Foreword

John R. Ehrenfeld

With this two-volume collection, the editors, Matthias Ruth and Brynhildur Davidsdottir, and the other contributors have made an important and substantial contribution to the still evolving field of industrial ecology. This first volume focuses on the basic notions of industrial ecology, on the dynamics of material flows, and on the role of agents in dynamic industrial ecosystems.

In the more than ten years that have transpired since the emergence of the idea that economic/industrial systems generally exhibit features analogous to natural ecosystem, the field has taken root. Industrial ecology now has associated with it activities in many universities, consultants with programmes based on industrial ecological principles, and applications of these principles showing up in corporate strategy, product design and public policy. The key principles spring from the above-mentioned ecological analogy and include such notions as industrial metabolism (flows of energy and materials), loop closing and symbiosis, all of which mimic forms and processes found in *healthy* ecologies.

The stressed term above, healthy, lends a normative dimension to the field, beyond the merely descriptive character of analogies. Environmental management and its successor concept, sustainability, have become firmly embedded in high-level societal activities in virtually every economic sector and industrialized nation. The relevance of these terms is tied to a still-growing consciousness of the fragility of the Earth's ecosystem and its criticality as the primary life support system of our species and indeed all life. International consensus about global warming and its impact on climate has now heightened interest in acting to preserve the environment for the present and for future generations.

Among many potential pathways toward sustainability, one stands out as the choice of most industrial and governmental strategies: eco-efficiency. Eco-efficiency, the idea of providing more value for less impact, is contained in many other prescriptive statements, such as dematerialization, decarbonization, detoxification, factor X reduction, cradle-to-cradle, and so on. Healthy ecosystems are naturally "eco-efficient". They recycle the nutrients found in their local environment by closing material loops.

Detritivores turn the wastes produced in the food web into nutrients for species in other places in the web. The source of energy is renewable solar energy. It is only a very small jump to get from this observation to a normative possibility for industrial ecology: produce a more sustainable world by designing economic/industrial systems to look and behave more like ecosystems.

This possibility has taken hold in several important areas, for example, in the design of technological artifacts (design for environment) and in the design of industrial organization (eco-industrial development). In both of these cases, analytic and design tools, based on material and energy flows, have been developed and applied. Other analytic models and tools have been developed for larger systems, such as national or regional material economies (flows), but these have not achieved the level of design applications as the above two cases. It would seem, based on a patently unscientific assessment by this author, that the “simpler” the system, as in product systems, the more the ideas of industrial ecology have found their way into practice. Simple in this sense has several aspects, temporal and organizational. Products generally have shorter lifetimes than industrial systems especially looking at common consumer products such as automobiles, mobile phones or computers.

The present generation of industrial ecological models and tools largely springs from relatively static analyses. The assumptions that are made in applying the tools generally assume that the context of the analysis approximates the conditions during the actual lifetime of the system under the analyst’s lens. These tools also generally do not take into account sociological and organizational processes that are involved in putting the prescriptions into play. Again, for product systems, this limitation is not critical as to technical considerations, although it is part of the reasons that the outcome the designer or strategist had in mind may turn out differently.

Furthermore, these first generation models are almost exclusively based on assumptions of linearity with respect to the technical components and on normal rationality with respect to the human elements, in those cases where consideration of actor behavior enters the analytic framework. And finally, much of the work reflects the reductionist nature of the technical disciplines on which industrial ecology rests. This statement should not be read as a criticism of this sociological fact, but merely as an argument for expanding the intellectual basis for what has been the mainstream of research and analysis within industrial ecology.

Readers who are familiar with my recent writings know that I believe that the limits of the present linear models, including those representing ecosystem processes, correspondingly limit the ability of the workers in the field to muster convincing arguments that industrial ecology can be a powerful

new frame for thinking about and acting towards sustainability. Eco-efficiency thinking is extremely important in revealing ways to stop and even reverse the apparently inexorable trajectory towards breakdown and destruction of the natural world with consequent immense potential social implications. But eco-efficiency, like efficiency in any setting, ignores possible absolute limits to growth and also the existence of feedback loops internal to the socio-economic system. William Jevons, writing in 1865, noted that coal consumption in England eventually rose in volume even after the large increase in efficiency produced by Watt's steam engine. Jevons' notion lives today in the current notion of the rebound effect, which implies that eco-efficiency (creating wealth in the process) will produce more investment and more consumption, eventually outstripping any gains from technological improvements.

If one stops for a moment and thinks about the more complex situations mentioned above, the next generation of analytic and design tools will have to incorporate models of processes that more realistically reflect the messy way that the world does, unfortunately for analysts, really work. As the editors of this volume point out, this requires that new ideas must be injected into industrial ecological thinking and research. For example, ways to account for changes in material stocks over long periods are now being incorporated into frameworks for analyzing material flows in large and long-lasting systems as several chapters indicate. As the title indicates, the editors have deliberately taken on the challenge of extending these primarily linear models to account for both temporality and for human behavior.