Technological innovation fostering sustainable development

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1. Objectives and methodology

The purpose of this research project is to study under what conditions technological innovation can foster and promote sustainable development. It considers all forms of technological innovations that are potentially conducive to sustainable development: process innovations, product innovations, organisational innovations, market innovations. It also looks at the entire chain of innovation and gives particular attention to the existence of many innovation schemes.

The project has five scientific objectives corresponding to operational concerns:

- studying the ambivalent role of technological innovation, analysed as one of the causes of non-sustainable development and as a key factor of a new means of production, compatible with sustainable development;
- characterising the innovation technologies and processes conducive to sustainable development, taking account not only of their environmental aspects, but of the other dimensions of sustainable development as well;
- using case studies to investigate the social-economic aspects of these innovation technologies and processes conducive to sustainable development;
- situating technological innovation in relation to other instruments to promote sustainable development;
- studying the obstacles and the incentives to setting up policies for innovation and dissemination of technologies conducive to sustainable development; putting the conclusions into perspective in the Belgian context.

By enrolling the FTU Work and Technologies Research Centre in social-economic research networks on innovation, we were able to situate the objective of sustainable development with reference to a more general analytical context – R&D policies. This is one of the original aspects of the study.

Each objective requires the use of the appropriate working methods. Consequently there is no uniform methodological approach. Several working methods were used:

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- In the theoretical approach, based on the discussion of current literature, we give priority to a *confrontation of sources* from different fields, particularly confrontation between social studies on innovation and studies on sustainable development.

- To characterise the technologies conducive to sustainable development, an inventory of innovations was taken on the basis of a sample of articles in the specialised press, and a *method of classification* was developed.

- For the *case studies* in innovating companies and in industrial research centres, *a semi-directive interview guide* and check list were developed, to take account of all aspects of the process of disseminating innovations, as well as the incentives and obstacles for decision takers and companies in adopting sustainable development criteria.

- A *comparative analysis grid* was drafted to review some 20 programmes to stimulate or support innovation, in Belgium and elsewhere, from the standpoint of sustainable development.

One aspect common to all the methods used, is that we have favoured a multidisciplinary approach, which takes account of technological, ecological, economic, institutional and social aspects. This multidisciplinary approach was furthered by the broad range of qualifications represented in the research team.

2. Presentation of the results

2.1. Innovation strategies in companies

Three approaches were used to study innovation strategies in companies with regard to the objective of sustainable development. Initially, a survey was done on a sample of environmental innovations, to identify the characteristics of these innovations. The results showed, however, that very often it is difficult to characterise a technology as favourable or unfavourable to sustainable development as such, insofar as the innovation process is a criterion which is much more relevant than the technology itself.

In a second stage, a series of case studies were done in innovating companies, particularly to apprehend the various aspects of the innovation processes and to identify any specific characteristics of innovation that foster sustainable development. Alongside these case studies, we did a comparative analysis of various surveys on innovation objectives and procedures considered from the standpoint of sustainable development.

2.1.1. The survey on the environmental innovation “shop window”

The objective of the survey is to test a grid characterising technologies conducive to sustainable development. The method consists of observing the way communications on technological innovations serving sustainable development are worded, the “shop window” so to speak, during a given period (eight months in 1997-98). The inventory includes two types of information sources:

– advertising sources: articles, brochures, company activity reports, presentations at conferences or specialised trade fairs;

– environmental reports published voluntarily by companies located in Belgium. This source of information concerns companies which, a priori, are more sensitive to environmental problems and are concerned with their internal and external communication. They therefore provide a specific subgroup in the sample.

In both categories of sources, innovations consist on one hand of *offers of technologies,* which are presented on the market by their designers or suppliers, and on the other hand *investments in technologies*, as they were described by the companies that implemented them. The financial aspect of the investments is not taken into account. The chosen sample reflects the shop window, but not the markets, of innovations favourable to the environment.

Three categories of criteria are used to classify and characterise the findings.

– The first series of criteria considers the *objectives of innovations*: prevention, end-of-pipe processing, rehabilitation, monitoring, substitution, saving resources.

– A second criterion concerns the distinction between *add-on technologies* and *integrated technologies*. Add-on technologies are added to existing processes or products in order to reduce the environmental damage associated with production or consumption. Conversely, in the case of integrated technologies, the environmental characteristics are incorporated in the concept of the process or product itself.

