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Towards Industrial Ecology: Sustainable Development as a Concept of Ecological Modernization

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ABSTRACT This paper deals with the key role of ecological modernization in bringing about sustainable development. So far, two strategies of sustainable development have been discussed: sufficiency and efficiency. Sufficiency is preferred by the organized ecology movement (non-governmental organizations (NGOs)), meaning self-limitation of material needs, withdrawal from the free world-market economy and an egalitarian distribution of the remaining scarce resources.

Contrary to that, industry and business have adopted the 'efficiency revolution' as a strategy to allow further economic growth and ecological adaptation of industrial production by improving the environmental performance, i.e. improving the efficient use of material and energy, thus increasing resource productivity in addition to labour and capital productivity.

There are good reasons for both sufficiency and efficiency. Nevertheless, they do have important shortcomings. An additional, third kind of transformational strategy needs to be pursued. In the present name-giving context, one could call it the strategy of 'consistency'. A term with a similar meaning in the current discussion is 'industrial ecology'. Industrial ecology aims at an industrial metabolism that is consistent with nature's metabolism. The transformation of traditional industrial structures, which are often environmentally unadapted to an ecologically modernized consistent industrial metabolism, implies major or basic technological innovations, as being different from incremental efficiency increasing change. Copyright © 2000 John Wiley & Sons, Ltd.

Key words: ecological modernization; industrial ecology; sufficiency; efficiency; consistency

Introduction and summary

This paper deals with core aspects of ecological modernization, and how these have been received in the debate on sustainable development during the Rio de Janeiro process, particularly by two social milieus: one being industry and business; the other representing the red–green current of the ecology movement, which, at the Rio conference in 1992, was part of the group of non-governmental organizations (NGOs).

The NGOs' understanding of sustainable development has been formulated by themselves as an anti-industrial and anti-modernist strategy of 'sufficiency', meaning self-limitation of material needs, combined with 'industrial disarmament', withdrawal from the free world-market economy, and an egalitarian distribution of the remaining scarce resources. Contrary to that, the industry's understanding of sustainable development is the 'efficiency revolution'. Industry and business are looking for a strategy that would allow for further economic growth *and* ecological adaptation of industrial production at the same time. The means for achieving this goal is seen in the introduction of environmental management systems aimed at improving the environmental performance, i.e. improving the efficient use of material and energy, thus increasing resource productivity in addition to labour and capital productivity.

There are good reasons for both sufficiency and efficiency. Nevertheless, I will argue that both strategies do have important shortcomings, so that, even if combined, they will not yet represent a sustainable answer to the ecological challenge. In order to open up a truly sustainable development path, an additional, third kind of transformational strategy needs to be pursued. In the present name-giving context, one can call it the strategy of 'consistency'. A term with a similar meaning in the current discussion is 'industrial ecology' (Socolow *et al*., 1994; Ayres & Ayres, 1996). Industrial ecology aims at

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an industrial metabolism that is consistent with nature's metabolism. The transformation of traditional industrial structures, which are often environmentally unadapted, to an ecologically modernized, consistent industrial metabolism implies major or basic technological innovations, not just incremental efficiency-increasing change and minor modifications of existing product chains.

The content of this contribution can be seen as a piece of policy design. It is of a conceptual nature, i.e. it is not mere theoretical analysis, nor is it a report on empirical research work. It should be stressed, however, that the issues discussed here were not worked out by voluntaristic 'scenario writing', but closely correspond to empirical, practical and historical knowledge.

The concept of sustainable development in the Rio process

The meaning of sustainable development

When using the term sustainable development, reference is made to the meaning this term has taken on in the Rio process and its written documents. The Rio process refers to the ongoing international interaction between new social movements, academia, politics and business that has led to the formulation of environmental policy strategies in the context of the United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro in 1992. The Brundtland report (WCED, 1987) belongs to the most important written documents of the Rio process, as does *Agenda 21* (UNCED, 1992), or specific environment-related contributions such as *Sustainable Netherlands* (Buitenkamp *et al.*, 1992) by the Dutch *Vereniging Mileudefensie* (Friends of the Earth Netherlands), or *Changing Course* by the World Business Council for Sustainable Development (Schmidheiny, 1992a).

However controversial these contributions may be in detail, they basically agree upon the threefold mission any politics of sustainability has to fulfil:

1. to promote further *economic development*, while
2. ensuring *ecological sustainability*, by not exceeding the earth's carrying capacities, and
3. bringing about *social equity*, by creating a better balanced distribution of opportunities to use natural resources and sinks, and giving access to a fair share of the wealth produced.

Sustainable development not only deals with the interdependencies between economy and ecology, but also combines the ecological question with the social question on a global scale. A complete formulation would thus have to read 'sustainable and equitable development'. But the participants in the Rio process tend to differ with regard to their main focus of concern, and economic and ecological goals seem to be more objectively measurable than the goal of equitable distribution. Thus, it is not by chance that the shorter term 'sustainable development' is likely to prevail, and that speakers of less-developed countries have cause for complaint, particularly about a widespread attitude among Europeans who tend to see sustainable development as an exercise in the conservation of nature and in environmental management, while forgetting about equitable distribution and economic growth in less-developed countries.

Polanyi (1944) described 'the great transformation' from traditional to industrial society as a process of disembedding the growing industrial system from its social and natural context. Following this perspective, one can conceive of sustainable development as a concept aimed at re-embedding industrial activities into their social and natural context. There are two re-embedding relationships: one concerning the ecological links of the industrial economy, and one concerning its social links. Accordingly, two types of rules have been postulated in the Rio process: the so-called management rules, concerning the ecologically proper use of resources and sinks, and a set of distributional rules.

