROM, NL), W. **Gunter** and B. **Hitchon** (Alberta Research Council, Can), H. **Herzog** (MIT, USA), D. **MacDonald** (Alberta Department of Energy, Can), P. **Riemer** (Greenhouse Gas Programme, IEA).

Contacts

C.A. Hendriks, IPTS,
tel. +34 5 44 88 207, e-mail: chris.hendriks@jrc.es
W.C. Turkenburg, Utrecht University,
tel. +31 30 253 76 00, e-mail: turkbrg@chem.ruu.nl

About the authors

Professor Wim C. Turkenburg is Head of the Department of Science, Technology and Society at Utrecht University, the Netherlands. Since 1974 he has been working on energy and environment-related topics. Amongst other posts held, he has been Chairman of the World Energy Council Working Group on Wind Energy, Vice-Chairman of the UN Committee on New and Renewable Sources of Energy, and lead Author of the IPCC Assessment of Energy Supply Options to Mitigate Greenhouse Gas Emissions. He is a Member of the Advisory Council of the Dutch Ministry on Housing, Physical Planning and the Environment.

Knowledge-intensive Innovation: The Potential of the Cluster Approach

Dany Jacobs

Issue: In many cases and increasingly in the future, industrial innovation requires the intelligent connection of different forms of knowledge, technologies and skills. A cluster approach provides a relatively new basis for the development of effective innovation strategies.

Relevance: Traditional industrial policy focused to a large extent on managing the decline of industries ('backing losers'), or targeting future growth industries ('picking winners'). An important advantage of the cluster approach is that it focuses on the existing strengths in an economy and takes into account the potential of connecting different economic activities and forms of knowledge ('border crossing'). As innovation increasingly boils down to knowledge intensification in all industries, the cluster approach can help policy-makers facilitate the emergence of new forms of knowledge pooling.

Industrial policy in the post-war period

Broadly speaking, we can distinguish five periods in industrial policy since the Second World War:

- The late forties and fifties: post-war reconstruction and the introduction of new production and organization methods from the USA, partly through the Marshall Plan.
- The sixties and the beginning of the seventies: keynesian growth policy which looked more to tackling the business cycle than to the structure of the economy.
- The seventies (mainly): defensive industrial policy: managing the decline of industries in crisis, such as steel, ship building...
- The eighties: aggressive technology policies: the generic stimulation of new advanced technologies (information technology, biotechnology, new materials, new light technologies, also, increasingly, environmental technologies).
- The nineties (still developing): cluster approach, taking into account the specificities of the industrial structure.

Industrial policy shifted in the seventies and eighties from a focus on 'backing losers' to 'picking winners'

In relation to the definition of industrial and innovation policy, the latter three phases of industrial policy are particularly relevant. In the first of these three phases governments tried to manage the decline of sectors and industries which threatened to collapse under the pressure of international competition.

This defensive approach ('backing losers') to policy was rationalized by pointing to the importance of employment in these sectors, but in the end it has mainly proved to be a failure. The aggressive technology policies which to a large extent replaced this approach, can be characterized as 'picking winners'. In this second phase governments tried to target future growth sectors. The lesson learnt from this approach is that it is very hard to predict which technologies and which sectors will be the future winners. Very few of the technologies believed to be interesting ten years ago, lived up to expectations, unless they were defined in a very broad way (such as information technology, biotechnology...). Moreover, in as far as these technologies did prove to be important, success on the market was limited due to the fact that many countries targeted the same technologies. The bandwagon effect in governmental policy thus reduced the possibility of reaping profits. In many cases, the approach led to over-investment in some industries, with increased cost competition as a result (Brahm, 1995).

Since the beginning of the nineties a new approach based on clusters has gained in popularity - although not in all countries with the same vigour -, especially since governments have started concentrating more on their specific strengths instead of trying to imitate foreign successes. The cluster approach in a certain way is more modest in its ambitions, although it could be stated that it tries to combine the strong sides of the previous two phases.

The point of departure for cluster-based policy is the existing strength in an economy. It focuses on those concentrations of business activity which have already proven their strength and viability on the world market. But there are some differences with traditional sector-based approaches. First, the relation between strengths cutting through different industries (e.g. relation between certain industrial or even agricultural and service specializations) is

The cluster approach of the nineties concentrates on existing strengths in an economy

Old policies in a new disguise

The periodization of industrial policies in the overview above is, of course, somewhat schematic. The transition from one form of policy to another is never clear-cut, and old habits and reflexes may survive for a long time. So it is no surprise that old forms of industrial policy reappear in a new disguise.

Since the concept of clusters became fashionable, governments have occasionally tried to continue some of the previous policy approaches under the guise of cluster policy. The defensive phase can be traced in attempts to 'maintain clusters' where core firms run into problems (e.g. the aeroplane manufacturer Fokker in the Netherlands) or where clusters are simply a new label for traditional sector approaches; the aggressive phase can be found in attempts to create totally new 'innovative' clusters. For aggressive technology policies there may be a starting point in clusters, provided that aggressive policies are rooted in existing strengths. The scope for starting a new cluster from scratch is, however, restricted: the costs are very high and the chances of success limited (cf. Nelson, 1993).

In order to avoid wish-driven and unsuccessful policies, it is better to build on the present structure of the economy. The fact that cluster policy directs attention from the macro level to the meso level of economic activity, hopefully makes governments aware of this actual structure, thus preventing them from implementing unrealistic policies. Generic policies at a macro-level may still be needed but the increased pressure to create value by means of further specialization, forces governments to set priorities.

The scope for starting a new cluster from scratch is restricted: the costs are very high and the chances of success limited emphasized. And second, partly related to this, the emphasis lies then on intensifying the use of knowledge in these strong clusters and on enhancing constructive interaction between different parties in the network. This may lead to new, promising combinations (e.g. in the field of multimedia), but rooted in already existing strengths.

As each country or region has its own pattern of specialization, cluster policies as a rule strengthen competition based on differentiation and specialization, instead of competition based on imitation and cost. The diffusion of cluster policies is quite uneven between countries and policy practices are also differentiated. Furthermore, the concepts which are used are not always the same, but most countries in Europe have adopted some kind of cluster policy in one form or another. Governments which were the most explicit in this respect were, for example, those of Denmark, the Netherlands, the Flanders region in Belgium, Quebec in Canada, Finland and also the new South African government. Countries where a certain cluster approach already has a longer tradition, but under different labels, include France (cf. the **filière** approach) and Italy (cf. the 'Terza Italia' literature).