– A third criterion refers to the distinction between *incremental innovations* and *radical innovations*. Incremental innovations are improvements made to products or production techniques, in order to improve quality, productivity or diversity. Radical innovation, on the other hand, constitutes a breach in the evolution of processes or products, involving a transformation production or marketing methods, and of professional skills.

An analysis of the results showed predominance of add-on technologies over integrated technologies (table 1). The proportion of integrated technologies is nevertheless higher in the sub-sample of innovations found in environmental reports. This may be an indication that companies showing greater awareness of the environment also give higher priority to integrated technologies.

Table 1
Proportion of add-on technologies vs. integrated technologies

	Advertising sources		Environmental reports	
	Offers	Investments	Offer	Investments
Add-on technologies	76 %	61 %	32 %	53 %
Integrated technologies	24 %	39 %	68 %	47 %
	100 %	100 %	100 %	100 %

Table 2 shows the breakdown of the sample in terms of the various environmental objectives. End-of-pipe technologies are more common in all parts of the sample. These attempts to reduce environmentally harmful aspects can be considered as a response to environmental

regulations. Technologies to save energy, water or raw materials come in second place. These innovations lead to a direct reduction in production costs for companies so the investment pays for itself fairly rapidly. Compliance with regulations and cost reductions therefore appear to be the main incentives for innovation.

Table 2
Innovations according to their environmental objectives

	Advertising sources		Environmental reports	
	Offers	Investments	Offers	Investments
Prevention	9.6 %	8.2 %	2.0 %	5.8 %
End-of-pipe	49.3 %	52.3 %	49.0 %	49.0 %
Rehabilitation	5.3 %	2.1 %	1.3 %	4.0 %
Monitoring	19.6 %	4.8 %	0.0 %	5.8 %
Substitution	3.3 %	6.6 %	19.6 %	9.2 %
Saving resources	12.9 %	26.0 %	28.1 %	26.2 %
	100.0 %	100.0 %	100.0 %	100.0 %

As concerns the third criterion (incremental or radical innovations), it is almost impossible to assess this on the basis of secondary sources, without knowing anything about the concrete conditions of implementation of the innovations in the firms in question.

The criteria used to characterise the “shop window” for environmental innovations are therefore not sufficient to understand the paths that lead to innovations conducive to sustainable development. For this reason, other methods were used to apprehend these pathways.

2.1.2. Case studies in innovating companies

The sample of case studies includes both companies producing innovative technologies and user companies (or both at the same time). In both cases, the *innovation process* is at the heart of the case study. Innovations to be targeted concern environmental aspects as well as energy, raw materials and transport, and generic technologies, like building material technologies or information and communication technologies. The indices of the “sustainable development” aspect are concern for the long-term on one hand, whereas many environmental technologies are short-term solutions, and, on the other hand, awareness of the North-South problematic (transfer of technologies, cooperation, etc.). Another possible index is the business ethics aspect.

On the basis of various secondary sources (directories, activity reports, articles), 11 companies were chosen for the final sample of case studies, using pragmatic criteria of feasibility, availability of preparatory documentation, and a favourable predisposition in our first contact with these companies. The case studies were done on the basis of semi-directive interviews, with an interview guide and an analysis grid.

Table 3 proposes a summary of the main characteristics of the innovating behaviour of these 11 companies.

