Appendix 4.3 –Deliverable D3

Project no. 502487

Project acronym: POPA-CTDA

Project title:
Policy pathways to promote the development and adoption of cleaner technologies

Instrument: STREP

Thematic Priority 8.1, Policy-oriented research (SSP), FP6-2002-SSP-1

Deliverable number D3
Industry Sector Background Study

Due date of deliverable: May 30, 2004
Actual submission date: May 29, 2004

Start date of project: January 1st, 2004 Duration: 24 months

Organisation name of lead contractor for this deliverable: JRC-IPTS

Revision [draft]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	R

Contents

1. INTRODUCTION

According to the concept of sustainable development advanced by the World Commission on Environment and Development and popularised at the 1992 Rio Earth Summit, the economy and the environment are interdependent. On the one hand, advances in technology and economic growth are needed to solve environmental problems, but at the same time this economic growth can not be sustained if the natural resource base is degraded[1].

In this respect, clean technologies that lower the costs of environmental protection can play a significant role. They enable to meet increased demands for a cleaner environment by reducing the environmental impact of economic growth while, on the other hand, they reduce any impact of higher environmental standards on GDP growth itself. They play an important role in de-coupling environmental impacts from economic growth. In Gothenburg, the European Council agreed on its strategy for sustainable development with four priority areas: climate change, transport, public health and natural resources. These issues are to complement the social and economic aspects of sustainable development, which are being dealt with in the so-called "Lisbon process" of Spring Summits. The EU’s Sustainable Development Strategy seeks to promote economic growth and social cohesion without deteriorating environmental quality. The Lisbon Strategy is a commitment to bring about economic, social and environmental renewal in the EU with the objective of making the EU the most competitive knowledge-based economy. Fostering technological progress and renewing the EU capital stock are major aims of the Lisbon Strategy[2].

Today’s significant increase in clean technologies use is due to a confluence of environmental, technological, economic and social forces, which include[3]:

- Changing markets, from the globalisation of suppliers and customers to the emerging markets of the developing world, are dramatically expanding the demand for goods and services around the globe. The challenge for companies and countries in the developing world is how to grow new business and economies without the concomitant growth of resource extraction and pollutant emissions that have characterised economic progress in industrial societies.
- Changing technologies, including continued innovations in microelectronics, biology, chemistry and physics have significantly improved the environmental performance of technologies. Emerging scientific disciplines, such as bioengineering and nanotechnology are facilitating improvements in products and processes that dramatically cut waste and emissions and reduce resource use.
- Changing social pressures have pressed companies to address the needs of society and the environment as never before. Issues, such as climate change, deforestation, air pollution and water pollution have pressed industry to find

[1] Promoting Growth and Job creation through Emerging Environmental Technologies. Hoerner A., Miller A., Muller F. National Commission for Employment Policy. Research Report 95-3. 1995
[2] Report from the Commission. Environmental technology for sustainable development. 2002
[3] The Clean Revolution: technologies from the leading edge. Makower J. GBN. 2001

and improve products and processes in order to de-couple environmental impacts and economic growth. The increased attention paid to sustainable development has increased the demand for clean technologies.

Clean technologies include both process integrated technologies (PI) preventing pollutants being generated during the production process, and end of pipe technologies (EP) that reduce the release into the environment of any pollutants that are produced. End of pipe technologies do not have side-benefits, such as cost saving or increased throughput and its implementation is mostly driven by legislation.

Process integrated technologies also include new materials, energy and resource-efficient production processes as well as environmental know-how and new ways of working (Makower, 2001).

The European Commission adopted an ambitious Action Plan (COM (2004) 38) to improve the development and wider use of environmental technologies. Many new environmental technologies have great potential to improve the environment and, at the same time, boost the competitiveness of companies. The main objectives of the Action Plan are:

- To remove the obstacles so as to tap the full potential of environmental technologies for protecting the environment while contributing to competitiveness and economic growth.
- To ensure that over the coming years the EU takes a leading role in developing and applying environmental technologies.
- To mobilise all stakeholders in support of these objectives.

The aim of the POPA project is to assess the drivers and barriers for the development and uptake of cleaner technologies by businesses and households across the energy, agricultural, transport and industrial sectors of the economy. The project will clarify what are the barriers impeding progress of cleaner technologies and what policy initiatives, and additional research tasks, are needed to address these barriers. The output of this policy-targeted research will be of particular use to policy makers looking for new tools and insights into how to encourage innovation and use of cleaner technologies and hence help in the practical implementation of sustainable development.

2. POLICY DEVELOPMENTS

The development of clean technologies in the manufacturing industry is largely dependent on the present and forthcoming regulatory framework. A general statement acknowledges that it is impossible to draw some simple and general conclusion about the link between regulation and innovation. It cannot be alleged that such and such regulatory measure lead inevitably to more innovation. Indeed, there are many subtle variations within each category of regulations. Moreover, most regulatory constraints generate contradictory effects on innovation. They tend to stimulate certain phase of the process of innovation and to block others.

However, by looking at specific regulations, it remains relevant to examine the nature of the innovation effects of regulation, how the regulations influence innovation decisions and output etc. In fact, the stimulus-brake approach that deals with the question whether regulation acts as a brake on innovation or a stimulus is not appropriate for environmental regulation in particular, and for social innovation in general. It is not appropriate basically because it neglects the discriminating effects of regulations on innovation. The innovation effects of social regulation are not a matter of slowing (or speeding) but of changing the direction of technical change and the nature of innovation output. In other words, regulations act both as a focusing device and a filter (Kemp et al., 2000). A clear and ambitious framework is a prerequisite for promoting the development of new environmental technologies. From this perspective, it is possible to report the main EU policies that may influence cleaner production and the development of cleaner technologies.

2.1 Liability

The White Paper on environmental liability adopted by the Commission in February 2000 stated the need for European Community action on liability for environmental damage. Environmental liability aims at making the causer of environmental damage (the polluter) pay for remedying the damage that he has caused (the polluter pays principle). The application of this method encourages the various parties concerned to take more precautions and reduce pollution. In January 2002, a proposal for a Directive on environmental liability with regard to the prevention and remedying of environmental damage has been adopted. The Directive will induce operators of risky or potentially risky activities to be more careful and will therefore contribute to innovation: it will encourage them to develop and use environmentally safe technologies and processes.

Liability for waste, including producer responsibility for post consumer waste, may thus favour cleaner production. Producer responsibility for post consumer waste emerged in Germany in the late 1980s. From there it has now spread to many other European countries and relates by now to a variety of products including packaging, automobiles, kitchen apparatus and electronic goods. Liability-based approaches have significantly helped low-waste technologies in production, regarding products and along product life cycles (Reinjders, 2003).

2.2 Permits

The legal basis to include cleaner production process in permits in the EU is the IPPC Directive (96/61/EC). This Directive aims to achieve integrated prevention and control of pollution arising from a wide range of industrial and agricultural activities and a high level of protection of the environment as a whole. This purpose takes place within the context of a permit system for installations. Since October 1999 the Directive has applied to new installations or to existing installations which experience significant changes. Member States have a transition period until October 2007 to ensure that other existing installations fully comply with the Directive[4].

The permit system aims to ensure that operators of installations take preventive measures against pollution, in particular through the application of the best available techniques (BAT). This system also aims to ensure that no significant pollution is

[4] See the Report from the Commission on the progress in implementing Council Directive 96/61/EC concerning IPPC [COM (2003), 354].

caused, that the waste that cannot be avoided is recovered or safely disposed of, that energy is used efficiently, that accidents are prevented and their consequences limited and that the site of operation is returned to a satisfactory state when the installation closes. So the Directive aims at acting as a preventive instrument to promote sustainable production patterns. This represents a driver for the dissemination of environmental technologies in industry[5].

Nevertheless it is still too soon to judge the environmental impact of the Directive's application. Since October 1999 (the deadline for transposition in the Member States), few new installations have started operating and not many substantial changes have been made to existing installations already subject to the Directive's provisions. The Commission invites a number of Member States to move more quickly towards full application of the Directive in order that all their existing installations may achieve conformity by the set date of October 2007. For the new Member States, issuing IPPC permits for existing installations represent secondary obligations that can be completed after accession. For the time being, Latvia has made rapid progress in implementing the IPPC directive. More generally, accession will bring increased and challenging requirements to environmental administration in the acceding countries, and additional tasks in relation to monitoring, inspections, permits and reporting.

The obligation to implement Best Available Technologies by 2007 is a key aspect of the IPPC Directive. The results of the study of the impact of BAT on the competitiveness of individual plants (Hitchens et al., 2001[6]) show that there is no evidence that BAT prevented companies using them and achieving good environmental standards from remaining competitive both nationally and internationally. The study underlines that investment cycles are a key factor for the competent authority to take into account. Indeed, a planned renewal of plant machinery is an appropriate momentum to make environmental investments. The study also found that, in many cases, BAT plants tend to be large, already strongly competitive, growing and endowed with quality skills but also undertake an above average of R&D. These advantages facilitate compliance with BAT. There can be specific cases where the operator does have the necessary means to upgrade the installation to the BAT. This might be a particular problem in regions whose development is lagging behind, or in declining industrial regions but also for small and medium-sized enterprises (SMEs).

Danish, UK and Dutch laws have largely used permits to stimulate cleaner production (Reijnders, 2003). Their experience confirmed that it is possible to define for specific types of companies best cleaner production practices without negatively affecting the financial performance of companies. The future diffusion of cleaner production will be influenced by two things: the ability to regularly update such best practices to incorporate technological progress and demonstration projects by referent companies.

2.3 Financing of cleaner production investments

Financial support is an important aspect for promoting cleaner production investments and the European Investment Bank (EIB) actively supports Cleaner Production

[5] It is also a key element of several thematic strategies being developed as part of the Sixth Community Environment Action Programme (OJ L 242, 10/9/2002, p.1-15).

