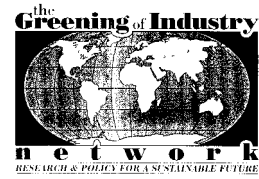


THE GREENING OF INDUSTRY FOR A SUSTAINABLE FUTURE: BUILDING AN INTERNATIONAL RESEARCH AGENDA



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In 1995 the coordinators of the Netherlands Advisory Council for Research on Nature and Environment (RMNO) and the Greening of Industry Network initiated a process of developing an international research agenda on sustainable development and the role of industry. The purpose of this initiative was two-fold:

- To develop a research agenda on the process of greening of industry in the context of sustainable development which defines main research priorities for the coming decade;
- To provide a clearer perspective on how research priorities are currently developed and how to improve this process.

After a two year process of discussions via workshops and interviews including various stakeholders, four main research themes were selected:

- Transformation towards sustainable development
- Changing consumption patterns
- Finance, capital and performance indicators
- Technological breakthroughs

We hope to solicit a discussion on the future of the greening of industry research agenda. This article is based on a report *The Greening of Industry for a Sustainable Future: Building an International Research Agenda* (1997). © 1997 by John Wiley & Sons, Ltd and ERP Environment.

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INTRODUCTION

The greening of industry is often perceived as a vital process in the future health of our planet. Why is business behaviour considered so vital? A number of answers are possible, among them:

- Business is a major user of energy and materials and producer of pollution;
- Business is also a producer of solutions;
- Business could become an example for society;
- The greening of business will involve and transform many stakeholders in the industrial function of society, including government, employees, suppliers, customers and investors.

The greening of industry should not be confused with sustainable development, which is a goal for society as a whole.¹ Still, a key question for the sustainability agenda is whether business can make a difference and integrate environmental and sustainability imperatives into its structure, culture and action. Follow-up questions concern the kind of

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conditions under which business could contribute; what does a 'green business' which contributes to sustainable development look like? What kinds of knowledge generation and diffusion would be helpful in the process? This last question led to the development of this research agenda.

Aims and focus of the research agenda

The partners in the initiative to build this research agenda, the coordinators of the Greening of Industry Network and the Netherlands Advisory Council for Research on Nature and Environment (RMNO), believe that the fast growing new research area, often labelled as 'the greening of industry', could benefit from a process of setting priorities. The aims of the initiative are:

- To develop a research agenda on the process of greening of industry in the context of sustainable development which defines main research priorities for the coming decade;
- To provide a clearer perspective on how research priorities are currently developed and how to improve this process.

The agenda focuses on social science, including a number of research fields such as business studies, sociology, technology studies, environmental studies, environmental economics, but also includes those parts of engineering studies and ecology which relate to the greening of industry. Yet, the emerging research field on the greening of industry is hard to define through its contributing disciplines only. The knowledge is not only generated in research programs of universities but also in projects funded by various government agencies and projects developed within a business context. In this sense the research area of greening of industry reflects current trends in the research system. Following Michael Gibbons we can define these trends as a focus on application-oriented, transdisciplinair, heterogeneous, and non-hierarchical organised research.²

The agenda is intended as a vehicle for communication. It should be read as an exploration and

¹Tom Gladwin, The Meaning of Greening: A Plea for Organizational Theory, in: Kurt Fischer and Johan Schot, *Environmental Strategies for Industry. International Perspectives on Research Needs and Policy Implications*. Island Press: Washington D.C. 1993, pp. 37–62.

²Michael Gibbons et al., *The New Production of Knowledge. The Dynamics of Science and Research in Contemporary Societies*, London: Sage 1994). See also Arie Rip, An exercise in foresight: the research system in transition to what? in: S.E. Cozzens et al (eds), *The Research System in Transition*. Dordrecht: Kluwer Publishers 1990, pp. 387–401.

invitation for further discussion. Such discussions could involve all people and organisations involved in the production of new knowledge on greening of industry for a sustainable future. For example, research councils, universities, consultants, NGOs (non governmental organisations), business and government.

