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INDUSTRIAL SYMBIOSIS AND ECO-INDUSTRIAL NETWORKS

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Abstract: *A key point in progressing towards a sustainable society is finding means to reduce the environmental load of industrial activities. For this, we need the reorganization of industries. The Zero emissions concept is a shift from the traditional industrial model to integrated system in which everything has its use. This concept envisions all industrial inputs being used in final products or converted into value-added inputs for other industries or processes. In this way, industries are reorganized into eco-industrial networks such that industry's wastes or by-products are fully matched with the input requirements of another industry and the integrated whole system produces no waste. This linking of industry is called industrial symbiosis. Industrial symbiosis, as part of the emerging field of industrial ecology, demands resolute attention to the flow of material and energy through local and regional economies.*

Key Words: *zero emissions, industrial symbiosis, eco-industrial networks*

INTRODUCTION

All natural resources are finite and the faster we use them, the sooner they will disappear. Mankind has existed for over a million years, but the situation has changed totally due to the large numbers of people on the Earth and their increased dependence on natural resources. Running out of energy and other raw materials is inevitable. Our social-industrial system is unsustainable. It consumes and emits a huge amount of raw materials and energy, without (or with little) consideration of long-term effects on ecosystems and the future generations. Also, it generates vast amounts of waste and by-products which are disposed and have negative impact on our environment. So, we have to take an action – we must conserve our natural resources by maximizing the usage of raw materials and elimination of waste. It requires humans to do more with whatever they produce. This concept is called "Zero emission". In practice, Zero emission concept means conversion and use of process outputs as inputs for other processes. That means that one industry's waste stream can be used by another as a primary resource.

In order to facilitate an exchange of materials and resources, companies need to work together to determine what unwanted by-products and waste exist, and what their potential applications are. Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water and/or by-products. In this way, industries are reorganized into eco-industrial networks such that one industry's wastes or by-products are fully matched with the input requirements of another industry and the integrated whole produces no waste.

ZERO EMISSION CONCEPT

The concept of zero emissions is based on improving technologies and processes to the point of maximum resource productivity and virtually no waste. This goal can be approached in a number of ways, including technological innovation, pollution prevention, cleaner production, by-product synergy or industrial ecology. All of these are ways of eliminating wastes or turning wastes into profitable resources, while preventing harm to environmental and human health.

Zero emissions represent a shift from the traditional industrial models in which wastes are considered as a norm, to integrated systems in which everything has its use. This concept envisages all industrial outputs being used in final products or converted into value-added and low-cost inputs for other industries or processes. Energy and material synergetic process, cascade use of materials, process networking and thus industrial clustering are required in industries for complete use of resources and thus for emission minimization.

INDUSTRIAL ECOLOGY (IE)

Industrial ecology is the study of material and energy flows through industrial systems. The name comes from the idea that we should use the analogy of natural systems as an aid in understanding how to design sustainable industrial systems. IE uses the metaphor of sustainable natural ecosystem as a model for transforming unsustainable industrial systems [2].

In essence, the field of industrial ecology is oriented at researching ways of incorporating ecological theories, functions and limits into the design of industrial production systems, processes, and products, transforming the current system from a linear to a circular system. It is concerned with the shifting of industrial process from linear (open loop) systems, in which resource and capital investments move through the system to become waste, to a closed loop system where wastes can become inputs for new processes.

There are at least three key elements of IE. The first element is its system approach where IE studies the whole system that includes the material and energy flows, rather than just studying a component of the system. The second element of IE is that it takes into consideration the material and energy flows in and outside a company boundary.

The third element is the use of key technologies as a crucial component to achieve the transformation from an unsustainable industrial system to a viable industrial ecosystem.

Industrial ecology is based on two main premises:

- Nature can serve as a model (e.g. nothing is a "wasted"): By applying nature's lessons, we can create diverse, stable, resilient, and efficient economic systems.
- "Systems" perspectives are key. Communities need to be examined in the context of the broader natural ecosystems on which they depend.

ECO-INDUSTRIAL DEVELOPMENT (EID)

Eco-industrial development is a subset of sustainable development but walks in largely uncharted territory. It also reflects the three Es of the sustainability territory: *economy* (increase business success), *environment* (decrease pollution and waste) and *equity* (eco-industrial development is an environmental justice strategy where placards are replaced by jobs, and toxics by transparent concern for workers and community health).

In the context of sustainable development, eco-industrial development is arguably the goal with which the theory and practice are concerned. The goal of eco-industrial development is not to do the same with less. *Its charge is to do far more with far less.* The eco-industrial approach seeks to reduce business costs, increase competitiveness and productivity, and improve environmental performance. Industry is an instrument of human intention and, as such, can refocus itself in ways that profitably meet human and environmental needs.

EID is a community of manufacturing and service business seeking enhanced environmental and economic performance through collaboration in managing environmental and resources issues including energy, water and minerals [3].

In essence, eco-industrial development is an overarching framework for the recreation of enterprises at micro level, how communities are organized and how we live and work at larger scales.

INDUSTRIAL SYMBIOSIS (IS)

Industrial symbiosis is based on the concept of industrial ecology and eco-industrial development. It refers to the network of product, by-product and waste exchanges that reduce the ecological footprint of industrial areas [1].

