INDUSTRIAL ECOLOGY – ONLY NEEDED IN THE NORTH?

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Abstract

The predominant focus within Industrial Ecology research and industrial practice has almost exclusively been on the industrialised North. This paper first seeks explanations for this. Then, an analytical framework for conditions influencing industrial-ecological innovation capacity in countries in the South is presented and discussed. Next, several developments are pointed to that may possibly lead away from the Northern bias within industrial-ecological research and practice. This is followed by arguments for why industrial-ecological principles may advantageously be employed in the South to a larger extent than what is currently the case, and how this may contribute to the further development of industrial ecology as a discipline. Finally, future research challenges within this subfield of industrial ecology will be discussed.

1. Introduction

Research and industrial practice within industrial ecology today still focuses much more on the industrialised North than the developing South (1, 2). It is also far more concerned with our responsibility towards future generations than of today's problems of global distributive justice. This article will first attempt to explain why this is so. Then, a number of developments will be pointed to that may further increase the focus on the South within industrial-ecological research and practice. This is followed by arguments for why industrial-ecological principles may advantageously be employed in the South to a larger extent than now, and how this can contribute to the further development of industrial ecology as a discipline. Finally, future research challenges within the field of industrial ecology in a North-South perspective will be discussed.

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The article thus points to the fact that it is still a considerable distance between the potential for a holistic approach to environmental problems embodied in industrial-ecological *principles*, and industrial-ecological *research and practice* today. However, this should be regarded as a challenge to the discipline of industrial ecology, rather than a capitulation to an impossible task (3). Indeed, there is evidence that the discipline is already taking the challenge seriously (see Ch. 2 below).

2. Industrial ecology and the countries in the South

There is still disagreement both among researchers and industry representatives about what principles and practices are actually included in industrial ecology. While most researchers and practitioners would agree that the unit of analysis is material and energy flows, views differ widely as to (den Hond 2000):

1) whether industrial ecology should restrict itself to describing these material and energy flows, or engage in analysing the systems for managing them, or even suggest improvements to these systems; and
2) what the system boundaries should be (regardless of whether a limited or extensive approach is chosen under point 1).

Because industrial ecology is a new concept, the discipline is so far a collection of very different terms and strategies with different scope, rather than a clearly defined and unitary theory specifying clear strategies for its industrial implementation (O'Rourke *et al.* 1996). It is possible to carve out a set of fundamental characteristics of industrial ecology (see below). However, this does not prevent different actors from claiming that everything from incremental improvements in existing (environmentally harmful) products in a limited geographic area, to radical change in the global industrial system in an environmentally friendly direction, fall within industrial ecology.

This article rests on a broad interpretation of industrial ecology, which includes both physical, biological, chemical, organisational and institutional aspects of material and energy flows, as well as the flows' transboundary character. Focusing only on material and energy flows within a strictly defined and limited ecosystem is very useful; however, such an approach needs to be accompanied by studies acknowledging

the global character of many material and energy flows, and the distributive aspects of these.

In the first textbook in industrial ecology, Graedel and Allenby (1995) describe industrial ecology as ”the science of sustainable development”, a view shared by many of the pioneers within the field (4). Graedel and Allenby have also proved the most cited definition of industrial ecology, which clearly shows that a holistic approach to energy and environmental questions forms part of the fundament for industrial ecology (Graedel and Allenby 1995, my emphases):

“Industrial ecology is the means by which *humanity* can deliberately and rationally approach and maintain a desirable carrying capacity, *given continued economic, cultural and technological evolution*. The concept requires that *an industrial system be viewed not in isolation from its surrounding systems, but in concert with them*. It is a systems view in which one seeks to *optimize the total materials cycle* from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital.”

Sustainable development is based on both the principle of distributive justice today, and the principle of intergenerational equity. Indeed, in their pioneering article on industrial ecology in *Scientific American*, Frosch and Gallopoulos (1989: 106) state that “[a]n ideal industrial ecosystem may never be attained in practice, but both manufacturers and consumers must change their habits to approach it more closely if the industrialized world is to maintain its standard of living – and the developing nations are to raise theirs to a similar level – without adversely affecting the environment.” However, within industrial ecology, the notions of equity and justice are absent – and it is by no means certain that these ever will be present (5). As mentioned above, industrial ecology seeks inspiration from natural ecosystems. Contrary to what is the case in social systems, concepts like equity and justice are absent in ecosystems. However, the fact that industrial ecology does not focus on equity and justice does not render developments in the South irrelevant for industrial ecology.

Industrial-ecological research and practice today have much in common with ecological modernisation, which is a generic term for descriptions and analyses of established government and economic actors response to pressure for action in environmental matters (6).

Within ecological modernisation, environmental challenges are regarded as possibilities, not symptoms of a crisis. It is deemed possible to decouple economic growth from environmental degradation, by developing and employing more environmentally friendly technological and economic means. In this way, it becomes possible to reach economic growth goals and solve environmental problems simultaneously (Cohen 1997: 109, Pepper 1999). Such solutions are sought through co-operation between relevant actors rather than radical institutional change.

There is clearly a potential for more fundamental processes of change in industrial ecology principles than what is the case with ecological modernisation. Ehrenfeld (1997) emphasises connectedness, community and co-operation as central concepts in industrial ecology. In many ways, today's societal system, with a fragmented and reductionist bureaucracy, and emphasis on individualism and competition, is the very opposite of these concepts (7). Furthermore, the use of concepts within industrial ecology research is to a much larger extent than ecological modernisation influenced by conditions characterising natural ecosystems.

In a contribution regarded as essential within the industrial-ecological research community, Ehrenfeld (1994) claims that what he calls the industrial ecology paradigm is based on the following fundamental elements:

1. *The globe is a closed ecological system*. Development of the character and scale of today is not compatible with long-term ecological survival. The goal is therefore regarded to be to optimise material cycles – both in terms of capital-, energy- and resource use – from raw material via processed material and product to waste product. Design for the environment is also central in this regard. Such an optimisation is also believed to lead to increased competitive power.

2. *Human society and the ecosystem have been developed in a close relationship with each other*. Nature has intrinsic value, visualised through economic activity, and human beings therefore have an ethical and moral responsibility towards nature.

3. *Sustainability means that human and natural capital is maintained intact independently of each other.* In other words, industrial ecology often operates with a "strong" definition of

sustainability. A ”weaker” definition would only require that the sum of human and natural capital is kept intact.

4. *Policy:* Economic activity based on services, not goods, is given priority. Quality of life is emphasised rather than living standards. Taking technological realism as a point of departure, the precautionary principle, including a conscious product policy and life-cycle assessment, should be employed to meet uncertainty.

As shown in point 1 above, the central idea of industrial ecology research is that industrial activity should mimic the natural ecosystem as much as possible. The linkage between the company and its role in a local ”ecosystem” within the framework of a closed *global* ecosystem is at the core of most industrial ecology thinking (8).

Several contributions within the field of industrial ecology discuss how much the technology's environmental effectiveness needs to improve in order to maintain environmental quality in an area given that other factors contributing to total environmental damage increase – the so-called Factor X problem (Jansen 1994, Brattebø 1996, von Weiszäcker *et al.* 1997, Allenby 1999: 22-33). The most important of these factors are usually deemed to be population growth and increased welfare (the increase in the number of accessible goods per person).

Therefore, is it peculiar that most industrial ecology research in practice concentrates on a very small part of the global ecosystem, namely the well-developed, industrialised countries in the North. In addition, this the part of the whole where modern industry after all has come farthest in the direction of copying the natural ecosystem, where population problems are the smallest, and where the gap between desired and actual welfare is at a minimum (9).