Economy's ecological link, and categorical imperatives of use ('management rules')

A number of important principles of modernization, the supposed failure of which had only recently been declared, were reborn in the Rio process. This was especially true of world trade and development, which are now being revitalized in an expanded context of globalizing markets and production structures. One of the most important concerns in the concept of sustainable development is to overcome poverty in less-developed countries by enabling them to catch up through a renewed process of modernization designed to permit environmentally sound growth. Accordingly, Rio's *Agenda 21* (UNCED, 1992) deals not only with the global protection of certain transnationally significant ecosystems, but also with such directly related issues as increasing global prosperity and transferring capital, science and technology.

To define the ecological sustainability of economic development, the Brundtland report set up a number of rules for the use of resources. These 'management rules' have since been accepted as a basis for further work (WCED, 1987, pp. 44–60). The following five rules are among the most important.

- Population development must be in keeping with the carrying capacity and productive forces of the ecosystem.
- Ambient concentrations of pollutants in environmental media and living creatures must not exceed their absorption and regeneration capacity.
- The consumption rate of renewable matter and energy (e.g. water, biomass and, to some extent, soil) must not exceed their given rate of reproduction.
- The consumption rate of exhaustible resources (ecologically sensitive resources such as land or oil, coal and natural gas, but not commonplace materials such as sand and stones) is to be minimized by
  - (a) substituting renewable resources for exhaustible ones;
  - (b) increasing material and energy efficiency; and
  - (c) recycling to the extent that is ecologically reasonable and economically justifiable.
- The development and introduction of ecologically benign, clean resources, technologies and new products is to be intensified.

In the interest of establishing a consistent industrial ecology, the last rule would seem to be the most important as an imperative for innovation and substitution. However, it is given relatively little attention in the Brundtland report, the Rio documents, in contributions by NGOs, and even by business. One of the reasons may well be that substituting ecologically problematic material flows and innovating cleaner products and processes involves a considerable degree of science and research, know-how, capital, legal regulation, effective administration and political stability (Wallace, 1995). Given the economic and technological disparities between north and south, the topic of innovation and substitution is unlikely to receive priority in the north–south dialogue any time soon.

By contrast, the first rule—appropriate population development—is given a great deal of space in the documents. But it is apt to be suppressed in the current discussion in most of the European countries, presumably because the question of whether people are allowed as many offspring as they wish collides with religious traditions and modern ideals of individual liberty and self-actualization. But with the issue of an equitable global distribution of resources, one cannot help but be aware of the challenge the question of population control poses.

The rules listed above are helpful orientations. It should be noticed, however, that they are empirically empty categorical imperatives. One of the great problems of contemporary research on ecosystems is that it is hardly ever able to determine clear, critical, maximal and minimal limits for population sizes and the carrying capacity and regenerative capacity of ecosystems. Attempts to empirically define and measure sustainability have not been successful so far, even if they produce ever more valuable insights into the complexities of ecosystems (Munasinghe & Shearer, 1995). In addition, limits to growth, which no doubt always do exist, are incessantly being extended or restricted, and qualitatively changed by both geogenic and anthropogenic processes.

Economy's social link and categorical imperatives of distribution

The sustainability rules for getting access to and using resources and sinks in a just way are oriented to the principles of equity and the common interest. The rule of distribution says that the equity of resource use is to be guaranteed under both the current world population, primarily by overcoming poverty, and future generations. The distributional equity it proposes is thus intergenerational and intragenerational: 'social equity between generations and within each generation . . . Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987, pp. 32, 43). It gives overriding priority to 'the essential needs of the world's poor' (WCED, 1987, p. 43).

This noble rule, too, is blemished by being a mere categorical imperative. As such, it is understandable as a normative construct, but it is not tied to empirical premises, not yet linked to specific historical conditions. As far as the economics of welfare and distribution go, and from a philosophical viewpoint of equity, one immediately recognizes the endless conflicts over values and measurements that will inevitably ensue from the application of such a rule. This is not to argue against the rule but to point out that it does not apply to just anything, and that the different and even contradictory notions of justice linked to it need to be clarified (Bryant, 1995; Huber, 1995).

The role of social democrats in the Brundtland commission and the role of NGOs in authoring the concept of sustainable development stands out when it comes to the question of the equitable distribution of benefits. When in doubt, they tend to understand equity as equality, and the call is raised for 'equal access to the resource base' and 'equal distribution' (WCED, 1987, pp. 29, 32). It goes without saying that this quasi-socialist definition of sustainable development will remain controversial.

A clearer notion of the controversy over distribution emerges in a study called *Sustainable Netherlands* by Friends of the Earth Netherlands (Brakel & Buitenkamp, 1992; Buitenkamp *et al.*, 1992). The study became a model for similar approaches in other European countries, e.g. the report on *Zukunftsfähiges Deutschland* (Futurity for Germany) by the Institute for Climate, Environment and Energy in Wuppertal (Loske & Bleischwitz, 1995), commissioned by the NGOs B.U.N.D., a large conservationist organization, and MISEREOR, a development aid charity of the Catholic Church.

Without wishing to oversimplify these studies, one may say that their approach consists essentially in adding up the resources and sinks (environmental media) available in the foreseeable future and dividing them by the number of living human beings. One thus arrives at per capita quotas or, in other words, contingents of resources and emissions. Accordingly, the Dutch, for example, would be entitled to 80% less aluminum, 45% less agricultural land, 40% less water and 60% less CO_2 emission than they have today.