[6] IPTS report EUR 20133 EN. See also the results of a stakeholder workshop held in May 2002, ‘The Economic Consequences of the IPPC Directive’.
http://europa.eu.int/comm/enterprise/environnement/index_home/ippc/bat_conference.htm

financing, mainly through the provision of long term loans. Notably in association with the EIF (European Investment Fund), venture capital is provided to SMEs, sometimes for Cleaner Production activities. The Commission also aims to develop further Europe's risk capital market through the action plan 'The European Agenda for Entrepreneurship' and the Innovation Action Plan.

The Commission has already begun to explore with the EIB Group how to maximize the use of existing instruments and whether there is a need to create new ones to share the risk of investing in environmental technology projects and companies, notably through risk capital funds[7].

To encourage demonstration projects, the LIFE programme represents a significant instrument in the Community. The LIFE, the Financial Instrument for the Environment, co-finances environmental initiatives in the European Union and certain third countries bordering on the Mediterranean Sea and the Baltic Sea and in central and east European accession candidate countries that have decided to participate in LIFE. This instrument enables demonstration and development of new methods for the protection and the enhancement of the environment. The dissemination of results is an essential element of the programme.

The EU has allocated approximately 300 million Euros to the LIFE-Environment programme for the period 2000-2004. The rate of Community co-financing can be up to 30% for projects generating substantial net revenue, 50 % in other cases.

The new acceding countries have been encouraged to participate to LIFE. They have also benefited from the PHARE programme which is currently the European Community's main instrument of financial and technical cooperation with the candidate Central and Eastern European countries (CEECs)[8]. Moreover, community pre-accession aid in the environmental sector has been stepped up since 2000 using the pre-accession structural instrument (PASI), which relates to the environment and transport.

In order to ensure that financing solutions do not unduly distort competition in the internal market, the European Commission adopted in 1994 Community Guidelines on State Aid for Environmental Protection (94/C/72/03). These guidelines aim to strike a balance between the requirements of competition and environmental policy, given the widespread use of state aid. Generally, state aid is justified when adverse effects on competition are outweighed by the benefits for the environment. Recent experience suggests that the framework is not properly adapted to the increasing sophistication of investments in environmental technologies, nor to new forms of public/private partnership. Therefore the Commission will review the framework and decide on any necessary adjustments to the existing Guidelines. It remains that the Community Guidelines on State Aid for Environmental Protection are relevant for CEE countries in the EU approximation process. Especially expenditure policies of environmental funds in CEECs should be gradually brought in line with the guidelines.

[7] See ETAP [COM(2004)38final] for more details on current and foreseen EIB activities.

[8] The European Bank for Reconstruction and Development is also an important institution in this domain. EBRD's Cleaner Production Financing activities are conducted in the countries of Central and Eastern Europe and the former Soviet Union. An example is a technical co-operation project in Poland, which aims to demonstrate that Cleaner Production projects can provide attractive opportunities for commercial financing.

Environmental aids to encourage the funding of clean investments are taken by Member states. For example, the Austrian Federal Ministry of Transport, Innovation, and Technology (BMVIT) has developed a five-year research and technology Program on Technologies for Sustainable Development. It initiates and supports trend-setting research and development projects and the implementation of exemplary pilot projects. One subprogram, called The "Factory of Tomorrow"[9], aims at zero-waste, zero-emission production, and produces and provides products and services of tomorrow using materials of tomorrow to meet tomorrow's needs. It focuses on innovative development in the field of sustainable technologies and innovations in production processes, in the use of renewable raw materials and in products and services. Similar initiatives can be observed in other countries where environmental agencies play a significant role at a national or a regional level (Germany[10], France, UK etc.).

2.4 Mix of instruments

In the recent period, emphasis has been placed on diversifying environmental instruments and, in particular, on introducing environmental taxes, environmental accounting and voluntary agreements. No progress can be made unless environmental legislation is actually implemented, and effective implementation involves introducing incentives for economic operators. Through an appropriate mix of instruments, business focus, direction of technical change and nature of innovation output are likely to change. Ideally, when further developing EU environmental policy in the field of industrial installations, it is important to ensure optimal consistency between the instruments and also a continuous search for dynamic efficiency.

The legislative framework

The legislative framework of the European Union provides for a high level of environmental protection. Several Directives have been or are being adopted in order to improve air quality (Air Quality Directives[11], National Emission Ceilings Directive[12]), water quality (Water Framework Directive[13]), waste management (Landfill Directive[14], Waste Incineration[15]).

Some Directives target specific industries (refineries[16], mining[17]) and, for the most part, regulations cover the main heavily polluting industries (chemicals, iron and steel, refineries, cement, metallurgical, pulp and paper). Large Combustion Plant[18], Solvent

---

[9] http://fabrikderzukunft.at/english.htm

[10] cf. The portal of the Federal Environmental Agency on environmental technology transfers http://www.cleaner-production.de

[11] Council Directive 96/62/EC on ambient quality assessment and management. Three 'daughter' Directives supplement Directive 96/62/EC to address specific air pollutants. Directive 1999/30/EC sets limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air. Directive 2000/69/EC sets limit values for benzene and carbon monoxide in ambient air. Directive 2002/3/EC is relating to ozone in ambient air.

[12] Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants.

[13] Directive 2000/60/EC establishes a framework for Community action in the field of water policy.

[14] Directive 1999/31/EC on the landfill of waste.

[15] Directive 2000/76/EC on the incineration of waste

[16] Directive 2003/17/EC amending Directive 98/70/EC relating to the quality of petrol and diesel fuels.

[17] Proposal for a Directive on the management of waste from the extractive industries COM (2003), 318.

[18] Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants.

Directives[19], Seveso II Directive[20], Chemicals Policy[21], Environmental Impact Assessment Directive[22] are part of the broad range of regulations targeting manufacturing industry. Most of the Directives are mainly based on the setting of emission limit values for a number of key pollutants. They complement the IPPC Directive (96/61/EC).

Environmental taxes

The recent trends show that a number of member states have increased environmental taxes. Scandinavian and Benelux countries have been especially active in this field but ecotaxation can also be found in the United Kingdom, France, Italy, Germany and Portugal. In the European Union the share of environmental taxes in total taxes and social charges has been steadily rising from 5.84% in 1980 to 6.71% in 1997 (EEA, 2000). Countries in transition have also introduced substantial environmental taxes. Major targets of taxation in the EU and transition countries are energy, water and wastes. However environmental taxes have also emerged for specific substances used as inputs (for example pesticides). Selective tax reductions, especially selective lowering of the value added tax, have also been used to a limited extent (e.g. Spain, UK and Netherlands).

Emissions trading scheme

A relatively new development in the European context is the use of emissions trading. This instrument is part of the European strategy to implement the Kyoto protocol on limiting climate change[23]. The Member states have to prepare allocation plans. These plans must set targets that produce real emission cuts. They must be in line with each EU country meeting its target under the burden sharing agreement. However, differences exist across countries since some countries are well below their Kyoto targets, particularly Germany and the UK. In any case, the process of setting these targets must be, as stated in the Directive, objective, transparent and open to public comment and feedback.

Voluntary approaches

During the last years, the use of voluntary agreements such as the European Eco-Management and Audit Scheme (EMAS)[24] kept on growing[25]. Among the new Member States, the Czech Republic has been very involved in the spread of this tool. Traditionally the Czech Republic has been a highly industrial country. During the communist regime the emphasis was on heavy industry, coal mining, steel, heavy machinery and bulk chemicals. Since the start of the accession process, great emphasis

[19] Directive 1999/13/EC on the limitation of VOCs due to the use of organic solvents in certain activities and installations.

[20] Directive 96/82/EC on the control of major-accident hazards involving dangerous substances.

[21] Directive 67/548/EEC, Directive 76/769/EEC and more recently the new system for assessing and controlling the use of both existing and new chemicals Registration, Evaluation and Authorization of Chemicals (REACH).

[22] In accordance with Directive 85/337/EEC.

[23] The European Emissions Trading Scheme is based on Directive 2003/87/EC, which entered into force as part of EU legislation in October 2003. The scheme will commence in January 2005.

[24] Regulation (EC) No 761/2001 allowing voluntary participation by organisations in a Community eco-management and audit scheme (EMAS).

[25] The number of EMAS certification was 1269 in December 1997 and reached 3498 in December 2003. http://europa.eu.int/comm/environment/emas/index_en.htm

has been placed on the implementation of environmental management systems under the ISO 14000 and the EMAS programme, in which the Czech Republic has been the most active Candidate Country. It benefited as the only country from the EMAS programme set up by DG Environment aiming to transfer know-how from the Member State to the Czech Republic.

Despite a relatively significant use of voluntary agreement within Member states to address a wide range of environmental problems, there is a high diversity in the type of voluntary approach. In particular, they differ regarding the parties involved in the negotiation (public authorities, private parties), the underlying scheme (target-based or implementation-based) and the type of monitoring and sanctions. Belgium, the Netherlands and Denmark have great experience in legally binding and negotiated agreements between public authorities and industry. The Union is currently striving for environmental agreements in a number of environmental fields such as the use of PVC, integrated product policy, waste management and climate change. Environmental agreements are a form of self-regulation as they are not binding at Community level. However, the Commission can encourage them, recognise them (this applies to self-regulation) or propose that the legislature make use of them (this applies to co-regulation). The 4th Annual Report on CO2 Emissions from New Cars[26] shows that the car industry has made progress in meeting its commitments from the voluntary agreements with the Commission to produce cars that emit less CO2. CO2 emissions from new passenger cars sold in the EU decreased by 10.8% between 1995 and 2002. The EU's goal is to reach a 35% reduction by 2010 at the latest. As CO2 emissions are the main contributor to climate change, it is of major importance that the car industries stick to the target and keep reducing emissions.