This agenda will discuss a few top priorities in some more depth (instead of a longer listing of many research items). This implies, of course, that many research themes of interest are not on this agenda. We will focus only on those which are considered of the utmost importance by all the people involved in developing this agenda. Each priority theme will be introduced by a brief discussion providing some of the insights and questions generated in the interviews and workshops. Parts of the discussion will have a normative framing reflecting the normative content of most of the interactions we have had. At the end of each section a number of specific research questions will be formulated. In an epilogue, we will address the issue of knowledge appropriation. How do researchers and practitioners acquire their knowledge? We will argue for the importance of non standard institutions and networks as carriers for knowledge production and diffusion.

The process of building a research agenda

The agenda was built in an interactive process which involved both producers and users of knowledge. It was done through series of partly parallel steps of:

- Analysis of Greening of Industry Network literature (papers, conference summary reports, books).³ This analysis resulted in a listing of 12 themes.

³The Greening of Industry Network has organised four international research conference (Noordwijk aan Zee 1991; Boston 1993; Copenhagen 1994; Toronto 1994) including about 250 papers and four summary reports: Jacqueline Cramer, Kurt Fischer and Johan Schot, *The Greening of Industry*, Apeldoorn/Boston 1992; Nicholas A. Ashford and Ralph Meima, *Designing the Sustainable Enterprise*, ERP Environment Shipley 1994; Sarah Clarke and Susse Georg, *From Greening to Sustaining: Transformational Challenges for the Firm*, Technical University Denmark, Copenhagen 1995 and Dave Angel and Joseph Huber, 'Building Sustainable Industries for Sustainable Societies' published in *Business Strategy and the Environment*, 5 (1996) 3, 127–136. In addition two books have been published following from these conferences and other Network activities: Kurt Fischer and Johan Schot, *Environmental Strategies for Industry*, Washington D.C.: Island Press: 1993, and Peter Groenewegen et al. (eds.), *The Greening of Industry Resource Guide and Bibliography*, Washington D.C.: Island Press, 1996.

- Analysis of RMNO literature resulting from a process of research agenda building in The Netherlands;⁴
- interviews with representatives from industry, academia, government and international organisations.
- Three workshops as part of Greening of Industry Network events (workshops in Washington (May 1995), Lausanne (October 1995) and Toronto (November 1995) involving about 60 people including researchers and representatives from business, government and NGOs.

The following themes are identified as main priorities:

1. Transformation towards sustainable development
2. Changing consumption patterns
3. Finance, capital and performance indicators
4. Technological breakthroughs

These themes partly overlap. In particular, theme 1 is an overarching question and the other three can be perceived as aspects of the transformation process. However, they all reflect a particular and succinct perspective on the greening of industry for a sustainable future and deserve separate attention.

TRANSFORMATION TOWARDS SUSTAINABLE DEVELOPMENT

The sustainability imperative: eco-efficiency versus system change

Since its rebirth through the publication of the report of the World Commission on Environment and Development *Our Common Future* in 1987, sustainable development has become a key mobilising force for many resources and actions of business, government, NGOs, researchers and others. Also in our interviews and workshops the idea of sustainable development often became a focus for much debate on what it is and what to do about it from a business perspective. It turned out to be very difficult to come to an agreement on this. In most discussions two different sets of imperatives for business emerged which could be labelled as 'eco-efficiency' and 'system change'. The eco-efficiency imperative was often put forward by the business community (although not exclusively), and the system change imperative was favoured by the

⁴This process has resulted in long-range vision document called *Ruimte voor Ecologische Modernisering* (Room for Ecological Modernisation), RMNO, June 1996.

academic community (again, not exclusively). We will discuss both imperatives using the often normative language of its proponents.⁵

The eco-efficiency imperative is based on the idea that companies must come to terms with the new realities of population growth, increased evidence of global warming, ozone depletion, loss of fertile soils and forests. These new realities will change the markets (customers' attitudes) and lead to tougher government regulation. This will change the bottom-line of each company now and increasingly in the future. Costs related to pollution will become staggering. Customers will ask for green products and they will even select companies on their proven ability to produce green products. Instead of waiting for government action and lobbying to get the right kind of action, companies must seek value creation through minimising resource input. According to its proponents, eco-efficiency leads to economic and ecological efficiency. Through a process of innovation companies will be able to produce competitively priced goods and services which satisfy human needs and bring quality to life. At the same time the ecological impacts and resource intensity throughout the product life-cycle progressively reduces, ideally to a level at least in line with the Earth's estimated carrying capacity. Several strategies have been worked upon, including:

- Dematerialisation;
- Minimise the energy intensity of goods and services;
- Enhance recyclability;
- Maximise the use of renewable resources;

An important aspect of an eco-efficient strategy is its service orientation. Value creation must be sought through focusing on providing the service connected to their products to customers instead of selling as much products as possible. For example, chemical firms active in agro-chemicals could shift from the sale of chemical products to the selling of pest management services. Car manufacturers could become mobility providers instead of car sellers. Part of the imperative of eco-efficiency proponents is the importance of stakeholder relationships, including, among others, suppliers, customers, investors, employees, citizen groups and the wider public. Perceived benefits of these relationships are:

⁵Of course there are differences between various proponents, we have captured the core of each position and represent it in a stylised form.

- Some of the most important ideas that will yield both added value and reduce ecological impact will come from these stakeholders;
- They will provide support and acceptance of corporate activities.
- They will help developing a new eco-efficient corporate culture. Such a culture entails a firm commitment to reducing material and energy consumption throughout the life-cycle and a responsibility for the companies' products from cradle to grave, or from conception to resurrection.

Proponents of eco-efficiency do not ask for less government regulation. On the contrary, they consider the existing – often weak and inconsistent – regulation as a policy failure which is in urgent need of repair. Two changes are needed. First, future regulation must make 'prices tell the truth', that is incorporate all environmental costs. This will create better markets and make eco-efficiency more profitable. Second, governments are the only party which can determine the extent to which pollution is acceptable; they have the authority to do so. Their task is to provide long-term planning horizons and space for firms to act in.

The system change imperative often starts with criticising the eco-efficiency imperative. Some of these criticisms are:

- A high efficiency could still lead to too much environmental degradation;
- The use of a particular product may be harmful, and it is not likely that companies will change their core product mix. So, a change will not come from existing companies alone, even if they show eco-efficient leadership;
- Sustainable development is not only about ecological impacts but also about equity on a global scale;
- Sustainable development requires companies to operate on a long-term time scale which might imply giving up shorter-term value creation and money-related performance indicators.

The core of the system change view is that companies and the economic system need to be perceived as part of a larger social and ecosystem. Consequently, the companies need to be compatible with these larger systems. This could in some cases still imply a high production volume, but only on the condition that it does not threaten the ecosystem. For example, this would be the case if production causes bio-degradable waste, or if production is part of a closed loop. To determine any further action, a basic understanding and appreciation of

both the ecosystem and the social system are perceived as crucial.

Within the system change view much emphasis is put on a needed value change. Decision makers within industry must develop new values reflecting sustainable development. Core values often mentioned are:

- *Wholeness.* Decision makers within industry must understand and accept the systemic relationships between company behaviour and impacts, referred to as externalities in economic theory. This will lead to a vision of shared responsibility and community among all stakeholders.
- *Care for future generations.* Decision makers need to listen to a new stakeholder and a new ethical category, notably future generations. For business this will imply creating some kind of visible stakeholder, for example through appointing a 'future generation representative' at the board level and working with long-term planning horizons.
- *Smallness.* Some recent management theories and practices adhere to the idea of smallness because it is more profitable. Organisations are discovering the economic benefits of small work teams and defining responsibilities at the lowest level possible. Others argue that organisations applying smallness are also more likely to focus attention on saving energy, preventing waste and using renewable resources. Sustainable development implies accepting limits, also of growth levels of companies. Companies have to become innovative on how to produce value added and high quality products for all stakeholders, including nature and future generations, without growth.

Analysing the differences: the importance of the transformation process

The mutual exclusiveness of both imperatives was emphasised in the discussions we had. Others, however, including representatives from business, government and the research community have argued that eco-efficiency and system change are complementary processes. Both imperatives must be read as 'mental maps'. They help to develop a better view on key uncertainties, strategies, issues and desired futures. In this way, they could serve as vehicles for communication among various stakeholders in a process which leads to sustainable development. Proponents of both imperatives agree on the need for such a transformation process. We heard many times that action must not be delayed!

Accordingly we concluded that a key research item is to identify mechanisms and ways of transforming our society to a sustainable one. To specify this general research question it is helpful to use the eco-efficiency and system change mental maps.

