Green technology foresight of products and materials – some reflections and results from an ongoing Danish project

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This article presents some methodological and theoretical reflections and some preliminary results from an ongoing Danish "Green Technology Foresight" project about environmentally friendly products and materials, where the environmental potentials and risks from three technological areas – nanotechnology, biotechnology and ICT (information and communication technology) – are analysed. The preliminary results presented here focus mostly on ICT.

1 Introduction

The Green Technology Foresight – Nano/Bio/Info (GTF-NBI) project is financed by the Danish Environmental Protection Agency (EPA) and runs from February 2004 to May 2005. It is carried out by the Technical University of Denmark and the Institute for Product Development in Lyngby, and Risø National Laboratory near Roskilde. The project is co-ordinated by the Department of Manufacturing Engineering and Management at the Technical University of Denmark, Lyngby, and the System Analysis Department at Risø National Laboratory. Important target groups for the project are the Danish Ministry of the Environment and The Danish Ministry of Science, Technology and Innovation and related directorates etc. of the European Commission, design and innovation functions in companies, consultants, universities, business, environmental and consumer organisations, and the international research community working on environmentally sound innovation processes and sustainable transition.

The aim of the Green Technology Foresight project is

- To analyse the environmental potentials and risks related to the three technological areas within the coming 15 – 20 years, especially in relation to chemicals.
- To identify areas, where Denmark has competencies, which might contribute to enhanced competitiveness of Danish companies and position Denmark within environmentally sound design of products and materials.
- To analyse how environmentally promising innovation paths might be supported in Denmark and in the European Union.

The GTF-NBI project is based on the following five types of analyses aimed at collecting and analysing information about ongoing research, innovation processes and applications and about plans and visions for future research, innovation and applications:

- Analysis of present emerging applications of technologies within the three areas of Nanotechnology, Biotechnology, and Information and Communication Technology (ICT). The impact of corporate practice, structural conditions in value chains, and use patterns on the environmental potentials and risks are discussed as are the prerequisites for further dissemination and implementation.
- Analyses of the priority mechanisms in research and innovation, the existing knowledge regimes in research and innovation, and the visions shaping the innovation processes, including the role of environmental concerns in the research.
- Development of scenarios for probable, future innovation paths and possible alternative innovation paths. Necessary choices for alternative paths to emerge and stabilise are discussed.
- Dialogue processes among carriers of the technological areas and actors from environmentally important Danish product areas about the possibilities of applying technologies within the three areas for environmental improvements. Dialogue about policy recommendations between governmental authorities, researchers, industry and NGO's.
- Contrasting the environmental potentials and risks related to the three technological areas with the societal discourses around environmental problems (like assessments of the environmentally important product groups in Denmark) (Hansen 2003), goals and targets in the national environmental policy and discussions of whether there are better ways to solve important environmental problems.

2 Theoretical approach

The overall analytical approach presented above is based on theories within the Science-Technology-Society (STS) approach:

- Societal knowledge production seen as network processes between governments, businesses, users and consumers, knowledge institutions and institutional actors like business, environmental and consumer organisations (Gibbons et al. 1994).
- Innovation theory about processes of stabilisation and transition in innovation systems, including theories related to path dependency, path creation, sustainable transition and development arenas (Karnøe and Garud 1998; Rip 2003).
- Research and development processes seen as socio-technical processes shaped by actors' ideas about the future and by their actions, where persons, technology etc. consciously or unconsciously are given roles in research, innovation and future use of a technology. Theories about actor-networks, laboratory programmes and techno-economic networks are used (Callon 1991).
- Environmental assessment organised as social and scientific processes by using methods like life cycle assessments and chemical assessments and methods of dialogue-based environmental assessment, where the focus of the environmental assessment is shaped in interaction among actors (Bras-Klapwijk 1998).
- Governance of science and technology as policy network processes involving many different stakeholders (Schot et al 2001).

The following paragraphs explain how the concepts of laboratory programmes and techno-economic networks are applied in the project and outline how the descriptions of possible future development paths are shaped in the project.