But for whom is this calculation equitable? First, the volumes to be distributed do not usually represent constants, which is always a consideration in distributional conflicts. Resources are scarcer at some points in time than at others. Very few resources, then, can be distributed homogeneously and purposefully over space and time. Dutch agricultural land cannot be transferred to Bangladesh. Besides, the Bangladeshi could not pay for it, and the agricultural capital accumulated by the Dutch would have to be expropriated. Alternatively, ought the Dutch to give away 45% of their agricultural yield to the Bangladeshi or take 45% of the Netherlands' agricultural land out of production? Or should perhaps the 16 million inhabitants of the Netherlands have their country take in 7 million Bangladeshi? Obviously, the programme of *Sustainable Netherlands* does not give due consideration to certain ecological and geogenic facts of life. Presumably, an attempt to put it into practice would itself not be very sustainable.

A radically egalitarian version of need equity is underlying the programme, whereas principles of achievement-based equity and legal and legitimate possession are completely negated. An absolutely equal per capita quota of resource intensity is used as the index for need equity. But certain circumstances are tabooed. In various respects, for example, it is both equitable and inequitable to bring few or many children—hence, resource-intensive needs—into the world. However, given the development of the welfare state and the international discussion on basic needs, one would expect a different, more appropriate approach to prevail. Need equity would not then be tainted by crude resource communism. Instead, it would be satisfied by the fact that all people on earth would be given a certain minimum share of resources that would have to be large enough to guarantee an existence worthy of human beings, but not more, so as to avoid violating achievement-based equity and the social policy principle of less eligibility.

In this context, achievement-based equity is to be taken into consideration primarily in terms of resource and sink efficiency. The one who understands how to exploit resources more efficiently and reduce the specific environmental burdens of using them should be entitled to take in the full benefits. Indices for this are the consumption of resources and the demands made on environmental media per product unit or unit of service (as in the material intensity per unit of service (MIPS) proposed by Schmidt-Bleek, 1994). In each case, the *absolute* resource *intensity* is to be measured against the *relative* resource *intensity* (per capita), as these are to be measured against the resource *efficiency* (per economic unit).

However controversial it may be, achievement-based equity also exists as acquired purchasing power. Acknowledging it as a fact, if not accepting it outright, brings up the issue of the equity of possession. Whoever entertains a concept of resource distribution that requires the expropriation of existing property is playing with the fire of renewed cold or hot wars. A non-belligerent policy, even one that has good reason to aim for changing ownership structures, cannot help but begin with the status quo.

Solow calculated that about 88% of the advance in industrial productivity (and, hence, growth in prosperity) stem from the productive forces of science and technology—i.e. from the modernization of technology, skills and organization (in short, from the development of productive capacities)—and that only 12% stem from capital growth, which in certain nations in certain periods may include gains from colonialist exploitation (Solow, 1957, pp. 316–320). Capital growth has thus always been of little significance in this regard. The lead enjoyed by the advanced industrialized countries is explained primarily by the cumulative build-up of productive *capacity* created by many generations in the course of great sacrifice, and times of social conflict and class struggle. Recognition of productive capacities that have been built up over many generations is as much part of intergenerational equity as the opportunity for future generations to achieve something similar.

The distribution of resources *is* unequal in favour of the rich. But neither a unilateral renunciation by the rich nor a gratuitous transfer from the rich to the poor can improve the structural predicament of the poor. Improvement comes about only by structural change and capacity-building, because only productive capacities can mobilize capital, labour, and natural resources in effective and efficient ways.

Earth policy and global politics

The discussion on sustainable development has helped to identify fields of 'earth policy' (Weizsäcker, 1989); that is, areas of environmental policy with transnational economic and thus political impacts. By virtue of their resulting significance in world politics and global economic policy, certain environmental policies require internationally agreed procedures for the scientific study of problems, as well as for the formulation of problem-solving policy and its technical, organizational, and economic implementation.

These fields of earth policy issues and action include

- climate and air-quality control;
- forests in general and tropical rain forests in specific;
- oceans and thermal cycles;
- soil erosion and desertification;
- biodiversity of earth's flora and fauna; and
- the genetic patrimony of the human race.

Treating these problems and fields of action resurrects old questions of national sovereignty and colonialism. Only occasionally do political borders coincide with the boundaries of natural ecosystems. Air-mass currents, rivers and oceans, forests and deserts, radiation, and weather and climate follow their own laws, the context of which extends, in principle, from the regional to the global. Superimposing political maps onto ecological ones, one finds complicated import–export flows of environmental freight and complex vectors of interference.

Protecting the environment in one country necessitates comparable and complementary efforts in others. It makes little sense, for example, to stop coal burning in Europe with its 500 million inhabitants, if China with its 1.7 billion people will increase coal consumption tenfold in the years to come. Ascertaining the marginal utility of environmental protection costs is meaningful only on the basis of international comparison. Countries and regions of the world today are interdependent ecologically, much as they are economically, technologically, etc. Clearly, the ecological interdependencies contradict the purported independence postulated by the principle of national sovereignty. At this point, the principle of non-interference or non-intervention becomes partially absurd, and yet remains indispensable in the interest of orderly procedures (Litfin, 1998).

Because countries differ in relative weight and in their degree of dependency on others, charges of neo-colonialism were revived in the Rio process. The suspicion is that rich countries, hoping to perpetuate their advantages and prosperity, will seek to misuse the ecological issue to saddle poorer countries with exorbitant environmental protection measures, while erecting protectionist barriers against new industrial countries' products that they claim represent 'ecodumping.' Sustainable development is playing an ever more important role in the World Trade Organization (WTO), known previously as the General Agreement on Tariffs and Trade (GATT).

