Paper presented at the POSTI conference
Policy Agendas for Sustainable Technological Innovation
University of East London, 1-3 December 2000

Technological innovation fostering sustainable development: some case studies in Belgium

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This paper presents some results of a research project carried out in Belgium, under the research programme "Levers for sustainable development" (1997-2001) of the Federal Science Policy Office (SSTC) (1). The general purpose of this project is to understand the societal conditions of design and diffusion of technological innovation that should be shaped in order to foster sustainable development. The project intends to answer the following research questions (2): what are the criteria for identifying technological options fostering sustainable development ? Who are the stakeholders and how do they interact ? What impacts have these technological options on competitiveness and employment ? What are the links between technological innovation and the other political instruments of sustainable development ? And consequently, how to understand and develop the related policy issues in Belgium ?

As the project is still in progress, the present paper mainly focuses on some empirical results and draws some general comments about the innovation process. The final report and conclusions of the research project are due to the end of February 2001.

Empirical data at the Belgian level were collected through three different approaches:

- an analysis of the "shop-window" of sustainable technological innovations;
- an analysis of the place of sustainability among the various motivations for innovation in enterprises;
- case studies in Belgian enterprises.

1. The shop-window of sustainable technological innovations

Methodology

An analysis of the "shop-window" of sustainable technological innovations was carried out at the first stage of the project, in 1998. It relies on an inventory of 800 environmental innovations presented in several technical journals, technology fairs and environmental

(1) A presentation of the programme and the research projects can be found on www.belspo.be

(2) Vendramin P., *Technological innovation for sustainable development*, in *TA-Datenbank Nachrichten*, vol. 6 n° 2, ITAS, Forschungszentrum Karlsruhe, Juli 1997.

reports. It may be considered as a sample of "best available technologies", from the point of view of their potential users at the country level. The inventory can split into two parts:

– *Advertisement sources*. Information was collected during a period of eight months in French-speaking specialised journals in the area of clean technology and environmental management, available in Belgium but published in Belgium or France. Other data came from environmental technology fairs. Recorded innovations may be either product or process innovations, or both.

– *Environmental reports*. A second sample of innovations was collected in the voluntary environmental reports published by Belgian enterprises in 1997-98. This information source is related to a sub-group of enterprises that are supposed to be more aware of sustainability issues, as they voluntarily undertake internal analysis and external information.

In both categories, recorded innovations consist of either *technology offers*, which are presented on the market by their manufacturers or providers, or *technology investments*, as described by the users who have implemented them.

Three kinds of criteria are used in order to characterise the collected information and data.

1. A first set of criteria concerns the purposes of innovations. Six different purposes are taken into account:

   - preventing technologies, aiming at reducing accidental and pollution risks;
   - end-of-pipe technologies, aiming at limiting or processing harmful environmental effects in the areas of air, water, waste, soil or noise;
   - rehabilitation technologies, in order to restore damaged ecosystems;
   - monitoring technologies;
   - substitution technologies, aiming at replacing harmful substances or processes by environment-friendly alternatives;
   - saving technologies, reducing the use of non-renewable natural resources.

2. A second criteria concerns the distinction between *add-on technologies*, which are simply added to existing production systems without modifying them, and *integrated technologies*, concerning substitution, optimisation, recycling or any other "built-in" innovation, which modifies the production system. This distinction refers to a "technology assessment" approach to sustainable technology (3).

3. A third criteria is related to the taxonomy of innovation developed by Christopher Freeman and Luc Soete and used in earlier FTU studies (4). It distinguishes *incremental innovation* and *radical innovation*, pointing out the decisive role of the latter in structural industrial changes. This need for radical innovation is also commented by other authors,

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(3) Coenen R., Klein-Vielhauer S., Meyer R., *Umwelt un wirtschaftliche Entwicklung*, Technikfolgen-Abschätzung Büro (TAB), Bundestag, Bonn, 1996.