The proponents of eco-efficiency stress the need to make a change now and emphasise the importance of tool development (such as life-cycle analysis, environmental management systems, performance indicators and new reporting practices), showcases and guidelines. For the proponents of the system change, these tools are certainly important for the transformation process. They point to the fact that some of these tools help to develop a system view. For example, life-cycle analyses put the products in the context of the entire production and consumption chain. Reporting activities acknowledge the importance of the broader social context. However, the development of these tools is at best a first step in a new process. System change proponents believe that the use of life-cycle analysis and the production of environmental reports could lead to the development of new partnerships which could become carriers for a collective value learning process. Such partnerships must preferably have a regional scale, integrating all activities needed to provide services such as housing and mobility for example. Regional partnerships will create a direct relationship between environmental and social impacts and economic activities, involve communities directly, enhance local and regional consensus seeking democratic processes and exclude much of the free rider behaviour of many firms today. The sustainable development slogan 'think globally, act locally' will have a chance to proliferate. Partnerships could also be organised around functions, bringing together producers, consumers and waste managers. Such networks would become sustainable development junctions which will shape the nature and direction of the transformation process.

Another important potential sustainability junction is between business schools and training programs in which business leaders of today and tomorrow get their education. It was often repeated in the sessions we had that current courses do not reflect the sustainability agenda. At best, environmental management is added as a separate course; it is not integrated into the entire training for business leaders.

Research priorities

From this discussion we can infer the following research priorities:

Research Priority 1: Tools in action

Research on evaluations of tools such as performance indicators, reporting mechanisms, life-cycle analyses and environmental management systems. These evaluations must include both efficiency and system change parameters. Important research questions are:

- (a) How effective are these tools? What kind of performance changes do they deliver; do they help shape new values and develop new partnerships?
- (b) How and why are they used by management, and by external stakeholders such as the financial community, environmental groups, employees and governments? Do they meet the information needs of these audiences?
- (c) To what extent are mandatory, international standards for performance indicators, reporting mechanisms, life-cycle analyses and environmental management systems both feasible and desirable?
- (d) To what extent do these tools reflect the sustainability agenda and so incorporate social and development issues?

Research Priority 2: New roles for Government

In both mental maps government are perceived as central. They must take on a new role. Important research questions are:

- (a) How to shape effective government action to set conditions which will provide a framework for firms willing to contribute to the transformation process towards sustainable development, including large efficiency gains and system change?
- (b) What role for economic instruments, voluntary agreements and command-and-control regulation? These instruments have been evaluated extensively for their short-term efficiency and effectiveness. New research is needed to evaluate them from the dynamic long-term perspective of a transformation towards sustainable development.

Research Priority 3: Dynamics of emerging new partnerships

Another central element of the transformation process is the development of partnerships. For eco-efficiency proponents such partnerships serve as sources for innovation and gaining acceptance. For system change proponents they help building new relationships and values. Important research questions are:

- (a) Why do partners enter the partnership? Which forms of partnership are most effective in terms of original motivations but also in terms of improvement of environmental and sustainability performance?
- (b) Which factors hamper and accelerate the process of building partnership networks?
- (c) To what extent can these partnerships become carriers of new activities which will change existing production and consumption patterns in a more radical way?
- (d) How to characterise, analyse and evaluate learning processes which take place in these networks?

CHANGING CONSUMPTION PATTERNS

Learning new ways of consuming

In our interviews and in the workshops we heard a widespread agreement that any change towards sustainable development must involve changing consumption patterns and life styles. Existing consumption is defined as unsustainable. Especially system change proponents refer to the issue of intra- and inter-generational equity, in their view the very core of any definition of sustainable development. What if the poor in this world and future generations were to embrace the present consumption patterns of the rich, mainly in the West today? There is only one answer possible. The environment would be eroded and destroyed beyond the ability of nature for repair, given existing rates of population growth and short-term technological opportunities for producing eco-efficient products and services. Another argument, often put forward by eco-efficient proponents, is that industry has been targeted by regulation for some decades. Business has learned how to acquire and transform resources in an efficient way. Consumption has not been regulated, while most of the loss of resources occurs at the point of consumption. Consumption is naturally dissipative. Most consumption goods are used only once, and many are very expensive to recycle. A basic question for those businesses developing eco-efficient products is if consumers will be prepared to pay for these products. Will people follow concerns expressed in many opinion polls? System change proponents often point out, however, that these new eco-efficient products serve niche markets which are limited. New products enter the market place which do not substitute for existing polluting products. New needs are generated without changing existing unsustainable lifestyles.