2.4 New approaches to promote stakeholder improvement and life-cycle thinking

The Sixth Environment Action Programme "Environment 2010: Our future, our choice" [COM (2001) 31 final]

The Sixth Community Environment Action Programme (6EAP) lays down the key environmental objectives and priorities for the next ten years starting as from 22 July 2002. The 6EAP focuses on four priority areas for action: climate change; biodiversity; environment and health; and sustainable management of resources and wastes. The Sixth Programme proposes a new approach to the development of environmental measures so that the parties concerned and the general public are more involved in their application. This approach includes a broad dialogue and the participation of industry, NGOs and the public authorities.

Thematic strategies

The 6EAP gives a mandate to develop seven *thematic strategies* for priority areas of environmental policy. Air pollution[27], waste prevention and recycling[28], sustainable use

[26] The report and further information can be found at:
http://europa.eu.int/comm/environment/co2/co2_home.htm
http://europa.eu.int/comm/enterprise/automotive/pagesbackground/pollutant_emission/index.htm

[27] The Clean Air for Europe (CAFE) Programme set up in 2001 is aimed to establish a long-term, integrated strategy to tackle air pollution and to protect against its effects on human health and the environment.

of natural resources (Resource Strategy), Soil protection, Sustainable use of pesticides, Protect and conserve the marine environment, Urban environment. The concept of thematic strategies should be seen as a complement to the full implementation and review of the effectiveness of the existing legal framework. The thematic strategy is to be defined in a broad approach, involving all relevant stakeholders. This is a new way of developing environmental policy for complex priority problems that require a broad approach.

Action Plan dedicated to environmental technologies

The *Environmental Technology Action Plan (ETAP)* defines a number of actions to promote the development and adoption of clean technologies. This action plan includes a series of measures to overcome barriers that are holding back the development, diffusion and use of promising technologies that are able to contribute to both increased environmental protection and higher economic growth and employment. Thus ETAP draws on the general regulatory context conducive to the adoption of preventive strategies in business. A key aspect of the plan is the support of demonstration and pilot projects. In this respect, the establishment of technology platforms for some complex technologies as well as networking testing centres are part of the priority actions of ETAP. Such actions should contribute to the diffusion of clean technologies.

Integrated Product Policy

In February 2001, a Green Paper on integrated product policy has been drawn up. It is aimed to present a strategy for strengthening and refocusing product-related environmental policies with a view to promoting the development of a market for greener products and, ultimately, to stimulating public discussion on this topic. The *Integrated Product Policy (IPP)* approach is a way to promote not only sustainable production patterns but also consumption patterns. Indeed, it looks at the whole of a product's life-cycle, including the use phase. IPP is new on the European level. Several Member States (e.g. Sweden and the Netherlands) and some regions (e.g. Bavaria) have developed IPP initiatives, and many companies have designed their own IPP type initiatives or are already carrying out "life-cycle thinking". However, IPP has not been attempted at EU level before. This promises new challenges (e.g. which stakeholders to deal with) but also new opportunities, as products are increasingly mobile throughout the EU. By encouraging greener public procurement, green corporate purchasing and expanding Community labelling initiatives, information and awareness of consumers are likely to be improved. The IPP approach can thus reinforce liability-based approaches, in particular relative to automobiles or electronic goods. Indeed, although recent policy initiatives have paid more attention to design, it still lacks a full life-cycle perspective (Waste Electrical and Electronic Equipment Directive[29], the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment Directive[30] and the End of Life Vehicles Directive[31]).

---

[28] http://europa.eu.int/comm/environment/waste/strategy.htm
[29] Directive 2002/96/EC
[30] Directive 2002/95/EC
[31] Directive 2000/53/EC

3. ENVIRONMENTAL ISSUES

Industry is an important provider of income and employment in many countries in Europe, but is often associated with pollution. Manufacturing industry is responsible for a wide range of environmental pollution: emissions to air (acidifying substances, greenhouse gases, persistent organic pollutants), emissions to water, contamination of soil and the generation of wastes. However, industrial pollution has decreased substantially over the past 30 years in most western European countries. Around 75% of industrial pollution indicators (air emission, water and energy use) show improvement between 1992 and 1999 (EEA, 2003).
As a result of legislative and institutional improvements, significant progress in environmental protection has been made by all new Member States. The state of environment has improved in particular with regard to air and water pollution reduction. However a number of hot-spots areas remain at risk and air pollution remains a problem in most cities.

3.1 Waste

Total waste quantities continue to increase in most European countries. The European Environment Agency[32] estimates that more than 3 000 million tonnes of waste are generated in Europe every year. This equals 3.8 tonnes/capita in Western Europe (WE), 4.4 tonnes in Central and Eastern Europe (CEE) and 6.3 tonnes in the countries of Eastern Europe, the Caucasus and Central Asia (EECCA). Total waste quantities are continuing to increase in most WE and EECCA countries for which data are available. In CEE, the picture is more mixed: quantities are increasing in some countries (Czech Republic, Hungary and Poland) and decreasing in others (Estonia and the Slovak Republic). In general, limited data sets preclude an accurate assessment.

Manufacturing industry, construction and demolition, mining and quarrying, and agriculture are the main sectors that contribute to waste generation. The European manufacturing industry generates approximately 740 million tonnes of waste every year.

The range of industrial wastes generated is as broad as the manufacturing industries that generate them and the waste management options used (recycling, recovery and disposal). The stages of the product life cycle lead also to different types of waste (production, packaging and end-of-life). Those produced during the production process may be reduced thanks to clean processes. Manufacturing waste consists of food, wood, paper, chemical, non-metallic mineral, basic metal and other waste. West European countries generate most food, wood, paper, non-metallic and other manufacturing waste than CEE countries that generate most manufacturing waste from chemical, iron and steel industries. The generation of manufacturing waste increased from 50% to 59% (1995/1998).

Excessive quantities of waste result from low durability of goods, inefficient production processes and consumption patterns. Manufacturing industry can play a central role in reducing the amount of waste generated by:

[32] EEA, 2003, Europe’s environment: the third assessment, Environmental assessment report No 10.

- Incorporating life-cycle analysis in the design and manufacture of goods and services.
- Undertaking eco-design thanks for example to design for disassembly, design for recycling, improvements of products lifetime, repair possibilities and reuse of components.
- Promoting sustainable use of materials and energy.
- Eliminating or reducing the use of substances or materials hazardous to health or to the environment.

3.2 Water pollution

In its environmental assessment report (2003), the Europe Environment Agency estimates that, on average, 42% of total water abstraction in Europe is used for agriculture, 23% for industry, 18% for urban use and 18% for energy production.

In the countries of Central and Eastern Europe, demands for agriculture, particularly for irrigation, growing urbanisation, continuing inadequacies in waste water treatment and increasing leisure activities create high stresses on water. However the decrease in industrial and agricultural activities during economic transition led to a marked decrease in water abstraction for these uses. But the lack of capacity and financial resources for monitoring and for implementing essential measures and technical improvements is still significant in these countries (EPA, 2003).

High organic matter concentration has several effects on the aquatic environment including reducing the chemical and biological quality of water, biodiversity, etc. Discharges of untreated or poorly treated sewage, industrial effluents and agricultural runoff are the main sources of organic matter.

Concerning the issue of hazardous substances concentration in surface waters and groundwater, there is generally little comparable information at the European level. It is clear that many water bodies are heavily contaminated by hazardous substances that include heavy metals, pesticides and other organic micro-pollutants. These hot spots are often downstream of major cities and/or major installations (e.g. industry or military) and/or mines.

In May 2001, a Common Implementation Strategy (CIS) for the Water Framework Directive (WFD) has been agreed by the European Commission, Member States and Norway. The main aim of the CIS is to provide support in the implementation of the WFD, by developing a common understanding and guidance on key elements of this Directive. Experts from the above countries and candidate countries as well as stakeholders and non-governmental organizations are all involved in the CIS process[33].

3.3 Air pollution

According to EEA (2003), emissions of carbon dioxide are responsible for over 60% of the EU contribution to the "enhanced" greenhouse effect; methane emissions (in particular due to waste sector and coal mining industry but also to agriculture and changes in land use) contribute another 20%; nitrous oxide, ozone (generated mainly by automobile exhaust fumes) and industrial gases such as sulphur hexafluoride and

[33] More information on the WFD and the CIS can be obtained from: http://europa.eu.int/comm/environment/water/water-framework/index_en.html

halocarbons contribute the remaining 20%. Overall emissions of carbon dioxide by EU manufacturing industry (the major part comes from industrial combustion of fossil fuels particularly by the iron and steel, non ferrous-metals and pulp and paper industries) have fallen by over 11% over the period 1985-2000.

Industrial acidifying emissions (sulphur dioxide, nitrogen oxides and ammonia) have been reduced over the last 20 years; in particular emissions in central and Eastern Europe, mainly as a result of economic restructuring, switching from coal to gas and more desulphurisation from power plants. Western Europe will need to reduce emissions further to reach the 2010 targets.

Other important air pollutants emitted by the European industry are airborne heavy metals and persistent organic pollutants.

In the new member states, emissions of acidifying compounds fell since 1990 mainly as a result of economic restructuring, switching from coal to gas and more desulphurization of emissions from power plants. In 2000, a large part of the ecosystems in these countries were estimated to be protected against further acidification (EEA, 2003). However, many hot-spot areas remain at risk in Central Europe. Eutrophication of ecosystems also remains a significant problem as well as emissions of ozone precursors.

3.4 Energy use

According to EEA (2003), total energy consumption fell by 7.5 % in Europe between 1992 and 1999. This was mainly the result of reduced energy consumption in Eastern Europe, the Caucasus and central Asia (EECCA), attributed to economic decline rather than increased energy efficiency. Energy consumption in central and Eastern Europe (CEE) also fell due to a combination of economic restructuring and the implementation of energy efficiency measures.