Very few material cycles are limited to countries in the North. Quite on the contrary: as a consequence of globalisation, North and South no longer only share the atmosphere, the biosphere and the oceans, but are also both part of a ”global metabolism”. Extraction of virgin materials, production, transport, consumption and disposal of a product take place in different locations around the world. As a large share of these processes take place in the South, the objective of optimising material cycles will be difficult to achieve without focusing more on problems related to such processes in the South. Many will claim that this already happening today, as products produced and

consumed in the North are subject to life-cycle assessments. However, I argue that it is unfortunately not that simple (see Ch. 0).

In point 2 in Ehrenfeld's categorisation above, emphasis is put on the mutual interplay between human beings and nature. It must be assumed that this interplay is present in other countries than those of the industrialised North, and that human beings' moral responsibility for nature thus also pertains to activity taking place in these areas.

Similarly, it is difficult to limit the "strong" definition of sustainability in point 3 above to countries in the North only. If human and natural capital is to be maintained intact independently of each other in the North, while nature is sacrificed at the benefit of economic and industrial development in the South, such a principle will not be worth the paper on which it is written.

The main policy-related challenge for business and government actors both in the North and the South is to provide people – or the consumers if you want – in the South service-based economic growth. Such a strategy can, and should, be based on technological realism and the precautionary principle.

Although industrial ecology is a dynamic and new field, it is possible to discern some core activities characterising industrial ecology (10). This does not change if we take countries in the South as a point of departure. The first main characteristic is a *systems perspective* in space and time. The spatial dimension points to the value of giving equal attention to all stages in a product's value chain, while the time dimension directs attention towards the need for a long-term perspective. *Dematerialisation* – the decoupling of material input and economic growth – is the second characteristic of industrial ecology. It is not enough to keep material inputs constant while gross national product (GNP) increases, given that we are talking about a society that already has an environmental and/or resource problem.

The third characteristic is *the emphasis placed on network-related initiatives and co-operative solutions*. This is based on the insight that a company alone can do little in terms of furthering sustainable development, while much more results can be obtained through co-operation, for example by triggering processes of change in other companies. The principle of extended producer responsibility (see Ch. 0 below) can be derived from this perspective.

In addition, industry often emphasises *competitive power* as a central element in industrial ecology. Researchers acknowledge the economic motive as a driver for change, but do not consider its position as so central as the other elements mentioned above. Industrial ecology must be based on government-industrial partnerships, but the key goal is macro level environment and resource gains.

The overall impression of a brief review of the literature on industrial ecology in the South is one of fragmentation and insufficiency (11, 12). Isolated contributions can be found in most research fields within industrial ecology – encouragingly enough, both from researchers in the South and the North – especially from the last 3-4 years. However, among the few studies conducted on questions related to the South, many are in the outer edge of what is usually regarded as industrial ecology research and practice. Most studies are also conducted in newly industrialised countries (NICs), or in relatively well-developed areas in other countries (e.g. China's coastal areas).

A search in the *Journal of Industrial Ecology*, regarded as the central journal within the field of industrial ecology, only produces three articles that explicitly address industrial-ecological practice in the South (Hamner 1997, 1998; Beukering and Duraiappah 1998). All these focus on Asia or specific Asian countries; searches on South-America and Africa produce no result. There are, as far as I have been able to see, no articles that explicitly discuss which barriers that must be overcome in order to realise in the South the potential that lies in the industrial-ecological principles described above.

The exception to the rule of a lack of attention to countries in the South in industrial-ecological literature are contributions on cleaner production (see van Berkel *et al.* 1997 for a discussion of the relationship between cleaner production and industrial ecology). Some regard cleaner production as a distant relative (or forefather) of the industrial-ecological family, but the term has developed considerably since U.S. environmental authorities launched it in 1982 as a description of methods for waste minimisation and improved resource utilisation. Today, the *product* to an increasing extent is becoming the centre of attention, in contrast to the focus on *production and technology* that prevailed until about 1990 (13). Erkman and Ramaswamy (2000: 1) describe industrial ecology as the application of

cleaner production on the system level – in industrial clusters, industrial zones, or regions.

The *Journal of Cleaner Production* contains articles both on cleaner production in Asia in general (Hamner 1999, Visvanathan and Kumar 1999), and articles covering particular countries in the South. With one exception (Retta's (1999) study of Ethiopia), the latter category is constituted by studies of Asian countries, for example India (Ramachandra *et al.* 1999), Thailand (Vigneswaran *et al.* 1999), China (Peltier and Ashford 1998, Xin 1998), and Taiwan (Tang *et al.* 1999).

Articles on life-cycle assessment covering the Pacific Asia region can be found in the *International Journal of Life-Cycle Assessment* (Zakaria *et al.* 1999, Hassan *et al.* 1999). There are also a number of articles on LCA in India (Sharma, Beukering and Nag 1997, Sharma 1999, 2000, Mathur and Bansal 1999), and Korea (Lee 1999, Tak 1999). However, articles on Africa and South America seem to be absent.

In journals like *Environmental Management*, and *Resources, Conservation and Recycling*, there are a few contributions covering waste, reuse and recycling questions in the South. Johnstone (1998) discusses which implications the Basel convention has for these areas. Again, articles covering Asia can be found, e.g. focusing on India (Gupta *et al.* 1998, Kuniyal *et al.*1998), China (Chung and Poon 1998, 1999), and Taiwan (You *et al.* 1999). Within this category, we also find contributions focusing on countries in South-America (Stern *et al.* 1997, on Ecuador), and African countries (Kironde and Yhdego 1997, Agunwamba 1998, Mato 1999, Kasseva and Mbuligwe 2000), but these to a lesser extent focus on reuse and recycling.

As industrial ecology is about optimising energy and material flows, it is worth mentioning that many comprehensive studies taking the South as their departure have been conducted within the field of new and renewable energy (see for example Reddy, Williams and Johansson 1997, and Kammen 1999).

Studies of global industrial environmental standards' effects on countries in the South, and of these countries' opportunities to participate in the process of establishing these standards, should also be mentioned (Gleckmann 1996, Som *et al.* 1998). For example, the working group for trade and environment within the China Council for International Co-operation on Environment and Development, in co-

operation with the International Institute for Sustainable Development in Canada, has studied how China should tackle global environmental standards and ecolabelling. There are also isolated studies within other areas, as Kurasaka's (1996) study of extended producer responsibility in Asia.

"The Third International Conference on EcoBalance" in Tsukuba, Japan, also fostered interesting contributions, for example Fawer (1998) and Werner (1998). In a piece published in the web edition of the *International Journal of Life-Cycle Assessment* (14), Fawer asks whether life-cycle assessment is a "luxury tool", that should be employed in countries in the South only if and when these countries have come to terms with fundamental environmental problems as large concentrations of pollutants, end-of-pipe-solutions etc. In spite of the barriers that must be overcome, he concludes that life-cycle assessment is a useful tool for analysing environmental impacts in the South as well – especially if a simplified approach is used, and data access is improved.

Ramaswamy (2000) as well as Erkman and Ramaswamy (2000) highlight the value of industrial ecology in planning in less developed countries, using several International Centre for Advancement of Science and Technology (ICAST) projects in India as examples (15). They illustrate how mass flow studies can increase awareness that not only industry but also households, small enterprises and agriculture contribute significantly to resource use and pollution. Using the leather tanning industry in Tirupur, India, as an example, they also point to the need for new tools measuring the societal cost of resource use in developing countries. In this region, water and firewood is scarce. In fact, ICAST analyses have showed that the leather tanning industry's excessive consumption of these resources has incurred so high societal costs that water recycling would be profitable, and a local entrepreneur sold water recycling equipment to the industry. Analyses also pointed to the high calorific value of textile and paper wastes, which is now partially replacing the use of scarce firewood.

Using University of Kaiserslautern projects in Gujarat, India, and Java, Indonesia, as examples, von Hauff and Wilderer (2000) discuss the potential and barriers related to the development of eco-industrial networking in developing countries. They highlight a number of organisational and institutional barriers that may leave the potential of eco-industrial networking unused, lack of trust being the most

important. Other potential hurdles mentioned were financial difficulties, lack of environmental education, bureaucracy, lack of transparency, corruption, nepotism and political interference in technical decisions (16).