It is difficult to define one single cluster approach, therefore clusters classification facilitates tailor-made strategies

A myriad of approaches

An important impetus was given to the cluster approach by the publication of Michael Porter's The Competitive Advantage of Nations (1990). Porter was, however, not the first and certainly not the last to write about clusters, networks or economic webs. Before Porter, for example, there was already a huge French literature on **filières** and networks and strategic alliances were also extensively discussed by many authors. At about the same time as Porter, people like Chris Freeman, Richard Nelson, and Bengt-Ake Lundvall published or edited books on 'national systems of innovations' in which the specialization and specificity of different countries were emphasised. And, more generally, there has been a whole literature which put the influence of institutions on development back on the agenda.

More specifically, a myriad of cluster definitions and approaches has come into existence. In this way, it has become rather difficult to talk about **the** cluster approach. In the author's opinion this is not a drawback, but on the contrary, quite inspiring. Ard-Pieter de Man and the author have looked at the various dimensions that different kinds of cluster approach try to tackle. In many cases, business people or policy-makers try, in one way or another, to concentrate on certain of these dimensions when they talk about cluster strategies or policies. In this way the different possible cluster dimensions can be seen as a menu, out of which these business strategists and public policy-makers can choose, according to the specific situation they are confronted with (Jacobs & De Man, 1995/1996). By making the dimensions of clustering explicit, a basis upon which tailor-made strategies and policies can be developed has been provided.

In general, three broad definitions of clusters can be distinguished, each emphasising different dimensions (for these dimensions see the separate box):

1- Regionally concentrated forms of economic activity within related sectors, usually connected to the knowledge infrastructure (research institutes, universities, etc.).

2- Vertical production chains: rather narrowly defined sectors in which adjacent stages in the production process form the core of clusters (e.g. the chain of supplier-assembler-distributor-customer). Networks surrounding core firms fall under this heading as well.

3- Industries, defined at a high level of aggregation (for example 'the chemical cluster') or collections of sectors at an even higher level of aggregation (like 'the agro-food cluster'). These are usually called 'mega-clusters'. On the basis of input/output analysis for the Netherlands, a subdivision into ten mega-clusters has been defined (Roelandt et al., 1997).

Following the 'subsidiarity principle', it seems appropriate to develop cluster policies at the level at which most overall competitive advantage can be gained, but at the lowest level which is feasible. So, for different levels local, regional, national or international policies may be relevant. From experience it becomes clear that especially where clusters are already local, or where the coaching of SME's by larger firms, the adaptation of products to local markets or the close co-operation between firms and their main suppliers (co-development, co-production) are concerned, locally organised clusters are important. On the other hand, where clustering is already transnational (e.g. aerospace), or entails huge economies of scale (certain developments in basic science and technology; some lateral 'new combinations', large demand-oriented 'demonstration projects', such as those targeted by the task forces of the Fourth Framework Programme), there will be substantial European-level value added.

Innovation and knowledge intensification

The diversity of possible cluster dimensions and approaches may not, however, displace the

Cluster dimensions

Ard-Pieter de Man and the author have distinguished seven dimensions according to which - in many cases in combinations - clusters are constituted. These dimensions also provide the basis for the development of tailor-made strategies and policies (Jacobs & De Man, 1995/1996). These are the seven identified:

- geographical: the spatial clustering of economic activity, ranging from quite localized clusters (e.g. horticulture in the Netherlands) to really global ones (e.g. aerospace);
- horizontal: several industries/sectors can be part of a larger cluster (cf. the Box on 'mega-clusters' in the Dutch economy);
- vertical: adjacent phases in the production process can be present in clusters (similar to the concepts of value systems, filières, networks of suppliers). Important in this vertical dimension is the question of which actor in the network is 'pulling' the innovative activities;
- lateral: different sectors with which certain capabilities can be shared and economies of scope achieved, leading to new combinations (e.g. the emerging multimedia cluster);
- technological: a collection of industries which share a basic technology (e.g. the biotechnology cluster);
- focal: a cluster of firms around a central actor: a firm, an extended family, a research centre, an educational institute;
- the quality of the network: not only the question of whether firms really co-operate is of interest here, but also the way in which they do so. Networks are not necessarily idyllic collections of firms in which renewal is automatically stimulated. Networks can also thwart innovation and encourage defensive behaviour. Relationships with suppliers can stimulate innovation, but can also be used to pass expenses on to partners and to squeeze them financially. In the latter case, networks may be neither sustainable nor stimulating.

Cluster levels should be defined in order to obtain the best possible competitive advantage at the lowest level feasible

Innovation policies will have to be based on the differing individual characteristics of mega-clusters, becoming cluster specific

Mega-clusters in the Dutch economy

On the basis of input/output analysis for the Netherlands, we have arrived at a subdivision of this economy into ten different 'mega-clusters': assembling industries, chemical industries, energy, agro-food, construction, media, health, commercial services and non-commercial services. Through an analysis of knowledge flows (based on the Dutch 'innovation surveys') it was also discovered that the innovation character of each of these mega-clusters is quite different: three clusters appeared to be 'net exporters' of knowledge to the other clusters: the assembling industries, the commercial services and the chemical industries. The first two of these were quite generic 'exporters', exporting knowledge to all the others. The health and the non-commercial services (including the large knowledge institutions) are also net knowledge exporters, but to a lesser extent. Two clusters appeared to be net importers of knowledge: construction and the media. Finally, three clusters (agro-food, energy, transport) were rather 'autarkic', producing knowledge mainly for themselves. (cf. Roelandt et al., 1997).

The hypothesis ensues that these characteristics of different mega-clusters will also be found in other countries or in the EU at large. In the author's opinion, innovation policies at the different levels will have to take these different characteristics of mega-clusters more into account, and also, in this sense, become more cluster-specific. Stimulating innovation in the construction clusters really entails other priorities and approaches than in the health cluster.

attention from the main common features of all of these. First, the point of departure for any cluster-based policy is the existing (to an important degree 'clustered') strength of an economy. As stated before, there is a huge variety in the geographic scope of different clusters: in cut flowers (including related services) it is a relatively small part of the Netherlands, in aerospace or larger parts of defence-related industries, it is the continent. And second, the main objectives of all cluster-related policies are the intensification of the knowledge-content in these strong clusters and the enhancement of constructive interaction between different parties in the cluster. These objectives are mutually reinforcing, as the increasing knowledge-intensification of the entire economy makes it increasingly difficult for individual firms to incorporate the whole knowledge chain.