Yet, as a matter of fact, self-inflicted economic harm has ensued from lack of environmental protection. The costs of environmental damage always come to several times the costs of environmental protection. As shown by the problems associated with the export of hazardous waste, the affront represented by inferior or completely non-existent environmental and health protection represents also a kind of neo-colonialism. Moreover, every long-term environmental impact, whether it is passed from the wealthier to the poorer, as can occur between any two parties, is a *de facto* physical intervention of a colonialist nature when it involves uncompensated externalization of environmental damages (as is the case with the policy of high smokestacks).

A neo-colonialist reproach of a different sort is levelled at the factual access of the prosperous and monied to the resources and land of the less wealthy. Producing the cotton consumed in Germany today, for example, requires tracts of land about twice the area of the Federal Republic (Griesshammer, 1993, p. 50). Our 'ecological footprints' are reaching far beyond our immediate surroundings (Rees & Wackernagel, 1994). Of course, the same is true for what used to be called colonial goods and southern commodities such as rubber, cane sugar, coffee, cocoa, peanuts, bananas, lemons, oranges and, today, soybeans, all of which are all but impossible to raise in middle and north-western European countries. These export goods, as any others, are interpreted by some radicals as naked confiscation of resources or outright occupation of land.

Such charges of neo-colonialism usually spring either from Marxist theories of exploitation (unequal exchange) or from the purist nationalist ideology of self-sufficiency. But there is nothing to be said against 'ecological footprints', international division of labour and world trade, as long as the sum of all 'footprints' does not exceed the earth's carrying capacity, and as long as the price paid for the products covers all costs, including the prices of primary materials, the work force and 'rent' for the land used, at levels that allow for the reproduction of these factors. Nothing is seen to be wrong, for example, if agricultural products are imported in Europe from the United States, for then it is regarded as an example of a beneficial mutual division of labour in the framework of a free world order.

The real problem is that, for example—for reasons of ruinous price competition owing to oversupply in an attempt to earn hard foreign currency in order to pay back foreign debt or import foreign goods—prices paid for Third World goods at the world-markets do not always fully contain these reproductive costs; that is, the costs of the land, the work force and the environment remain to a certain extent externalized instead of being fully internalized. But it is hard to say to what extent this is a home-made problem of the exporters, or irresponsible negligence on the part of the importers.

Transformational strategies for a sustainable development

The recommendations in UN documents and other literature on sustainable development (Barbier, 1987; Harborth, 1991; Lélé, 1991; Amelung, 1992; Dietz *et al.*, 1992; Kommission der Europäische Gemeinschaften, 1992; Jansson *et al.*, 1994; McKenzie-Mohr & Marien, 1994) can be grouped into three different strategies for achieving sustainability:

- *sufficiency* with regard to population growth, as well as the level of affluence, life-style and consumption patterns;
- *efficiency* with regard to production processes and the use of products; and
- ecological *consistency* of production processes and products in order to achieve compatibility between the industrial and natural metabolism.

The main strategy of NGOs: sufficiency

The NGOs—associations for the conservation of nature, grass-roots citizen's initiatives, human rights associations, Third World action groups, religious charities and church organizations—continue to play an influential role in the Rio process. Among the active and important NGOs are the International Union for the Conservation of Nature and Natural Resources (IUCN), with its 1980 World Conservation Strategy, the World Wide Fund for Nature (WWF), the Global Tomorrow Coalition (GTC), Greenpeace, Robin Wood, Friends of the Earth, or *Brot für die Welt* (Bread for the World).

Their criticism of the industrial society traditionally includes a broad range of issues, from the utilitarian world-view over capitalist free-market economy to science and technology. But they tend to focus on the evils of a life too good for being pure and sane. High levels of affluence are seen by them as worshipping the golden calf. Instead, they are out for being worshippers of a simple life pleasing to God and nature. For reasons of sustainability, as well as solidarity, one shall stop running the endless race for positional goods, and turn to becoming caring and sharing instead.

The concept of sufficiency again raises the question with which two Swedish futurologists shaped the debate about growth in the early 1970s: how much is enough? The answer was, and still is, that one cannot know exactly the limits of carrying capacities, but that moderation, thus applying the precautionary principle, definitely seems called for because things cannot continue the way they are now in the long run. The word at that time was not 'sufficiency' but 'self-limitation', be it as voluntary simplicity ('living poor with style'), or be it as authoritarian management in an ecodictatorship. Whether voluntarily or by force, establishing sufficiency means doing without.

Sufficiency as a strategy of self-limitation within the boundaries of low-level production and consumption is open to the same criticism today as the one aimed at concepts of zero growth or a shrinking of the economy a quarter of a century ago. It is unrealistic because of the inexorable worldwide advance of utilitarian thinking and the pursuit of happiness as the greatest possible material benefit for the greatest possible number of people. It is undesired in that imposing it by force would destroy due process and civil rights and liberties. And it is both ineffective and defective because freezing current or even lower rates of consumption under present, ecologically inappropriate conditions of industrialization and a world population of 6 billion—before long, 10–12 billion—would sooner or later result in ecological catastrophe. If one earnestly wanted to pursue a strategy based purely on sufficiency, it would imply scaling world population back to pre-industrial proportions. How should that happen? Could friends of nature become enemies of humans? Arguing for lower levels of consumption in the name of social equity, while neglecting the problem of high levels of population, remains ambivalent.

The call for sufficiency, however, can claim the irrefutable truth that there really is no such thing as insatiability and that every real system is still finite within its niche in space and time. Of course, the limits of satiation have their own dynamics. It remains to be seen whether there actually are 'new models of wealth' (Loske & Bleischwitz, 1995). But abiding social debate over the issue of ecologically appropriate life-styles is essential—primarily, however, for creating a sustainable value base and cultural conditions of environmental action, and to a much lesser degree, for directly controlling environmental impacts.