Table 3
Case studies – main characteristics of innovating behaviour

Type of company	*Type of innovations*	*Characteristics of the innovation process*
Paint	– Substitution of products and raw materials	– Incentives: stricter regulations, competition, health and safety. – Collaboration with collective industrial research centres
Colourings	– Substitution of products, new processes. – Waste water treatment, saving resources	– Incentives: quality of products, viability of the company, quality of the environment and quality of work, mobilisation of the personnel. – Laboratory geared to developing new processes rather than monitoring; collaboration with universities. – Participatory approach to seeking technological solutions (working groups, vocational training, social dialogue).
Pharmaceutical products	– Products and processes – Services associated with products – Developing methods of analysis of product life cycles and impact.	– In the top 20 worldwide for the R&D/turnover ratio. Laboratories with 1500 researchers. – "Sustainable performance management" pilot project. – Business ethics code, including environmental responsibility; member of the World Business Council for Sustainable Development.
Solar energy panels	– New techniques to reduce the price of products	– European R&D partnerships – Partnerships for the transfer of technology to southern hemisphere countries.
Assembling windmills	– Design, electronic control, control of installation conditions	– Creation of joint-ventures to design and implement new sites using windmills.
Electro-mechanics	– New, single product (hydro-electric mill)	– Innovation led by an inventor-entrepreneur, internal organisation to promote creativity.
Transformation of metals and new materials	– Photovoltaic cells in flexible materials	– Innovation of products for market niches with high value added. – System of suggestion of innovations via intranet. – Award of ethic certificates: Ethibel and Dow Jones Sustainability Group Index. – Proactive, demanding attitude with regard to the authorities and support to R&D.
Tannery	– Processes, waste management	– Incentives: quality of products, reducing damage to the environment. – Partnerships blocked by protection of manufacturing secrets.
Spinning mill	– New products	– Little internal potential for innovation, seeking partnerships with suppliers. – More recent R&D partnerships with collective industrial research centres.
Waste processing	– Computerisation, electronic control, soil treatment	– Developing high level expertise for the entire waste management industry. Maintaining an "engineering culture". – Acquisition and adaptation of technologies. – Taking steps to obtain environmental certification.
Generation of electricity	– Rational use of energy – Renewable energies	– Incentives: evolution of markets, environmental challenges, cost reduction. – Defining a new internal strategy of long-term innovation. Synergy with a design and engineering subsidiary. – Setting up an internal environmental management system and audit.

Three groups can be identified from the characterisation of companies in terms of their approach to innovation and impact of innovation on sustainable development:

1. *Large companies*. These are not defined exclusively by their size, but also by their membership in an international group or commercial network. Sustainable development is

an element of the long-term strategy, because economic and environmental aspects are increasingly interdependent. The companies generally adapt the concept of sustainable development to their activities, making it an "ad hoc" concept.

Large companies generally have R&D structures or sufficient financial resources to have access to technologies developed by others. For them, technological innovation is a means of standing apart from competition, by proposing new products, improving performances, decreasing production costs, while reducing the harmful aspects associated with production.

In the perspective of dematerialisation of the economy, several companies have decided to combine services with their products or to increase the service content of what they offer. This policy helps them reduce production of goods, which creates waste, and increase production of services, so as to better meet client demand, and to increase client loyalty. This additional contribution requires skills which are not easily standardised, so it becomes simpler to circumvent competition than for simple manufactured products. The environment is clearly an argument of this strategy.

The implementation of communication strategies is a marketing innovation. Not only does the company inform the general public of its efforts to reduce its environmental impact, but in addition, it listens to its clients and tries to gain acceptance of its employees. A sophisticated form of the communication strategy consists of taking part directly in the development of restrictive measures (emission standards, branch agreements, etc.). This effort seems to show a proactive approach to companies on the environmental question, but on the other hand, it could be a way to impede environmental progress by means of a lobbying policy.

2. *Small innovating companies*. They are often in fairly small niche markets (in any case in Belgium to date), but they are convinced that their products correspond directly to a sustainable development perspective. They are impatient with the slow progress of the public authorities' implementation of a real global strategy to fight the greenhouse effect and enact environmental protection. Their small size prevents them from having an effective lobbying policy. But this does not mean they are passive – they develop strategies to ensure their maintenance or growth on the current market.

   Although they are aware of their small size on the world market, these companies do not feel self-conscious about technological innovation. They consider that they can develop sufficient know-how to remain in competition, at least in certain, very specific niches. They pay great attention to their employees and create a favourable climate for R&D. Innovation is their credo.

3. *Other companies*. Harmful environmental effects do not threaten their activities in the short run. Sustainable development is not a strategic component, but one aspect among others to be taken into account.

2.1.3. Analysis of the results of existing surveys on innovation

The comparative analysis covers the results of three recent surveys, which provide helpful information on innovation processes, new forms of management, including knowledge management, and on the contribution of technological information to sustainable

development. These consist of the partial results – concerning Belgium – in the second Community Innovation Survey (CIS-2), done on a European scale in 1997-1998, the survey done in 1998 by the "Fondation de l'Entreprise" (FDE) on new forms of management and finally the public survey done in 2000 by the World Business Council for Sustainable Development (WBCSD).