Energy consumption in western Europe (WE) increased, roughly in line with economic growth, a trend that is expected to be followed by CEE and EECCA as the countries in these regions complete their transition to market-based economies. To minimize the environmental impacts associated with energy use in Europe, a substantial switch to less-polluting energy sources and large improvements in energy efficiency is needed.

The fact remains that energy efficiency has improved in the NMS and candidate countries due to positive measures undertaken, but also due to economic restructuring. Nevertheless, it remains well below the EU 15 average and the intensity of energy consumption per unit of production is still much higher than in the EU 15.

3.5 Noise

Noise can be a threat to human health and to the environment. It can damage hearing, cause lack of sleep, create a disturbance, intrude upon the quiet enjoyment of one’s surroundings and deter wildlife. The European Union’s Integrated Pollution Prevention and Control Directive (EC/61/96), which was introduced across Europe to improve the standard of environmental protection, does recognise noise as a pollutant.

Noise can be produced from a variety of sources and in a number of ways, such as:

- Impact noise, which can include both the impact itself and any subsequent resonance from the action of a fan, jet or pump.
- Vibrating surfaces

Control of these noise sources at the point of generation is the best way to ensure that noise does not cause an unacceptable impact on the environment.

3.6 Soils

In Europe, soils are also the subject of main threats: erosion, decline in organic matter, soil contamination, soil sealing (caused by the covering of soil for housing, roads and other infrastructure), soil compaction (caused by mechanical pressure through the use of heavy machinery, overgrazing or sporting activities), decline in soil biodiversity, salinisation (excessive accumulation of soluble salts of sodium, magnesium and calcium) and floods and landslides. All these processes are either driven or exacerbated by human activity and some degradation processes have increased over recent decades. The economic consequences and restoration costs linked to the threats to soil are huge.

4. TECHNOLOGIES

Key goal of this chapter is to provide criteria for the selection of two case studies within the sector industry and to supply a list of technologies / technology clusters suitable for detailed analysis within the project. The selection of the case studies is not part of this paper, but will be on the agenda of the 2nd milestone meeting on May 28, 2004 in Brussels.

4.1 Definition

Subject of this project are not technologies per se but "clean or environmental technologies". According to ETAP and to this project, environmental technologies are technologies, which are suitable to protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes. This covers end of the pipe technologies for treatment of pollution after it has been generated, as well as process and product technologies that generate low or no waste and pollution. Environmental technologies are not just individual technologies but are *embedded* in technological systems. So new environmental technologies may be associated not only with incremental or radical innovations but also with *system innovations* understood as changes to the whole system relating to provision of a particular function, involving change at multiple levels, including both organisations and institutions.

4.2 Technological mega trends in industry

Innovation as a pre-condition for market success

Innovation has become more and more an essential pre-condition for competitiveness on the European and global markets and the prosperity and survival of enterprises. European enterprises with their high labour costs can only successfully compete on European and global markets, if they are able to offer attractive leading edge products to reasonable prices. This needs innovations, both for product design and for the production and manufacturing technologies.

Computerisation of production and supply chain management

The dissemination of information and communication technology (ICT) for goods and services of the enterprises is still an ongoing process, and no saturation level is observable. This holds for production and manufacturing technology, as well as for the equipment of products and the supply chain management. In many cases this has positive effects on the environment. E. g. a more precise control of production processes is associated with lower raw material use or lower emissions. IC technologies are often an essential part of clean technologies.

Modernisation of the capital stock by adoption of clean technologies

Industrial environmental protection was initially dominated by the installation of end-of-pipe equipment to clean or treat effluents and residues before releasing it to the environment. These techniques in any case increase production costs and have no advantage for the core production process itself. The tendency is now towards the use of cleaner technologies in the production process. In many cases, it is possible to both improve the cost efficiency of the process and its environmental performance. Therefore, dissemination of clean technologies, which can be fostered by suitable policy instruments, has become an essential tool for the modernisation of the existing capital stock. And a modern capital stock is a grant for competitiveness on the EU and global markets.

Implementation of generic technologies in a wide range of applications

The implementation of generic technologies, like nano-technology, IC technology, molecular biotechnology or materials science, for design and manufacturing of new products or to improve existing products is a permanent challenge for enterprises. At a micro level, one issue is to know how to get firms change their existing technological trajectories to new ones based on generic technologies? At a more global level, the questions are numerous, for example: What are the indirect implications of the implementation of generic technologies in particular applications? Do new branches/industrial sectors emerge, e.g. are production capacities / logistics necessary, do new services emerge, and what is their ecological impact?

Technical progress in generic technologies is an essential driver for product and process innovation. But not all enterprises are even successful in this implementation. Stimulation of the necessary cooperation and networking in this field between companies and research bodies throughout Europe is an ongoing task for politics.

4.3 Selection criteria for technologies

In the scope of this project, two case studies have to be defined, each dealing with an environmental technology and/or a cluster of applications. To come to a comprehensible case studies definition, criteria for the selection of the most suitable technologies have to be established. The selection criteria must cover several dimensions. The case studies should be of relevance for the issues which are currently on the political agenda. They should provide solutions for pressing environmental problems and be of economic relevance for the European industry. They should have the potential to shape the technological future, bear social advantages and be of importance for all the European regions. Considering these the criteria in Table 1 are suggested.

Table 1 Selection criteria

A Political rank

1. priority issue of ETAP (climate change, water supply and sanitation technology, sustainable production and consumption, soil protection) / priority actions of ETAP (pilot, demonstration and dissemination actions; technology platforms; testing, performance verification and standardization program)
2. contribution to energy policy, security of supply
3. contribution to chemicals policy (REACH)
4. contribution to waste policy (WEEE, RoHS, packaging, used cars etc.)
5. contribution to water regulation
6. contribution to air quality (Clean Air for Europe)
7. contribution to IPP
8. contribution to Resources Strategy

B Environmental rank

9. energy conservation
10. control / abatement of greenhouse gas emissions
11. control / abatement of air pollution
12. control / abatement of water pollution
13. abatement of raw material depletion
14. sustainable waste management
15. sustainable management of water bodies
16. soil protection
17. noise

C Economic rank

18. potential for European lead market
19. high market potential
20. cost effectiveness (first assumptions)
21. low present or hindered dissemination
22. high dissemination potential
23. participation of SME
24. barriers at the development stage
25. barriers at the application stage
26. role of public research laboratories or public/private partnerships

D Technical rank

27. leading edge technology
28. shaping the technological future

29. proved technical feasibility[34] of technologies or components
30. strong traditional position of European vendors

E *Social rank*

31. creation of jobs
32. improvement of employment conditions
33. health protection
34. consumer protection
35. availability / accessibility for different societal groups (aspects of social exclusion)
36. relevance for different age-groups (aspects of an ageing society)
37. useful for handicapped persons

F *Geographical rank*

38. importance for the majority of the new member states
39. importance for the majority of the EU-15 countries

4.4 Boundary conditions for case studies

Some *boundary conditions* have to be observed in finally selecting case studies and their technology fields. They act as KO criteria:

1. Potential to gain global market leadership for European industry
2. Manageable within the scope and budget of the project
3. No double work to other sectors (energy, transport, agriculture)

4.5 Proposed environmental technologies

In a research project on the "Future of Manufacturing" in Europe, funded by the European Commission and conducted by the Institute for Prospective Technological Studies (IPTS) and partners, imaginative pictures about future technologies that are likely to shape the European manufacturing sector over the coming years were drawn. In a report on industrial approaches and transformation processes (ISI/IfM 2003), "all design, planning and production processes in between the material production and the finished product (process manufacture, discrete manufacture and assembly)" were covered. Disassembly and remanufacture were also encompassed. It was aimed to identify upcoming technological trends with a focus on sustainability issues. Fraunhofer ISI and iwb of the Technical University of Munich analysed (discrete) mechanical manufacturing and process (chemical) manufacture.
Taking into account the scope of the POPA-CTDA study and – implicitly - the above mentioned criteria,

- in particular a rather medium term time horizon (< 2010), warranting the criterion of proved technical feasibility of technologies or components,
- measurable or at least describable environmental benefits, and
- different other criteria, e. g. environmental, economic, and technical rank as well as the boundary conditions mentioned above,

[34] The technical feasibility should be regarded in relation to the time horizon for the potential market penetration of the technologies considered in the project (5-8 years).

a pre-selection of technologies / technology clusters could be derived from that survey of technologies. See Table 2 in the appendix.

4.6 Selection procedure for case studies

As previously mentioned, two technologies have to be selected for detailed analysis. This selection will be oriented on the criteria and boundary conditions outlined in the previous sub-paragraphs. As agreed within the project team, one case study will be conducted by IPTS, the other one by Fraunhofer ISI.

4.6.1 Selection procedure

For the assessment and ranking of technologies, each criterion of Table 1 has been assigned with up to 5 points. 0 points mean no contribution, 5 points mean excellent contribution. After assigning the points to each criterion for each individual dimension, the mean value has been calculated for each individual dimension. Summed up, these mean values over all six dimensions from A (political rank) to G (geographical rank) gave the total score. Applying this procedure the top score would be 30 points.

4.6.2 Case study 1: Hydrogen technologies for industrial processes

Applying the described assessment procedure, hydrogen technologies in Table 2 gained the top scores from the contributing partners from Fraunhofer ISI. The scores are in the range between 12.4 and 18.2. It has to be pointed out, that the absolute level of the scores is subject to individual estimation and the crucial factor is the distance between the top scores and the scores for the "runners-up". These were applications of information and communication technologies (scores from 8.8 – 17.7), and Nanotechnology (12.3 – 13.5).