The knowledge-based economy is, therefore, also increasingly a network economy, characterised by ever-more 'new combinations' between specialised firms. Generic innovation policies at the macro-level may still be needed to some extent, but the increased pressure to create value by means of further specialisation forces governments to set priorities. Moreover, it appears that the innovation pattern of the different larger 'mega-clusters' in the economy is quite different (Roelandt et al., 1997; see the Box on mega-clusters in the Netherlands). As a result, cluster-based innovation policies will increasingly have to take the specificities of innovation in these clusters into account. Innovation policies in a net knowledge-importing cluster such as construction will, to a large extent, be different from those in knowledge-exporting clusters such as the commercial services or a more knowledge-autarkic cluster like agro-food.

Basically, in relation to clusters two main policy alternatives can be distinguished, which should complement each other:

- policies aimed at intensifying the use of knowledge in existing clusters;

policies aimed at creating new networks of constructive co-operation within clusters.

As stated before, knowledge intensification includes many more knowledge fields than those of pure technology: it is also, for example, related to 'competing for foresight', the creation of new, attractive products and marketing concepts, forms of best practice management in different fields of management (manufacturing, concurrent engineering, logistics, teamworking, the learning organization) (cf. Jacobs, 1996). The different dimensions around which clustering takes place, also draw attention to different aspects of knowledge intensification and innovation in clusters:

- the technological dimension: maintaining and developing high-level technological competences;
- the vertical, horizontal and lateral dimensions: the interaction between the different actors in clusters upstream (close interaction with suppliers, including different knowledge institutions and specialized commercial services) and downstream (specifically the interaction with the demand side: retailing, the end customers);
- the geographical, focal and vertical dimension as well as the quality of the network are important for the diffusion of knowledge and innovation towards SME's. The organisational side of innovation is of importance here as well. The ability to organize networks, both inside firms and between them, is an important innovation-enhancing capability. It is therefore necessary to stimulate firms to think about their strategic position within networks.

As innovation increasingly boils down to knowledge intensification in all industries, the cluster approach provides an important basis for designing the necessary new forms of knowledge pooling. The variety of necessary forms of knowledge, which have to be dealt with also shows that bridging and brokering institutions will have to play a role in many cases. Cluster-related industrial policies may stimulate 'new combinations' and support them by indirect means (especially in the field of education and research and through diffusion-oriented bridging institutions like the Dutch Innovation Centres). At the European level, a programme like Eureka has played an important role in bringing together possible partners which were not able to find the necessary complementary knowledge at the local level. And demonstration programmes like those around the Task Forces (e.g. car of the future, new transport concepts) also play a role in forging new combinations.

As stated above, especially where clustering is already transnational (e.g. aerospace) or entails huge economies of scale (basic science and technology; some lateral 'new combinations' like multimedia, large demand-oriented 'demonstration projects') there will be substantial European-level value added. Besides this, there is also room for promoting similar new transnational combinations at a lower level, for example, in border regions. As initial transaction costs for SME's in relation to international co-operation may be prohibitive, groups of SME's from different countries could be supported, for example, in common endeavours to try to benefit from the combination of their mutual knowledge, especially where spin-offs may materialize, or where economies of scale may be realized when entering their respective markets.

It has to be emphasized, however, that firms must recognize these opportunities within the framework of their own strategies. Governments at the different levels may draw attention to possible threats and opportunities and support common initiatives to tackle these to a certain extent. The fact remains, however, that the firms themselves have to be responsible for the processes which follow on from these and their possible success.

Knowledge intensification and innovation will reflect all the different dimensions within clusters, not only the technological

New forms of knowledge pooling may benefit particularly from European-level efforts in areas where clustering is already transnational

About the author
Dany Jacobs (1954, Bruge, Belgium), Organization Sociologist. From 1982-1988 Researcher at the Institute for Political Sciences, University of Nijmegen. PhD in 1988 with a thesis on the 'National and International Economic Regulation of the West European Steel Industry'. Since 1982, Senior Researcher/ Consultant at the TNO Centre for Technology and Policy Studies (TNO-STB) in Apeldoorn, the Netherlands, and since 1997, Special Professor for Innovation and External Organization at the Eindhoven University of Technology.

Keywords
Clusters, networks, knowledge, technology, policy, innovation

References

- Brahm, R., *National targeting policies, high technology industries and excessive competition,* Strategic Management Journal, Vol. 16, p. 71-91, 1995.
- Jacobs, D. *Het kennisoffensief. Slim concurreren in de kenniseconomie,* Samsom, Alphen a/d Rijn, 1996.
- Jacobs, D., De Man, A.P. (eds.), *Clusters en concurrentiekracht,* Samsom, Alphen a/d Rijn, 1995.
- Jacobs, D., De Man, A.P., *Clusters, Industrial Policy and Firm Strategy: A Menu Approach,* Technology Analysis & Strategic Management, no. 4, p. 425-437, 1996.
- Nelson, R. (ed.), *National Innovation Systems,* Oxford University Press, Oxford, 1993.
- Porter, M., *The Competitive Advantage of Nations,* Free Press, New York, 1990.
- Roelandt, T., Den Hertog, P., Jacobs D., *Nederlandse clusters in beeld,* Economisch Statistische Berichten, p. 124-128, 12.2.1997.

Contact

Dany Jacobs, TNO-STB
tel. +31 55 5493 483, fax +31 55 542 14 58, e-mail: Jacobs@stb.tno.nl or D.Jacobs@tm.tue.nl

Information and Communication Technology

Distance Learning: Opportunities and Problems

Maria Laura Bargellini

Issue: Education and training play a primary role in the "Information Society". The rapid evolution of science and technology requires continuous professional updating since nowadays teaching - so far confined exclusively to school years and institutions - is seen in the context of a lifelong learning process. Furthermore, technological innovation has contributed to the development of better teaching support tools, thus allowing for a flexible and individual learning plan which provides people with equal opportunities of access to and success in school and work activities.

Relevance: The penetration of new communication and information technologies in the fields of education and training requires that standards be set and that roles and teaching methods be redesigned in order to better benefit from the opportunities offered by technological innovation. Teaching approaches have to be designed with a user-centred approach in order to be pedagogically effective, thus integrating and supporting a lifelong education and professional training without producing a negative impact on learners' individual development and their projection in society.

Analysis

Departing from the general scenario of the UNESCO **Lifelong Learning** guidelines, the EU **Distance Learning** and **Teletraining** actions (Articles 126, 127 of the Maastricht Treaty, **SOCRATES** and **LEONARDO DA VINCI** programmes) and the US **Technology Literacy Challenge** initiative, this article deals with the new opportunities and problems related to the introduction of the new information and communication technology in school teaching and lifelong training.