Another interesting contribution in the direction of industrial ecology in the South, is Wehrmayer and Mulugetta (1999). The book contains contributions covering all continents in the South. It is divided into the themes of globalisation; the role of business and industry; national strategies; trade and the environment; and organisational and structural challenges related to sustainable development in the South. The environmental challenges and problems related to industrial and business activity in the South (as multinational corporations' environmental performance and environmental regulations' effect on industry's competitive power) is given most attention. Interestingly, one chapter asks which *possibilities* producers in the South have today and will get in the future because of the increased focus on sustainable production and consumption (Robins and Roberts 1999).

References to questions related to countries in the South may also be found in key contributions within industrial-ecological research, for example Ehrenfeld (1994, 1997 – see Chs. 0 and 0 for more details) and Tibbs (1992). However, the role of the South is fairly marginal in these contributions as well. Tibbs focuses especially on the unique possibility we have today to establish basic infrastructure in the South that is more in accordance with the principle of dematerialisation (see also Ch. 0), and the market opportunities this implies for industry in the North. He also underlines the necessity of a global and systemic approach to the development of energy infrastructure.

While the number of contributions on industrial ecology in the South to the key journals in the field is very limited indeed, there are a number of encouraging initiatives for education and industrial collaboration within industrial ecology. A few examples (rather than a complete list) will be presented below.

A number of countries are either considering the inclusion of industrial ecology principles in their national industrial strategy (Thailand, Taiwan) or in the industrial strategy of selected regions (China and India) (Chiu and Pascual 2000).

The United Nations Development Programme (UNDP) launched the Private Sector Participation in Managing the Environment (PRIME) in 1998, together with the Department of Trade and Industry (DTI) on the Philippines, which is the implementing agency. Among the activities are a by-product exchange program, involving five industrial estates, to recycle used oil and packaging materials; the development of eco-industrial parks; waste minimisation programmes; and an initiative for industry self-regulation through private-public partnerships, the development of Business Agenda 21's and environmental management systems (17).

ICAST has initiated many more Indian projects than those mentioned above, and also has considerable activity in other developing countries (18). It is also involved in an Indian-Dutch research co-operation programme within industrial ecology (see Pangotora, Erkman and Singh (eds.) 1999).

An industrial symbiosis project has been initiated at the University of Cape Town, South Africa. It aims to map and exploit financial, market and supply chain linkages between small and medium-sized enterprises, in order to optimise environmental and economic performance. The project is part of a larger portfolio of cleaner production demonstration projects whose aim is to adapt cleaner production tools to the realities faced by South Africa (19).

The U.S. Environmental Protection Agency (EPA) has since 1994 sponsored a prototype eco-industrial park in the U.S.-Mexican border area of Brownsville, Texas/Matamoros, Mexico. While this project is included in the domestic U.S. initiative for the development of eco-industrial parks, it is situated in a cross-border area characterised by poverty and unemployment. The project is focusing on cross-border co-ordination problems, and has thus broadened the eco-industrial park concept to include facilities outside the physical park area. Detailed computer modelling of regional material and energy flows has been used as a way to connect businesses and recruit more participants (20).

Furthermore, numerous international cleaner production initiatives (e.g. those of UNEP and OECD) concentrate on countries in the South, and include research, development and technology demonstrations. Many countries in the South have also established national cleaner production centres or have entities performing the functions of such (21).

The need to draw lessons from case studies of industrial-ecological practice in the South is evident. However, few if any of the contributions reviewed are explicitly linked to the national and international framework conditions in which they are embedded. In an attempt to improve this situation, the concepts of industrial-ecological innovation capacity and capability are discussed in the chapter below.

3. Framework conditions for industrial-ecological capacity and capability

The possibility for countries in the South to leapfrog over the environmental problems associated with industrialisation as it has taken place in the industrialised countries is alluring both for decision makers in the South and environmental aid bureaucracies in the North. However, such initiatives for comprehensive and fundamental change will probably face many challenges. One of the most important of these is the (unfortunately rather widespread) misconception that countries in the South passively will play the role of playgrounds for the North's experiments for sustainable development. Furthermore, it is important to note that not only the *material* infrastructure is insufficient in the South. The *organisational and institutional* infrastructure in these countries has clear weaknesses as well. Together with cultural differences this makes large-scale initiatives for sustainable development much more complicated operations than the purely technical aspects should imply, and has so far prevented the South from catching up with the North's technological lead in one major leap as a result of technology co-operation (22).

Under which conditions is environmental and energy technology transferred from the North to function in the South? It may be fruitful to distinguish between (23):

- institutional framework conditions;
- economic and financial framework conditions;
- cognitive and informational framework conditions; and
- technical framework conditions (24).

Institutional framework conditions should here be taken to mean institutional, organisational and legal structures that define the norms and rules of the political game in the energy and environmental area. The general economic and financial situation, sectoral segmentation of the economy, the capital situation, the prising of natural resources, intellectual property rights and patent matters are among the aspects included in *economic and financial framework conditions*, while *cognitive and informational framework conditions* describe under which conditions knowledge about environmental and energy matters is produced, distributed, interpreted and used. By *technical framework conditions* is meant technical standard; access to raw materials; and scientific and technical education within the environmental and energy field. Each of these dimensions has local, regional, national and international aspects.

If (the energy and environmental sectors of) a society has positive values along all or most dimensions of the above-mentioned framework conditions, it bodes well for the will and ability of the country's institutions, business and industry, non-governmental organisations (NGOs) and research communities to identify, develop and implement technologies and strategies whose aim is to further industrial-ecological principles. This can be termed industrial-ecological innovation *capacity* (25). While *capacity* is used to describe conditions on a societal level, *capability* describes the ability that relevant industrial actors have to transform this capacity to commercially viable products. Or, more precisely: technical, managerial and institutional abilities that make companies able to use equipment and technical information effectively in order to create products that support industrial-ecological principles (cf. Lall 1993).

Especially in the organisational and institutional area it is central to examine the linkages within – and, not the least, *between* – the two system levels; the span between the actions of the company and the opportunity structures within which these actions take place (26).

Particularly the cultural and bureaucratic conditions for the development – and not the least the *use* – of environmentally friendly technology in the South should be subject to intensive research. Studies of technological development are full of success stories whose only message is that a technology is successful – because it is successful. Technology cannot be both cause and effect – simultaneously. However, this does not prevent studies of technological development from

considering the fact that technology can both influence social relationships and be influenced by such (Bijker 1995). The fact that both these causal paths are possible, also means that a given technology may be perceived differently in different cultures and societal systems; a spade is not necessarily a spade everywhere.

Thus, it is possible that a technology that works in, say, the United States, does not function for those who are to use it in Zambia. Then, the only solution is to ”reinvent” the technology in the society to which it has been transferred (Olsen 1995), that is, to reinterpret the technology into a new context. This is obviously impossible to carry though without a balanced and close co-operation with representatives of industry, research communities, and government organs in the society in which the technology is to be employed.

Ehrenfeld (1994) discusses these aspects. He emphasises that “new paradigms” (cf. Ch. 0 above) mean cultural change both in the form of change in the visions people wish to live according to, in “artefacts” (defined as organisational forms, and technological systems), and in the underlying ”interpretative filters” that to a large extent influence both our own behaviour and organisations’ response to surprising contextual changes.

The innovation – or perhaps rather *re*innovation – aspect is in other words central in the coupling of industrial-ecological innovation capacity and capability. In my opinion, this aspect has not to a sufficient extent been related to industrial-ecological research. To include the innovation aspect is particularly important when industrial ecology research and practice direct their attention towards the South. Research on technology co-operation between North and South shows that, so far, too much focus has been directed towards transferring nuts and bolts, without thinking about whether the recipient is able to *use* these nuts and bolts when the donor country’s representatives withdraw. Instead of delivering “finished” products, more effort should put into developing the recipient country’s capacity to build up a strong and independent environmental technology industry that can co-operate with industry in the North on an equal basis (27).