The analyses will focus on hydrogen based thermal production technologies, including fuel cells. The main focus lies on applications in industrial production processes rather than the application in products. Examples to be mentioned and yet to be defined in more detail are the substitution of fuel cells for conventional industrial CHP, hydrogen as a means to store power generated from renewable sources or waste heat, and – possibly with a slightly wider time horizon but still within the boundaries defined in paragraph 4.3 - applications of hydrogen in the processing of iron ore and other thermal metal reduction processes. Applications for decentralized appliances in industry plants should be investigated as well, but the mere product development of fuel cells, e. g. for mobile electronic equipment are not part of the case study. The application in the transportation sector (fuel cell vehicles) will be subject of another separate case study within the POPA-project.

With respect to the boundary conditions listed in chapter 4.4, there is no doubt that hydrogen technology is a technology cluster, where it is highly desirable for the European Industry to gain global leadership.

On the other hand, one has to bear in mind that this technology cluster is a rather broad one and within the framework conditions of budget availability for the research project, synergies with other ongoing projects have to be realised. Nevertheless, hydrogen technology was selected as topic of case study 1.

4.6.3 Case study 2: White biotechnology

White biotechnologies represent the application of biotechnology to industrial processing.

A critical consideration of this technological cluster shows that these applications could make substantial improvements to the quality of life. In particular white biotechnology could also have significant benefits through reducing pollution, waste and material and energy inputs (EuropaBio, 2001; IPTS/ESTO, 2002[35]). Examples of white biotechnology are: bio-based polymers, biological processes for vitamin production, and enzymes for the textile industry. White biotechnology has become much more broadly applicable due to recently developed genetic techniques. Multiple enzyme variants, for example, can now be created at high speed, which are then screened for fit with the desired application.

Even though industrial and environmental biotechnology has significant potential benefits, particularly for environmental sustainability, these two related applications have attracted considerably less attention than health or agricultural uses of biotechnology. Part of the problem is related with the existence of multidimensional barriers (technological, economic, and institutional) that need to be further examined.

The OECD is making efforts to propose indicators (others than R&D spending and patents) that can identify environmental and other social benefits of biotechnology. Such indicators will be critical for the analysis of drivers and barriers of white biotechnologies within the POPA project.

5. BARRIERS AND DRIVERS

Most of the factors affecting clean technologies diffusion can act as both barriers and drivers to innovation depending on the specific circumstances, time and contexts where these factors are considered. The drivers and barriers could be grouped in the following dimensions (Montalvo, 2003): government policy, economic opportunities, markets, communities and social pressure, attitudes and social values, technological and organisational capabilities.

5.1 Government Policy

It is recognised that policy intervention in the form of environmental regulation enforcement is one of the major drivers for environmentally responsible behaviour within industry and, as such, a major driver for adoption of environmental technologies.

The application of government policies can take various forms, ranging from command and control to voluntary programs and market-based instruments. Various studies tried

35.

to compare the efficiency of these instruments (Downing and White, 1986; Milliman and Prince, 1989; Fischer et al., 2003). It turns out that an unambiguous ranking of policy instruments is not possible. The ranking will rather depend on several factors such as the costs of innovation, the extent to which innovations can be imitated, the environmental benefit function, the number of polluting firms etc. In practice, performance standards and economic instruments are complementary tools. Neither regulation nor economic instruments are *per se* unsuitable to further cleaner production. Whether an innovative response will occur depend on the level of the stimulus and the responsiveness of the problem sector to the stimulus. Thus an analysis of environmental innovations should not neglect the complexity of the determinants influencing innovative behaviour of firms.

Apart from dealing with issues of environmental protection, one main side effect of regulatory pressure is to direct innovation in pollution prevention technologies. Regulation is able to impact on the nature of innovation output leading to new processes, new products, new inputs or new organisational methods but also to incremental or radical changes. Depending on the way regulation is designed and based for example on technology-forcing or performance standards, possibilities of adaptation for firms will be more or less important. Indeed emission and discharge rate standards provide little or no incentive to go beyond the required standard reduction and, as such, they fail to promote and sustain R&D and investment in innovation. Furthermore, new processes are seldom required by permit writers, end-of-pipe is much more common in this context. With the IPPC Directive in place, this has good opportunities to change and governmental policy will not only be a major driver for end-of-pipe technologies but also for clean technologies.

In the new Member States, compliance with legislation is a major driver for eco-efficient innovations. For example, implementing BAT-compatible technologies in accordance with the IPPC directive will necessarily attract cleaner technologies by the affected sectors. The execution of the directive will have an estimated cost of 6.9 Billion EUR in Poland, 3.7 Billion EUR in the Czech Republic, 0.5 Billion EUR in Estonia and 1.7 Billion EUR in Hungary[36]. These costs include other costs than technological investments as well. Moreover, problems exist in relation to the difficulties of environmental authorities in obtaining adequate funding and staffing as well as a persistent lack of co-ordination between policy sectors. These factors have hampered the progress made to date.

5.2 Economic opportunities

The adoption of new technologies by firms is clearly dependent upon their economic attractiveness (profitability). When clean technology adoption involves technological leaps, this will require a shift to fundamental changes in the process or product. At this stage, the main issue for actors is to cope with uncertainty and to find financial support.

Economic risk and uncertainty are central concepts for innovative activities. Frequently cited benefits for adoption of new technology including clean technology are off-setting rising costs of compliance, savings of raw materials and energy, higher quality of products, increased capacity and efficiency gains. The often close relationship between environmental and economical improvements stemming from clean technology in a way

[36] REC study for the Danish Ministry of the Environment.

creates a problem with respect to capital access since: there is a lack of clean production definitions in investment banking protocols and there is a lack of expertise to evaluate economic and financial aspects of cleaner production project efficiency and investment (Huhtala, 2003).

After accession, the new Member States are to receive further financial support for environmental projects. Through Structural and Cohesion funds, the new Member States will receive financial support for the implementation of the investment heavy directives for which transition periods have been granted. It is important to ensure sufficient funding at EU level after the end of the current programming period (2006) and also at national level as new Member States should then find their own financial resources in order to meet their obligations. The binding nature of the transition period targets and clear final deadlines for directives for which transition periods were awarded justify reserving adequate financial and human resources for implementation at national level.

5.3 Markets

Market failures in relation to the environment are still dominant but in recent years, there are consistent reports that indicate that the market might already in some cases start to play an important role in promoting environmental responsiveness in industry. The major market driving force is generally consumers with high environmental awareness. If a firm is consistently facing demands of sound environmental products in the short and medium term from their customers, they might venture for long term investments in clean technologies as well. The characteristics of the market and the competitiveness also influence the diffusion of clean technologies, e.g. firms confronting more heterogeneous, hostile and dynamic markets can be expected to seek branding and try to entice consumers with environmentally friendly products.

In a similar way, firms operating in countries with lax environmental regulation but serving mature global markets with preference for environmentally sound products are more likely to embrace clean technologies. Supply chains can also play an important role, in sectors where price of raw material are high accompanied with demands of environmentally sound intermediate goods up-stream in the supply chain, a higher degree of adoption of clean technologies can be expected.

5.4 Communities and Social Pressure

This refers to the level of awareness of the different stakeholders concerning environmental and sustainability issues and how active such stakeholders are to push for changes in current industrial environmental behavioural trends. However, the lack of clear understanding of what the concept of cleaner production entails and encompasses can restrict a more decisive participation of some stakeholders, e.g. in the financing community.

Stakeholders with the potential role of pushing clean technologies can be found both within and outside the firm or industry. Examples of the former are investors, shareholders and high-ranking staff and employee morale due to high environmental awareness. The public image and social legitimacy in relation to environmental behaviour should not be underestimated. However, experience has shown that external stakeholders have played a more important role. Though there is little empirical evidence concerning the role played by diverse stakeholders, it is clear that especially local communities with concern also for human health has long functioned as the main watchdog but also consumer groups, NGOs and Green parties should be mentioned in this context.

In the new member states, pressures from domestic markets on enterprises to improve their environmental (and public safety and health) technology and performance has been improving due to extensive awareness-raising activities by active international and local environmental and consumer protection NGOs, by highly increased attention of academia and media, and by various government initiatives. Despite higher awareness, environmental deliberation in the new Member States is still under EU average. Awareness is also behind from the level that could dramatically increase consumer pressure on companies to implement clean technologies. Consumers' purchasing power is not eligible to cover the often higher prices of environmentally sound products. Therefore consumer pressure is still low. Nevertheless market pressure is increasing through the various elements of the supply-chain in some sectors. Quality management and environmental management systems are often requirements from suppliers. The number of EMS registrations increased by 631 per cent between 1999 and 2002. EMS is recognised as a driver at many companies due to the fact that process-based and continuous improvement approach leads to the recognition and realisation of eco-efficiency projects.

5.5 Attitudes and Social Values

Related to the just previous mentioned factors, attitudes and social values of specifically important stakeholders - normally Chief Executive Officers (CEOs) - are often of key importance. It is believed that sustainable entrepreneurship lies mainly in the personality, ethos and position of high-ranking officials and above all of CEOs. Likewise, if these attitudes are lacking, firms that have other strong incentives pushing for adoption of clean technologies like e.g. government policy, markets and economic opportunities may still not opt to do so. The attitudes can thus play a decisive role.

As reported by company leaders in Hungary concerning environmental drivers[37], only legal authorities, managers and owners are the main stakeholder groups with significant influence on corporate environmental efforts. From most of the other stakeholders they do not feel any kind or weak (environmental) pressure.

5.6 Technological and Organisational Capabilities

The capacity at industrial or firm level to change or lack of capacity can be just as important as any other factors in the decision making process of taking on a new technology or not. This can be dependent on technologies already in place as well as expertise at the site. Moreover, some specific organizational performance requirements may be necessary to adopt a new technology.