The Belgian part of the CIS-2 survey shows that the reduction of harmful effects on the environment, energy savings and the reduction of consumption of resources are not among the major incentives for innovation. The size of companies is a factor that discriminates to the benefit of large companies.

From the FDE survey we retain that the practice of R&D is the most common means of access to technologies. As concerns the dissemination of technologies, the findings of the FDE survey show limited participation of companies in technology fairs. Finally, the discriminatory effect of the size of the company must be retained with regard to many aspects: practice of an R&D, organisation of an R&D department, the existence of a formal procedure for following up suggestions made to the R&D manager, the establishment of partnerships, access by computer to outside information, internal distribution of information collected outside, the appointment of a training manager, formal follow-up of training courses, launching projects from several departments, using multidisciplinary teams. This effect disadvantages small companies, except as concerns computer access to outside information.

In small businesses, more limited formal training courses and less frequent implementation of projects across several departments entailing multidisciplinary teams have an effect on management skills. From this perspective, the authorities must take this into account by developing policies targeting small business, to avoid a growing gap between large and small companies.

From the standpoint of measures to be deployed in public policies to accompany innovation, the results of the WBCSD inquiry show:

- the need for public intervention given the difficulty for managers of convincing shareholders of the profitability of sustainable development strategies;
- the advantage of technological forecasting to pinpoint the most promising technologies, from the standpoint of their sustainability, their acceptability for the public and as well as their economic perspectives (market size, growth rate, field and intensity of competition);
- the challenge for companies of managing skills in order to enact sustainable innovations.

2.2. Incentives to technological innovation conducive to sustainable development

2.2.1. The challenges of sustainable development for innovation policies

Sustainable development poses many challenges for collective monitoring systems and incentives to innovate:

1. Filling *market gaps* as concerns technologies conducive to sustainable development, by

using various schemes to narrow the gap between the private return and the return to society, between the current and future generations.

2. Supporting *dissemination of clean technologies*, low on consumption of resources, by favouring the dissemination of information and knowledge.

3. Promoting *technological diversity,* to avoid getting locked into technologies which may present long-term risks.

4. Reinforcing the *long-term innovation capacity* by favouring the development of skills and strategic prospecting.

5. Laying down procedures to *improve coherence of the various agents,* to encourage appropriation of technologies by users and by society.

6. Encouraging *citizen participation* in developing effective scenarios for a social-economic assessment of technological choices.

2.2.2. The main instruments for stimulating technological innovation

The "Trend Chart on Innovation" launched as part of the European Commission innovation programme refers to three major categories of instruments for stimulating technological innovation:

1. *Promotion of an innovation culture*. Promoting an innovation culture includes measures to stimulate creativity, initiative, taking calculated risks and accepting a certain social, geographic and professional mobility. The promotion of the culture of innovation also has to do with developing skills. Likewise, it targets the capacity to anticipate needs and sensitivity to public opinion.

2. *An incentive framework*. Setting up a favourable context for innovation targets promoting of the development of innovations, by stimulating both competition and cooperation, and providing better protection for intellectual and industrial property.

3. *Reinforcing the ties between research, innovation and markets.* Various measures can be adopted to improve the way the fruits of research are transformed into the products and services: exercises in strategic planning in order to develop long-term objectives, the creation and spinning off of innovating companies, stimulation of cooperation with the public sector, private sector and education.

Using the frame of analysis of the "European Trend Chart on Innovation", we have done an analysis of 20 programmes to stimulate innovation, in Belgium and elsewhere, that each illustrate one of the lines of action of the trend chart. Table 4 indicates the programmes chosen to illustrate these action lines.

Table 4
Objectives of the Trend Chart on Innovation and illustrative programmes to illustrate it

Objective	***Illustrative programme***
Developing an innovation culture	
Training, awareness	National action plan "Environmental education for a sustainable future", 2000.
Negotiation, mediation	European research project called "Strategies towards the Sustainable Household" (SusHouse), in five countries, 1998-2000.

