Editorial: on the strategy of industrial ecology

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Abstract: If the engineering and natural science aspects of industrial ecology theory are to influence decision-making and a change toward sustainable development in practice, a bridge between industrial ecology and management, business studies and the study of organisations must be established. Continuing a recent debate in industrial ecology literature this editorial elaborates on this challenge to move the study of the physical flows of materials and energy toward the human dimension affecting and affected by these flows. The six articles in this issue of *Progress in Industrial Ecology* are reflected upon the perspective to bridge industrial ecology to business and management studies.

Keywords: engineering; natural science; industrial ecology; management studies; business strategy; sustainable development.

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1 Introduction

Fragmentation is a common feature of modern science and the culture of modernity. The pressure to produce ever more specific and detailed results pushes the researcher to define and narrow down the aims and scope of the work. Simultaneously, there exists such a large number of scientific journals nowadays that it is very difficult to follow journals or articles that are not directly related to one's own discipline. This tendency of fragmentation is also visible within the research field of sustainable development. The amount of new tools, instruments, indicators, and concepts seems to be growing rapidly. Cleaner production, pollution prevention, life cycle assessment, materials flow analysis, industrial ecology, ecological economics, corporate environmental management, and corporate social responsibility all seem to have their own research communities, journals, and annual conferences.

To limit the boundaries of research is typical in all sciences, but perhaps natural sciences and engineering are stricter in this sense than social sciences. Industrial ecology has mainly been developed within research communities that represent engineering and natural science. The social science dimension is a more recent characteristic of industrial ecology work. It is clear that one field cannot solve all the problems in the world and boundaries are needed. But at the same time, it is clear that sustainable development is an interdisciplinary and transdisciplinary challenge; and the many fields, concepts, and tools within the broad field of sustainable development must be used together in a strategic manner to contribute to the societal goal of sustainable development. That is, the many tools and concepts and disciplines must be used in a strategic manner, not only as competing or conflicting. However, it is difficult to develop strategic thinking or concepts and models of strategy if the available sources are only those of natural science and engineering. Therefore, this editorial, inspired by the six articles in this issue of *Progress in Industrial Ecology*, wants to reflect on this question of how we can use industrial ecology concepts and approaches in a strategic manner.

The recent editorial article of *Business Strategy and the Environment* special issue 'Business and Industrial Ecology' (Korhonen *et al*., 2004) identified three themes as organising categories in linking industrial ecology to management, to business studies, and to policy studies. The message was that the dominant natural science and engineering aspects of industrial ecology need to be bridged to business studies, management and organisational studies, to policy studies and to social sciences. Without this link, materials and energy flow analysis and the information provided by industrial metabolism studies will not lead to a real change in practice. If the aim is to influence decisions, behaviour and actions of industry, decisions-makers, and individual consumers, then input from more social science-type work is needed. Furthermore, as noted above, without a strategic and management dimension, the rapidly growing number of tools, instruments, metrics, indicators, approaches, and concepts in sustainable development will create confusion among the users of the tools, policymakers, industrial companies, and other societal actors (Robèrt *et al*., 2002). Instead of only creating new and more detailed tools and instruments, there is also a need to consider how these tools and instruments can be used together in parallel. Strategic thinking is needed so that the user can employ the many tools neither as each other's substitutes, nor as competing, but as complementary tools with a common purpose of sustainable development.

The editorial will elaborate on themes that might be fruitful in establishing the link among industrial ecology, business, and management studies. After this, the six articles in this issue of *Progress in Industrial Ecology* are reflected upon these themes.

2 Business, management, and industrial ecology

The three main themes discussed are:

1 interorganisational management studies

2 development and management of industrial ecosystems

3 industrial ecology as a vision and a source of inspiration for management strategy.

2.1 Interorganisational management studies

In corporate environmental management literature, Roome (2001) and Sinding (2000) have viewed interorganisational environmental management as a potential application area for Industrial Ecology (IE) theories. Sinding referred to the definition of Sharfman *et al*. (1998) of interorganisational environmental management:

> "…activities between a firm and either a supplier or customer, where the firms jointly engage in any process that alters, considers, monitors, evaluates, assists, directs, impacts, affects, *etc*., any activity either within a firm, its business units or between firms that has a meaningful environmental consequence."

Seuring (2004) analysed relevant concepts and tools, considering industrial ecology as a potential form of interorganisational environmental management. The analysis included environmental life cycle management, environmental or sustainable supply chain management, and integrated chain management.