At a higher level of aggregation, the system might become more rigid and everything is highly interdependent and, thus, the compatibility of a new technology with existing infrastructure is vital. The cost of replacing a complete production process can be extremely high and lock-in effects are common. Due to the size of investments and longevity of production processes it is very likely that the diffusion of new processes will occur in an incremental way, following the natural cycle of technological stock replacement. These natural investment cycles have an impact on the awareness of the

[37] Research study of the Hungarian Academy of Sciences, 2000

existence of technological opportunities as well as the degree of techno-economic attractiveness (i.e. efficiency, quality, cost reductions, productivity etc.). This is particularly true in the sectors with long life time of capital stock (cement, iron and steel, refineries etc.).

The intangible capacity to adopt a new technology (the absorptive capacity, enhanced by skill and R&D) can be just as important. It has been reported that insufficient expertise and understanding of clean technology and the current training and clean technology capacity building at the sector level play a role to consider in the uptake of new technologies. Studies have shown a significant correlation within industries over time between the rate of expenditure on pollution abatement and the level of R&D spending. These factors can be expected to be even more critical within SMEs where less R&D generally is carried out. Moreover, the adoption of a new technology implies the need to integrate new knowledge and sometimes large organisational changes.

In the new member states, SMEs of the CEE region contribute 30 to 65 percent of the total employment and their contribution to GDP varies between 30 and 60 percent. SMEs provide work for about 35% of the active population in Slovenia. In Hungary, there are about 850 000 SMEs, employing more than 2.5 million people and generate approximately the third of the country’s exports. This significant part of the companies are unable to step forward from legislation following and their ultimate goal is only legal compliance. These enterprises have a limited resource basis compared to larger firms, with respect to financial and management resources.

6. SECTOR DEVELOPMENT[38]

The European manufacturing industry is likely to undergo dramatic changes over the next two decades. Its future will be shaped by different influences linked to technology, economy, policy and society evolutions.

6.1 Generic drivers of change

The key generic drivers of change in European manufacturing principally relate to:

- *Globalisation and an increasingly competitive business environment.* Geopolitical factors, such as the future balance of economic and political powers between the main economic regions, the emergence of new economic powers (for example China, India, Korea, Brazil, etc), global priorities in the governance of trade (e.g. WTO), political instability and threats of armed conflicts that may limit energy and resource availability will also affect the European manufacturing sector. The pressure on industry to successfully compete in globalised markets will require rapid responses to continuously changing business environments.

- *Socio-demographic change.* It will be very likely that the European industry will be confronted with a considerable older workforce compared to today. Moreover the issue of workforce mobility and the availability of skilled staff might become a critical factor for manufacturing. Manufacturing will be called upon to provide

[38] Section developed mainly based on the “The future of manufacturing in Europe 2015-2020. The challenge for sustainability” Geyer A. et al. 2003.

solutions for new societal needs and the challenges of the ageing Europe and a culturally more diverse society.

- *Environmental issues and sustainability.* European industry may have to comply with stricter environmental regulation and might be confronted with new policy incentives to improve environmental performance. The priorities and policies to balance the environmental, social and economic dimensions of sustainable development will influence strategic decision making in manufacturing companies. Changes in consumer preferences and market demands may require the design of more sustainable products and services.

- *Societal values and public acceptance of technology.* The example of the reluctance of citizen in many European countries to accept nuclear power as a means to cut CO_2 emissions or the debate on GMOs show that public concerns must be taken seriously when science and new technology is adopted and exploited.

- *The regulatory environment and the system of European governance.* The modality of policy making in Europe, which principally refers to the goals, objectives, priorities, and instruments for implementation of a broad set of policy fields affecting manufacturing (e.g. trade, industry, competition, labour market, education and training, environment, health and safety, security, consumer protection and security regulation) might trigger and facilitate change in the manufacturing industry.

- *Advances in science and technology.* Progress in some R&D areas as for example materials science, microelectronics and information technology, biotechnology and nanotechnology will profoundly affect manufacturing and enable industry to offer better products and services to their customers. The advances could also require completely new sets of skills and may change our understanding of production and consumption.

6.2 Specific structural transformations

If we look at more specific structural transformations sketched in the report 'The Future of manufacturing in Europe 2015-2020', different sectoral evolutions can be outlined. Such evolutions will occur in combination with advances in material science, microelectronics and information technology, biotechnology and nanotechnology. Depending on future policy styles and on public values and demand patterns, the degree of uptake and diffusion, and the nature and extent of applications for the technologies developed in the sectors may differ. Likewise the time-scale necessary for experiencing the economic impact of emerging technologies may vary across the area.

- *Electronic components*

Of major significance to this sector are issues of development of new generations of micro-processors, advanced embedded software products or better sensors.
Alternative transport and mobility models may make particular demands on electronic components, such as shared transportation systems, or leasing or rental models for cars.
The proliferation of the use of mobile and other devices give rise to concerns of potential health risks. In the perspective of higher levels of recycling, wastes of electric and electronic equipment (WEEE) also remain an important issue to be addressed by the electronic industry in its whole. The available experience with recycling of computer

equipment underlines the need for design for disassembly in order to reduce recycling costs.

- *Measuring, testing and control instruments*

The sector can be thought as pervasive enabler that has significant impact on the development of the broader economy. Products of the sector are applied both directly and as process control and diagnostic tools in such diverse industries as automotive production, telecommunication, environmental engineering, chemical and pharmaceutical industry and knowledge intensive business services. The rising need for environmental protection is also a source of demand for monitoring of environmental regulation (e.g. lower emission rates, reduction of pollution of industrial activities). This requires more sophisticated measuring and sensing devices.
Nanosensors and nanodevices, as well as biosensors for control devices are examples of new applications in the sector. Tackling future metrology needs, especially related to nanotechnology (i.e. standards on measurement, testing, quality and performance of nanotechnology devices), are expected to be critical issues for instrument engineering and the electronic industry.

- *ICT developments*

ICT developments will provide new ICT tools, new software for data management and sharing, modelling and simulation tools and new visualisation tools.
Contrary to the renewables for which the raising use is likely to depend on high energy prices, modelling and simulation, micro-production technology and improved process technology do not depend on energy prices. Thus improvements in industrial resource efficiency are even likely if energy and resource prices remain on low levels over the next fifteen to twenty years.
One important aspect with ICT adoption is that it might change the organisation and spatial distribution of manufacturing networks.

- *Challenges for the automotive manufacturers*

The automotive sector has to face a variety of influences taking place along the whole product chain. Vehicle manufacturers are likely to become more and more systems integrators and closer cooperation with suppliers will be needed.
Concerning motor vehicle engines, some experts argue that fuel cell technology may not be in widespread use in 2015-2020 since there are more cost-effective solutions much easier and earlier available that would allow reducing energy consumption. Issues related to hydrogen-option and also to the mobility provision option (inter and multimodality vs. single-mode) are fundamental changes depending on major policy-decisions.
Given the continuous integration of automobile and electronics systems during the last years, new electronic components and ICT will continue to drive and affect technological development in the motor vehicle industry.
The service components added to the products represent a major trend, in particular in relation with new forms of mobility systems. As such manufacturers might give more attention to the development of integrated product-services. If such a trend gains momentum, manufacturers will have to acquire new technological and business competencies
End of life vehicles remain an important issue. Disassembly processes, taking into account the total product life-cycle, may be improved and optimised. In a general way,

improvement of life time control and management of automotive products may become of major importance for the sector.

- *'Green' chemicals*

Both the petrochemicals and the fine chemicals sector will face the challenges that are mentioned above (cf. §6.1). The petrochemical sector is energy intensive and its development strongly influenced by feedstock availability and energy prices which are set on global level. The main market for petrochemical products is still Europe, whereas there might be a trend to shift production to oil-producing countries or countries in the Far-East. The production of customised polymers will be central for the long term competitiveness of the sector. New polymers, bio-polymers and polymers to replace silicon in electronic components are examples of possible new applications, as well as new chemical processes and new catalysts.
In the fine chemicals industry, nanopowder technology and new production concepts such as soft-chemistry, ionic solvent and sol-gel processes might be adopted by 2020, provided that processes can be sufficiently up-scaled. Hybrid materials and mixed materials (e.g. metals, ceramics, polymers) will represent a critical market for fine chemicals. Enzymatic catalysis, GMO-engineered chemicals and some types of bio-feedstock will be part of the future developments of the sector.

Overall, the developments sketched in this section are likely to have repercussions on other sectors, for example aeronautics, textile industry, food and beverages, pharmaceutical, medical instruments and other sectors which draw heavily on metrology and standardisation. Most of progress likely to occur involves interdependent advances and system innovations i.e. changes in complementary technologies and infrastructures but also in supportive institutions.

6.3 Sector development in the new Member States

Considering the new member states, industry is characterised by a considerable amount of financially weakly established SMEs, older companies, which have found new markets dominantly in the EU, and newly established companies. From 1993 especially until 1997 a remarkable growth has been experienced in the industrial sector and from 1992 to 2003 a 40 per cent increase has been achieved in manufacturing output. During this time the employment in the sectors has decreased by 40 per cent.

A strong competitive advantage for the CEE economies is the lower wage costs, especially in the labour intensive sectors such as textiles industry. However, wages are increasing throughout the region and maintaining competitive advantage productivity will be needed to be further increased. Investors usually bring know-how and capital to these sectors and generally move companies to compliance with EU legislation. New member states were already exposed in the pre-accession phase to competition from EU producers. Therefore enlargement has not been a shock in respect for many CEE companies.

In almost all countries, electrical engineering, the production of motor vehicles and the furniture industry have made above-average progress in productivity. In the Czech Republic, Poland, Slovakia and Estonia, mechanical engineering recorded a significant increase in productivity. On the other hand, below-average progress in productivity was seen in the following sectors: food, textiles and clothing, leather and footwear, timber, paper and chemicals. "As a rule, technology-intensive industries are among the winners. Traditional industries often use standard technologies.