Technological forecasting	Workshop OCDE "Technology foresight for sustainable development", 1998.
Regional prospecting	Regional sustainable development plan for Baden-Württemberg (Technology Assessment Academy, Stuttgart), 1994-1998.
Technology assessment	Long Range Research Initiative (LRI), European Council of Chemical Industries (CEFIC) and the corresponding bodies in the USA and Japon (1999-2004).
Objective	***Illustrative Programme***
Information for professionals	Kenniscentrum voor Beste Beschikbare Technieken, VITO (Mol), Flemish Region (since 1995)
Clustering	Environmental Cluster Research Programme, Finnish Ministry of the Environment, 1997-2000
Support to local authorities	Programme d'intervention des délégations régionales de l'Agence pour l'Environnement et la Maitrise de l'Energie (ADEME), France, depuis 1990.
International cooperation	Programme of research and liaison between universities for development (PRELUDE), since 1985.
Reinforcement of a framework conducive to innovation	
Financing	SOLTHERM Programme (promotion of solar water heaters) in the Walloon Region, 2000-2010.
Taxation	Investment bonuses and fiscal incentives for small business, Walloon Region
Public orders	Committee for ecological and sustainable public supply contracts, Sweden, 1998-2001.
Management contract	Management contract with a technological operator between WIN (Wallonie Intranet) and the Walloon Region.
Cooperation between research, innovation and markets	
Support to design	ADEME programme for the eco-design of products (1999).
Support to research	Programme "Strategische Technologieën voor Welzijn en Welvaart" (STWW), Flemish Region, 1998-2000.
Support to technological development	Prométhée Programme, DGTRE, Walloon Region, with the support of the European programme, "Regional Innovation Strategy" (1998-2001)
Support of demonstration	Environmental Technology Verification Programme, US Environmental Protection Agency. since 1990.
Support to recycling	Recywall, economic interest grouping, Walloon Region
Technical-economic guidance	Industrial Assessment Centres Programme (IAC), Office of Industrial Technologies, Federal Dept. of Energy, USA.
Venture capital financing	Ecotech Finance SA, Wallonie.

2.2.3. The role of sustainable development in collective industrial research centres

To complete this approach in terms of schemes to support innovation, it seemed useful to have a look at an aspect which has been specific to the Belgian innovation system for quite some time: collective industrial research centres. Five institutions were analyzed: two collective research centres in the strict sense, one public research centre in the Walloon region, a technological centre created under Objective 1 in Hainaut and a sectoral centre belonging to the private sector.

Collective research centres are highly sensitive to the problem of sustainable development and their level of skills enables them to imagine original solutions. They regret not being able to develop them sufficiently, particularly for lack of sufficient public resources made available for their generic research projects on preventive solutions, upstream of production processes.

2.2.4. An emblematic technological field: generation of electricity from renewable energy sources

The energy sector is a good illustration of the whole range of instruments that the authorities should deploy to stimulate the development and distribution of technical innovations. The relationship between the requirements of sustainable development, the need for innovation and the role of the public authorities is illustrated on the basis of two concrete cases: the

results of the European project ATLAS in which both Flanders and Wallonie took part, and the case of the renewable sources of energy in the generation of electricity.

The ATLAS project, carried out in the context of the European program Joule - Thermie, gave a broad summary of energy technologies. This summary includes a state-of-the-art report on various technologies, an analysis of obstacles to dissemination and the review of incentive measures to be adopted. The results show:

- differences in technological maturity, underlining the importance of the demonstration phase;
- obstacles to dissemination: notably the lack of information on the degree of technological and commercial maturity of innovations, a lack of confidence of investors, including institutional investors, and the price of traditional energy which is too low and does not take account of negative external effects;
- the need to simultaneously deploy technical and non-technical measures (financial, environmental and organisational).

In its report of October 2000, the Commission for analysis of electricity production modes and energy conversion (Commission AMPERE) assesses the potential of renewable energies for generating electricity at 10 percent of current consumption. This potential could be reached at the 2010-2020 horizon.

The main obstacles to their dissemination, already mentioned in the ATLAS project, are the poor price ratio compared to conventional electricity, and the economic, political and institutional weight of conventional electricity generators. Other obstacles have to do with the environmental impact assessment, competition for use of space and administrative measures of various types which can have distorted or contradictory effects. Three types of measures can be envisaged to promote development of renewable sources of energy for the generation of electricity: actions on cost, administrative measures and demonstration initiatives. R&D can play a significant role in reducing costs.