2.1 Laboratory programmes

The concept of laboratory programmes is used in the analyses of how researchers organise their the focus of their research and is based on the assumption that research processes are not arbitrary, non-biased search processes. Through the concept of laboratory programmes it is possible to identify what is influencing the choices and drawing the attention of the researchers. This concept argues that the "world" is researched against the background of the researchers' own understanding of the world, which could be called the researchers' "map" of the world. This means that research in this foresight project is not analysed as the researchers' simple search for solutions to well-defined problems. Rather the problems are seen as shaped parallel to the solutions developed during the research, when certain achievements are reached in the research process. This implies that sometimes the solutions are found first, and afterwards the researchers try to find societal problems, which they think could be solved by these solutions. This implies, so to say, that what is legitimate as parameters, problems etc. within a researcher's understanding and what is outside an understanding is shaped at the same time. The discourses around genetically modified (GM) food and plants show many examples of this kind of reverse search processes. GM researchers and companies have pointed to pesticide resistant plants as an efficient agricultural strategy and after critique from the environmental movement also as an environmental strategy due to its claimed potential for reduced pesticide consumption. However, other researchers and the environmental NGO's pointed at the risk of getting locked into a pesticide-dependent track for ever and the risk of transfer of genetic material coding for pesticide resistance to other related plants.

2.2 Techno-economic networks

During the identification and analysis of emerging applications and the priority mechanisms in research and development, the techno-economic networks are identified, of which the interviewees (researchers, companies etc.) are either part of, or which they (directly or indirectly) anticipate will be developed in the future as part of possible future applications. As part of the analyses of the techno-economic networks, focus is on the dynamics between the past experience of the interviewee, the ongoing activities and their thoughts about the future development and applications. It is also important to analyse relations to existing innovation paths and how these seem to have an impact on the research and innovation or how the innovation paths and the companies and institutions shaping and "carrying" them might be challenged or might be enrolled in certain visions for the future.

The focus on techno-economic networks supports the analyses in the following ways:

- In the analyses of *emerging applications* of a technology it is necessary to understand the background for the breakthroughs, the dead ends etc. in research and development activities. It is not enough to know whether it now is possible to manufacture for example a certain type of bio-chip, but also whether this is based on a certain type of equipment, material, co-operation with others, demand from clients etc. is important knowledge. This will tell about path dependency and path creation in research and development (and thereby also the potential influence of certain equipment, clients etc. in the future). It is also important to understand the technological systems around the applications like necessary supply of energy and materials, standards, competencies etc., which are emerging or need to emerge, so that relevant life cycles and environmental aspects can be identified and prerequisites for further dissemination can be analysed.
- In the analyses of *research and development* it is important to understand the background and the prerequisites for the expectations of the actors: What is the role they are anticipating that for example nanoparticles will have (for example, a certain behaviour in terms of reactivity, stability etc.). Who are expected to be the future users? In which technological systems does this imply that the nanoparticles etc. will be integrated? What are the scientific and technological breakthroughs which are considered as necessary in order to obtain the results and obtain a 'working' version of whatever component it might be? In this way it is possible to develop a picture of the future research needs as seen by the actors. These pictures might later on become the basis for the development of recommendations for future research, regulation etc. The shape of possible future applications will also enable the sketching of elements in some future life cycles as basis for life cycle based environmental assessments of the environmental potentials and risks.

2.3 Constructing possible development paths

The interviews of different actors should be compared in order to identify mechanisms in research and innovation processes and draw up possible (maybe conflicting, maybe converging) scenarios. The identification of such possible futures within a scientific or technological field can be based on identification of emerging irreversibilities (Rip 2004) as explained in the following. The thoughts of researchers (and other actors) about the possible futures are based on combined thoughts about technological and social aspects of the future in the sense of thoughts about the scientific and technological progress and about the society, which is going to use or implement this progress. The dynamics of these expectations and the agenda building are part of what can be recognised through (Rip 2004):

- shared research agendas among actors;
- collective learning processes, maybe as forced or antagonistic learning;
- emerging mutual dependencies in network linkages.

Changes might be seen at three different levels, where relations between changes at the three levels are indications of emerging irreversibilities (Rip 2004):

- macro level: overall societal visions ('rhetorics');
- meso level: research programmes and investments;
- micro level: heuristics in actual research practice.