Industrial ecology is the study of materials and energy flows in societal systems and between societal systems and ecosystems (Erkman, 1997; Jelinski *et al.*, 1992). The central focus on materials and energy flows requires that societal, economic, and industrial systems are studied from a systems perspective. All societal actors affect and are affected by the physical flows of matter and energy. The physical flows do not respect administrative or political boundaries or borders. It is clear that interorganisational environmental management is the best place to start bridging industrial ecology to management studies.

However, the link will not be easy to achieve. It may create confusion among organisations and decision-makers. For example, Environmental Management Systems (EMS) usually focus on an process or a firm and try and optimise its material and energy flows. Sinding (2000) notes that one of the barriers of interorganisational environmental management is that tools and concepts such as EMS that have an internal focus have been institutionalised. He further argues that such intraorganisational approaches and tools can be added to an existing organisation without significantly affecting its fundamental structure.

The modern paradigm requires that an organisation should be assessed clearly in terms of its performance. High levels of accountability must exist. The modern society favours performance reliability and high levels of accountability (Sinding, 2000). In turn, this leads to organisational structures that are easily reproducible, *i.e.*, organisations are by definition resistant to change. Intraorganisational environmental management tools such as environmental accounting and reporting naturally require a high level of reproducibility, *i.e.*, environmental report of the current year must be compared to the environmental report of previous years. Intraorganisational environmental management seems to be a convenient way to proceed with this ‘new’ issue of the environment and sustainable development. Intraorganisational environmental management approaches can fit in the normal organisational structures and management routines that are already intraorganisational or focused mainly on the single organisation.

In turn, interorganisational approaches do not fit into existing organisational structures or management models in the modern corporate world. Interorganisational environmental management has not been institutionalised (Sinding, 2000). Interorganisational approaches would require more fundamental questions, for example, what is the social responsibility of the firm, where is the boundary beyond which this firm does not need to concern over environmental aspects and impacts, how can this particular organisation contribute to global sustainable development, now and in the future, or is an organisation that is dependent on suppliers of oil or fossil fuels able to change its suppliers into those that produce renewable fuels and engage in management practices for this process?

According to Sinding, interorganisational environmental management approaches such as industrial ecology are rare and have not been institutionalised due to organisational inertia that maintains the intraorganisational environmental management practices. The systems approach in IE requires a broader view than in traditional intraorganisational environmental management (one on networks of firms). Consider a situation in which EMS and industrial ecology concepts, *e.g.*, industrial symbiosis (for industrial symbiosis, see the articles by Jackson and Wolf *et al*., in this issue), may support conflicting decisions for the individual firm. EMS suggests reduction of waste flows at the level of a single organisation. But in industrial symbiosis, these waste flows could serve as valuable inputs for other firms in the network to substitute for system external resources, *e.g.*, imported fossil fuels if the wastes are suitable as fuels. Which is more important as a strategic goal, the environmental performance in the eyes of stakeholders of an individual firm, or the environmental performance of the larger firm network system as a whole?

Correspondingly, if industrial ecology is to be successfully applied in business and management studies as a form of interorganisational management, then the diversity of the actors and stakeholders must be considered. The actors are affecting and affected by the flows of materials and energy and the diversity of the actors may make the situation unclear, difficult to structure and manage. The goal of achieving a consensus approach and a common culture, vision, and a strategic management plan for a firm network is a very difficult task. All individual actors and organisations have their own strategic goals, management structures, routines, and decision-making structures. All actors have different preferences and interests. It is clear for both of these challenges that when conflicting tools and the diversity of the actors are involved, input from business studies, management, and organisational studies and from social sciences is needed. Materials and energy flow analysis alone cannot solve these situations that have a social, cultural, and organisational context.

Robèrt *et al*. (2002) have provided a fruitful strategic sustainable development model (see also Korhonen, 2004a). It has been developed by ten scientists who have pioneered in some of the most commonly used tools in sustainable development, including those that focus on materials and energy flow studies and analysis. The model's aim was to provide a framework in the context of which many tools and concepts could be used in parallel and as each other's complements in a strategic manner. The model attempts to give a basis for a wide inter- and trans-discipline and cross-sector consensus building concerning the overall goal and objective of sustainable development. This overall vision and objective could be shared among scientists from different disciplines, policymakers, business, and other societal actors. If the different actors, sectors, and tool users can agree on an overall goal, then there is a possibility to use the different tools as complementary in order to achieve this goal.