2.2.5. General assessment schemes to stimulate innovation

Generally speaking we see a very broad range of interventions intended to direct and stimulate innovation on a collective basis, including the three major families of instruments presented in the European Trend Chart on Innovation. These instruments must be envisaged in combination, rather than separately. An important aspect is the acceptance of sustainability among other criteria currently applied (applicability, technical performance, job creation) in the various types of intervention of public authorities. Working in a network – research consortiums, strategic clusters, development of new public/private partnerships, voluntary negotiations, communication actions – constitutes the dominant emphasis of collective actions to stimulate innovation conducive to sustainable development.

The main difficulties encountered in supporting sustainable innovation are found in highly monopolistic sectors, which are not inclined to innovate, or scattered sectors where it is difficult to disseminate innovations. The major challenge lies with small business, not only in terms of financial support, but also in the form of technical-economic guidance, providing information and independent assessment, aid to marketing and export of new sustainable

products or processes.

The collective procedures to channel innovation also vary with the degree of maturity of the technology in question. At the emerging stage, collective intervention will concentrate on supporting fundamental research, anticipating future technology and technology watch, assessment of long-term risks. At the stage upstream of technological development, collective intervention will target sharing the cost of material and immaterial investments required for innovation, taking account of market needs, and thinking about economic valorisation at an early stage. Downstream, collective intervention is not limited to technical measures, non-technical measures can also play a role. The challenge downstream mainly consists of initiating a market in order to enable large-scale distribution of new sustainable products or processes.

3. Conclusions and recommendations

3.1. Main conclusions of the research

Making technological innovation serve sustainable development is a complex challenge, because the concepts of innovation and sustainable development both cover several aspects. This research report has tried to identify those aspects and to explore the ones which seemed most determinant.

One of the objectives of the research project was to characterise technologies serving sustainable development, while realising that the characterisation cannot cover the technology itself exclusively, but should also refer to the development and dissemination process. This is an important distinction and a major observation. The distinction between add-on technologies and integrated technologies proved to be significant, but less pertinent than we would have thought. In addition, technologies serving sustainable development cannot be limited exclusively to environmental technologies. Case studies show that companies which innovate in a sustainable development perspective must implement a combination of process innovations, product innovations, organisational innovations and market innovations among which priorities are established pragmatically, in view of opportunities and constraints.

Obstacles to the distribution of technologies conducive to sustainable development are not principally due to a deficit in available technologies. These technologies have very different degrees of maturity. The maturity, demonstration and validation phases have an important weight on factors which explain the success or failure of the dissemination of innovations.

The effects of environmental policies on innovation are undeniably positive, but the responses of companies are very flexible. On one hand, technological responses that the companies develop depend on many factors in the context, related to the industrial structures, the general state of the environment, institutional and social factors. In addition, effects such as a given environmental measure on certain types of innovation are very diverse – at times favouring radical innovations and at others incremental innovations or the dissemination of existing technologies.

Case studies show a large variety of innovation strategies. Size is important: a large company can define a long-term strategy, mobilise its R&D resources, improve its internal and external

communication and lobby, whereas a small company will prefer to invest in the most up-to-date innovations or market niches and mobilise the creativity of all its personnel.

Policies to stimulate technological innovation conducive to sustainable development must take account of the flexibility of the responses to environmental constraints and the diversity of strategies. A strong point of innovation policies is that they can play an integrating role with regard to industrial policies and environmental policies, and they can influence urban planning, employment and vocational training policies. Another strong point is their capacity to induce anticipation of future technologies.

Transformation of policies to stimulate innovation can be seen from two standpoints. On one hand, criteria on the quality of the environment and sustainable development have made a significant, but still insufficient, breakthrough in the traditional schemes for supporting innovation: aids and subsidies, financial incentives, guidance systems. In addition, new types of actions are appearing or being reinforced: clustering, consortiums of R&D across several sectors, voluntary agreements, public/private partnerships, communication actions, organisation of interaction between researchers and users. Conversely, it seems that human resource and skill management, particularly the development of skills, and the mobility of R&D personnel and the capacity to communicate, are still weak links in the chain of the innovation process conducive to sustainable development. As for the missing links, these are essentially in the dissemination of innovations. This aspect is treated in more detail in our recommendations.