The scenarios enable anticipation of the possible impacts of the scenarios and discussions of whether these impacts are desirable. An example of a scenario and its possible impact is the development of nanosensors, which are expected to become so small and so cheap that they can enable much more measurements of chemicals in the environment, in wastewater etc. Besides the environmental impact from the sensors themselves and the potentials for better environmental management from better data, there could be an indirect environmental impact of the nanosensors, if the development of nanosensors makes authorities, industry and the general public believe that "we anytime and anywhere can detect environmental impact". Such an understanding could imply an attitude saying that "we don't need to prevent environmental problems, and we don't need to be cautious" and thereby be a threat to more preventive environmental strategies. In the discussion of such a scenario, it is important to explore whether lack of environmental data hitherto actually has been limiting the environmental management or may be has rather been a question about the level of environmental regulation industry has been willing to accept. If the latter is the case the development of nanosensors might not imply more concern for the environment.

3 Project results

The project results will be published around May 2005. Before that, the draft policy recommendations with proposals for strategies and measures, which could ensure a stronger future focus on environmental aspects of nanotechnology, biotechnology and ICT, will be discussed at an international conference on eco-innovation in Copenhagen in April 2005 organised by the Danish Environmental Protection Agency and the European Environmental Agency.

The three technological areas are quite different with respect to level of maturity. ICT is to day widespread in society, in households, business etc. The so-called new or modern biotechnology has developed during the last 30 years or so. Especially the use of genetic engineering has been and is highly debated. Nanoscience and nanotechnology is a broad field of different scientific and technological fields within chemistry, physics and biology, where only a few products have yet been developed to a level of commercial production. The analyses of biotechnology in the project have among others focused on the use of enzymes in industrial processes, the production of bio-polymers, bioethanol and base-chemicals and bioremediation. The analyses of nanotechnology have among others focused on remediation of pollution, so-called functional surfaces with new properties, the application of catalysts, and small-scale analytical equipment.

The preliminary results from the analyses of ICT are presented in greater detail in the next section.

4 Case study ICT: preliminary findings

This paragraph summarises the preliminary analyses of the possible future dynamics in the interaction between ICT and environment and the interaction between regulation and innovation and the possible changes in environmental impact (Pedersen et al 2005).

The analyses of ICT have identified five fields of ICT application as environmentally important:

- Development of the environmental knowledge base
- Design and planning of products and processes
- Process regulation and control
- Intelligent products
- Transport and logistics

All five areas show that the use of ICT will not automatically imply environmental improvements, although the analyses show some future potentials for environmental improvements. Furthermore, new and reinforced risks are also an expected impact of the development.

Environmental impact of ICT equipment and infrastructure

An increased amount of electronic products and a more dispersed use of sensors and other devices imply increasing problems with electronic waste. Increased use of pervasive computing might also cause health problems due to electro-smog and safety problems on account of interference between different devices operating in wireless networks. There is need for research into these risks, which are not fully understood and which might have long term effects, which indicates the use of precaution as an important principle in the future development and use of wireless networks.

Miniaturisation of products does not imply less resource consumption since the smaller dimensions might demand higher quality of materials, which implies more processing and maybe higher amounts of waste. The role of the future implementation of the EU directives about waste, energy consumption and hazardous substances need to be analysed further with respect to the handling of these problems.

Developing the environmental knowledge base, design and planning of products and processes, and process regulation and control

There are potentials for environmental improvements from use of ICT-based tools and devices for data collection and processing, information exchange, product and process design, and process regulation. However, environmental concerns are seldom the driving force for the development and application of these tools and devices. More data processing capacity enables the processing of more environmental data and more complex calculations, but it is the aim of the application that determines whether environmental achievements are obtained. The interviews have shown one case of direct integration of environmental criteria into tools for product and process design. Other tools aim at more general resource efficiency, probably often determined by the prices for energy and materials. It was stressed at one of the project workshops that governmental regulation is the only strategy for getting environmental concerns integrated into these development paradigms.

Intelligent products

The analysis of the product development paradigms of vacuum cleaners shows that the biggest reduction in energy consumption might not be achieved through the development of products with sensors and more electronic equipment (so-called more 'intelligent products'). Instead the focus should be on a change in the market dynamics away from high engine capacity as primary focus through a combination of eco-labelling and the design of new product concepts with a basic focus on understanding of the service of cleaning.

The analysis of the automobile shows that the interaction between ICT and environment is very complex. A product like a car is not just an intelligent, energy efficient engine but consists of a combination of a number of technologies, which implies that the final product might not be more efficient despite more efficient engines. Furthermore, the role of the car is shaped by a great number of actors and dynamics. The governmental regulation has an impact on the price of the car and the price of the fuel. The societal and local dynamics in housing, employment, infrastructure etc. have a big impact on the actual purchase and use of the car. The need for transport is not a fixed need, but is shaped by the availability of the car, so the access to the car influences the need for transportation. This example – like the case about design and optimisation of products and processes – shows that governmental regulation is needed in relation to all phases of innovation: the choice of research strategy, the innovation of products based on combinations of technologies and the development of the market dynamics around the products.