In particular, it analyses the following aspects:

- social: distance learning also enables the weaker to access education and training;
- pedagogical: teachers must play an active role in tele-education to guarantee the pedagogical content of multimedia tools along with the continuity of tried and tested didactic solutions. The potentialities and limits of virtual reality are outlined in the learning and experimentation context;
- methodological: didactic tools must be user-oriented and solutions need to be found to promote the useability of multimedia tools rather than their potential for advanced features;
- quality: it is necessary to adopt procedures and rules validating the quality and usability of the multimedia teaching product.

The new paradigm of education

The new paradigm - based on educational approaches and products which use the new communication technology - emphasizes the **learning** pattern rather than the teaching model. While the latter is centred on teachers and their knowledge, the former allows learners to play an active role by building, according to a **personal learning action plan,** the knowledge and training path best suited to their own pace and style.

New communication technologies afford an active role to the learner in the context of lifelong learning

All of the above forms part of a new scenario where learning is not confined mainly to school years. On the contrary, the need for knowledge and training lasts a whole lifetime **(lifelong learning)** both at the professional and the personal level.

Certain factors exist which make telematics applications meaningful, proper and necessary:

- the uniqueness of the expert/teacher;
- the distance between teacher and students;
- the high number of people that can be reached with one lesson;
- the need to learn according to different times and paces.

The **learning circles** - made up of a class and a teacher not necessarily located in the same place - can create community moments and complement each other into a sort of high-synergy **virtual community.** The latter may naturally evolve into telework, with the consequent creation of a highly interactive **virtual project nucleus.**

Teledidactics makes learning more widely accessible and shifts the emphasis from the classroom to a virtual project nucleus

Within the new learning panorama, the concepts of time and space change and teledidactics is available to users where and when it suits them. The result is an increased number of potential learners since the historically weaker and more discriminated can also access training and learning.

The use of advanced communications technology in the distance learning field will have a considerable social and economic impact, especially in respect of:

- the phenomenon of premature school leaving and the consequent dispersion and unemployment of young people;
- the social and professional promotion of women;
- the organisational changes as well as the continuous processes of on-site training and retraining - especially in SMEs - in order to keep pace with advanced technology and to be competitive within the international market.

Methodology, actors and roles in advanced teaching

Telematics applied to education and training requires a change in planning methodology as well as in the actors involved and the roles they are assigned.

Not only is advanced technology not used within the school structure as a whole, it is even regarded with distrust and, in some cases, rejected. Such a negative trend must change rapidly in order to prevent the school from losing its driving role in social development and from being - paradoxically - the island and the cradle of technological illiteracy.

The state of technological illiteracy in which schools find themselves cannot be overcome by simply equipping all classrooms with computers, rather the whole didactic architecture, as well as the teaching/learning pattern, must be redesigned.

This will provide the classroom protagonists with a renewed role. Teachers - who during their educational mission transferred objective knowledge - will now be the learners' collaborators in discovering, penetrating and coming to know new horizons, thus leading to a constructed and dynamic knowledge. Yet they will still act as guides for the achievement of an individual learning method.

A new actor is being outlined: the **mentor** whose profile and mission are clearly defined in the English 'Campaign for Learning'. The mentor is the person in charge of the individual support and encouragement of the student, yet he will not have the task of proposing the direction students should follow.

The slow development of school programmes and structures clashes with the fast-paced evolution of basic technology. Moreover, the market is ready to offer multimedia educational experiences.

In order to fit the real needs of users, two indispensable rules must be identified and adopted in view of the introduction of multimedia teaching both at school and training levels:

- The first rule assumes that didactic products and tools be designed with a user-centred model in order to be pedagogically effective.
- The second rule consists in promoting the participation of teachers and training operators as the protagonists in the design of multimedia teaching-support tools. This ensures the attainment of a learning path extending from general education to professional training, to retraining in specific skills and eventually to the reconversion imposed by technological innovation. Since 'general education must provide preparation for a vocational skill, and vocational training must continue to develop the basic competences provided by general education'.

Observatories and 'pilot centres' should be set up as points of reference for the collaboration of schools, training centres, research bodies and industries in terms of methodology as well as of project realization. National and international 'pilot centres' could become meeting points to generate moments of training, constructive discussion and evaluation of the opportunities and the arisen as a result of the use of new technology in the fields of teaching and public life.

Validation and quality in the teledidactics product

The delay in introducing telematics in the school structure is considerable when compared to the increasing availability of multimedia tools.

At the EU level, two proposals should be forwarded:

- The adoption of rules and standards to drive the evaluation and validation methodology, metrics and process of the multimedia product, validating its usability as related to scientific and didactic content;
- The creation of a standard certifying the multimedia product's conformity to EU directives, so that a product can be defined as a text for school and training.

Hence a visible label will certify the validity of the presented product to orient the choices of school operators, trainers and parents.

Technology at the service of users and standards definition

Increasingly sophisticated screens and ever-richer image-processing software have given way to the creation of visual interfaces enabling users and machines to interact through the synthesis and the power of the iconic message. With these interfaces, interaction is possible by selecting symbolic and metaphorical images evoking concepts, commands and functions. Yet we are still far from a direct and unique interpretation of icons. Thereby, we may run the risk of crowding the user's mind with different icons representing identical concepts and functions.

Today, the increasingly widespread use of some operating systems and network navigators is becoming a real standard. Yet there is still a need to forward a research proposal and to ensure Europe's

New roles will have to be defined: mentors will emerge as important new actors in the educational process

Pilot centres could be set up as points of reference for collaboration on methodology as well as project realization

The adoption of standards and validation guidelines in respect of useability would be extremely helpful

Information and Communication Technology

The standardization of visual interfaces is required for clarity of understanding and subsequent speed of learning

Scarce resources in schools can be complemented by the provision of multimedia facilities

engagement to realize and adopt a universal icon representation standard. Definition of a standard link, access and navigation visual interface in educational multimedia is suggested, with the aim of reducing learning time and smoothing the transition from one product to another.

In such a context, reference must be made to recent studies (Albert Badre, Ben Shneiderman) who propose useability indicators such as Learning Time, Task Performing Time, Number of Errors made by the user to execute a task, and to the VENUS project (ESPRIT III #6398) in which these are tested during the validation of visual interface.

An easier-to-use product as well as a smoother transition from one product to another, enables the neophyte user not to get tired and frustrated and, ultimately, not to reject the proposed telematics tools.

Virtual reality and learning: How to see the invisible

The application of **virtual reality** technology to learning allows for the projection of the movement-perception learning method beyond the limit of a manipulated reality.