What do we as consumers really need? This seems to be the key question for most of the people involved in building this research agenda. They argued that we have to circumvent a difficult paradox: that as a society we seem to be addicted to the stream of new products and enjoy the high living standards made possible by these products. At the same time we, as consumers, producers, governments, cannot avoid noticing that these products have led to unsustainable production and consumption patterns. This addiction frames the needs of the consumers and accordingly the markets for the producers. A way out which emerged during our discussions is to start of process of developing more sustainable lifestyles. Such a process must be perceived as a search and learning process aiming at discovering and exploring new ways of framing and living our basic needs, while accepting that these will vary among people, regions, countries. It will involve experimentation and interaction among many stakeholders. Mutual learning between producers, consumers, rich and poor, for example is needed. Based on our literature review and discussions it is clear that learning processes can flourish only when a number of conditions have been met.

Firstly, learning processes require openness and access. When critical information is withheld uncertainty increases about the motives and aims of the other party. Therefore, the present trends towards information disclosure is vital and must deepen to the extent that the wider public gets access to any critical information they want. Nowadays secrecy at the company level often precludes such openness.

Secondly, the learning needs to be meaningful, that is, connected to concrete decisions and providing access to decision-making areas. Something must be at stake, otherwise people will lose interest in participation and interaction. The present trend of companies to develop new partnerships with NGOs and citizen groups already goes a long way. However, it often stops short at the corporate board rooms where external stakeholders are not allowed to come in. Involvement of NGOs and citizen groups is often too late in the process, after some crucial decisions have been made. The questions left often focus upon conditions for acceptability. This is clearly visible in product design and development where environmental criteria are becoming corner stones in the development of any products but do not enter the precluding phase of product choice and definition. The question not addressed is: 'Do we need this product and will it be sustainable in a world of 8–10 billion people?' Bringing in citizen

groups and NGOs in the critical early phases would help starting a learning process on the needs of present day society.

Thirdly, learning requires orchestration and coordination. Governments are often called upon to do this job. However, governments are sometimes not well suited to do it because they are too much a stakeholder themselves. It has been suggested several times in our discussions that new emerging networks among the stakeholders could also perform this job.

Finally, learning needs to be enhanced by vision. Thus the construction of scenarios embodying various visions is vital.

Research priorities

From our analysis we have developed the following research priorities:

Research Priority 4: Sustainable consumption indicators

- (a) Research on the development of indicators for sustainable consumption. How to define sustainable consumption and measure any progress towards it.

Research Priority 5: How to develop new consumption patterns?

- (a) Which conditions, accelerators and barriers, and circumstances will help consumers and producers to re-evaluate their existing needs? In particular, which tools such as consensus conferences, dialogue workshops, societal experiments, will help producers and consumers to reframe their needs in a sustainable way?

FINANCE, CAPITAL AND PERFORMANCE INDICATORS⁶

An emerging process of greening of finance

Our interviews and workshops highlighted a number of issues pertaining to the financial community. Fundamental questions regarding the role of financial markets, including investors, bankers and insurers, in a sustainable world, were raised along with more practical issues of how to make actual environmental improvements at the com-

pany level by changing financial performance indicators.

Many, especially proponents of eco-efficiency have come to the realisation that environmental care can often go hand in hand with increasing profits. Indeed, different sectors of the financial community can benefit in a variety of ways from the expansion of environmental considerations within business. Investors and bankers can increase value and insurers can decrease risk.