Perhaps it becomes easier to understand how essential the innovation aspect is if a broad understanding of technology is taken as a point of departure. A cogwheel is useless if nobody knows why and how it is made, how it is used, what it can be used for, and who could

benefit from using it. Technology should therefore be taken to mean not only the artefact, but also the knowledge needed to make, use, maintain and further develop it, and the institutional framework needed for people to be able to use the technology in a proper manner (Müller 1984, Lall 1993, Lorentzen and Granerud 1999).

4. Why the focus on the North?

Although there are examples of industrial ecology research and practice in the South, as seen in Ch. 0 above, it still is reason to ask why industrial ecology research and practice not to a larger extent focus on other areas than the developed North.

One viable argument is that the discipline so far has had to struggle hard enough to establish itself where it was initiated – in North America, Europe and Japan – and that "conquering" the world therefore has had to wait. It takes time to obtain legitimacy among business and industry, relevant authorities, and – not the least – within university communities. Language and cultural barriers might also partly explain why industrial ecology has so far been concentrating on challenges in the North.

Markets in the North are more well-developed than those in most countries the South. A holistic approach to the environmental problems related to a particular product or service is gradually becoming a more important element of competition in these markets. The focus on the North in industrial-ecological research and practice can therefore also stem from the fact that markets in the South still are insufficiently developed, both in general terms and within the environmental and energy sectors in particular.

To what extent industrial ecology principles and practice can be said to be present in the South, is also to certain degree a question of whether the point of departure is a limited or a more extensive definition of industrial ecology (see above).

Another important reason for the lack of interest for the South within industrial ecology may be that the discipline – and its representatives – is closely related to companies in the North. This has been important to maintain a serious and objective image. As many associate environmental and development questions in the South with

radical castles in the air, there may be scepticism towards engaging in such activities.

Related to this is the research communities' dependence on funding from companies. So far, industry in the North has been most concerned with complying with environmental regulations at home, and has mainly wished to finance initiatives within this research area.

However, the most important – and best – reason for the focus on the North within industrial ecology is that it has been natural to face problems where they were most urgent. There has been a gradual realisation that a situation where 20 per cent of the world's population consumes 80 per cent of the Earth's resources cannot continue, and that a re-adjustment to a more sustainable system requires so fundamental changes that new concepts were necessary. However, now the production and consumption pattern associated with the North is becoming a global phenomenon. Therefore, the rest of the world must also be included in the focus of industrial-ecological research and practice.

5. Why focus on the South?

There are a number of reasons why industrial-ecological research and the practice of such principles in industry in my opinion need to focus more on the South.

- First, many of the factors that have caused the focusing on the North are changing. The positive aspect of these processes of change is that the climate for profitable, environmentally friendly investment in the South seems to be better than ever. Their negative side will appear if industrialism is spreading to new areas whilst the companies being the carriers of industrialisation face no environmental obligations.
- Second, it is difficult to argue on a moral basis that North should not contribute actively to environmentally friendly development in the South, without having to confront a number of skeletons in one's cupboard.
- Third, there are a number of arguments why industrial ecology as a discipline would benefit from increasing its focus on countries in the South.

5.1 Changes in framework conditions

A number of the factors I believe have contributed to the lack of interest for countries in the South within industrial ecology research and practice is about to change. Some of the most important causes of this change are that

- the environmental technology industry in the North seeks new markets;
- environmental requirements following the whole life-cycle of products are emerging in the North, and form the basis for global industrial environmental standards; and
- bi- and multilateral donors try to provide the necessary framework conditions for private investment and the establishment of new businesses in the environmental and energy sectors in the South.

Behind these trends lie more fundamental developments: increased acceptance both in the North and the South for the use of market mechanisms in environmental policy; globalised production of goods and services; as well as the globalisation of environmental problems, of the actors fighting the sources of such problems, as well as of the attempts to solve them. In short: neither technology nor environmental problems will respect frontiers in the future (Jansen 1994).

5.1.1 Globalisation of industrialisation, environmental problems – and the struggle against them

The countries in the South want to reach the level of welfare of the countries in the North, and they have so far chosen to do it through industrialisation in much the same way as countries in the North did. It is in the self-interest of decision makers within government and industry both in the North and the South that this development continues, and it is difficult for the opposition in the North to argue on a moral basis against this (see Ch. 0). Therefore, a world-wide industrialisation is already well underway.

In parallel with the global industrialisation, environmental problems are globalised. So is the consciousness about these problems. This is related to the fact that many environmental organisations in the North are globalising their activity to match their industrial opponents,

that environmental organisations in the South seek allies outside their own country, and the globalisation of media and communications.

5.1.2 Environmental technology industry in the North seeks new markets

In a "precautionary perspective", distinguishing between environmental technology industry and other types of industry becomes meaningless; all kinds of industry will have to develop competence and concepts to meet challenges related to material and energy use. However, the seed to such a development is often sown in niche communities.

In the North, a sizeable environmental technology industry has for example developed as a result of gradually stricter environmental regulations the last 25 years or so. This industry, and knowledge industry related to it – now seems about to direct its focus towards new markets in the South, as markets in the North have matured. This group will co-operate with development aid authorities in their own country, apply for multilateral or international funding, or sell products on pure commercial terms. Part of the strategy of such companies will probably also be to lobby for stronger environmental regulations in potential export markets. Hopefully, such industry will also actively seek partnerships with similar companies in the South that know the particular export markets in detail.

Two fundamental developments *within countries in the South* may attract environmental technology industry in the North:

- Markets in the South are gradually being opened for import of foreign technology, and it has become easier for foreign companies to establish activities and invest there.
- The demand for environmental technology in these markets is increasing. As explained below, environmental consciousness is increasing both among people at large and among decision-makers.

There are examples of companies – also within conventional industry – that try to influence local authorities to implement stricter environmental regulations because this increases their profit opportunities (28). Governmental agencies in these countries are often

open for such initiatives – particularly the environmental authorities, which may in some cases take the role of an "environmental organisation" within the state apparatus. This may especially be the case if the initiative contributes to ease the implementation of environmental initiatives that the environmental bureaucracy wants to push through in spite of resistance from conventional industrial sectors.

5.1.3 Increased environmental consciousness in the South – combined with strong pressures for further development

Many countries in the South are under authoritarian rule. However, it seems to be a trend towards more co-operation between governmental agencies and non-governmental environmental organisations. One reason might be that cash-strapped governmental agencies to make use of all the help they can get to solve environmental problems – as long as these environmental organisations keep their activities within certain limits. For example, the Chinese environmental protection minister awards prizes to more or less independent environmental organisations, and encourages his own ministry to establish quasi-state environmental organisations; simultaneously, Chinese authorities persecute *Falun Gong*, which in many other countries would be regarded as a harmless religious movement.

The environmental problems in many countries in the South gradually become more visible. In some areas, the problems are so serious they constitute a security threat both in the short term and long term. One would think that environmental questions are not of interest for large parts of the population in the South, as they are only able to focus on meeting their basic human needs. However, this is only partly true. First, a sizeable part of the population in many of these countries does not live from hand to mouth, and can therefore focus on other questions than those related to survival. In fact, in some limited areas in the South the population has a living standard comparable with many areas in the North. Second, environmental problems may directly impinge upon the fulfilment of people's basic needs, and thus force them to focus on environmental matters. For example, access to clean drinking water has been among those most focused upon in the village-level elections in China.