Such a consensus would be important for solving the above challenges when linking industrial ecology to business and management studies and applications. Without a consensus on the overall goal and the general direction, it will be difficult to use different tools as complementary. There is no consensus on what is the ultimate goal that the tools are trying to achieve, *e.g.*, whether the goal is reducing the environmental burden of an individual firm or the entire local/regional firm network, or sustaining development of the global society. The second challenge mentioned above – the need for a network-wide strategic management plan in an industrial ecosystem – would also be easier to confront if the actors would share a consensus on the overall generic direction of sustainable development.

Undoubtedly, there are many barriers to a consensus approach in practice. Nevertheless, a scientific consensus was achieved with ten experienced scholars in sustainable development work in Robèrt *et al*. (2002). This success provides a vision for others to consider. The key is that the overall goal is generic and qualitative, not detailed and quantitative. This is because of the lack of sufficient knowledge and because of continuous uncertainty on detailed quantitative ecological and social impacts in extremely complex societal systems and ecosystems now and in the future. Furthermore, it is very difficult to reach a consensus on detailed, fixed, and quantitative goals (or agree on numbers). This overall goal will be elaborated further in this editorial, but those interested are encouraged to read Robèrt *et al*. (2002).

2.2 Development and management of industrial ecosystems

Industrial ecology theories and concepts come from engineering and natural sciences. The main tools used are descriptive industrial metabolism tools including materials flow analysis, substance flow analysis, and life cycle assessment. The business, management, and policy prescriptions for actually achieving more sustainable solutions in practice have been neglected. As noted above, this is not necessarily negative, because it is impossible to include everything under a single field of science.

However, the recent years have seen many new tools and concepts within sustainable development research. A limit has been/will be reached when this complexity leads to fragmentation and decisions that are not strategic and based on the sustainability perspective. Furthermore, authors in the field of industrial ecology are calling for work on the human dimension of materials and energy flows (Cohen-Rosenthal, 2000; Ehrenfeld, 2000; Boons and Roome, 2001; Andrews, 2003). Some authors also see that some of the core positions in industrial ecology theories and concepts such as the natural ecosystem metaphor and inspiration it generates may actually offer fruitful contributions to social sciences, business and management studies (Ehrenfeld, 2000).

This editorial's position is that the bridge between IE and management studies is important. The information gathered by materials and energy flow analysis tools should be used in the context of management and administrative systems as input to conduct planning, vision building, practical implementation, monitoring, auditing, and reporting. Industrial ecology theory could address the following issues that are important influences if industrial ecosystems are to succeed in practice and create a real impact on business and other societal actors:

- visions, policies, and strategic goals of the organisation
- management and administrative structures and routines
- decision-making structures and platforms
- concrete actions and practical measures, tools, indicators, and metrics
- periodical internal and external audits and reviews
- information dissemination and reporting
- tools for this, *e.g.*, ICT (information and communication technology)-based
- education and training
- coordinating activities and coordinators
- political support, *e.g.*, public-private and stakeholder partnerships
- government policies, legislation, economic instruments such as taxes, voluntary agreements between government and industry.

One potential strategy to try to establish and organise industrial ecosystems is the 'anchor tenant approach' (Chertow, 1998). This is an industrial symbiosis firm network where one very influential actor is identified and used as a support system for the entire network. This network driver could be, for instance, an actor that is already advanced in waste management and utilisation techniques and is already engaged in different cooperation activities with the other actors in the firm network. The key actor could be a firm that already utilises many different waste flows from other actors in the system as raw material or fuel. Likewise, it also has products as well as by-products and wastes to give/sell to other actors that are able to use these as valuable inputs substituting for virgin inputs. Through its cooperative and communicative actions with the other firms in the network the key actor could introduce new ideas for the other actors to establish new cooperative links between them, not only between the actors and the anchor tenant. It could use its already existing experience on inter-firm waste utilisation as a source in these processes.

Obviously, much more work is needed to address the many difficulties and limitations related to the anchor tenant strategy. Such barriers include path dependency or risk of 'technological lock in' situations (Salmi, 2003; Norton *et al*., 1998) that may occur if dependencies build up among actors in a strict manner, making it difficult to break free from these links and innovate in different and new organisational arrangements. Similarly, work on social and cultural aspects and issues related to trust (Gibbs, 2003) are important to better understand the functions of firm networks. Nevertheless, the anchor tenant strategy could serve as an initial step to build management approaches and strategies for such firm networks as in the ideal of a local/regional industrial ecosystem or industrial symbiosis that would develop toward more sustainable material and energy flows. PIE published a double special issue on 'Sustainability Networks' with 14 articles that included discussion on decision-making, stakeholder and management systems/model aspects of industrial symbiosis and industrial recycling networks (see Posch, 2004; Strebel and Posch, 2004).