The screen becomes a tool for penetrating the world of the invisible; the learners can navigate through a space in which they can interact with the structure of the infinitely small and of the immensely great. They can **touch** objects, **observe** and **experiment** in a visible reality where **entities** and **concepts,** so far accessible only to their minds, take shape.

The abstract becomes concrete and can be explored to the same extent as the physical world.

The users can investigate, discover, learn and subsequently, intellectualize, synthesize and abstract with much more awareness.

Virtual laboratories: The risk of 'aided manipulation'

Observe, manipulate, try and retry, analyse, confront, interpret results, these are not only the fundamental actions on which the movement-perception method is based, but also represent the stages of the experimental approach, i.e. the instrument used in science in order to explore the matter surrounding us. It is this very instrument that is to be used in order to transfer knowledge and make students become thoroughly aware of what constitutes a physical law, a chemical formula or a biological classification.

Laboratories, experimenters, equipment and materials enable learners to reproduce experiences, endow them with a deep and longer-lasting cognitive growth, encourage them to adopt a correct and scientific survey approach, make differences, divergences and peculiarities of didactic subjects visible and palpable, and finally enable learners to choose their school orientation more awarely.

Unfortunately, at present such facilities are considerably insufficient in the school structure. Today, the new information technology can bridge this gap by offering multimedia products or remote connections allowing for learners' distance participation in experimental experiences.

Yet this opportunity must not lead to the use of multimedia technology as a substitute or a by-product of real experience, nor to the complete replacement of direct manipulation by aided manipulation.

Financial support and incentives should be allocated in order to set up excellent virtual multimedia laboratories in schools as well as to create real educational structures, equipped with ever-increasing assets in terms of facilities.

Information and Communication Technology

The solitary planet

The use of the new teaching technology derives from the need to reduce the distance between teachers and students. Yet we might witness a paradox. The radical change of the teaching approach and the emphasis laid on the learning approach may lead to the replacement of teachers with experts or specialists. Likewise, active students may be considered as autodidacts who are responsible for their own studies and choose what, when and where to learn.

Should it spread to the lowest education levels, such a new didactic approach could lead to a subsequent problem requiring attention. Since learners choose their own learning path, the result may be:

- the dispersion of the common basic knowledge assets handled in primary and secondary schools, where interpersonal relationships are facilitated and fostered;
- the generation of more specialized and structured learners - if compared to the orientation they have chosen - their overall culture, however, may be less complete and flexible. They may be more isolated, more distant, less open to group experiences or social relationships.

With the inappropriate use of telematics tools, the habit of learning together would be lost; school would no longer be considered as a moment of team growth nor training courses as a moment of social growth; learners would no longer make comparisons or be able to integrate; there would be no synergy. All factors that have contributed to the growth and progress of society as well as to the achievement of ambitious goals in respect of co-operation among nations.

In order to encourage the use of telematics tools in the school and labour activities, the new didactic technology should first be applied to the following fields:

- the creation of a European citizenship;
- the creation of highly competitive European industries;
- the fulfilment, in the short term, of the demand for new professional skills;
- the establishment of minimum common basic competences to be defined and acknowledged by member states as to the real mobility of students and workers, in order to prepare the transition from an industrial society to a cognitive society.

Therefore, rather than reforming school from the outside by changing programmes and methods, perhaps it is necessary to propose a change in teacher-training structures. The key role played by teachers in changing education has been acknowledged in the International Conference on Education.

Only by aiming at teachers' assimilation of the new technological instruments, can the latter be integrated in the learners' training programmes. Synergy is thus generated between technology and content rather than simply overlaying new technology without following the methodological and pedagogical approach.

Such is the purpose of the action plan for a European Education Initiative, 'Learning in the Information Society', launched by the EU. Its action lines are oriented towards the promotion of the **'training and support for teacher and trainers (...) aimed at using new technology in their teaching methods'.**

Conclusions

The cautious use of new technology will act as a bridge between **education** and **production.** It will renew and increase the number of young people in the labour world, and will allow for the

The distance learner should not become isolated and should continue to acquire basic social interaction skills

It will be important to promote a change in teacher-training structures for continuity of the methodological and pedagogical approaches

permanent training required by SMEs. Only the incentivation of innovation in professional training will produce real innovation.

At the same time, caution will be needed in order to prevent the opportunities offered by the new teaching information technology from turning into distortions or negative effects, thus worsening the phenomenon of an imbalanced and non-homogeneous cultural growth which disregards the related pedagogical and socialization aspects.

Should this happen, the result would not only be direct damage but also the rejection or limited acceptability of the new teaching tools. This would delay their introduction, thus thwarting their great benefits.

Keywords
Distance learning, education, training, multimedia

References

- Olimpo, G. *Telematica e didattica.* Rivista di Informatica AICA, Vol. XXIV, no. 2, p. 129-141, 1994.
- Ronchi, A.M. *Realta' Virtuale e Didattica.* Energia Ambiente Innovazione Rivista ENEA, Rome, p. 23-29, February 1995.
- Bargellini, M.L., Fontana, F. et al. *Venus Project Experimentation at ENEA's pilot site.* ENEA Technical Report RT/INN(96)14, Rome, 1996.
- Batini, C. and Bargellini, M.L. *Sistemi informativi per la diffusione dell'informazione. Metodologia di progettazione.* ENEA, Rome, 1990.
- Bargellini, M.L. *Distance Learning, le nuove tecnologie per l'istruzione e la formazione.* ENEA Technical Report RT/INN(96)1, Rome, 1996.
- Bargellini, M.L., Fontana, F. et al. *L'immagine e la conoscenza: interfacce visive per la consultazione delle banche dati* ENEA Technical Report RT/INN(95)20, Rome, 1995.
- European Union, European Commission White Paper on teaching and learning: *Towards the learning society.* Brussels, November 1995.
- European Union , Report of the Task Force, *Educational Software and Multimedia working document of the Commission services,* July 1996.
- Decision n° 819/95/EC of the European Parliament and of the Council of the European Union. Official Journal of the European Communities, no. L 87/10, 20.4.95.
- European Union, DG XXII, Study Group on Education and Training Report, *Accomplishing Europe through Education and Training.*
- UNESCO *Report of the Commission on Education for the Twenty First Century,* UNESCO, Paris, October 1995.
- Ball, C. *Individual Learning: A Personal Learning Action Plan.* Proceedings of Lifelong Learning for the Information Society Conference, Genoa, Italy, 24-28 March 1996.
- Royal Society for the Encouragement of Arts, Manufacture and Commerce. *Your personal learning Action Plan: Make it happen.* Campaign for learning, Trichom Press, London, 1996.
- *Perspectives on distance independent education.* Journal of the American Society for Information Science, Vol. 47, no. II, November 1996.