The political leadership usually understands the seriousness of environmental problems perfectly well – often even better than

wiseacres from the North do. They may have clear opinions on strategies for more environmentally friendly development, and for environmental and energy-technological co-operation with the North. However, at the same time they are under pressure from business and industry, especially from environmentally harmful and/or energy-intensive industry, and fossil energy producers. Pressure may also come from those parts of government having a stake in economic development. Economic problems stand in line, and are often given priority. However, this desperate situation also holds opportunities – especially for a research and business area like industrial ecology.

Exactly the fact that countries industrialising today must tackle all environmental problems and all problems related to economic development *simultaneously*, makes win-win solutions the only realistic option if countries are to provide financing themselves (29). A core element in industrial ecology is to couple the solving of environmental problems with economic efficiency and profit.

The challenge for industrial-ecological research should therefore be to contribute to the design of projects and products that both improve people's possibilities to satisfy their basic needs (e.g. clean drinking water and clean air), and *simultaneously* contribute to avoid production of environmentally harmful substances or adjust human activity in a more environmentally friendly direction. An important example is that initiatives and products combating air pollution may simultaneously reduce emissions of greenhouse gases in areas where climate problems still are poorly understood and/or regarded as irrelevant compared to air pollution.

Pollution problems that countries in the South face today perhaps remind of the problems confronting countries in the North the last 40-50 years. However, this does not mean that we have to solve these problems in same way as we did in the North a generation ago. Here, industrial-ecological research and practice can play an important role. In the period 1950-70 *dilution* was considered as the main remedy in the struggle against industrial pollution. In the 1970s, *clean-up strategies* gradually took over, in parallel with stricter government regulation of industrial emissions and waste. In the 1980s, *recycling* was put in focus. Today, we are on the way to acknowledge that reduced production and consumption of goods (and to a certain extent services), and the replacement of environmentally hazardous material and products, is a better way of solving environmental problems. The

prevention of environmental damage is also emphasised, through design of production processes and treatment of materials and waste flows with regard to minimising energy consumption in a product system, all the time with life-cycle assessments as a point of departure (Brattebø 1996, Marstrander and Brattebø 1997).

5.1.4 Bi- and multilateral obligingness towards private investment in energy and environmental sectors in the South

As mentioned above, solutions that alleviate more than one environmental problem simultaneously and are profitable have the best chance of obtaining local financing in the South. However, during the last decade it has been a considerable growth in environmental initiatives financed through bi- and multilateral aid. In the same way, more and more multilateral aid initiatives directed particularly towards projects in the environmental and energy sectors have been developed – projects that the host countries are not capable of financing themselves. The Global Environment Facility is perhaps the most well-known example of such an initiative. A newcomer in this regard is the World Bank's Prototype Carbon Fund, based on the flexible mechanisms under the Kyoto Protocol (30). How important this change is, is underlined by the fact that it has taken place in a period when development aid's proportion of GNP in donor countries has declined (31).

The proportion of foreign direct investment in countries in the South has increased substantially in the same period. Therefore, an interesting feature of bi- and multilateral environmental aid initiatives is that they increasingly make use of economic incentives to encourage business and industry in the North to invest in projects in the South. Another example of how the regulatory apparatus is adapted to private or quasi-private investment in environmental and energy sectors in the South is the flexible mechanisms under the Kyoto Protocol (most importantly, the Clean Development Mechanism). Just as stricter environmental regulations in the North stimulated the emergence of environmental technology companies and research communities, these financing opportunities stimulate industrial growth and innovation – hopefully both in the South and the North.

5.1.5 The need for guidelines for private actors' activity in the South

However, private actors' activity in the South is not only a blessing. There are indications that some companies in the North – be it multinational corporations, or small- and medium-sized companies – move (parts of) their activity to countries in the South because these countries have poor or lacking environmental regulations in addition to cheap labour as comparative advantages (32). In 1993, United Nations' Benchmark Corporate Environmental Survey Report for example stated that many multinational corporations lack both general environmental improvement programmes and specific environmental initiatives towards their activity in the South, and that companies' environmental performance is better in areas with strict environmental regulations (Ehrenfeld 1997) (33). In the wake of the increase in foreign direct investment in the South, a discussion has also been started on whether ethical and environmental guidelines for such investment are necessary, and, if so, how they should be designed.

Theoretical and methodological tools employed within industrial-ecological research may give valuable documentation on environmental aspects of activities in the South of private actors from the North. This may form the fundament for the formulation of guidelines for such activity – and for documentation on the part of industry that these guidelines are complied with.

5.1.6 Life-cycle requirements to products in the North, and global industrial environmental standards

As mentioned in Ch. 0, very few material cycles are limited to countries in the North. Quite on the contrary; materials extraction, production, transport, consumption and disposal of a product often take place on different locations across the globe. Therefore, the industrial-ecological principle of optimising material cycles will be difficult to follow without focusing more on problems related to optimising material cycles in the South.

The goods bought by consumers in the North are subject to increasingly strict environmental requirements. This has lead to more focus being put on subcontractors of the companies actually selling the goods in the North. Many of these subcontractors are located in the

South. This means that more and more attention will be directed towards companies in the North's activities in the South. If they shall be able to tackle this development in a way that benefits both themselves and the consumers, they must have support from research that combines knowledge of the unique technological, cultural and societal context that subcontractors are located in, with knowledge of industrial-ecological principles and tools.

Among these tools are global industrial environmental standards, of which the most profiled is ISO 14000, published by the International Organisation for Standardisation (ISO). ISO14000 certification is site-specific. A possible positive aspect of such a standard is that proactive multinational companies can document that they are continuously improving the environmental management systems of their factories in the South, through certifying one factory after another. However, the standard only measures whether an organisation has a system for continuous improvement of its environmental performance, and not whether the organisation's activities as such are environmentally friendly or environmentally harmful (34). A possible problem is thus that, in principle, all types of activity can be certified, as long as a system for environmental improvement has been established – no matter how environmentally harmful this activity is (35). In a situation where countries in the South might have to resort to using possibilities to pollute as a comparative advantage to secure economic growth, it is thus important that industrial-ecological research communities and proactive business and industrial actors co-operate closely (cf. Gleckmann 1996).

5.2 Moral aspects

According to many contributors, especially from industry, one of the main ideas of industrial ecology is to increase companies' competitive power, and to use market mechanisms to the benefit of the environment. Some will therefore question whether it is morally acceptable to encourage increased co-operation between North and South within industrial-ecological research and practice. The main argument is that this will contribute to the development and maintenance of a system based on economic growth just like the pattern set by industrialised countries in the North (36).

Such arguments can very easily be misinterpreted in the direction that those voicing them are against economic growth in

countries in the South. This would be a rather controversial claim, given the differences in living standards between North and South. Another reason why I doubt such a well-intended "non-interventionist strategy", is that it may easily become naïve, and thus counterproductive. As mentioned above, political and economic elites both in the North and South in my opinion have a self-interest in global industrialisation. If this argument holds, economic globalisation will take place irrespective of whether industrial-ecological research and practice focus on the South or not. In my opinion, the choice for industrial ecology therefore stands between the following:

- actively contributing to putting the global industrialisation into a critical systems perspective, and exploiting the industrial and research potential embodied in such a development; or
- taking a passive role, and remain a spectator to an economic development that is not based on holistic systems solutions, while the opportunities to test technology and tools adapted to the realities of the North in a new context, disappear.

I believe that it is more sensible to contribute to an industrialisation in the South based on:

- a large proportion of environmental technology industry;
- other types of industrial activity taking place more in accordance with industrial-ecological principles; and
- communication and energy-infrastructure being developed in accordance with these principles as well.

The opposite strategy – that is, to wait and see – does not match very well with the precautionary principle, which is central within industrial ecology. In addition, it is, as mentioned above, morally questionable to deny the South the economic growth we have allowed ourselves to experience – and that we so far have done very little to limit. Then it is better after all to give the help we can in order to give economic growth in the South as good a content as possible.