If, and when, the industrial ecology tools such as materials and energy flow analysis, life cycle assessment, and substance flow analysis become everyday tools in organisations, then there is a need for management, administrative, and strategic frameworks and models with which these tools can be used to their fullest extent. The tools should be assessed based on their contribution to the overall goal of sustainable development. Natural science and engineering tools that describe how materials and energy flow may not be able to influence the existing core values, organisational culture, learning, basic organisational structures, the vision building and the overall goals of the organisation if appropriate contexts and strategies are not identified within which the materials and energy flow tools can be used.

Van den Bosch and van Riel (1998; see Schot, 1992) simplify their definition of a firm's environmental strategies according to two broad categories: 'buffering' and 'bridging'. In buffering, defensive strategies are adopted to resist significant changes. The suggested solutions are mainly technological. Matutinovic (2001) argues that modernity and the dominant culture of today is self-referential. When a social or cultural system is self-referential, it is not challenging the existing fundamental and basic paradigm, which today is clearly unsustainable (Ehrenfeld, 2000). Self-referential cultural and social systems operate according to the old and existing concepts, visions, and world-views. These kinds of systems seek to reproduce themselves and increase their power. The change is small and incremental. New metrics, tools, and instruments may be created but they are used for the underlying paradigm. Example given by Matutinovic is household waste management efforts that concentrate on technology, *e.g.*, waste incinerators or recycling techniques or some new machines. Actors and organisations tend to favour the old existing paradigm and the 'technological fix', while the real solution to the waste problem would lie in the fundamental change of our personal values and behaviour in the culture of our consumer society.

In van den Bosch and van Riel (1998), bridging strategies are related to more creative and innovative thinking that better tolerates uncertainty and change. The materials and energy flow tools of industrial ecology should not only be considered in the context of the buffering-type strategies. If they are, the value added to sustainable development may even be counterproductive. That is, if the tools are only technical instruments used for purposes that are inherently unsustainable, the tools simply make the existing unsustainable systems and structures stronger. Such a risk exists and it also happens. The tools of industrial ecology are orientated on engineering and natural science, *i.e.*, type of tools that are used for such technological solutions to problems that are preferred in buffering strategies. Not considering the fundamental culture and the paradigm of the organisation, it may be convenient to adopt these for their instrumental and technical value. The important challenge for linking industrial ecology to business studies and management is that new frameworks and models are created where industrial ecology can also serve as a vehicle for challenging the existing paradigm of the corporate world and influence newer sustainable organisational cultures.

Life Cycle Assessment (LCA) is perhaps the most commonly used tool of industrial ecology. Welford (1998a) shows how LCA can be used beyond its technical and instrumental (quantitative flow analysis) value. LCA looks at the entire life cycle of products because it includes both the sourcing of raw materials and the use and consumption stages in the cycle. In the global market economy, production and consumption are often geographically separated from each other. Raw materials might be extracted from the developing countries under poor social and environmental conditions. The case may be the same when harmful wastes and emissions are dumped in distant countries.

Therefore, Welford notes that LCA could be used to its fullest strategic potential if the sustainable development aspects of equity, corporate social responsibility, and the vision of locally more self-sufficient economies, *e.g.*, in the developing countries, would be included as strategic questions when LCA is used as a tool in business strategy. LCA could be beneficial in identifying activities that violate these sustainability principles in the global market economy. Furthermore, as LCA focuses on consumption and the use of a product, the environmental impacts of which may arise many years, even decades, after the product is manufactured, LCA could contribute to addressing the challenges of taking the futurity aspect of sustainability into account.

2.3 Industrial ecology as a vision and a source of inspiration for management strategy

Use of metaphors has been at the core of the young industrial ecology theory (Allenby and Cooper, 1994; Ehrenfeld, 2000; 2003). Metaphors cannot be wrong or right, only useful or not (Ehrenfeld, 2003). The use of metaphors was identified as one possible path to bridge industrial ecology research to business studies and management (Korhonen *et al*., 2004) with the theme: *Industrial ecology as a vision and a source of inspiration for management strategy*.

Sustainable development and corporate social responsibility require radical and fundamental changes in the values, visions, and goals, in the culture, organisational structures, actions, and operations of companies (Welford, 1998b; Ehrenfeld, 2000). Welford notes that through the pressure from stakeholders industry has become actively involved in the environmental debate, and the industry has sought a discourse on the environment which suits its other aims and objectives. Competition, globalisation, mass production and consumption, the technological fix and economic growth have provided the old existing paradigm to which the environmental work has been added without changing the basic paradigm. According to Welford, this is not surprising because the industry is firmly wedded to the system that caused the environmental crisis in the first place (Welford, 1998b). The author sees this as a normal tendency of modernity, where the present and the future are a linear extension of the past. He argues that critical theory could offer a source for new models that break from business-as-usual and enhance some sort of discontinuous change.