Acknowledgements
The author would like to thank Mrs Giuseppina Cuteri for her valuable collaboration.

Contact
Maria Laura Bargellini, ENEA
tel. +39.6.30484236, fax +39.6.30484055, e-mail: bargellini@casaccia.enea.it

About the author

Maria Laura Bargellini graduated in physics at the 'La Sapienza' University of Rome From 1979-1983, she worked as an Administrator at the OCDE NEA (Nuclear Energy Agency) Data Bank, Saclay-Paris, on the evaluation of nuclear computer programs Since 1983, she has been working at ENEA, Italy She has been involved, as expert Designer, in national and EU projects on the development and management of numerous databases and multimedia information systems relating to the diffusion of information on innovative technologies. Her research fields are focused on conceptual database design methodology and visual interface validation methodology, with particular regard to useability aspects Within ENEA, she worked as Project Manager on the VENUS project (Visual Enquiry User-oriented System), under ESPRIT III Her current research interests are oriented to the distance learning field

European Standardization and Product-integrated Environmental Protection

Juliane Jorissen and Gotthard Bechmann

Issue: As part of the efforts to achieve a single European market, responsibility for standardization of products is being transferred from the national level to European level. This has led to fears in some Member States that environmental aspects will be given less importance than was previously the case in some national standards. On the other hand, there are also hopes that European standardization efforts will provide environmental aspects with coverage for a broader range of products than was the case in national standards.

Relevance: If the idea of environmental protection goals integrated in products could be anchored successfully in European standardization, the harmonization policy of the EU, though primarily serving the establishment of a single European market, could also play an important role in promoting environmental objectives.

Introduction

In view of the growing importance of harmonized technical standards, the Committee for the Environment, Nature Conservation and Nuclear Safety of the German Federal Parliament charged the German Parliament's Office of Technology Assessment (TAB) in 1993 to conduct a study on the possibilities and problems associated with the attainment of environmental protection goals within the framework of European standardization. This article presents the main findings of that study, since they are of equal relevance to other Member States and the Union, although the situation varies a great deal from one country to another.

Object and objectives

In introducing the so-called "New Approach" in 1985, the European Community adopted a model of technology control by deregulation which has a long tradition in many countries of the European Union. Its key feature is co-operation between legislators and independent industrial organizations. The European legislator restricts its role to the definition of general safety requirements to be met in products and refers to technical standards for their implementation. These are currently being drafted by the European standardization bodies, CEN/CENELEC, largely under their own responsibility. Once a product has been manufactured in accordance with these standards, it is assumed that it also fulfils the legal requirements.

The new approach of the EC to harmonization is based on co-operation between legislators and independent industrial organizations

Environment

Responsibility is transferred to the private sector to comply with EC safety and technical standards, which does not guarantee environmental protection

The advantages inherent in this new approach to harmonization are generally said to be the following:

- accelerated achievement of the single market;
- effective elimination of technical trade barriers;
- relief of the community legislator from the need to draw up detailed technical regulations;
- rapid adaptation of product requirements to the state of the art in technical development;
- better acceptance of standards by the industries involved.

However, these indisputable advantages are accompanied by a shift of responsibility for action to the private sector, which calls for systematic control by EC agencies of the harmonised standards. The directives mainly define general safety goals whose practical implementation leaves private European standardization organizations with considerable discretion. Establishing technical standards always requires balancing the interests of health and environmental protection against economic factors. It is thus up to the standardization bodies to decide on the tolerable risk in handling products for the general public.

The procedure also may not guarantee the consideration of environmental protection. The principle of 'territorial representation' practised in European standardization foresees that only such harmonized national positions can be argued as have already been achieved by compromises. This implies a loss of pluralistic rights of participation for all those parties which, for institutional, organizational and financial reasons, have fewer opportunities to make their voices heard, including, in particular, consumer and environmental protection interests.

Ensuring a high level of environmental protection in product-related standardization

The Maastricht Treaty firmly established the protection of the environment as an independent objective and as a cross-sectorial task. A factor of particular interest in this respect is the Commission's commitment to base its proposals for the single European Market in the areas of health, safety, environmental protection, and consumer protection on a 'high level of protection'. However, the rather vague term 'high level of protection' should be made more tangible if it is to assume the character of a legal regulation beyond the mere indication of a general political direction. The Maastricht version of the EC Treaty could, in principle, provide sufficient starting points for this.

If the harmonized standards fail to consider adequately such areas of public concern as environmental protection, energy conservation and resource conservation, this could cause the member countries to block the commercialization of products meeting the standards. Achieving the high level of protection guaranteed in the Treaty must therefore be in the interest of the Community and, hence, also of the European standardization bodies. These bodies are well aware of their duties in environmental protection, as is demonstrated by various efforts over the past few years to improve the institutionalized and administrative preconditions for the systematic inclusion of environmental aspects in product-related standardization. It will not be an easy task, however, to guarantee a long-term high level of environmental protection in product standardization, especially if the demand for greater environmental compatibility of products clashes with the need to improve the efficiency of achieving the single market and accelerating standardization activities.

Defining legal requirements as precisely as possible would be helpful. However, given the wide range of products covered in many directives, this will be difficult. It may be easier to provide a more precise wording of the specific mandates of the standardization bodies.

On the whole, however, these proposals indicate that relatively tight constraints are imposed on any attempt to improve, by more precise legal conditions, the way in which environmental interests can be considered in standardization. If the efficiency of standardization is not to be jeopardized, standardization bodies must be left sufficient discretion for their own definitions so as not to impede technical and functional innovations.

Reforming the Standardization Process

There is great interest in procedural guarantees seeking to establish a balanced process of drafting standards. To some extent it is considered as tolerable for the government to waive its right to issue regulations in favour of private standardization organizations if the standards are formulated by expert bodies in a regular, transparent procedure with the representative participation of interested parties and of the public.

Those defending the interests of environmental protection have argued that it is hard for them to make optimum use of existing opportunities for participation, due to their very limited resources in terms of manpower, organization, and funding. Hence, in order to establish 'equal opportunities', there are demands to enable the participation of both government agencies working in the field of environmental protection and representatives of environmental associations. In order to meet the requirement of transparency, particular demands are made for early access to information about impending standardization projects in sufficient advance for the public to raise objections, and for the obligation to provide record of decision. In the opinion of the experts consulted by TAB, this obligation would not have to extend to all aspects of technical standardization, but mainly to the consideration of environmental risks and health risks caused by products. It was also suggested that the scope of discretion in evaluation should be illustrated by at least two alternative proposals complete with the underlying reasons. Finally, the majority of experts felt that there should be a legally binding EC directive regulating procedure.