Transport and logistics

Three application areas for the use of ICT in transport and logistics have been analysed: telework, e-business and logistics as those ICT applications with the most far-reaching implications for transport behaviour in the future. The expected growth in telework will mainly derive from socio-economic changes: Still more people are employed in job functions suitable for telework (partly as a result of the use of ICT), and new management cultures based on self-leadership are becoming more widespread. In addition to this the average travel distance between home and the work place is growing due to the development in housing costs and the centralisation of business activities in fewer and bigger plants. However, also in the future, a limited number of employees will be able to telework due to the type of work they do, for example within manufacturing, cleaning, social care etc.

Mobile telework will be more widespread as mobile communication solutions will offer the same facilities at comparable costs as those offered from the office. This will reduce the costs of business travels (as lost working time today constitutes a major part of the costs) and may therefore cause an increase in business travel transport due to the ongoing globalisation of manufacturing and trade and the resulting need to visit facilities, suppliers and customers in other parts of the world.

The long term impact of e-business depends very much on how e-business will develop in the future. The major barriers are not related to development of suitable ICT applications, but to organisational problems and the development of viable business models. The question is whether it is likely that e-business will provide a viable alternative to daily shopping or will it just add to the daily traffic.

Although the application areas studied have very different implications on transport behaviour, they will all add up to a situation with more flexibility in transport. This holds in particular for passenger transport. The regular transport related to commuting and shopping in certain hours will be replaced by more differentiated transport needs, where some people will be able to avoid rush hours and the most populated routes. This will enable a better utilisation of the transport capacity for passenger transport. The needs for passenger transport will become more dispersed. First, commuting will take place less frequently. Second, the possibilities for telework will enable more people to live in remote rural areas. This could challenge the existing infrastructure of public transport, and tends to strengthen individual transport solutions.

With regard to freight transport the situation is a bit different, as improved logistics will enable more flexibility. On the other hand e-business will lead to more transport of small batches with high urgency to professional and private customers. The concept of just-in-time production in industry will also imply more transport due to the request for more frequent supply of small batches of materials and products.

5 Perspectives in STS-based green foresight

As a summary the ambition with the Green Technology Foresight project might be characterised as:

- Showing that environmental impact cannot always be connected to materials or processes per se, but is shaped during activities of research, innovation and application of technologies. Therefore research, innovation and application areas like products, branches etc. are all important policy fields in the regulation of technological change and environmental impact.
- Showing that the scope of the environmental assessments of research, technology etc. needs to be defined in an open, democratic process.
- Showing that different technological paths might involve different technologies, competencies, infrastructures etc., so that identification of forks and cross roads for important choices in the future development is important.
- Showing that technologies are not individual chemicals and materials, but whole systems and that these systems and their interaction with other systems need to be included in the identification and assessment of environmental aspects.
- Showing that different solutions to environmental problems might be compared and that the comparison might go beyond the simple comparison of chemicals and resources, and include, for example, cultural impacts, like the impact on our understanding of nature.
- Identifying the ”hype” in relation to potentials for remediation and prevention of environmental problems and identifying what might be or become more real potentials.
- Identifying the prerequisites for innovation paths, which support the implementation of the environmental potentials.

It is a challenge to establish an open, democratic societal discussion about these technologies and the impact and about alternative strategies, because researchers and universities today often are dependent on external funding, which might encourage them to promise large positive impacts of the technologies. At the same time universities increasingly engage in setting up companies and taking patents themselves, which might make them less interested in public discussions of the technologies, the impact, the prerequisites for realisation of potentials etc. Maybe the above mentioned ambitions for the Green Technology Foresight project are too optimistic, but this kind of project could be an opportunity to get at least early and more open and sound discussions of societal interests than seen in the early days of genetically modified plants and food and also help to ensure that alternative strategies for achieving the environmental promises of so-called high technology become part of the societal debate. We should not forget that the environmental movement was successful in contrasting pesticide resistant plants and the promises for reduced pesticide consumption with other strategies like organic farming.

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