(4) Valenduc G., Vendramin P., *Le travail au vert*, Editions EVO, Bruxelles, 1996.

who suspect that an excessive focus on incremental innovation would trigger a "lock-in" effect in existing technologies (5).

Although the method can be considered as original, it suffers from inherent limits and weaknesses:

- The inventory is based on environmental technologies, but not on technologies fostering sustainable development, in a broader meaning. Criteria of sustainability, such as inter-generational equity and solidarity, are not taken into account here.

- The sample of innovations reflects the "shop-window" of technology, without being representative of the technology markets.

- The third criteria (incremental or radical innovation) is practically impossible to assess from secondary sources, without knowing anything about the conditions of implementation of innovations in the concerned firms.

Results

The analysis shows a predominance of add-on technology rather that integrated technology. The share of integrated technology is however higher in the sub-sample of innovations coming from environmental reports. It may indicate that the firms showing better environmental awareness devote a more important part of their investments to integrated technology (table 1).

Table 1 – Breakdown add-on technologies / integrated technologies

	Advertising sources		Voluntary environmental reports	
	Offers	Investments	Offers	Investments
Add-on technology	76 %	61 %	32 %	53 %
Integrated technology	24 %	39 %	68 %	47 %
	100 %	100 %	100 %	100 %

Another specific feature of the sub-group of innovations coming from environmental reports is the higher proportion of substitution technologies. The breakdown of innovations according to the purposes (criteria n°1) is indicated in table 2.

Table 2 – Breakdown of innovations according to their purposes

	Advertising sources		Voluntary 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 %

(5) Faucheux S., Nicolaï I., *Les firmes face au développement soutenable : changement technologique et gouvernance au sein de la dynamique industrielle*, dans *Revue d'économie industrielle*, n°83, 1998 (p.130).

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	12.9 %	26.0 %	28.1 %	26.2 %
	100.0 %	100.0 %	100.0 %	100.0 %

Data of table 2 also show that end-of-pipe technologies are the most widespread, in whatever part of the sample. Such innovations are mainly aimed at avoiding environmental harmfulness. They can be considered as responses to environmental regulations. The second rank is attributed to energy, water and raw material saving technologies. Such innovations can directly reduce the production costs of the enterprises and provide a quick return on investment. Compliance with regulation and cost saving appear as the main drivers for innovation.

As a more general conclusion, the criteria used in the characterisation of the "shop-window" of environmental innovation are not sufficient to understand the pathways towards sustainable technological innovation. It is impossible to assess whether a technology is sustainable or not, without understanding not only technology itself, but the whole innovation process and the behaviour of the firms. The two next sections will consider these aspects of firms' behaviour and innovation process.

2. Sustainable development among the motivations for innovation

Methodology

The analysis is based on the Belgian data of the European CIS survey, which intends to analyse the various motivations for innovation in the enterprises. The "Community Innovation Survey" (CIS) is an initiative of the European Commission. The second CIS survey was carried out in 1997 and published in 1999, but the collected data concerned the period 1994-1996. A common methodological framework was used in all the Member States, in order to allow cross-country comparisons. Belgian data were collected by the Federal Science Policy Office. Detailed data are not yet published, but available for researchers. The Belgian sample is made of 1377 industrial enterprises and 915 service enterprises.

This paper only presents findings drawn from the Belgian data. Our comparisons with other European countries are still in progress. Despite the common methodological framework, it appears that the definition of innovation can be slightly different from a country to another. For instance, Belgium has opted for a restrictive concept of innovation, limited to technological innovation; the innovative character must be assessed not only in relation to the firm itself, but also to the state of the market. Other countries, such as the Netherlands, adopt a wider definition of innovation, taking into account the whole innovation process and scope.

Other surveys can provide complementary information on the innovative behaviour of Belgian enterprises and the role of sustainability as a potential driver for innovation. The "Fondation de l'Entreprise" (FDE) carried out in 1997-98 a survey on the knowledge society

and the new forms of management (6). A part of this survey concerned the R&D function in the enterprises, both as a process of knowledge creation and management, and as a learning activity within the firm. The survey does not include any direct item related to sustainable development, but it highlights some findings of the CIS survey.