Enhanced political legitimation of standards

If there is no meaningful and feasible alternative to the EU approach towards harmonizing legal provisions, the European legislator must ensure that this co-operative legislative procedure is given democratic legitimation. Standards replacing government regulations protecting the public must be subjected to effective control by the bodies of the EC to ensure that the goals of the EC Treaty and the requirements under the respective directives are met. The experts consulted by TAB submitted various proposals on this aspect, such as the adoption of standards by the Commission within the framework of 'closed-loop' legislation, delegating a voting representative of the Commission into standardization bodies and the introduction of a 'conformity check' by the Commission.

It is still a matter of debate how to design this control without overtaxing the technical and manpower resources of the Commission and, above all, without jeopardizing the basic idea underlying the new approach, namely

The failure of standards to take sufficient account of issues such as environmental protection may lead to resistance to their adoption by member countries

More precise legal stipulations on harmonization would be helpful, although restrictions on standardization bodies render this difficult

The standardization process could be reviewed to include participation of interested parties and the public

The problem is posed of legitimating standards while respecting the basic deregulation principle of the new approach deregulation. Should government control of standardization procedures turn out to be unfeasible, the only alternative to reduce the delegation problem is to weaken the significance of standards for product harmonization. If standards were reduced to the status of mere recommendations by private associations, there would be no legitimation problem and, hence, no need for government control. It is doubtful whether this can be achieved without undermining the confidence of producers in harmonized standards, and thus jeopardizing the integration goal.

Possibilities of national policy to influence the design of framework conditions for European standardization.

Any active environmental policy of the member countries seeking to make increasing use of European standardization as an instrument of proactive environmental protection, will have to both make use of the remaining, increasingly narrower, national scope for action and, above all, co-operate at European level.

The executive branches of the member countries can exert direct influence on European legislation through their representatives in the Council of Ministers, which votes by qualified majority on these issues, and they could use that influence to achieve an ambitious level of environmental protection in the product related directives under the new approach.

Keywords

Standardization, environmental protection, harmonization policy

Reference

• TAB Report on the Attainment of Environmental Protection Goals within the Framework of European Standardization, German Parliamentary Office of Technology Assessment, 1993.

Contacts

Juliane Jörissen, Forschungszentrum Karlsruhe, ITAS,
tel: +49 7247/82 2994, fax: +49 7247/82 4806
Gotthard Bechmann, Forschungszentrum Karlsruhe, ITAS,
tel: +49 7247/82 2705, fax: +49 7247/82 4806, e-mail: bechmann@itas.fzk.de

About the authors

Both authors are researchers at Karlsruhe Research Centre's Institute for Technology Assessment and Systems Analysis (ITAS)
Juliane Jörissen holds an engineering degree in regional planning from the University of Dortmund Her main interests include environmental impact assessment, the legal aspects of technology assessment and sustainable development Much of her recent work has been for the German Parliament's Office of Technology Assessment (TAB), including projects on groundwater protection and European standardization
Gotthard Bechmann studied law, political science and sociology and holds a degree in law from Frankfurt University His main areas of research are the science system, technology policy, risk, environmental law, the sociology of technology and technology assessment He has taught at the Universities of Bremen and San Sebastián

IPTS publications for 1996

- ADEME-Prospectives de la biomasse pour l'énergie dans l'Union Européenne-EUR 17260 FR
- Aguado-Status and Prospective Analysis of the Photovoltaic Technology-EUR 16391 EN
- Allgeier (ed.)-The IPTS Report-ISSN 1025-9384
- Bonazzi-Euro-Mediterranean Policies and Olive Oil : Competition or JobSharing? - Agro-food technology transfers for sustainable development in the Mediterranean : a strategic approach for an environmentally sound food security-EUR 17270 EN
- Bonazzi-Il Mercato dei Diritti di Emissioni Inquinanti : Metodologie, stato dell'arte, Prospettive e una proposta per l'Italia-EUR 17269 IT
- Bontoux-Prospective technological study on materials/Chemical-feedstock recycling and energy recovery from municipal plastics waste - Project I.1a: Preliminary survey of current projects on plastics recycling by chemolysis-
- Bontoux-Survey of current projects for plastics recycling by chemolsis:Prospective technological study on materials/chemical-feedstock recycling and energy recovery from municipal plastics waste -EUR 16459 EN
- Bontoux-The recycling industry in the European Union : impediments and prospects-EUR 17271 EN
- Brossa-Prospective technological study on materials/Chemical-feedstock recycling and energy recovery from municipal plastics waste - Project I.3: Preliminary survey of current projects on energy recovery from municipal plastics waste-
- Cahill-Industrial Efficiency - A Literature Synthesis-EUR 16447 EN
- Canarelli-Knowledge Extraction from Data Using Genetic Algorithms-EUR 16446 EN
- Canarelli-Neural Networks: a Tool for Analysing Real World Complex Systems-EUR 16445 EN
- Canarelli-The Method of Fuzzy Scenarios: Principle and Application to the Future of Congestion in Urban Centres-EUR 16444 EN
- De la Torre , M. González (eds.)-Annual Report 1995. Institute for Pospective Technological Studies -EUR 16405
- Demicheli, L. Bontoux-Survey on Current Valorization of By-Products from the Olive Oil Industry-EUR 16466 EN
- Fahrenkrog, D. Kyriakou-New technologies and employment: Highlights of an ongoing Debate-EUR 16458 EN
- Gómez*, M.L. Borra*, M. Aguado (eds.)-Conclusions of the Forum "European Enterprises facing technical and legal barries to renewable energy, Seville, 23/24 November 1995 (Organised by SODEAN, UNESCO, IPTS, ECD, BESEL)-EUR 16390 EN
- Group of Bertino S.Gomez y Paloma-East-West Agro-Food Systems Toward the Third Millennium-ART 43171
- Groupe CM International-Technology Gaps & Sustainable Regional Development: an exploratory study - case of the agri-food sector in Andalucía, Ireland, South Brandenburg and Central Macedonia-EUR 17278
- Hardy-Politiques de développement territorial et investissements étrangers dans les pays du Maghreb-EUR 16419 FR
- Harvey (CEST)-AGILE Manufacturing - A Scoping Study-EUR 16469 EN
- J.R.Naegele (Co-ordinator), P. Canarelli, H. Hernández, T. Amorelli, M. Nicolai, F. Scapolo, C. Heller-The Car of the Future, The Future of the Car-EUR 17277 EN