3.2 Recommendations

The reasonable use of innovation policy instruments will have the effect of triggering change, but technological change can be ranked on a scale beginning with the status quo for a firm that is already in compliance with a new requirement, the dissemination of existing technologies, continual improvement, incremental modification, and ending with the radical modification of products and processes. The degree of change needed to cope with sustainable development requirements is certainly not limited to the status quo, nor to the dissemination of existing technologies nor even to incremental modifications. Radical innovations are necessary if technological development is not going to compromise the needs of future generations.

3.2.1. Meeting the challenges of sustainable development

To *fill the market gap* and the difference between private return and the return to society of investments in R&D, the following measures should be envisaged:

- financing fundamental research and basic technological research to give impetus to the development of clean, resource-efficient technologies;

- partnership policies can broaden the perimeter within which knowledge is voluntarily shared and reduce the problem posed by the imperfect appropriation of the results of R&D;

- policy to support demand by means of public orders, by reinforcing regulations and developing innovating financial schemes.

As concerns the *dissemination of clean, resource-efficient technological innovations*, the most urgent initiatives to be enacted, particularly for small business, are:

- amplifying demonstration programmes;
- providing independent information to the public authorities responsible for legislation or subsidies in a technological field;
- implementing programmes for certification and verification of improvements in performance;
- constituting "shop windows" to facilitate access to the internal market or the export market;
- supporting technological transfer particularly by means of technological guidance;
- training courses for graduates in applied sciences, putting increasing emphasis on the analysis of the life-cycle, eco-design, eco-efficiency.

To *promote technological diversity*, a critical mass of fundamental and basic industrial research must be reached and the constitution of research consortiums should be promoted. Research on generic technologies should be encouraged in cooperative research centres. Technological transition should be planned in consultation with all agents of technological development, in order to identify polluting technological systems on which rehabilitation technologies are simply being grafted, so as to move into integrated sustainable technologies.

To organise *reinforcement of skills in the long run*, we need to understand how skills are coded, renewed and managed within companies: this requires financing of studies on how learning is organised. As concerns continuing training, initiatives by the sector or across several sectors can promote methods that generate more sustainable industrial behaviour patterns (analysis of the life cycle, eco-efficiency, mastering environmental quality). From a longer standpoint, and at a more collective level, strategic anticipation of future technologies should also be done, in consideration of the economic stakes of developing a given technology, its social and cultural acceptability, and its competitive position and capacity for local dissemination.

Special care should be given to small businesses. Measures intended to increase their innovation capacity should enable them to develop promising technologies inside the company, to acquire technologies and know how to adapt them to their own needs, or to ask the pertinent questions in technological cooperation schemes.

As concerns *citizen participation*, this can be encouraged on various levels: when scenarios are determined for anticipating technologies, for early detection of risks, for a social-economic assessment of technological choices, and finally for the design and experimentation of products or processes with a technological component. This citizen participation should also concern acceptance of a cyclic economy which needs a change in production methods but also and above all in modes of consumption.

Developing *coherence among the agents* takes place on several levels. This requires integrating the criterion of sustainability in public decisions to support innovation, in import/export of technologies and in adopting regulations concerning technologies. It also

requires increased consultation among different levels of authorities and different fields of competence, to reach a better integration of incentive instruments, whether they concern innovation culture, the creation of framework conditions conducive to innovation, or improving the way the fruits of research are transformed into products and services.

3.2.2. Intervening throughout the innovation process

Accompaniment schemes can be deployed all along the technological innovation process—by the public authorities, by the private sector (at the level of the sector, across several sectors, or at company level), and by associative organisations. The scheme should be adapted to the degree of maturity of the technologies supported:

- early detection (technology watch, risk assessment, technology assessment, forecasting);
- financing basic research and interdisciplinary research:
- dissemination of design methods including an analysis of the life-cycle, eco-efficiency;
- development and demonstration;
- putting on the market: aid to technological verification, certification;
- dissemination: organisation of promotional events for sustainable technologies, adaptation of specifications of public supply contracts.

A *combination of accompanying measures* is desirable for coherent action on the many parameters that can influence technical change: combination of macro- and micro-economic measures, short-term and long-term measures, general measures and measures targeted to specific technologies.

Technological dissemination should be a major concern in supporting innovation conducive to sustainable development. Although there is a relative consensus on the identification of the technologies that promote sustainable development, there is total uncertainty about the delays within which these technologies will be on the market and how to distribute them on a large scale. Clearly, acceptance of technological development is the main problem at this time in steering technological change to effectively promote sustainable development.

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