A third survey, carried out at the international level by the Business Council for Sustainable Development (7), will be used as a reference case for checking firms' motivations.

Provisional findings

Table 3 summarises the motivations for innovation in industrial enterprises, as they result from the Belgian data of the CIS survey.

Table 3 – Motivations for innovation in the Belgian industry (1994-1996)

Motivations	Frequency of "very important motivation"
Increasing market shares, opening new markets	58 %
Improving product quality	58 %
Extending product variety	50 %
Reducing labour costs	37 %
Reducing environmental harmfulness	***30 %***
Improving production flexibility	27 %
Reducing raw material consumption	***27 %***
Replacing cancelled products	24 %
Compliance with regulations and standards	***22 %***
Reducing energy consumption	***21 %***

Source: CIS Belgian data, calculations SSTC/DWTC

Among the motivations for innovation, three of them are related to sustainable development: reducing environmental harmfulness, reducing raw material consumption and reducing energy consumption. A fourth one (compliance with regulations and standards) has a wider scope, but it includes environmental regulations and standards. The table shows that they are ranking relatively low in industrial enterprises, in comparison with the most important drivers. In service enterprises (including transport and trade), the ranking of these motivations is still much lower (less than 10 %).

A sectoral analysis shows that the motivations linked with sustainable development have a higher ranking in the food industry (NACE 15), the chemical industry (NACE 24-25) and the

(6) Janssen D., *Vers la société de la connaissance: resultats de l'enquête sur les nouvelles formes de management*, rapport de la Fondation de l'Entreprise, Bruxelles, n° 98/6, octobre 1998.

(7) World Business Council for Sustainable Development, *Building a better future: innovation, technology and sustainable development*, Progress report, Geneva, 2000.

metal manufacturing industry (NACE 28). They are very low in some traditional industries (textile and clothing, wooden products, machinery), as well as in the electronic industry.

The size of the firms seems to be the most discriminating factor. Table 4 shows a quasi linear relationship (weighted data) between the size of the firms and the total of "very important motivation" items of sustainability factors.

Table 4 – Relationship between the size of the firms and the "sustainable" motivations for innovation (number of mentioned items and weighted total)

Size of the firm (number of employees)	Reducing environmental harmfulness	Reducing energy consumption	Reducing raw material consumption	Total of mentioned "sustainability factors"	Weighted total, in function of the amount of enterprises
< 20	10	9	7	26	0.070
20-49	21	16	26	63	0.097
50-99	12	10	19	41	0.101
100-199	28	19	27	74	0.166
200-499	19	12	27	58	0.214
500-999	9	8	13	40	0.470
≥ 1000	15	13	16	44	0.602

Source: CIS Belgian data, calculations SSTC/DWTC

The size of the firms also appears as an important explicative factor in the FDE survey. This survey reveals a gap between SMEs (< 50 employees) and large firms (> 100 employees) for a set of indicators of the organisation of R&D in the firms, which are ranking much lower for SMEs than for larger enterprises:

- existing mechanisms for transferring suggestions and ideas from marketing and manufacturing to R&D;
- participation in technology fairs;
- internal diffusion of external scientific and technical information;
- follow-up of training activities;
- strategic warning;
- existing inter-departmental project groups and interdisciplinary project groups.

These indicators of the organisation of the R&D function are important as regards a complex issue such as sustainable development.

The survey of the World Business Council for Sustainable Development (BCSD) highlights another variable, which appears neither in the Belgian CIS nor in the FDE survey: the importance of the image and the reputation of the firm as regards sustainable development. The BCSD survey only concerns multinational companies, which have already taken some engagements towards sustainable development. Within this particular sample, the improvement of the "green image" of the firm seems to be one of the most important drivers for innovation, together with the competitive advantages through new products or services. A large majority of the enterprises (73 %) say that their business will be fundamentally transformed for environmental or social reasons in the next five years. They also mention that

the concern for sustainable development leads to a better involvement in forecasting and technology watch. Looking at the results of the BCSD survey, one can raise questions about another possible gap: the gap between a minority of "sustainability aware" firms and the rest of the economy. Although instructive, comparisons between the BCSD world survey and local CIS data is however very delicate and any comments have to keep careful.