Environmental management

Industry and business found themselves accused of being the main polluters since the 1960s. Therefore, they took a defensive attitude for a long time. The situation began to change in the mid-1980s, when the phase of 'resistant adaptation 1970–1985' (Fischer & Schot, 1993) came to an end in favour of a more active and even proactive attitude of business towards environmental protection. Within a short period of 5–10 years environmental management systems (EMS) were developed, and green business networks began to form and grow in size and numbers.

Among these green business networks are, for example, in Germany, the *Bundesdeutscher Arbeitskreis für Umweltbewußtes Management* (BAUM, Federal Working Group on Environmental Management; the acronym BAUM stands for 'tree'), established in 1984, and *Förderkreis Umweltfuture* (which could be translated as 'Futurity Support Group for Environmental Management'). The conceptualization and implementation of environmental management tools through business, academia and politics was flourishing (Steger, 1988; Dyllick, 1989, 1990; Kirchgeorg, 1991; Meffert & Kirchgeorg, 1992; Wicke *et al.*, 1992).

Soon after the green entrepreneurial pioneers, who came from rather medium-sized firms, big multinational corporations took the lead (Smart, 1992). This can be seen in the formation of green business networks since the beginning of the 1990s, such as the World Business Council for Sustainable Development, founded in 1992 by Stefan Schmidheiny, a Swiss businessman, at the initiative of Maurice Strong, who was then secretary general of the UNCED (Schmidheiny, 1992b). Other examples are the international Responsible Care initiative of the chemical industry, the European Partners for the Environment, the Social Venture Network, the International Network for Environmental Management (INEM), or the Global Environmental Management Initiative (GEMI). There are also bridging networks with a mixed membership from business, academia, NGOs and government, for example, the European Round Table on Clean Technologies, and the Greening of Industry Network.

EMS are being developed in all of the industrially advanced countries, and increasingly in new industrial countries too. Despite national differences in law and culture, the environmental management activities in Europe and America had a stimulating influence upon each other, and have developed similarly during the same time. Compared with this, it looks as if Japan and other Asian countries were following routes of their own. Japanese corporations, for example, tend to be reluctant with regard to environmental disclosures. There seems to be little environmental reporting and stakeholder communication (IISD, 1993). Japan seems to be more of a 'corporation-centered society' or 'company-centered society' (Shinoda, 1993; Matsuba, 1996) than American or European countries are. Thus, industry in Japan may be confronted less with political and civil society counterpowers. Even if a number of environmental policy tools and environmental management measures from the Japanese industry are known, it is not easy for a foreigner to obtain a comprehensive impression of current EMS practices in Japanese firms.

Today's leading companies in environmental management are multinational corporations or medium-sized companies with worldwide activities. In the course of the 1990s, it has turned out that they tend to adopt the highest environmental standards and the best available technology wherever possible, rather than to choose the lowest possible standards. There was evidence for the orientation towards higher-level environmental performance for some years already, for example, from the international pulp and paper industry (Lundan, 1995).

The original fear was that companies would seek to avoid tough environmental regulations by relocating production to locales with lower standards. The low-level expectation became known as the 'pollution haven' hypothesis. But a certain need for internal corporation-wide harmonization of rules and procedures, a certain necessity to avoid image-damaging and costly environmental risks, and to harmonize because of internationally integrated vertical and horizontal production chains represent incentives for the higher-level orientation. High-performing companies are likely to display high levels of ecological performance at the same time, and pioneers and early adopters of EMS are likely to be found among the market leaders and high performers in general (Azzone & Manzini, 1994; Elkington, 1994; Porter & Van der Linde, 1995). In addition to these complex but apparently existing competitive advantages (Bertolini, 1995), there is a negative incentive to avoid certain incalculabilities on the part of national and local environmental bureaucracies by 'outperforming' them proactively, even if principles of negotiated regulation and co-evolution of industry and regulators are nowadays being taken into consideration more than before. It is still government, not industry, who is setting the standards, but internationally active industries tend to disseminate the highest of the differing national standards (Angel & Huber, 1996).

The factors and motives driving companies to adopt environmental management practices are well investigated (FUUF, 1991; Jänicke & Weidner, 1995):

- laws, ordinances, targets set by local authorities, in 74% of cases;
- image, external stakeholder pressure, in 43% of cases;
- direct costs, cost control, alternative cost avoidance, in 40% of cases;
- securing market shares, strategic market position, in 13% of cases;
- general prevention of risks, in 10% of cases;
- doing what others do, in 10% of cases.

Generalizing these findings, one can distinguish three types of reasons for a firm to become greener.

1. *Legal reasons*. Compliance with the law and administrative regulations, on the basis of loyalty to the rule of law.
2. *Economic reasons*. Preventive cost reduction, cost competitiveness, and—becoming more important—the context of finance (Schmidheiny & Zorraquin, 1996). Bankers and insurers, for example, are demanding risk and pollution prevention for fear of liability assumptions.
3. *Social reasons*. Image, stakeholder demand, work force, consumers, etc.—in short, the necessities to be a fully integrated member of society and the international community. This reason should not be misconstrued as an idealistic need, but understood as an absolute necessity. A company's widespread acceptance and good reputation are decisive factors in areas such as attracting good personnel, getting on with authorities, banks and insurers, obtaining swift service from suppliers, and winning as many customers as possible to attain the greatest turnover possible.

The voluntary approach to environmental management continues to have an involuntary background of public pressure and national, as well as international, regulation. The need to comply with the laws still forms the backbone of any EMS. But as things evolve, more and more EMS go far beyond compliance. Even if this is not the place for a full discussion, the main elements of today's EMS shall be listed here. They can be grouped into three categories (see Table 1).