Radically new insights and new sources for ideas for such insights and inspiration for these could be offered by the creative and transformative power of a metaphor. Industrial ecologists have used metaphors derived from natural ecosystems in industrial systems. The most common metaphor is roundput, recycling of matter and cascading of energy (using residual/waste energy) in industrial and economic systems (Korhonen, 2004b). Others include diversity of the actors involved and cooperation and community in their relations. The metaphors have been used both for concepts that would inspire new world-views, values, new sustainability culture, and visions (Ehrenfeld, 2000), as well as for creating more practical analysis tools for industrial systems (Korhonen, 2004b).

Robèrt *et al*. (2004) have developed the metaphor of the game of chess for strategic sustainable development (see also Robèrt *et al*., 2002). They view chess as an important eye-opener for strategic planning and management in any organisation or complex system. An organisation wanting to contribute to sustainable development could ‘play the game of sustainability’. The message is that the traditional and still currently dominant planning methodology, forecasting, has some serious disadvantages. In forecasting, the future forecasts are derived from descriptions of previous and current trends applied to the future. The future vision is such that it is practically the same as the situation now, minus the problems and known negative impacts that one wants to get rid of. Problems and negative impacts are those that we have seen in the past or are seeing now. The argument is that taking the ‘now’ as the starting point makes strategic visions realistic. The conventional ‘SWOT’ analysis (Strengths, Weaknesses, Opportunities and Threats) is used to assess the current situation. Derived from that, future vision is developed.

There are three main problems in forecasting. First, by using the current situation as the starting point and the ‘realistic’ as the criterion of the strategic vision, greatly reduce the chances of coming up with visions that present a real and big change, a kind of radical and fundamental change needed for sustainable development. We are all familiar with comments and skeptics related to high prices of renewable fuels or those that state that companies do not have the time or the skills or other resources to invest in environmental management. The current situation, and usually its weaknesses and problems, reduce the innovation and creative power when developing strategic management visions for the organisation.

Second, if fixing current problems or getting rid of current known negative impacts is the vision, there is a risk that the basic principles that are the underlying source of current known impacts in ecological and social systems, but also of future unknown impacts, are not addressed. There are many examples of reductionist piecemeal approaches to policy and management that have resulted to problem shifting or problem displacement of current problems/impacts downstream instead of problem-solving upstream (Jänicke, 1990; Jänicke and Weidner, 1995). Air emissions have been converted to sludge disposed of to landfills that through decay processes also emit air emissions (Ayres, 1994), recycling of paper reduces waste paper at landfills, but increases cadmium containing de-inking sludge (Korhonen, 2004a), utilisation of forest residues from cuttings as fuels substitutes for fossil fuels in industrial energy generation, but removes nutrient rich forest residues from the forest ecosystem (Ranta *et al*., 1996) and production emissions have been reduced at the cost of shifting the problem to consumption emissions and wastes (Andenberg, 1998). Correspondingly, creating more fuel-efficient cars has increased fuel use and emissions rather than decreased them, because of the rebound effects or the negative growth effects (Jevons, 1990; Mayumi *et al*., 1998; Berkhout *et al*., 2000).

The focus on current and known impacts is not holistic. Instead of fixing current problems or reducing current known negative impacts, one should focus on the main mechanisms and principles that are the source of the current and known, but also of future unknown negative ecological and social impacts. Robèrt *et al*. (2002) have used the four-system conditions or sustainability principles of The Natural Step (TNS) as the basis of future strategic visions and the overall goal of sustainable development. The authors maintain that these would focus on the basic principles that determine how many and what kind of negative impacts are created in the future. Sustainability is achieved if nature is not subject to systematically increasing:

- concentrations of substances extracted from the earth's crust
- concentrations of substances produced by society
- degradation by physical means, and in that society
- human needs are met worldwide.

The third limitation of forecasting is that it results in strategies that do not really make a distinction between the overall and generic direction of change on the one hand, and its pace or the initial first steps, practical actions and concrete measures, on the other. This is because not only the initial steps and practical actions, but also the basic vision of the future are derived from looking at the current situation and trends of the known negative impacts we want to get rid of or reduce.