Some are against directing more industrial-ecological research and practice towards the South because this in their opinion forces "our" solutions on countries in the South. However, one of the clearest requirements from the South when signing the conventions drafted in

Rio in 1992 was that countries in the North have to transfer much more technology and funding than what is the case today. The claim that we force our solutions on the South through industrial ecology initiatives there, therefore seems to be based on the assumption that most states in the South do not have legitimacy in their own people, and that the opinion of the leadership is thus not representing the opinion of citizens of these countries. This might be the case for some of the countries we talk about here, but far from most of them.

The moral dilemma also has another facet, if a historical perspective is taken. How morally superior – not to say credible – would it be if we tell the countries in the South today that we do not wish to be involved in the environmental clean-up there, because this would strengthen a harmful system the North has introduced in these countries? These environmental problems have partly been caused by industry from the North. The South is part of the North's industrial metabolism – both because raw materials are often extracted in the South, and because people in the South consume products produced in the North (37). Not taking the responsibility related to the development of a global metabolism, can easily take on the character of "reversed imperialism" if we at the same time continue to extract cheap raw materials in the South to use in the North, and provide the South with second-best technology. Such a strategy would neither be morally superior nor long-term.

5.3 Focusing on the South as a contribution to the development of industrial-ecological research and practice

The conditions for focusing industrial ecology activities more towards the South are thus probably better than ever, and there are clear ethical arguments for making such a readjustment. But are not the problems related to realising industrial ecology's potential in the North large enough? Should industrial-ecological practice and research really enter the South, which likely offers even more severe bureaucratic, technical and environmental problems as well as larger cultural differences and communication problems than those encountered in the North?

Not doing so would, as written in the introduction and in Ch. 0, collide with many of the central ideas of the discipline, but there are many other arguments for why industrial-ecological research and practice should increase their focus on countries in the South.

Carving out central problem approaches: By directing attention towards problems countries in the South face, industrial-ecological research and practice may clarify the contrasts between those topics concentrated on today that are really important, and those topics that we can safely put on the waiting list for a while. One example of a question one could probably be more conscious about, is: Should we give priority to marginal improvements of already relatively well-functioning and environmentally friendly products and processes in the North instead of fundamentally changing the far less environmentally friendly products and processes in the South, performing much the same functions?

Studies in the South can also – often in a rather glaring way – contribute to enlarge, and thus visualise, factors that contribute to the failure of industrial-ecological initiatives. Most such factors are probably central in the North as well, even though they are less evident, and have therefore not been sufficiently analysed.

Testing the robustness of theories and tools: Employing in the South industrial-ecological theories and methodological tools currently being used in the North, will be a test on how universal they are. For example, how robust are the different valuation methods used in life-cycle analyses? Can they be employed in for instance India, China or Brazil without problems? Using theories and tools in the South would probably generate many additional interesting observations – which would not necessarily be the same, if different countries in the South were visited. Another example: is it meaningful to introduce extended producer responsibility in countries where the value of labour is very low, the value of waste comparatively high, and the number of urban poor rather high, like India today? (38)

Revealing implicit assumptions: Industrial-ecological research and development in the South would probably clarify a number of implicit assumptions underlying industrial ecology as the discipline has developed in the North. For example, industrial ecology in my opinion has a rather sceptical view of the role of the state both in environmental and energy policy and in industrial policy. This is perhaps especially obvious in the American literature in the field (39).

The best way of killing initiatives is to lash them in bureaucratic "red tape". Nevertheless, it is a fact that the state has played a very

central role in the introductory phase both within industrial development and initiatives within the environmental and energy sector in industrialised countries. The situation in the South today is not that different, which has gradually been acknowledged by major actors like the World Bank (1997) (40). However, although the growth of industrial ecology research and practice in the North can partly be ascribed to government regulations, industry has taken the lead. It is far from certain that it can play such an active role in the South. Perhaps the co-operative approach to environmental policy in some Northern European countries can function as a model for the development of environmental policy in the South? (41)

Illustrate how the North can learn from the South: It is not predestined that South should be learning from the North when it comes to industrial ecology. One example illustrating this can be found in the new renewable energy area. The largest number of photovoltaic systems per capita in the world is not in Germany, Japan or the U.S., but in Kenya (Kammen 1999: 13). The most comprehensive programmes for disseminating new renewable energy technology are not located in the North either, but in China (42), and India.

A common objection to this argument is that it is not *quantity* that counts, but *quality* – and that installed capacity rather than the number of systems should be the focus. While these arguments are valid, they do not challenge my point: What countries in the South can teach the North, is how to disseminate new environmental technology. It does not matter if a country's installed wind power capacity is high if this is concentrated in just a few major installations in a limited geographical area, thus involving only a limited number of people and institutions. Nor is it particularly interesting whether a technology holds a high technical quality if nobody wants to use it. In addition, can one say that a technology holds high quality if nobody uses it? Rather, this should be taken to mean that the purely technical aspects of the technology are well-developed, while market knowledge as well as the development and adaptation of supporting organisations are still on an early stage.

Examine the viability of the "leapfrogging" hypothesis: A number of contributions within innovation studies have pointed to technological "lock-in" as a problem in the North (Arthur 1989, 1996). There are also contributions specifically related to environmental and energy technology (see e.g. Jansen 1994: 516) (43). Ideas on eco-

industrial parks and –clusters were developed in the North, but have to a very little extent been implemented there. This is due to the fact that the industrial infrastructure is already established, and that strong interests wish to maintain it as it is (44). One of the very few examples of an "industrial symbiosis" in the North, is Kalundborg in Denmark (45). Because the infrastructure in the South is considerably less developed than in the North, it should – seen from a purely technical point of view – be easier to launch new technological systems and/or technologies tested in the North in these areas. Examples could be the production, distribution and consumption of new renewable energy, or eco-industrial parks (Tibbs 1992) (46). As such infrastructure would be *established* rather than replaced in the South, large initial investment costs would incur. However, the industrialisation in the South happens very fast; thus, the window of opportunity for establishing sustainable infrastructure in the South must be opened quickly, before all key infrastructure is established.

The term "lock-in" describes a development where a technology that has gained a market advantage wins more and more market battles, and thus strengthens its competitive power even more. The consequence of this is often large-scale investment in new projects and substantial research and development activity, which again contribute to learning more about how to lower costs and develop new and better technological solutions. The *technological* lock-in is followed by *institutional* lock-in. Around the "winning" technology, a network of commercial and government actors emerges, all of whom have (organisational) self-interest in expanding activity. Competence development in research communities, companies and research institutions is readjusted towards the dominating technology areas. Such "self-strengthening" mechanisms are often called "positive feedback loops". The consequence of such technological and institutional lock-in is obviously that existing technologies and the institutions related to these technologies may hinder the introduction of new technology that is desirable from an environmental point of view.

6. Research challenges

Are different framework conditions in the South a barrier for implementation of cost-effective environment initiatives? To what extent should different framework conditions in North and South be taken into consideration when formulating environmental requirements

to companies in the North? In spite of the arguments presented earlier in this article, some will surely ask themselves: As industrial ecology focuses on products in countries in the North and their eco-effectiveness through the whole life-cycle, this should include their eco-effectiveness in the South as well. Why focus on the South in particular, then? If the environmental damage caused by a product were large exactly in the part of product chain localised in the South, would not this be integrated in a life-cycle analysis? Furthermore, if it is most cost-effective to implement measures in the South, would not such measures be implemented today?

I will argue that it is not necessarily so easy. The argument on cost-effectiveness above does not take into consideration the fact that the technical, institutional, cognitive and economic framework conditions for production in countries in the South is qualitatively different from that in the North (see also Ch. 0). Exactly because stricter environmental requirements increase the focus on subcontractors, and more and more of these are located in the South because of the globalising production of goods and services, focus on these countries within industrial-ecological research should be increased.