Table 1. Main elements of environmental management systems

A. Environmental information (monitoring, analysis, reporting, communication)	B. Environmental organization and personnel development	C. Environmental strategic and operational management
Environmental statistics, performance measurement, benchmarking Environmental accountability Environmental auditing and risk assessment Life-cycle assessment and eco-balances Environmental issues management, reporting and communication (shareholders, stakeholders, personnel, suppliers, customers)	Environmental officers, environmental committees Green responsibilities from the board to the shop floor, top-down along the command line Environmental concern being an integrated part of every activity Environmental training and education Special campaigning (e.g. energy saving at the office) Green awarding schemes	Vision statement, mission statement (corporate identity, corporate culture) Green agenda setting, action planning, green targeting Compliance with legal regulations (auditing etc.) Implementing best available technology, Continual Improvement Process, Total Quality Management (ISO 14.000 ff, BS 7750/EU-EMAS) Green purchasing policy, supply-chain management Green sales policy, approaching the green-appreciative customer Product stewardship In-site and inter-site recycling, industrial symbiosis projects, closed-loop procedures Product design for environment Introduction of cleaner products and processes Substitution of environmentally benign materials for harmful substances and material flows

It can be seen from this list how things start by creating a knowledge base and finding general goal orientations, and, via organization and personnel development, finally lead into specialized fields of technology. This is interpreted by some deep-green critics, misleadingly so, as a technocratic tendency. Ecology is the science of the metabolism of populations within their living space. Today's 'ecological question' concerns the metabolism of industrial civilization within Earth's geo- and biosphere: the industrial metabolism (Ayres, 1993; Ayres & Simonis, 1994), which is realized through work and technology. That is why the metabolic relations need to be analysed in terms of science and engineering. The social and human sciences come in as soon as the question is about how and why metabolism is caused and controlled by economic, legal, institutional, political and cultural factors. These factors necessarily play an important and decisive role in any strategy of change, but the final change of the industrial metabolism is always put into practice through changes in work and technology. Even a pure sufficiency approach to sustainability has unavoidably final implications for work and technology, be it the simple result of making do with less of everything by decreasing, reducing and slowing down any productive and consumptive activities.

So it is basically not wrong to characterize even general sustainability strategies that include important economic, institutional, political and cultural elements by their technical implications. For example, it has become common knowledge that so-called end-of-pipe measures or downstream approaches to environmental protection are of limited value, and come with unintended side-effects. There is a preference now to look for process-integrated solutions wherever possible (Hirschhorn *et al.*, 1993). Accordingly, the environmental policy discussion aimed at prevention revolves around approaches with explicit technological features, such as clean technology (Kemp & Soete, 1992; Jackson, 1993; Kemp, 1993), eco-efficiency (Schmidheiny, 1992a,b; Weizsäcker *et al.*, 1995), material flow and chain management (Enquete-Kommission, 1994), economics of reproduction (Hofmeister, 1998), management of industrial metabolism (Ayres, 1993, 1996; Ayres & Simonis, 1994; Ayres & Ayres, 1996), as well as design for environment (Kreibich *et al.*, 1991; Stahel, 1991, 1992; Paton, 1994), bionics (Rechenberg, 1973; Gleich, 1998), eco-effectiveness (Braungart & McDonough, 1999), constructive technology assessment (Rip *et al.*, 1995), ecological modernization (Huber, 1995; Mol, 1995; Spaargaren, 1997), and industrial ecology (Graedel, 1994; Socolow *et al.*, 1994; Ayres & Ayres, 1996; a *Journal of Industrial Ecology* is published by MIT Press since 1997), whereby all of the approaches listed in the second group of the list have a focus on ecological consistency of industrial metabolism rather than 'dematerializing'.

Concepts such as these cannot be prescribed by government in the same way as emission standards, and certain end-of-pipe measures can be forced upon the actors. Therefore, the role of government and administration is shifting from interventionist command-and-control approaches to frame-setting, communicating and negotiating, and applying economic instead of bureaucratic instruments (Opschoor & Vos 1989; Prittwitz, 1993; Georg, 1994; OECD, 1994). Correspondingly, attention and expectations in environmental action are shifting from government to industrial corporate actors and their potential for product and process innovation based on capital- and knowledge-mobilizing capacities.

The current strategy of business: the efficiency revolution

For the time being, industry does not seem to be fully aware yet of the ecological transformation process it is an active and ever more important part of. The innovative capacities and tools of the EMS tend to be understood and used in a rather narrow sense, for example, in the sense of improving the input–output relations of *existing* production processes and product chains. Industry still displays a more or less disregarding attitude to new processes and products such as renewable resources and renewable energy. There is certainly some research and development work on alternatives that can be shown at press conferences, but there is no big investment in fundamentally new development paths.

This is understandable in so far as vested interests are touched—be it the interests of the managers, the shareholders, or the work force. For example, companies in the German energy sector have learned how to make a living by mining and burning brown coal. They have not learnt how to develop and utilize hydro-solar energy. Thus, the management, the researchers and technical staff, and the work force of these companies in general perceive the ecologically better alternative as a threat to their own existence—and in an attempt to find ways out of the ecologically untenable position, they become protagonists of the efficiency 'revolution' by heavily investing in still more efficient brown-coal-fuelled power plants.

The strategy of efficiency is aimed at applying principles of input–output rationalization even more systematically than has hitherto been the case. Desired production output is expected to be achieved with the least possible use of material and energy. This means improving the input–output ratio—that is, increasing the efficiency of material and energy use—thereby boosting *specific* resource productivity. The rise in the productivity of labour and capital is complemented by the rise in resource productivity.