Yet, the business people involved in our study felt there was a gap between this know-ledge and its application. It was felt that a great deal was known already about how to make changes towards sustainable development, but the financial sector is lacking access to such knowledge. If sustainability is our goal there must be a change in the way that the financial sector operates; there must be a move away from the emphasis on short term monetary profits, and a shift towards long term financial and other values as desirable business outcomes. Yet, the financial sector and business will not change if it remains driven by monthly ratings. We therefore need to change our current system of socio economic and financial models and indicators both at company level and at higher national and international levels, so that they incorporate non monetary concerns. Current accounting devices, at all scales, do not take account of these concerns. For example, GDP is still used to illustrate economic performance at the national level. Indeed, it also serves as an important feedback to national policy. Yet, GDP not only masks the breakdown of the social structure and the natural habitat upon which the economy and life itself ultimately depends. Worse, it actually portrays such breakdown as an economic gain. It is in these frameworks that we define economic success and it is therefore defined inaccurately. New models are needed that do not allow for this misrepresentation of social and environmental considerations.

There are many uncertainties surrounding the construction of such models. We must develop a standard system of environmental evaluation, and this itself is plagued with difficulties. Methodologies such as contingency valuation method, have been developed and are being improved, yet the evaluation of environmental resources will remain a contentious issue. How do you evaluate externalities and on what basis? Whose values will be represented in the evaluation, and whose will be left out? And what regulation is needed to make the internalisation effective, if any?

These questions highlight a crucial issue, as is often argued by academic proponents of system

⁶A first draft of this section was provided by Iain Watt, Clark University.

change. Sustainable development is not only concerned with environmental issues, it also involves a number of equity issues. How do our market instruments account for and help this? And has the financial sector a role to play here? The internalisation of environmental costs may lead to higher prices, and this affects the poor disproportionately. Equity issues are especially important at a global scale. For example, many industries in the South compete on the basis of lower environmental costs (especially if you consider the work conditions and the general standards of living of workers as environmental factors). Can businesses address these problems even if this means that they sacrifice their competitive position? These questions are crucial, now that the South represents a major growth area in the world economy.

Perhaps then we should consider if our global economic system is compatible with the goals of sustainability. Are the world's financial markets and those who work in and around them a force for sustainable human progress, or are they an impediment against it? Do the financial markets encourage short term, profit oriented thinking, or are they simply tools that reflect current concerns? Similar questions can be asked of business itself. Do the financial sector and business behaviour reflect broader societal values and goals, or do they have their own agenda? The current dominant paradigm is geared primarily to short term monetary profit. Is this a reflection of the society within which it operates, or does it represent a more fundamental characteristic of the financial sector and its involvement in doing business?

Research priorities

From our analysis we have developed the following research priorities.

Research Priority 6: Constructing and using new performance indicators by the financial community

- (a) Much of the work on the environmental behaviour of firms has looked at these issues in relative isolation, rather than intertwined with financial issues. A question that deserves more attention is how do financial concerns pervade strategies and actions of businesses, and to what extent is this a problem for sustainable development?
- (b) New tools for measuring performance, such as green accounting merging with social accounting, are under development. Research should

document these trends within industrial firms (see research priority 1), but also the way they are used and built into standard practice of the financial world. Research should also focus upon the implications of using new performance indicators, both intended and unintended;

- (c) Revising our standard performance indicators will lead to questions such as what is 'value'. How can we value 'values' other than monetary ones? Research must focus upon ways of constructing performance indicators for sustainable development which are useful for the financial community.

TECHNOLOGICAL BREAKTHROUGHS

The need for technological breakthroughs

A clear message in the discussions we had is a call for a more focused environmentally oriented technology policy. The demands on the Earth's resources will increase due to economic and population growth which leaves the necessity for a dramatic increase of resource efficiency as a primary strategy for avoiding environmental degradation. Several governments have, therefore, issued an environmental technology strategy.⁷

Several trends are visible in these strategies and also in our workshops and interviews. First, a main aim of any technology strategy must be to overcome the lack of investments in the diffusion of cleaner technologies. Currently most investments are done in the pre competitive R&D, while innovations coming out of these investments are not taken up by the private sector. This results in what might be called underutilisation of cleaner technologies. A number of barriers for a faster and deeper diffusion were mentioned. These include, for example, a lack of performance verification of the new emerging technologies, a regulatory system that favours entrenched existing technologies against environmentally and economic superior alternatives, costs, and low public acceptance resulting in uncertainty on market acceptance. This short list of