The game of chess is used as a metaphor to bring another new planning methodology into strategic planning and management of any organisation or project. This new methodology is 'backcasting'. The very term 'strategic' means that we know the direction that we will take in future. Hence, the overall goal and the vision, the principles of checkmate, is the key in backcasting in Robèrt *et al*. (2004). A future cannot be without negative social and ecological impacts, as these will always occur even if we do not want them to occur, *e.g.*, due to laws of thermodynamics, *etc.* We cannot know with detailed and quantitative results or prediction in an absolute manner how certain substances will affect ecological and social systems. However, we can approach a situation in which the main underlying mechanisms that systematically create different impacts are not allowed to influence the world in a manner that impacts are systematically increasing. The four sustainability principles above, the principles that are the underlying causes (if the 'not' is deleted) of negative impacts are the basis of the future strategic vision in backcasting advocated by Robèrt *et al*. (2002, see also Robèrt *et al*., 2004). This is called 'backcasting from basic principles of success for sustainability'.

In backcasting, the vision is not restricted by the problems and difficulties of the current situation. Rather, one asks where does one want to be in the future? This makes it possible to 'think out of the box', innovate, and be creative. The four principles, such as the principles of checkmate, are generic and qualitative, not specific and quantitative such as the known current impacts, *e.g.*, of acidification. The principles provide the overall direction. Similarly to the game of chess, there are many possible and alternative routes to reach a checkmate situation, which is the overall goal and the vision of the game. Therefore, backcasting from basic qualitative principles enables many actors to agree on the basic vision, because it is generic and qualitative. It would be very difficult to reach a consensus on numbers. Many actors can also use their individual creativity in finding ways to reach a situation of checkmate.

The planners identify a path 'back from the future' all the way back to the current situation after the vision is set in the future without thinking about the present situation. This path gives the planner the overall direction and vision for change. Thus, it is important to start and take the first steps toward the vision. This is the pace of the change. The pace is neither the same as the future vision nor successful outcome of long-term strategic planning and management. The current situation is now allowed to influence the decisions when first practical steps, actions, and concrete measures are implemented. But note that the current situation only influences the first practical steps and concrete actions, the pace of change. The overall direction *i.e.*, the principles of checkmate, remain the same. You cannot change the principles of checkmate. After the first practical step is taken, there is a new current situation which, again, is allowed to influence the next practical actions and concrete measures. Just like in chess, one always maintains the goal of winning as the overall direction (which is the principle of checkmate). A chess player also considers the fate of individual soldiers when individual moves are made. Although saving an individual soldier by considering a move is important, it is not allowed to change the overall direction of the game.

The strategic planning and management for sustainability – learned from the metaphor of chess – shows the need for a long-term strategic planning with a clear enough vision for sustainability. We cannot solely focus on practical actions, concrete measures, and tools. The focus on current impacts and their trends reduces the innovation potential of our planning. Backcasting makes a big change into a step-by-step approach that constitutes of small changes. It is actually realistic. It also helps to avoid blind alleys and dead-ends, *i.e.*, investments or first moves in chess, that do not allow future steps toward the ultimate vision, which is the checkmate.

One can invent a hypothetical example of this thinking. Consider an investment in a Co-production plant of Heat and Power (CHP). CHP increases the fuel efficiency of energy production, compared to condensing power plants that only generate electricity. CHP is a very capital-intensive investment and requires long payback times. If the plant is equipped with fuel processing and combustion techniques only able to utilise fossil fuels, then this is not a long term strategic investment for sustainable development. It ties up the money of the actors involved for a long time and 'locks' the situation, thus hampering innovation. A plant that would not have CHP but would instead have a suitable fuel processing and burning technique for biomass and renewable fuels and would have the additional flexibility to be converted into a CHP technique in the future, would be a more strategic investment. This is preferred even though its current fuel efficiency would be lower and fossil fuel consumption would be higher than the fossil fuel-based CHP plant. In other words, even suboptimal practical measures and concrete actions may be allowed if these are suboptimal from the perspective of the current situation and optimal from the perspective of the future vision of sustainability. However, this is not to say that the current situation would not be allowed to influence the practical actions and concrete steps that are taken. As in the game of chess, a smart player takes into account also the next moves, when the first moves are made.

3 The papers in this issue

Jackson (in this issue) provides a provocative review and critique on one of the most common approaches in industrial ecology: Industrial Symbiosis (IS). Two case studies on forest industry and forestry from British Columbia and from Scotland are analysed. The message of this contribution is that the engineering and natural science-based IS concept must be bridged to economics theory. IS, also known as eco-industrial parks, industrial recycling networks or industrial ecosystems, concentrates on local or regional networks of firms and other societal actors. In the IS vision, the actors of the system utilise each other's material and energy flows including wastes and by-products. IS is inspired by a metaphor in natural ecosystem's material cycles and energy cascades among plants, animals and decomposers. Jackson maintains that even if such onsite success stories could be achieved locally, the contribution to sustainable development is far from clear. The question raised is, what happens off-site outside the local network system boundaries, in other regions or in the global market economy?