In the context of the sustainability concept, the purpose of increasing efficiency is to achieve a relative, and perhaps even an absolute minimization of resource consumption and burden on the sinks (the environmental media air, water and soil). The means to do so lie in advances in operative technology (e.g. more efficient engines and other combustion equipment), recycling and cascade reprocessing of material in an economy of recycling. Materials are supposed to be used over and over again for as long as possible before they are lost for human purposes as waste in the natural cycle. Concepts relating to the durability of certain utility goods, such as clothes, furniture, electrical appliances and cars head in the same direction. (To the extent that the influence of fashions and rhythms of technological innovation are excluded from the equation, the concept of durability belongs more to the strategy of sufficiency.)

The efficiency strategy is the most applicable and appealing in the prevailing economic system. That is why newly converted industrialists are apt to go so far as to confound sustainability and efficiency. In reality, efficiency can only be intermediate between sufficiency and consistency. Ecologically inappropriate or incompatible material flows ultimately subject efficiency to the same limitations as the strategy of sufficiency. But a high level of material and energy efficiency is, of course, suited to expanding the latitude of sufficiency.

In the end, however, a substantial increase in efficiency may still be pretty insubstantial. For example, if both the fuel efficiency of cars and the mileage travelled by the vehicle pool are doubled, the ecological effect of economizing is nil. More generally speaking, halving the consumption rate of exhaustible resources means doubling the amount of those resources. That is a great deal, but in effect, too little. Things look better for renewable resources, where it is possible to approximate the ongoing recreation of production volume according to the economic logic of living on the yield, not on the capital.

A joint strategy for government, business and research: consistent metabolism in an industrial ecology

If, on the one hand, in following the sufficiency strategy, it was possible to reduce consumption by half—just to give a model calculation—the available environmental space would double. Translated into a time perspective, the breakdown limits to growth (in the sense of the Meadows modellings) would perhaps be reached in 100 years instead of 50 years. If, on the other hand, in following the efficiency strategy, resource productivity was increased by a factor of four, the time perspective would be 200 years.

One can certainly combine both strategies. Many NGO activists openly advocate such a combination, which is even seen by some as the 'yin and yang of sustainability' (Schmidt-Bleek, 1994). Contrarily, industrial worshippers of the efficiency revolution do not want to relate to sufficiency ideas aimed at limiting needs and consumption. In both cases, however, results are not satisfying. Even in combination, both cases would add up to 300–400 years—which is certainly six to eight times better than the 50 years for a business-as-usual scenario, but still not enough for being sustainable in a true long-term historical perspective. Bolder assumptions, for example, shrinking the affluence to a mere fourth of its present level, and increasing efficiency tenfold within the next 100 years, do not fundamentally change the message of the model calculation.

A basic and simple truth of ecology is that populations cause environmental impact, large populations major impact, and large industrial populations major industrial impact. An earth population of billions of people cannot prevent itself from operating on giga and tera levels of volumes. That is why a further transformational strategy for sustainable development going beyond sufficiency and efficiency needs to be adopted, a strategy of *qualitative* change of the industrial metabolism by modernizing the basic structures of technology and products, allowing for a permanent turnover of material flows on a large scale and in large volumes. This is what I previously referred to as the strategy of *consistency* (Huber, 1995).

Consistency refers to the nature of matter. Figuratively speaking, consistency means compatibility, coherence among things, correspondence among related aspects. Applied to the ecological issue, it means the environmentally compatible nature of industrial material flows and energy use. It means that anthropogenic and geogenic material flows symbiotically and synergistically reinforce each other, or that they do not interfere with each other. Consistent material flows are, therefore, ones that are either carried on with little interference in their own closed technological cycle, or ones that are so consonant with the metabolic processes of their natural setting that they fit in with relatively little problem, even when large volumes are involved.

There is a temptation to ask for practical examples of ecological consistency (not natural ones such as the anabolism of biomasses through photosynthesis and their catabolism through bacteria). In principle, one should not succumb to trying to give such illustrations, because technological forecasting for longer periods than 5–10 years has always been difficult and risky, if not impossible. Who around the year 1900 could really have predicted what technology around 1950 would look like and what it has evolved into since then?

Nevertheless, one could hint, for example, at the principles of ecologically appropriate farming. Every percentage point of growth of traditional industrial agriculture with its intensive use of heavy machinery, agrochemicals and irrigation, goes hand in hand with a corresponding increase in environmental damage. Ecologically appropriate farming, instead, maintains and improves the soil and water, thereby perpetually reproducing, and perhaps even increasing, the yield of biomass. So every percentage point of economic growth is welcome, because it means maintenance and growth of biodiversity and ecological stability at the same time. Under conditions of consistency, anthropogenic environmental impacts do not inevitably lead to environmental degradation, but make a lasting contribution to maintaining or enlarging ecosystems instead. In principle, the task of producing consistent new material flows is much greater and far more profound than that of minimizing traditional industrial material flows.

Another hint one could give, for example, are fuel cells and/or hydro-solar energy. The biggest ecological problems of today stem from the use of fossil fuels in 'hot' burning processes. Relatively 'cold' burning processes, such as in fuel cells, have much less environmental impact, and burning hydrogen instead of fossil fuels would practically lead to 'zero bad emissions'. If, in addition, the hydrogen came from solar sources, the total environmental impact would be very low, and thus—though it is certainly not a perpetuum mobile—would allow for permanent production activities on a very large scale, for example material recycling, because hydro-solar energy is material intensive. If the energy base is clean, and if the materials used are pure and of high quality (stoneware, concrete, metals, glass), a 'circular economy' would not be much of a problem. With regard to fibres and long-chain molecules (plastics, textiles, paper, wood), a similar statement with certain restrictions owing to the downgrading of the fibres and chains can be made. Limits to closed-loop procedures on a large scale are imposed by economics rather than physics (Ayres, 1996).