Energy-efficiency in the manufacturing sector has improved by 30 per cent between 1992 and 2002, however it is still three times more energy intensive than that in Western Europe. This is partly explained by the relatively low energy prices in CEE.

Chemical industry is a major end-user of *air pollution prevention* technology. In the sectors of *water and wastewater*, and *waste management*, municipal services are followed by various industries, such as mining, chemical, paper, wood, and food processing. Technologies related to *industrial wastewater and hazardous waste* featured prominently among high-demand categories.

APPENDIX Pre-selection and brief description of environmental technologies

Table 2

Technology	***Sector***
H_2- / fuel cell technologies	
- fuel cells for mobile electronic equipment	industry
- H_2-based thermal production technologies	industry
- H_2-technology and –infrastructure for other than industrial purposes	energy
- fuel cells for motor vehicles	transport
Applications of information and communication technology	
- ICT for process automation and control (manufacturing robots, autopilots for process control etc.)	industry
- traffic control and navigation	transport
- precision farming (GPS navigation in field preparation)	agriculture
Applications of biotechnology	
- white biotechnology (production of bulk material, energy sources etc.)	industry
- technologies to develop renewable as raw material resource for industry (bio-fuels, bio-plastics, bio-lubricants etc.)	industry
- environmental molecular biology	agriculture
- bio-based renewable energy technologies	energy
Industrial waste water treatment (including the effects of expanded use of treated recycled water)	
- membrane technology (separation processes)	industry
- other physical methods (plasma, UV radiation)	industry
Nano-technology (separation, enzyme production, surface structuring etc.)	industry
Recycling technologies	
- basic materials	industry
- electronic scrap	industry
Substitution of harmful substances in industrial applications	
- water based paintings	industry
- powder technologies for painting, gluing, and other coating purposes	industry
- use of supercritical CO_2 as a solvent	industry
Substitution of water as a transport medium in the sewage water system (vacuum exhaust systems)	industry, residential sector
Miscellaneous	
- new materials (superconduction for energy technology, polymer-electronics etc.)	energy
- solar and wind energy technologies (wind turbines, photovoltaic etc.)	energy
- clean and zero emission motor vehicles	transport

Brief description

Hydrogen / fuel cell technologies[39]

In principle, a fuel cell operates like a battery. Unlike a battery, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied. A fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other, generating electricity, water and heat.

A fuel cell system which includes a "fuel reformer" can utilize the hydrogen from any hydrocarbon fuel - from natural gas to methanol, and even gasoline. Since the fuel cell relies on chemistry and not combustion, emissions from this type of a system would still be much smaller than emissions from the cleanest fuel combustion processes.

Different types of fuel cells are developed: Phosphoric Acid; Proton Exchange Membrane or Solid Polymer; Molten Carbonate; Solid Oxide; Alkaline; Direct Methanol Fuel Cells; Regenerative Fuel Cells; Zinc Air Fuel Cells; Protonic Ceramic Fuel Cell.

There are many potential uses for fuel cells, in particular for stationary, residential, transportation, portable power and landfill and wastewater treatment applications. Currently, the cost of fuel cells is too high for them to be put in general use. Ongoing research aims to reduce the cost and thus increase demand. Right now, all of the major automakers are working to commercialize a fuel cell car. Fuel cells could power buses, boats, trains, planes, scooters, even bicycles. There could be fuel cell-powered vending machines, vacuum cleaners and highway road signs. Miniature fuel cells for cellular phones, laptop computers and portable electronics could also represent growing markets. Hospitals, credit card centres, police stations, and banks could use fuel cells to provide power to their facilities. Wastewater treatment plants and landfills could also use fuel cells to convert the methane gas they produce into electricity.

Fuel cells combine several benefits, in particular in terms of security of energy supply and environment. Because they are efficient, modular and fuel flexible, fuel cells can enable a transition to a secure, renewable energy future, based on the use of hydrogen. A fuel cell system that includes a "fuel reformer" can utilize the hydrogen from any hydrocarbon or alcohol fuel - natural gas, ethanol, methanol, propane, and even gasoline or diesel. Hydrogen can also be produced from electricity from conventional, nuclear or renewable sources. Hydrogen can be extracted from novel feed stocks such as landfill gas or anaerobic digester gas from wastewater treatment plants, from biomass technologies, or from hydrogen compounds containing no carbon, such as ammonia or borohydride. Electrolysis uses an electric current to extract hydrogen from water. Fuel cells, in combination with solar or wind power, or any renewable source of electricity offer the promise of a totally zero-emission energy system that requires no fossil fuel and is not limited by variations in sunlight or wind flow. This hydrogen can supply energy for power needs and for transportation. Environmental benefits associated with fuel cells are mainly constituted by energy savings and reductions in air pollution.

The European Commission has facilitated the establishment of a European Hydrogen and Fuel Cell Technology Platform aimed at accelerating the development and deployment of these key technologies in Europe. The platform should assist in the efficient co-ordination of European, national, regional and local research, development and deployment programmes and initiatives and ensure a balanced and active participation of the major stakeholders (i.e. industry, scientific community, public authorities, users, civil society). It should help to develop awareness of fuel cell and hydrogen market opportunities and energy scenarios and foster future co-operation, both within the EU and at global scale.

Applications of information and communication technology

The impact of ICT on environmental sustainability in the EU has been recently analyzed in a project commissioned by IPTS[40]. In this project, ICT is defined as information technology plus telecommunications equipment and telecommunications services. Information technology refers to the

39 Sources: http://europa.eu.int/comm/research/energy/nn/nn_rt_htp1_en.html; http://www.fuelcells.org/

40 Erdmann L., Hilty L., Goodman and Arnfalk P., 2004, The future impact of ICT on environmental sustainability, Synthesis Report, IPTS.

combined industries of hardware for office machines, data processing equipment, data communications equipment and of software and services (EITO, 2002[41]).

This study emphasizes that ICT interacts with the environmental indicators in three ways (Forum for the Future, 2002[42]):

- First order effects: the impacts and opportunities created by the physical existence of ICT and the processes involved
- Second order effects: the impacts and opportunities created by the ongoing use and application of ICT
- Third order effects: the impacts and opportunities created by the aggregated effects of large numbers of people using ICT over the medium to long term

Critical areas where ICT applications have a significant effect on some environmental indicators are outlined in the study, as well as the uncertainty associated with the impacts. Some of them are reported here.

- ICT has a high potential impact on the rational use of heating energy. Uncertainty is due to the fact that the conditions under which 'soft' measures supported by ICT (such as intelligent heating systems) really operate effectively and satisfactorily for the users are not well known.
- Networks and new types of ICT applications (such as pervasive computing) can play an enabling role for new types of service. Possible energy saving and dematerialization effects are associated with an ICT-supported product-to-service shift, especially for freight transport and waste.
- All ICT applications that make passenger transport more time efficient will immediately create more traffic and possibly more energy consumption. Transport demand is likely to increase and this has severe environmental consequences in energy use and greenhouse gas emissions, although ICT contributes to lowering the energy and GHG intensity of passenger transport.
- ICT can contribute to material savings in industry. There is a considerable potential to save materials by more intelligent process control. The size of adverse (or rebound) effect is uncertain.
- ICT has a potential to avoid a significant part of the GHS emissions caused by power generation if it can lead to manage distributed power plants and thus contribute to decentralized production from renewable sources or small Combined Heat and Power devices.

ICT have a potential to make resource and energy consumption more efficient. Rebound effects counterbalance these effects by increasing consumption. Therefore, the capacity of ICT to influence the demand side towards more sustainable consumption patterns is a decisive challenge.

Applications of biotechnology

As outlined in the OECD Biotechnology Statistics Framework (OECD, 2001[43]), biotechnology can be defined following two different choices: a single definition that covers all biotechnology activities and a list-based definition that asks about different types of biotechnologies. A single, broad definition of biotechnology is complicated by differences in the meaning of biotechnology by sector. In common usage, 'biotechnology' in *agriculture* usually refers to genetic modification (GM) and associated technologies such as DNA markers. *In contrast, the common definition of biotechnology for environmental and industrial applications mostly includes technologies that do not use GM organisms*, such as bioremediation for treating contaminated soils or bio-bleaching of wood pulp. In the *health sector*, 'biotechnology' refers to several advanced technologies, including genetic engineering, genomics and proteomics, but it can also include technologies, such as combinatorial chemistry, that have applications in traditional chemical synthesis. List-based definitions are particularly helpful when there is a need to examine the applications and benefits of biotechnology, since many of these will vary by the type of biotechnology in use.

Biotechnology is not new since its underlying processes have been used for thousand years, for example in the production of food (e.g.: wine, cheese). Modern biotechnology uses, amongst others, enhanced micro-organisms like yeast, moulds, and bacteria as 'cell factories, along with the enzymes derived from them, to produce a variety of goods. Biotechnology has found its entry into medicine (red biotech) and agriculture (green biotech), and now a new wave of modern biotechnology is gaining momentum – white biotechnology is the application of biotechnology to industrial processing.

41 EITO (2002), European Information Technology Handbook 2002, European Information Technology Observatory EITO.

42 Forum for the Future, 2002, The impact of ICT on sustainable development, in European Information Technology Handbook 2002, European Information Technology Observatory EITO.

43 OECD, 2001, The application of biotechnology to industrial sustainability, OECD, Paris.

A recent study by the European Commission (EC, 2001[44]) estimates that biotechnology has potential applications in economic sectors that accounted for EUR 450 billion of gross value-added and for 9 million jobs in the European Union in the mid-1990s. These maximum estimates are equivalent to about 9% of total value added and 8% of total employment. This represents a rather small share of total economic activity and puts the degree of pervasiveness of this technology into perspective.

Based on current research trajectories, the potential application of biotechnology is limited to some manufacturing sectors (pharmaceuticals, petroleum refineries, chemicals, food and beverages, wood, pulp and paper, textiles and instruments) and to the resource sectors, even assuming that the price of biotechnology is competitive with alternative technologies (Arundel, 2003[45]).