3. Case studies in Belgian enterprises

Methodology

In-depth case studies are now being completed in a sample of 11 Belgian enterprises that have developed innovative business, more or less linked to sustainable development. Case studies are carried out through interviews with players and stakeholders of these innovations. The purpose is to understand, at the "micro-level", what are the strengths, weaknesses, opportunities and trends in innovative processes oriented towards sustainable development.

This sample of 11 enterprises was selected according to two main criteria: they must be innovative; they must be engaged anyway in activities fostering environmental protection and sustainable development. They were selected from three directories:

- a list of enterprises that publish environmental reports;
- the directory of innovative enterprises of the Walloon Region (including those who receive public support for research and technological development);
- the directory of "Walloon technologies for the South", also published by the regional government.

Although relatively small, the sample includes a wide variety of enterprises:

- some of them are subsidiaries of a multinational group (5/11), while the others are self-standing firms;
- their core business concerns either the production of intermediate equipments in an innovative sector (4/11) or the production of final goods and services (7/11);
- some of them are submitted to strong environmental regulations (5/11) or not (1/11); others are (partially) involved in the production of goods or services supposed to foster sustainable development (5/11);
- regarding the capability of "defining the agenda" in the area of environmental protection, some firms have a leading position (6/11), while the others are rather followers (5/11).

Cases

We will present hereafter the cases of three firms, which reveal three different patterns in the innovation process or the implementation process of sustainable technology.

Case nr 1 is a steel wire processing multinational firm, based in Belgium, that undertakes a conversion process into a technology-driven business, which addresses high value niche markets in metal forming and coating technologies. The firm seeks for an integrated environmental approach, including environmental certification and ethical certification. Sustainable development is mentioned by the management as one of the values promoted by the firm.

The product innovation considered in the case study is the development of flat and flexible photovoltaic devices, using amorphic silicium. Such devices can be placed much easier on the building roofs than classical solar cells. Their yield is lower, but the technology allows to overcome the existing architectural barriers to the use of photovoltaic cells. The organisation of innovation is based on internal R&D and acquisition of technological know-how, through the purchase of an American company specialised in solar cells. The firm also organises an internal innovation forum, which collects ideas among the executives and employees. Knowledge management is a part of the strategy of the firm. Although the market of the new photovoltaic device is still very small, the firm develops a strategy to lower the production costs and to increase its competitiveness in relation to traditional photovoltaic cells.

Case nr 2 is a small enterprise, specialised in the design and assembling of windmills for electric generation. It is linked to a Belgian commercial agency of the world group Caterpillar. The research and engineering office plays a central role in the organisation of the firm. The firm is organised as a network firm, with a windmill factory in Belgium, foreign suppliers of components, a commercial network indirectly linked to Caterpillar, and various agreements with other windmill manufacturers in order to sell a wide variety of products, covering the full range of utilisations of windmills of any power.

The R&D function is also based on networking with universities and other laboratories. When the firm develops a new product, it also concludes joint ventures or commons subsidiaries with potential diffusion agents. Although the firm is very active in the area of sustainable energy supply, it does not refer to sustainable development as a strategic concept, but rather as a positive image. The problem-solving approach and the niche-market strategy are the main characters of the innovation process.

Case nr 3 is a Belgian subsidiary of an English chemical group. It produces colouring matters and pigments for textile and paper industries. The factory is confronted with a lot of environmental problems, mainly water pollution. The local management decided to start a participative approach to solve environmental problems. A working group with workers, engineers and managers has made an inventory of environmental threats and suggested opportunities and solutions. Trade unions were also associated. In order to finance the environmental investments, the working group has looked for resource saving and cost reduction in the whole production process. Quality of working life was also taken into account. Labour cost reduction and redundancies were excluded, because the management decided to consider the knowledge and experience of the workers as a part of the new investments.