The issues surrounding system boundaries have been addressed recently in industrial ecology and cleaner production literature (see Baas and Boons, 2004; Boons and Baas, 1997). A case study on industrial symbiosis in Finnish forest industry (Korhonen and Snäkin, 2005) revealed that although a local forest industry park is very advanced in waste material and waste energy utilisation and in substitution of these for natural resources and fossil fuels, it is impossible to define the industrial park's true contribution to sustainable development. For example, the biodiversity concerns related to Russian forests and landfill management issues in Germany would need to be evaluated as well. The forest industry park is linked to these questions. It operates in the increasingly global market economy.

The paper by Jackson can be relevant in bridging industrial ecology to business studies, to management and to the study of organisations for two reasons. First, the author combines his findings with economics theory, in particular, ecological economics theories on the relation of economic growth and environmental burden. Economics theory is the basis of business economics and management. Engineering and natural science aspects of industrial ecology need to draw from these sources if cooperation between industrial ecology and management study communities is achieved. Second, industrial symbiosis, if successfully implemented, is an example of interorganisational environmental management with cooperation among many actors. The paper shows that even though industrial symbiosis adopts more systems-based and larger system boundaries than conventional management systems of companies, it still leaves important sustainability issues outside the system boundary.

Another study on industrial symbiosis networks has been conducted by Wolf *et al.* (in this issue). The authors provide an important contribution by applying qualitative methodologies, *e.g.*, interviews, group discussions, participative observation, to analyse the views, perceptions, interests, and preferences of the actors involved in the case study in Sweden. The IS work, up to now, has mainly addressed the physical materials and energy flow metabolism of the network system. IS scholars have described the raw material and fuel use, by-product, waste, and emissions flows. Methods have included common industrial ecology methods of industrial metabolism or materials and energy flow analysis, life cycle assessment and substance flow analysis, *etc.* The social science or qualitative research methodologies have remained practically non-existent.

In addition, Wolf *et al.* (in this issue) reflect on the roles and potential of different actors to contribute to the industrial ecosystem project. They compare the roles of local public authorities and private firms affecting the system (see also von Malmborg, 2004; Heeres *et al.*, 2004; Eilering and Vermeulen, 2004). This paper has visible links to business and management studies and to interorganisational environmental management. It addresses the human dimension and social science-influenced methodologies in the case study and studies both the private and public organisations, their interests and preferences that are critical for the implementation and use of the results of materials and energy flow analysis in practical decision-making. The findings of the article can be compared with those of Harris and Pritchard (2004), who study how industrial ecology concepts and thinking can be used at different systems levels of actors, the company, region or the national level. Harris and Pritchard consider how industrial ecology learning can influence the strategy of these organisations on different system levels.

Bengtsson and Tillman (in this issue) offer a new contribution to, perhaps, one of the most commonly used industrial ecology methodologies: life cycle assessment. With a focus on social processes and actors' perceptions, the authors reveal interesting issues related to the user aspects of LCA. They find that the diversity of societal actors including public authorities, industry, nongovernmental organisations, and research institutes must be considered when industrial ecology and LCA studies are used in practice. Approaches that take this diversity of perspectives and views into account are highlighted. These authors employ qualitative research methods, such as group interviews, to learn about the stakeholders' perspectives and opinions on LCA. The authors emphasise the importance of interorganisational collaboration for learning and innovation. Such innovative capacity is needed to control the product life cycle environmental impacts. Life cycle impacts are affected by the many actors and processes along the product life cycle from 'cradle to grave' or from 'cradle to cradle'.

This article is also important for the goal of PIE to bridge industrial ecology to business studies, management, and to social sciences. First, it applies relevant methodologies in a way that is rare in common engineering or natural science-orientated LCAs. Second, the focus on practical applications and use of LCA results and the link of LCA with the many human stakeholders and their views affecting it and affected by it is a welcome research theme for industrial ecology. The future will show whether LCA can be successfully developed in life cycle management (LCM, see Sinding, 2000). LCM would not only provide decision-makers and companies with quantitative calculations and assessments of materials and energy flows, but it would also use this information in management and administrative systems of private and public organisations. LCA results would be included in their policies, strategic visions, objectives and goals, organisation of the environmental work and the definition of responsibilities and in implementation of the objectives with practical actions and concrete measures. Likewise, the auditing and review processes will be measured against the strategic visions and objectives to prepare the organisation for continuous checking and improvement of its management system. To achieve such a link among the engineering communities – which have designed LCA methodologies and the business and management scholars that study organisational culture, learning, behaviour, business strategies and management systems – more studies are needed on the user aspects of LCA and actors' views on LCA results.