⁷The National Science and Technology Council, 'Bridge to a Sustainable Future: National and Environmental Technology Strategy', Washington D.C., 1995; Danish Ministry of Environment, 'Cleaner Technology Action Plan, 1993-1997', Copenhagen 1992; Industry Canada and Environment Canada, 'A Strategy for the Canadian Environmental Industry', Ottawa, Ontario 1994. The Dutch Government published a whitepaper on 'Environment and Technology' in 1994 and is presently preparing a whitepaper on 'Environment and the Economy' which will include a technology policy section.

barriers already elucidates that many factors simultaneously impede the take up of cleaner technologies. These factors are interrelated and often reinforce each other. So technical constraints are not the principal limiting factor. The biggest barrier is the structure of the social, economic, political and cultural settings in which technologies are developed and diffused. This leads to a second aim for a focused technology strategy, it should look at ways of inducing change in the entire technological system, resulting in technological breakthroughs. The current system imposes a logic on economic behaviour which favours end-of-pipe solutions above more radical changes of products and processes. In our discussions it was argued that such change in technological systems would follow from a series of incremental changes of making the existing processes and products eco-efficient. Others argued, however, that a more radical shift, often called a paradigm shift, is needed. Several elements of a technological system change were mentioned:

- Such a change cannot be organised around a single issue. When a new system emerges, everything changes. A technology policy must look at the system level instead of individual technologies. Technological breakthroughs must not be equated with development and use of such individual technologies.
- The new system will partly be based on new partnerships and networks involving new firms.
- External pressure is needed to force firms, governments and others involved to go through such a process of change.
- Visions and learning processes are important elements of any major change process.

A third theme for an environmentally oriented technology policy is the issue of transfer of cleaner technologies to developing countries. A clear consensus emerged that this process must not be perceived as a supply-side issue. The Western World must not aim at selling its own products. A starting point for technology transfer must be to develop a better view on the demand of developing countries and helping them to set up a process of demand articulation. This will create a better environment for subsequent diffusion of cleaner technologies. In addition, technology transfer must not be perceived as a one-way process. Developing countries will have to develop new solutions and follow their own paths. Some of these solutions (for example decentralised energy systems, transport systems which rely less on private cars) may be relevant for the Western World as well. Thus technology policies must strive for a good balance between supplying

cleaner technologies on the one hand and articulating of the demand in developing countries and learning from their experiences on the other hand.

Research priorities

From our analysis of the discussions we developed the following priorities

Research Priority 7: How does technological system change occur?

- (a) Research on innovation and diffusion of cleaner technologies has been focused on barriers for individual processes and products. More attention must be given to the systematic nature of major technological change processes and ways of inducing such change by government policies.

Research Priority 8: How to make technology transfer between developed and developing countries more effective?

- (a) Research must look at ways of creating better communication and cooperation between supply and demand of cleaner technologies and systems.

EPILOGUE: THE RESEARCH-USER INTERFACE

In many discussions we had, the issue of better knowledge transfer between producers and users of research was mentioned. When we asked business people how they got the knowledge they wanted, it became clear that they most often use their own informal networks. Such networks could include other businesses, university researchers, consultants, governments and NGOs. The communication within such networks is not easy. Users need to appropriate the knowledge they want. This costs time and money and needs face-to-face interactions, hence the importance of informal networks. In addition, the distinction between the users and the producers of knowledge is not clear. In the process of transferring knowledge from the supply side to the demand side, needs and solutions become better articulated and specified. All participants contribute to this process with knowledge and they all use knowledge from others. So it is a mutual learning process. Two problems were mentioned when organising the research user interface through networks: first, how to ensure cumulative

knowledge production which could lead to the development of a robust body of knowledge, and second how to organise for accountability of knowledge production in complex and constantly shifting networks.

Two implications for research policy can be drawn from these findings. First, research policies must not frame the issue of knowledge transfer only in terms of dissemination and outreach. Instead research policies must aim at stimulating and underpinning communication processes within networks between users and producers of knowl-

edge. Second, such policies must focus at new ways of creating accumulation and accountability within systems of knowledge production which are not based only in standard institutions such as universities. The development of what might be called non standard institutions, networks between users and producers, which are major carriers of the development of new knowledge in areas such as the greening of industry must be guided to ensure a good balance between what has been called fundamental and application oriented or strategic research results.