But these applications could make substantial improvements to the quality of life. In particular white biotechnology could also have significant benefits through reducing pollution, waste and material and energy inputs (EuropaBio, 2001[46]; IPTS/ESTO, 2002[47]). Examples of white biotechnology are: bio-based polymers, biological processes for vitamin production, and enzymes for the textile industry. White biotechnology has become much more broadly applicable due to recently developed genetic techniques. Multiple enzyme variants, for example, can now be created at high speed, which are then screened for fit with the desired application.

The OECD is making efforts to propose indicators (others than R&D spending and patents) that can identify environmental and other social benefits of biotechnology. Many of the relevant policy issues for biotechnology concern the public interest – or how to ensure that biotechnology can meet its promise to improve the quality of life in both developed and developing countries.

Industrial wastewater treatment

Wastewater from households and industry represents a significant pressure on the water environment. As well as containing organic matter and nutrients, it can also contain hazardous substances. The level of treatment of the wastewater before discharge and the sensitivity of the receiving waters will affect the impact it has on the aquatic system. The move towards cleaner technologies is driven partly by EU directives such as the IPPC directive, which requires large facilities to use the best available technology to make radical environmental improvements.

Membrane technology and other physical methods (plasma, UV radiation) are of particular interest for wastewater treatment.

Nano-technology (separation, enzyme production, surface structuring etc.)

The science of manipulating individual atoms and molecules, to build machines using the molecular blocks or create materials by designing the properties to control structure is called “nanotechnology”. It is often difficult to give a precise definition of nanotechnology since they encompass multiple areas. Areas that are part of or related to nanotechnology are for example: nano & quantumelectronics, nanostructured materials, scanning probe techniques, molecular (materials for) electronics, molecular nanotechnology, computer modelling, mesoscopic physics / technology, supramolecular chemistry, cluster / mesoscience (Malsch, 1997[48]).

Nanotechnology is rather confined to research laboratories of universities (e.g. Kompetenzzentrum Nanotechnik at Kaiserslautern University in Germany). However, nanotechnology is progressively going into market and is gaining favour with number of venture capitalists.

The market for nanotech application tends to be segmented into: biological instrumentation physical (denser hard drives, smaller and faster chips, and better optical switches) materials development and other potential sectors within the life sciences industry.

44 EC, 2001, Towards a strategic vision of life sciences and biotechnology, Consultation Document, CEC, Brussels, COM(2001)454 final.

45 Arundel A., 2003, Biotechnology indicators and public policy, STI Working Papers 2003/5.

46 EuropaBio, 2001, White Biotechnology: Cleaner Processes for a Cleaner Environment, EuropaBio, Brussels.

47 IPTS/ESTO, 2002, The Assessment of Future Environmental and Economic Impacts of Process-Integrated Biocatalysts, Report EUR 20407 EN.

48 Malsch, I, 1997, Nanotechnology in Europe: Experts’ perceptions and scientific relations between sub-areas, IPTS report, EUR 17710 EN.

Nanotechnology may aid environment. Nanotechnology's potential environmental benefits may result, for instance, from filter systems for drinking or waste water, natural gas pipelines and smokestacks that can be designed at the molecular level, to remove even the most minuscule of impurities. For water, that means cleaner drinking. For gas, finer filtration means cleaner burning, with fewer smog-creating impurities.

Moreover, industrial plants may be able to use more sensitive emission "scrubbers" that screen even nano-sized flecks of soot from waste gases. Nanoparticles are also being examined for use as sensors to monitor air or drinking water for the presence of toxins. Farther out, such sensors might be networked to give a full picture of the environment and any encroaching pollutants. Pollution-absorbing nanoparticles that can be used to clean up tainted water or soil is another concept under study. And the entire concept of nanotechnology - building devices at the molecular level - means that products will be smaller. There is less waste in the production process and in the trash, when nano-devices are discarded at the end of their lives.

Nonetheless, as nanotechnology moves out of the laboratory and into the market-place, it is important to develop standards that ensure that its products and byproducts do not have harmful effects.

Recycling technologies

Initiatives to promote waste prevention and recycling are considered to be the most effective options for minimizing the environmental risks and costs associated with waste generation, treatment and disposal. Some EU directives, like the one on end of life vehicles and the one on waste from electronic and electric equipment, have a strong focus on recovery, reuse and recycling.

There is plenty of scope for increasing the level of recycling in almost all European countries. A major challenge is to establish new and, to some extent, more comprehensive collection and recycling schemes. For some waste streams (e.g. construction and demolition waste) solutions may be fairly straightforward, while others (e.g. waste from electric and electronic equipment) may demand a more complex system.

Basic materials and electronic scrap are likely to exhibit different drivers and barriers to their further development.

Substitution of harmful substances in industrial applications

According to the European Directive on the limitation of emissions of volatile organic compounds (VOCs) due to the use of organic solvents in certain activities and installations (1999/19/EC), solvents containing substances likely to have a serious effect on human health (carcinogens, mutagens, or toxic to reproduction), must be replaced, as far as possible, by less harmful substances within the shortest possible time.

The legislation limiting emissions of VOCs in painting activities aims directly to paint users, mostly professional, and has a decisive upstream impact on paint manufacturers. Water-based paintings and powder technologies for painting, gluing and other surface coating purposes have been developed to replace solvent-based paintings. Meanwhile, initiatives to replace organic solvents for example by using supercritical $CO2$ technology have been experienced.

Substitution of water as a transport medium in the sewage water system

To be completed

REFERENCES

Bank Austria Creditanstalt, 2003, *Restructuring of CEE manufacturing industry*, presented at the Euromoney CEE Issuers & Investors Forum in Vienna.

BAT's economic viability and their effect on competitiveness for SME's. The Leather sector. (http://europa.eu.int/comm/enterprise/environment/events/ippc_conference/gonzales.pdf), Workshop on the economic consequences of the IPPC Directive, Brussels, 16 May 2002.

Decision No 1600/2002/EC of the European Parliament and of the Council of 22 July 2002 laying down the Sixth Community Environment Action Programme was published in OJ L 242 of 10/9/2002. cf. http://europa.eu.int/comm/environment/newprg/

Downing P. and White L., 1986, *Innovation in pollution control*, Journal of Environmental Economics and Management, 13, 18-29.

EC DG Enterprise, 2001, *Competitiveness of the Chemical Industry Sector in the CEE Candidate Countries.*

EEA, 2003, *Europe's environment: the third assessment*, Copenhagen.

EuropaBio, 2001, White Biotechnology: Cleaner Processes for a Cleaner Environment, EuropaBio, Brussels.

European Environment Agency, 2000, *Environmental taxes: recent developments in tools for integration,* Copenhagen.

EUROSTAT, 2000, *Structures of the taxation systems in the European Union 1970-1997,* European Commission, DG Environment, Brussels.

Fischer C., Parry I. and Pizer W., 2003, *Instrument choice for environmental protection when technological innovation is endogenous,* Journal of Environmental Economics and Management, 45, 523-545.

Geyer A., Scapolo F., Boden M., Döry T. and Ducatel K., 2003, *The Future of Manufacturing in Europe 2015-2020 : The challenge for sustainability scenario report,* IPTS report EUR 20705 EN.

Hitchens D**.,** Farrell F., Lindblom J and Triebswetter U., 2001, *The Impact of Best Available Techniques (BAT) on the Competitiveness of European Industry*, IPTS Report, EUR 20133 EN.

Hoerner J.A., Miller A. and Muller F., 1995, *Promoting Growth and Job Creation through Emerging Environmental Technologies*, Washington, DC: National Commission for Employment Policy, Research Report No. 95-3, April.

Huhtala A., 2003, *Promoting financing of cleaner production investments – UNEP experience*, Journal of Cleaner Production, 11, 615-618.

Implementing the Community Strategy to Reduce CO2 Emissions from Cars: Fourth annual report on the effectiveness of the strategy (Reporting year 2002), COM (2004) 78 final. http://europa.eu.int/eur-lex/en/com/cnc/2004/com2004_0078en01.pdf

IPTS/ESTO, 2002, The Assessment of Future Environmental and Economic Impacts of Process-Integrated Biocatalysts, Report EUR 20407 EN

Kemp R., Smith K. and Becher G. (2000) 'How should we study the relationship between environmental regulation and innovation', in Hemmelskamp J., Rennings K. and Leone (eds), *Innovation-oriented environmental regulation*, ZEW Economic Studies, Physica Verlag, Heidleberg, New York.

Makower J., 2001, *The Clean Revolution: technologies at the leading edge*, Global Business Network, San Francisco, California.

Milliman S. and Prince R., 1989, *Firm incentives to promote technological change in pollution control*, Journal of Environmental Economics and Management, 17, 247-265.

Montalvo Corral C., 2003, *Sustainable production and consumption systems – Cooperation for change: assessing and simulating the willingness of the firm to adopt/develop cleaner technologies. The case of the In-Bond industry in northern Mexico*, Journal of Cleaner Production, 11, 411-426.

On the Road to Sustainable Production, Progress in implementing Council Directive 96/61/EC concerning integrated pollution prevention and control, COM (2003) 354 final, http://europa.eu.int/eur-lex/en/com/cnc/2003/com2003_0354en01.pdf

Pavlinek, P., 2002, *The Central and East European Automotive Industry Restructuring*

REC, 1997, *The Environmental Technology Market in Central and Eastern Europe: An Overview of the Czech Republic, Hungary, Poland, Slovakia and Slovenia*.

Reijnders L., 2003, *Policies influencing cleaner production: the role of prices and regulation*, Journal of Cleaner Production, 11, 333-338.

Stimulating Technologies for Sustainable Development: An Environmental Technologies Action Plan for the European Union, COM (2004) 38 final.