Brent's (in this issue) article attempts to respond to this challenge of life cycle management. He develops a new model in which three different life cycles are combined. Usually, life cycle thinking and LCA has been applied to products. This article applies life cycle thinking and LCA to projects and assets – which obviously influence the products and services – that a company or organisation is designing and bringing into the markets. The three life cycles are integrated and the difficulties to measure the environmental and sustainability performance of the three life cycles are discussed. The author argues that the integration of the three life cycles is the precondition of sustainability management in industry. Again, this paper is at the core of the objective to link industrial ecology to business and management studies. LCM is a form of interorganisational management and the link to project and asset life cycles is very important for bridging material and energy flow studies and LCA to decision making and practical management in private and public organisations.

Mohee's (in this issue) article compares two waste treatment/management techniques, composting and Anaerobic Digestion (AD) in the case of Mauritius. The paper includes a discussion on the importance of system boundary definition and the scope of the study for all life cycle assessments and the implications these have for decision making. The results are affected by the choice of issues addressed. In this case, anaerobic digestion would be ranked better if its renewable energy potential would be fully accounted for. AD is an example of a waste management technique with which an integrated waste management and energy production system could be built around of an individual actor, say, a farm. It is possible to utilise manure, food industry wastes, and biowastes from consumers as well as wastes from wood-based industries in AD to produce energy. The technique can generate electricity, industrial process steam, as well as district heat for all of these actors. In addition, AD can produce fertilisers to substitute for chemical fertilisers (and the energy needed to produce these). Therefore, AD is an example of a technique around which networks of many different firms and other economic and societal actors could emerge. This future potential of AD as an 'anchor tenant' of industrial ecosystems, industrial symbiosis, or industrial recycling networks should be studied, and considering the economic and social issues that influence its successful utilisation under different situational circumstances.

Sahay's (in this issue) article documents experience from another very interesting case study context. He presents a case study from India that shows a success story of Scooters India Ltd. The ongoing debate on business – environment win-win (Porter and van der Linde, 1996; Walley and Whitehead, 1996) – is taken as the starting point. The author argues that win-win, indeed, has occurred in this individual case, which implies there might be opportunities for small- and medium-sized industries in the developing countries to utilise the strategic opportunities of environmental management. Of course, this would be a very important vision for global sustainable development. The case further shows the importance of strategic long-term visions, proactive approaches to environmental management and the importance of bringing environmental management alongside other core questions in the business strategy of an organisation. Unique cases such as these could be reflected upon such radical and fundamental changes called for in the third theme identified above for bridging IE to business and management studies; *Industrial ecology as a vision and a source of inspiration for management strategy.*

4 Conclusion

The objective of *Progress in Industrial Ecology* is to bridge the engineering and natural science aspects of industrial ecology theory to decision making, to business studies, management, and study of organisations as well as to policy studies. This is critically important if a real change toward sustainable development in practice is to be achieved. The year 2004 was fruitful in terms of initialising the process of this challenge. Three projects, the *Business Strategy and the Environment* special issue ‘Business and Industrial Ecology’, *Journal of Cleaner Production* triple special issue ‘Applications of Industrial Ecology’ and the triple inaugural issue of PIE included in all 48 articles. All of these projects were designed to respond to the challenge of bridging industrial ecology to business, management and policy studies, to link the engineering and natural science aspects to those of social sciences.

As the scientific debate on sustainable development moves forward, increasing number of new technical tools, instruments, and new concepts and approaches are developed and applied. Instead of only developing new and more detailed tools, it is important to also consider how the different tools can be used in parallel and as complementary, instead of as conflicting and competing. For this, there is a need to develop strategic thinking and models for strategic planning and management for sustainable development. We need to reach a consensus on the basic generic qualitative principles of sustainability and sustainable development. This will enable us to use the more detailed and quantitative tools, instruments, and concepts for the common goal of sustainability. Such strategic models and thinking or consensus will not be possible if the modern scientific fragmentation continues and new approaches are launched without awareness of what are they launched for. This is a relevant and timely question for making progress in sustainable development through industrial ecology.

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