Innovation mainly consists of process innovation, with a mix of add-on and integrated technology. The organisational aspect of innovation was also important: together with the new techniques, a new organisation of work was implemented: team work, continued training, etc. Social values (participation, quality of work) are considered as a part of the project. The innovation strategy of the firm is based on responses to external pressures: environmental protection, competitors, new chemical standards leading to product substitution.

These three cases illustrate three different firms' behaviours in relation to sustainable development:

– a conversion strategy to new high-tech products, as a part of a general strategy of knowledge management, innovation management, and a move towards sustainable production;

– an investment in specialised environmental products, as a niche market for networks of SMEs;
– environmental protection and workers' participation as a key innovative factor in a traditional industry, looking for long-term competitive advantage coming from sustainable management.

4. Concluding observations and questions about the diffusion process

Is the diffusion process of "sustainable technology" very different from the diffusion process of other technologies ? In a comparative study of the diffusion of cleaner technology in Denmark and the Walloon Region, carried out by T. Kjoerboe in a ESST master thesis (8), the answer was: "not so much". They are promoted by "change agents" who use communication campaigns, economic incentives and other instruments to diffuse innovations among groups of potential adopters. The claim that the diffusion of cleaner technology is slow may be rather an impression than an established fact, as far as there is very difficult to draw a quantitative picture of the diffusion of such innovations.

T. Kjoerboe identifies some important characteristics of the diffusion process of cleaner technologies:

– They are not really different from other innovations, but they are preventive innovations. The reward is delayed.

– They are more risky than "add-on" technologies, both at the technical and financial level. There is not a definite sector of suppliers of sustainable technologies.

– The impatience to the diffusion is related to the urgent pressure of environmental problems and threats. Unfortunately, urgent problems and fast solutions are not always going hand in hand.

These features, related here to cleaner technology, can be easily extended to sustainable technology in a broader meaning. Sustainable technology cannot be analysed without understanding the complex interactions with other policies, both at the enterprise level and the public policy level.

At the enterprise level

Case studies at the firm level reveal that there is not a single pattern of interactions between market strategy, environmental pressure, innovation process, human resource management and the regulatory and political context.

Sustainable development opens opportunities for new products and markets, which are key drivers for innovation. Innovation is however not only based on technology, but also on a dynamic management of human resource and a long-term approach to the evolution of potential markets.

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8) Kjoerboe T., *Preventing prevention: why are cleaner technologies difficult to diffuse ?*, ESST master thesis, University of Roskilde and University of Namur, 1997.

Process and product innovation can also be stimulated, as a response to regulatory pressures or market changes. Substitution products and integrated technology are efficient entry-points in an innovation process that goes beyond end-of-pipe technology. Market knowledge and human resource management are nevertheless key success factors.

At the policy level

Four challenges can be deducted from the obstacles and difficulties in the diffusion of sustainable technologies:

– The linear model of technological innovation does not fit with the important role of "diffusion agents" and with the need for adaptation of each technology to its implementation site.

– The faintness of markets justifies an intervention of public authorities in order to establish support mechanisms, that should help to bridge the gap between the "private profitability" and the "societal profitability" in the long term.

– Criteria of sustainability should be included in the decision criteria used by public authorities when they allocate financial support for technological innovation or for import / export of technologies.

– Firms that do not fit with the classical "innovative profiles" cannot be left outside the public support to the diffusion process of sustainable technological innovation, because they can belong to the potential adopters of these innovations, even if they were not so innovative in the past.

Public authorities can use different tools: promoting a "culture of innovation"; developing adequate economic incentives, taking into account the long-term reward of sustainable technology; enhancing the link between research and innovation, for instance through sectoral research centres and through new mechanisms for technology exchange.

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