- L.Bontoux, D. Papameletiou (eds.)-Technology options for plastics waste management: Proceedings, Seville 20-21 November 1995-EUR 16460 EN
- Leone-Prospective technological study on materials/Chemical-feedstock recycling and energy recovery from municipal plastics waste -Project I.4a: Preliminary survey of current legislative activity in plastics waste management-
- Leone-Survey of current legislative activity in plastic waste management (Focus on Economic instruments) - Second Interim report --EUR 16467 EN
- M.Cepeda, A.Soria-Energy Demand and CO2 Emissions from the World Transport Sector : Past Evidence and Forecasts-EUR 17256 EN
- Moncada Paternò Castello-Studio di Pre-fattibilità di un "Agenzia Mediterranea in Sicilia per la Promozione delle Energie Rinnovabili e la Gestione Efficiente dell'Acqua"-EUR 17255 IT
- Naegele, T. Amorelli,-The future of non-ferrous metals-
- Nicolai-Prospective technological study on materials/chemical-feedstock recycling and energy recovery from municipal plastics waste - Project I.2: Preliminary survey of current projects on mechanical recycling of municipal plastics waste-
- Ribeiro-Desalination Technology: Survey and Prospects-EUR 16434 EN
- Rogers-Biotechnoiogy - Risk Analysis and Genetically Manipulated Organisms: The Japanese RegulatorySystem-
- Rogers-Biotechnology: Risk assessment and genetically modified organisms-EUR 16377 EN
- Rogers-The environmental busines - Corporate case studies: Waste minimisation/Cleaner technology-EUR 16376 EN
- Sorup-Sustainability Accounting - A support document for the preparation of the conference "Taking Nature into Account", Brussels, 31 May - 1 June 1995-
- Spiewak-Strategy for Solar-Thermal Energy Research, Development and Industrial Application-EUR 17276 EN
- Stamm'ler Jaliff, C.A. Jonsson, A. Ljungblad-Introduction of Modern Software Technology : a Case from Swedish Industry. Bilbao 26-28 September 1996-ORA/PRO 40168
- T.Gameson, P. DiPietrogiacomo, P. Sørup (eds.)-European research towards the XXIst century : IPTS workshop Sevilla, 29-30, August 1996-EUR 17257 EN
- Weber, G. Fahrenkrog-Sustainability and technology: A framework for discussion-EUR 16457 EN
- Weber, M. Nicolai-The Ethical Dimension of Technology Watch and Assessment, proceedings of a seminar on 25 March 1996 at IPTS in Seville-EUR 17279 EN
- Weber-Innovation diffusion and political control in the energy sector: a conceptual approach and empirical evidence from the case of cogeneration in the UK-
- Weber-Innovation, diffusion and political control: The politics, economics and technology of cogeneration (CHP) in the UK-EUR 16443 EN
- Weber-Technological change and energy policy in different national contexts ; Combined Heat and Power in the UK and Germany-EUR 17280 EN
- Zwick-Climate change - Analysis of causes, impacts and options-EUR 16402 EN
- Zwick-Climate change research and policy: Updates (A periodic survey: no. 7)-
- Zwick-Climate change research and policy: Updates - no. 8-

ABOUT THE IPTS

The **IPTS** is one of the seven institutes of the Joint Research Centre of the EU Commission. Its remit is the observation and follow-up of technological change in its broadest sense, in order to understand better its links with economic and social change. The Institute carries out and co-ordinates rseařch to imporve our understanding of the impact of new technologies, and their relationship to their socio-economic context.

The purpose of this work is to support the decision-maker in the management of change pivotally anchored on S/T developments. In this endeavour IPTS enjoys a dual advantage: being a part of the Commission IPTS shares EU goals and priorities; on the other hand it cherishes its research institute neutrality and distance from the intricacies of actual policy-making. This combination allows the IPTS to build bridges betwen EU undertakings, contributing to and co-ordinating the creation of common knowledge bases at the disposal of all stake-holders. Though the work of the IPTS is mainly addressed to the Commission, it also works with decision-makers in the European Parliament, and agencies and institutions in the Member States.

The Institute's main activities, defined in close cooperation with the decision-maker are:

1. Technology Watch. This activity aims to alert European decision-makers to the social, economic and political consequences of major technological issues and trends. This is achieved through the European Science and Technology Observatory (ESTO), a European-wide network of nationally based organisations. The IPTS is the central node of ESTO, co-ordinating technology watch 'joint ventures' with the aim of better understanding technological change.

2. Technology, employment & competitiveness. Given the significance of these issues for Europe and the EU institutions, the technology-employment-competitiveness relationship is the driving force behind all IPTS activities, focusing analysis on the potential of promising technologies for job creation, economic growth and social welfare. Such analyses may be linked to specific technologies, technological sectors, or cross-sectoral issues and themes.

3. Support for policy-making. The IPTS also undertakes work to supports both Commission services and other EU institutions in response to specific requests, usually as a direct contribution to decision-making and/or policy implementation. These tasks are fully integrated with, and take full advantage of on-going Technology Watch activities.

As well as collaborating directly with policy-makers in order to obtain first-hand understanding of their concerns, the IPTS draws upon sector actors' knowledge and promotes dialogue between them, whilst working in close co-operation with the scientific community so as to ensure technical accuracy. In addition to its flagship IPTS Report, the work of the IPTS is also presented in occasional prospective notes, a series of dossiers, synthesis reports and working papers.

The IPTS Report is published in the first week of every month, except for the months of January and August. It is edited in English and is currently available free of charge in four languages: English, French, German and Spanish.

S.P.I. 97.15

The European Science and Technology Observatory Network (ESTO):
IPTS - JRC - European Commission
W.T.C., Isla de la Cartuja s/n, E-41092, Sevilla, Spain
tel.: +34-5-448 82 84; fax: +34-5-448 82 35; e-mail ipts_secr@jrc.es

- ADIT - Agence pour la Diffusion de l'Information Technologique - F
- CEST - Centre for Exploitation of Science and Technology - UK
- COTEC - Fundación para la Innovación Tecnológica - E
- DTU - University of Denmark, Unit of Technology Assessment - DK
- ENEA - Directorate Studies and Strategies - I
- INETI - Instituto Nacional de Engenharia e Technologia Industrial - P
- ITAS - Institut für Technikfolgenabschätzung und Systemanalyse - D
- NUTEC - Department Science Policy Studies - S
- OST - Observatoire des Sciences et des Techniques - F
- SPRU - Science Policy Research Unit - UK
- TNO - Centre for Technology and Policy Studies - NL
- VDI-TZ - Technology Centre Future Technologies Division - D
- VITO - Flemish Institute for Technology Research - B
- VTT - Group of Technology Studies - FIN