Perhaps differences in framework conditions are perceived as barriers, and therefore prevent the most cost-effective initiatives from being implemented? Or is it correct that initiatives in the South that seem cost-effective on paper, in reality are not cost-effective, as transaction costs are so much larger there than in the North? How should these differences in framework conditions be taken into consideration in environmental requirements to companies in the North? These questions cannot be answered today, because few if any studies have been conducted in the area. This is a large future research challenge.

In the extension of the discussion on the difference in framework conditions one may ask whether life-cycle analyses also should specify which geographical area they have been conducted in (47). Such a discussion should in this case also include the different weighting methods used in LCA. Some of these partly take government policy in given environmental areas as a point of departure. This can be sensible if the country the analysis takes place in has a stable and proactive environmental policy, but it can also make life-cycle analyses victims of weak and shifting environmental policy. The risk of the latter-

mentioned type of environmental policy is presumably larger in the South than in the North, but this problem must be examined more closely before conclusions can be drawn. This discussion is part of a more general question: can the same industrial-ecological tools be employed in the North and South alike, or should they be adapted to different framework conditions?

In which geographical areas do we find the major part of environmental damage caused by products sold in the North? As discussed above, the geographical distribution of environmental damage from products is an interesting question for further industrial-ecological research, of both technical, social science and humanistic character. Is it correct that the largest share of environmental damage of many products sold in the North stem from for example resource extraction and raw material production in the South? If this is the case, to what extent have the relevant companies made efforts to make improvements in these links in the value chain? If this has not happened, why not? How can framework conditions be adapted in order to stimulate such initiatives? Regardless of what conclusions such research yields, they will be interesting: if the conclusions are that industry actually has implemented initiatives where problems are largest, this would in itself be an important finding. If this has not happened, the need is obviously still there for advice as to which improvements that can and should be made.

Factors that influence industrial-ecological innovation capacity and capability: The authorities in the North can to an increasing extent employ market and product-oriented strategies in the formulation of environmental policy. In many countries in the South, the state lacks both the sanction authority and the interplay with business and industrial actors necessary for such use of policy instruments. Because market mechanisms to a lesser extent are developed, the state often plays a far more important role than in the North – but has a much weaker position. Analyses of driving forces and barriers for industrial-ecological innovation capacity and capability in different areas – be it in the North or in the South – are therefore interesting future tasks. This discussion can be extended in the form of (comparative) case studies on different levels (societal, project). Corresponding studies can be conducted of capability on the company level in different cultural and societal settings. The theoretical challenge is to establish linkages between capacity on the societal level and capability on the company level, and especially to clarify the role of authorities in this regard.

Conditions for North-South co-operation within industrial-ecological innovation: Another central question a dialogue between universities in the North and South can focus on, is which factors that further and/or prevent North-South environmental and energy-technological co-operation, on national level, university level, and company level. Such co-operation must be balanced – both parties should learn rather than one teaching the other. It is a fact that both internal conditions in the North, aspects related to North-South co-operation, and internal conditions in countries in the South have contributed to problems in North-South co-operation. Studies of conditions for North-South co-operation within industrial-ecological innovation must have as an objective that the recipient country itself builds up competence – on both societal and company-specific factors influencing industrial-ecological innovation.

Mechanisms for public participation in decision making processes: It is important to develop mechanisms that can secure public participation in decision making processes related to the environmental risks of industrial projects, and to the initiation of environmental and energy technological projects in the South. This especially important if large-scale experiments with new energy infrastructure are considered. One possibility – which only to a very limited extent has been tested in connection with large projects in the South – is the consensus conference. This is a new form for technology assessment that gives a voice to laypeople as well. The consensus conference is a forum where laypeople ask an expert panel about one or more controversial questions related to research or technology within a particular area, assesses the experts' answers, and seek to achieve consensus about the answers to the questions on the basis of this.

7. Conclusion

This article started by pointing out that industrial-ecological research and industrial practice so far has almost exclusively focused on the industrialised North. This may be a consequence of the consolidation of the discipline, language and cultural barriers, different definitions of industrial ecology, and close linkages to industry.

Then, a number of changes were documented in the framework conditions so far forming the basis for the predominant focus on the

North in practice and research within industrial ecology. Among these are the globalisation of environmental problems, the industry causing these problems, and the struggle to come to terms with them; bi- and multilateral actors' catering for private environmental and energy initiatives in the South; the emergence of life-cycle environmental requirements in the North; and the fact that the environmental technology industry in the North seeks new markets.

Furthermore, arguments for increasing the focus on the South within industrial ecology were forwarded. Such a strategy might:

- clarify which problems within industrial ecology that are most urgent to solve in order to solve environmental and developmental problems, and which factors that contribute to the failure of industrial-ecological initiatives;
- examine whether industrial-ecological tools employed in the North are actually robust and universal;
- visualise – and question – possible implicit assumptions forming the basis for industrial ecology;
- following up companies that move their activities to countries in the South with poorly enforced or lacking environmental regulations;
- examine whether it, technically speaking, is easier to launch environmental and energy-technological innovations in the South, because infrastructure is less developed there; and
- show how some countries in the South have come further than many countries the North within some energy- and environmental areas, and that the North therefore may benefit from the South's experiences in these areas.

The article ended by delineating a number of challenges for industrial-ecological research. First, to what extent should different framework conditions in the North and the South be considered in the formulation of environmental requirements to companies in the North? Second, in which geographical areas do we find the major part of environmental damage caused by products sold in the North? Third, what factors influence industrial-ecological innovation capacity and capability? Fourth, What are the conditions for North-South co-operation within industrial-ecological innovation? And last, how can we develop mechanisms for public participation in decision-making processes?

Notes

(1) The article is based on Buen (2000). I would like to thank Kjetil Røine, Helge Brattebø, Andreas Brekke, Øivind Hagen, Edgar Hertwich, Elin Mathiassen, Hilde Opoku, Klaus Ole Vogstad as well as two anonymous reviewers for comments to earlier drafts of this article.

(2) When I make use of the terms "North" and "South", rather than "developed vs. developing countries" or "the first vs. the third world", this is because the two last-mentioned terms are very value-laden and politicised. Another reason is that it is difficult to find a common description of the countries focused upon in this article, namely those squeezed between pressing environmental problems and an even stronger pressure for economic and social development. Thus, one attempt is to state that the bulk of these countries are located in the South. However, this is also very imprecise, and rooms enormous differences both in terms of framework conditions for industrial and other types of activity, and the severity of environmental problems.

(3) The distinction between industrial-ecological *principles* on the one hand, and industrial-ecological *research and practice* on the other, is central in this article. The major part of the article focuses on the latter, therefore the term "industrial-ecological research and practice" sometimes be interchanged with the more general term "industrial ecology". This is not entirely correct, as the general term "industrial ecology" encompasses principles, research as well as practice, but it improves the readability of the text.

(4) Personal communication with John Ehrenfeld, Massachusetts Institute of Technology (MIT).

(5) Ibid.

(6) For more detailed discussions of ecological modernisation, see for example Hajer (1995), Spaargaren (1997), Blowers (1997) Cohen (1997) or Gandy (1999).

(7) Personal communication with Kjetil Røine, Industrial Ecology Programme, NTNU.

(8) Graedel (1996), goes one step further in this direction. He argues that it is no longer meaningful to distinguish between industrial and biological activity: "In a world in which no biological ecosystem is free of human influence and no industrial ecosystem is free of biological influence, it is appropriate to abandon the artificial division between the two frameworks and develop a new synthesis – Earth system ecology – as the logical construct for all of Earth's ecosystems".

(9) It is important to stress that industry in this context should not be interpreted only as economic activity based on the processing of raw materials but as a production system characterised by mass production in order to achieve economies of scale by means technically advanced equipment.

(10) The following is based on personal communication with Helge Brattebø, Industrial Ecology Programme, NTNU.