Further examples would certainly include biotechnological production processes instead of traditional physico-mechanical processes in the chemical industry (OECD, 1998). The latter operate at high pressures and temperatures that are dangerous and often toxic, and resource productivity is rather low. Biotechnological production tends to be 'soft' on a high level of both effectiveness and efficiency. This is all the more true if the micro-organismic helpers are genetically modified (GM). GM enzymes, bacteria and similar 'bio-work force' often do 10–100 times better than natural ones. Genetic engineering, as much as everything in evolution, may open up new risk potentials. Thus, it must certainly be considered in a critical and selective way. An important task, seen from today's viewpoint, will be to maintain diversity in seeds and semen. The manyfold environmental advantages of GM biotechnology, however, are so obvious that it will undoubtedly have an important role in the process of ecological modernization. Today, the followers of organic farming are fierce fighters against GM biotechnology. But in a generation's time or so, both sides may possibly have merged into an environmentally benign synthesis.

The strategy of consistency is fully in keeping with the objectives and principles of *integrated* environmental problem solutions (as opposed to end-of-pipe, or downstream, measures) and with all of the preventive EMS strategies of technological innovation listed above. Whereas the sufficiency version of sustainable development is a programme for the *conservation* of nature, and the efficiency version is a programme for the *improvement* of *existing* technologies and infrastructures in order to economize on natural resources and sinks, the consistency version of sustainable development is a programme for *innovation* of *new* technologies, products, and material flows in order to change the *qualities* of the industrial metabolism, thus rendering possible a true industrial ecology.

The notion of industrial ecology is close to the concept of consistency. Unfortunately, industrial ecology is often understood in a rather narrow sense as 'redesigning industrial processes so they mimic natural ecologies where there is no waste because all outputs become inputs for something else' (*Business and the Environment*, 1996, pp. 2–5). Hence, projects such as the 'Zero Emissions Research Initiative' of the United Nations University aimed at 100% recovery of the carbon dioxide emitted during the brewing of beer. The idea is that of an inter-site industrial symbiosis where waste streams from brewing, aquaculture, fish processing, greenhouses and algae production will feed on each other.

Industrial symbiosis projects like this one can certainly be useful and contribute to a better adapted industrial ecology. But the idea is not as new as the word is. Known long before as 'combined production' (in German *Verbundproduktion*), it has a certain tradition in centrally planned economy in general, and in the chemical industry in particular. There were certainly economic and ecological benefits to be experienced, but also evidence for undesired inflexibilities or lock-ins (e.g. difficulties to do away with the chlorine chemistry), because once such a structure has been installed, it is difficult to change one element without severe repercussions upon the others.

If it is possible, in special cases, to mimic nature, this may represent a valuable contribution. But usually we are dealing with technical artifacts non-existent in the non-civilized realms of nature. One should let oneself be inspired by nature's metabolism (e.g. in the sense of bio-evolutionism, or industrial symbiosis of hitherto separate material flows, as in the Kalundborg case),[1] but humankind will probably not be able to literally mimic nature. A similar comment could be made on the idea of zero emissions. Even if we agree upon keeping emission levels as low as necessary so as not to violate the earth's carrying capacity, the substantial question remains that of *what kind* of emissions we are dealing with. The environmental space for emissions of oxygen and hydrogen is of a much higher order of magnitude than that of gaseous carbons and nitrogen.

That is also to say that there still *are* limits to growth, and a strategy of consistency should not lead one to expect a boundless land of milk and honey any more than the other strategies do. The point is to avoid setting arbitrary and, hence, probably both tyrannical and incorrect ecological limits, and let them instead emerge from a process of innovation and development that takes full advantage of modern society's creative and productive capacities.

Introducing ecologically better adapted new technology means to develop 'basic innovations', in the sense of Schumpeter, which is nowadays sometimes called 'system innovations'. Bringing them about represents a complex enterprise, going far beyond the task of special process improvements, or single product innovations. Even very large multinational corporations do not have the size and the capacities to meet the challenges of basic system innovations by themselves alone. What is needed, and what has always been the case in the history of complex technological innovations, is a systematic, broad and long-term cooperation between government, research, industry and finance. This cooperation must be promoted on an international level as much as possible.

Complex innovations of the 'basic' or 'system' type come with both pleasant and unpleasant implications. They represent major structural change, and this means processes of 'creative destruction' (Schumpeter). There are winners and losers, and, therefore, social and political conflicts. New generation knowledge, know-how and skills imply a devaluation of older generation knowledge, know-how and skills. New capital stocks have to be built up, as old ones will have to diminish and dissolve. New sites and regions may see chances, while old ones face the dwindling of theirs. Thus, a programme of ecological consistency of the industrial metabolism is not only a call for the innovative productive capacities of industry and the means-mobilizing capacities of finance, or for the inventiveness of research, construction and design, but is concurrently as much a call for social support and political leadership.

The strategies of sufficiency, efficiency and consistency can be combined, although the degrees of combinatorial freedom are less arbitrary than one might think. The best overall strategy will be the one that places priority on long-term consistency and utilizes mid-term efficiency as much as possible, while fully acknowledging that certain limitations, thus sufficiency, must finally be respected.

Notes

1. In Kalundborg, Denmark, four big companies and a number of small businesses utilize each other's residual products in a network on the basis of bilateral contracts with freely negotiated prices—the Asnaes power station, Gyproc, a plasterboard producer, Statoil refinery, Novo Nordisk, a pharmaceutical and biotechnological group, and greenhouses and fish farms. The residual products exchanged are waste water and cooling water, steam, heat, gas, sulphur, gypsum and others.

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