(11) This would also be true for industrial ecology research and practice in the North, particularly due to the lack of attention given to organisational and institutional aspects of industrial ecology; however, the problem is arguable more severe in the South. The lack of attention given to the South within industrial Ecology can be further illustrated by the fact that the board of the International Society of Industrial Ecology consists exclusively of representatives from Japan, Europe and North America.

(12) Both contributions from authors in the North and authors in the South are included.

(13) Personal communication with Helge Brattebø.

(14) See article on the home page of the *International Journal of Life-Cycle Assessment*: http://www.ecomed.de/journals/lca/village/aboutLCAvillage.htm (accessed 13 February 2001).

(15) A book by the same authors will soon be available, please refer to Erkman and Ramaswamy (forthcoming, 2001).

(16) The University of Kaiserslautern takes part in the UNDP-PRIME co-operation project (see below), as does ICAST. For more information, see http://members.tripod.com/ieprime/home02.htm, http://www.skyinet.net/~ieprime/about.htm, or http://www.iephil.com (all accessed 5 August 2001).

(17) For more information, see http://www.icast.org (Accessed 5 August 2001).

(18) More details on the project can be found at http://www.environment.gov.za/cleaner_production/papers/plen7.html (Accessed 15 July 2001).

(19) For more information about the project, see Quinn (1997), or Pinchot (1995).

(20) Among them are Brazil, China, Colombia, Costa Rica, El Salvador, Guatemala, India, Kenya, Mexico, Morocco, Mozambique, Nicaragua, Tanzania, Thailand, Tunisia, Vietnam, Zimbabwe, and Ethiopia. For more details, see UNEP (2001). The web site http://www.unepie.org also contains a wealth of information as well as the useful Cleaner Production Newsletter.

(21) Please note that I use an extensive definition of technology, which includes the context in which the technical solutions are situated (for further elaboration see below).

(22) The rest of this chapter is partly based on Buen (2001).

(23) I think the term ”framework condition” is more balanced than both ”barrier” on the one hand, which might trigger overly negative associations, and ”driving force” on the other, which perhaps underestimates the barriers for further development.

(24) The term is related to the discussion on environmental capacity (Jänicke 1997) and technological capacity (Fransman 1984, Lorentzen 1988).

(25) This has to some extent been done within the theory on national innovation systems (see for example Edquist 1997) and theories on industrial clusters (Porter 1990, Eikeland *et al.* 1999).

(26) Here it may be fruitful to distinguish between different types of environmental technology. *Avoidance technologies* are technologies that avoid production of environmentally harmful substances or change human activity in ways that minimise environmental damages. *Monitoring and assessment technologies* are used to monitor environmental conditions in a given area, including emissions of environmentally harmful substances. The objective of *control technologies* is to render harmful substances harmless to the environment before they are emitted. *Remediation and restoration technologies* make harmful or hazardous substances harmless after they enter the environment. In this article the term is mostly used in the sense of avoidance technology, and *monitoring and assessment technologies*. For a more detailed discussion on different types of environmental technology, see U.S. White House (1994, 1995).

(27) Chinese authorities have introduced NOx requirements for *new* power stations. The Norwegian company Norsk Hydro has asked Chinese authorities to consider stricter NOx regulations for *existing* power stations as well, as this would perhaps opened the Chinese market for environmentally friendly additives from Norsk Hydro (Stenstadvold 2000).

(28) This is a central principle within industrial ecology, cf. Ch. 0, point 1 above.

(29) For more information on The World Bank's Prototype Carbon Fund, visit its home page: http://www.prototypecarbonfund.org (Accessed 5 August 2001).

(30) The last numbers, from 1998, are welcome exception in this regard.

(31) Arguing that only multinational corporations have varying environmental performance in the South would be too crude. On the contrary, it is worth noting that many export-oriented companies in the South have relations to small- and medium-sized enterprises in the North, rather than larger companies. Often such export-oriented

companies cause major environmental problems, both because they use outdated technology and because they often escape the government's environmental policy measures. At the same time, such companies are often local dynamos for change. Here, the potential should therefore be considerable for solutions in accordance with industrial-ecological principles. Even more so because relatively simple and cheap technology and/or process changes may have environmental as well as economic benefits. The challenge is to arrange for environmentally sensible, but labour intensive activity that also contributes to the build-up of local technological development and competence.

(32) For more details on the debate on the actual existence of "pollution havens" and an environmental "race to the bottom", see for example Hesselberg and Knutsen (1994), Jensen (1996), Engel (1997), as well as Letchumanan and Kodama (2000). This point is also related to the geographical distribution of environmental damage caused by products, see Ch. 0, "Research challenges".

(33) ISO 14000 defines an organisation as a "company, firm, enterprise or institution or part of or combinations of such, incorporated or not, public or private, that have their own functions and administration".

(34) The Principle of Environmentally Viable Application of Best Available Technology (EVABAT) has been left out of ISO 14000, while it is included in the European Management and Auditing Scheme (EMAS). ISO 14000 requires compliance with "applicable" laws and regulations – in practice, local or national regulations, that are not necessarily enforced.

(35) Thanks to Andreas Brekke for having clarified the argument for me.

(36) This question is also touched upon in Ch. 0, "Research challenges".

(37) The reason why I pose this question is not at all that it produces an unambiguous "no". Rather, it can be argued that it is *beneficial* to introduce extended producer responsibility as early as possible, at least for selected goods, so that routines are internalised. The value of labour in India will probably not stay as low in the future as it is

today, and the proportion of poor people will hopefully be reduced correspondingly. Thanks to Kjetil Røine for making me aware of this point.

(38) It is probably not a coincidence that most research on extended producer responsibility and government-industry co-operation has been conducted in Europe (see e.g. Lindhqvist 2000). Here the state has played a central role, through pressuring industry to take action by means of directives and legislation.

(39) For example, the *World Development Report* states that "[a]n effective state is vital for the provision of the goods and services – and the rules and institutions – that allow markets to flourish and people to lead healthier, happier lives. Without it, sustainable development, both economic and social, is impossible. Many said much the same thing fifty years ago, but then they tended to mean that development had to be state-provided. The message of experience since then is rather different: that the state is central to economic and social development, not as a direct provider of growth but as a partner, catalyst, and facilitator." Although some reservations are taken with regard to the role of the state, this is a far more balanced view on the relationship between state and market than the World Bank has had earlier.

(40) See Jänicke (1997) for an in-depth discussion of the possible relationship between corporative societal structure and proactive environmental policy.

(41) China for example has approximately 60,000 micro-hydropower plants and 150,000 wind turbines for household use – both largely based on domestic industries. While China – because of its enormous population – may constitute a major market for many goods and services even though the per capita diffusion of these is low, it is worth mentioning that China is also the largest market in the world for energy-efficient light bulbs.

(42) The discussion of "technological lock-in" is almost entirely based on Tangen, Christiansen and Buen (1998).

(43) Personal communication with John Ehrenfeld (MIT).

(44) Ibid.

(45) This argument is – and has long been – subject to many debates. Some of the strongest criticism has come from actors in the South, who regard it as patronising. The argument has its roots in phase theories within modernisation theory. For example, Rostow (1971) delineated five stages in economic growth: the traditional society, the pre-growth stage, the "take-off" stage (rapid industrialisation), development with technological maturity, and the development of mass consumption. The theory, originally published by Torstein Veblen, on the advantages of being backward is based on the following argument: Underdeveloped countries can learn from pioneer countries, are less restrained by established property relations, technological structures, and capital structures and other kinds of vested interests. These theories also provided the fundament for the argument that the environmental damage from human activities will be minor on a low level of development, increase very much in the stage between a low and a high level of development, and then be reduced on a high level of development. This is known as the environmental Kuznets curve (see for example Stern *et al.* (1996), Ekins (1997), Roberts and Grimes (1997), *Ecological Economics* (May 1998), and Munasinghe (1999)).

(46) Thanks to Klaus Ole Vogstad for making me aware of this possibility.

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