Industrial symbiosis, as part of the emerging field of industrial ecology, demands resolute attention to the flow of materials and energy through local and regional economies. IS engages different traditionally unrelated industries in physical exchanges of materials, energy, water and by-products that yield a collective benefit greater than the sum of individual benefits that could be achieved by acting alone. IS is achieved when two or more business cooperates and collaborates with each other by using by-

products or throw away material from each other. This would not only improve business performance by improving profits and attaining competitive advantage but also protect the environment by reducing waste and reducing use of natural resources.
The term symbiosis builds on the notion of biological symbiotic in nature where otherwise unrelated species living together, exchange in a mutually beneficial manner, so nothing is a "wasted". Sustainable communities should mimic the symbiotic and synergistic relationships and exchanges that occur in natural ecosystems. In nature, ecosystems are powered by renewable, solar energy, and organisms fill niches, forming mutually beneficial symbiotic relationships with other organisms. This facilitates the cycling of materials and energy, as opposed to the traditional one use / once through resource flows common in traditional communities.
Industrial symbiosis can be classified in tree groups: utility sharing and symbiosis among firms that are co-located (*eco-industrial park*), symbiosis among firms that are not collated and do not require strict geographical proximity (*eco-industrial network*) and symbiosis among firms that are virtually networked and could be spread at large distances (*virtual eco-industrial network/park* or *industrial symbiosis network*) e.g. regional network.
It is evident from the most often cited example of Kalundborg IS in Denmark (Figure 1) that the industrial symbiosis approach could be a very successful one, though the limited examples of such successful initiatives to date prove that it is not easy to plan, develop and manage IS networks. Kalunborg IS is built as a networking co-operation among six processing companies, one waste handling company and the municipality of Kalundborg, and they are successfully able to exploit each other's residual or by-products on a commercial basis, minimizing pollution and optimizing the use of various resources [4]. The symbiosis evolved gradually and without a grand design over the past 25 years, as the companies sought to make economic use of their by-products and to minimize the cost of compliance with new, ever-stricter environmental regulations. Bilateral exchanges of waste materials were primarily motivated by economic benefits, although as a result, tangible environmental benefits have been gained.

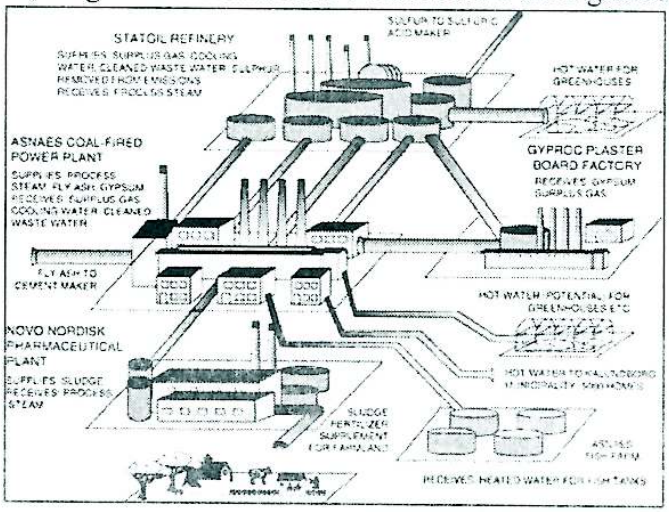

Figure 1. Industrial symbiosis, Kalundborg, Denmark

Originally, the motivation behind the networking of industries at Kalundbord was to reduce costs by seeking income-producing applications for unwanted by-products. Gradually, though, industry managers and local residents realized that they were generating environmental benefits as well. This project has enabled its participants to achieve substantial cost savings and to improve their resource efficiency.
Industrial symbiosis and by-product synergies can evolve naturally as businesses become aware of the availability of resources that otherwise would have been discarded or treated.

ECO INDUSTRIAL NETWORK

Traditionally, industries are always looked upon in isolation and not as a part of a broader system. As a result, the efficiency of the industry and the entire system to which it belongs is relatively lesser compared to it being a part of the system. Essentially, linkages between the isolated industry and its broader system need to be established to improve the efficiency. Many such linkages between individual industries and the broader system create a network of material flow thus maximizing resource efficiency of the system. By co-operating strategically, partners accrue greater financial and environmental benefits than they would by operating alone. If the goal remains the simultaneous achievement of the broadest possible business and environmental success, then they can be considered an eco-industrial network. This distinguishes an EIN from any association of businesses.
Eco-industrial networking (EIN) is a process that creates collaborative networks between businesses, governments, and communities to more efficiently and effectively use resources. In practice, this results in:

- Recovery and cycling of 'wastes' for use by another organization;
- Efficient and ecological infrastructure systems
- Increased economic diversification and value-added manufacturing opportunities;
- Leveraged partnership opportunities between a variety of private and public organizations; and
- Integral consideration of ecological, social, and economic impacts

The term, eco-industrial network, can include any grouping of interrelationships whether in an industrial district, park, region or country. A network can involve a limited number of symbiotic relationships involving a few materials and companies to more mature industrial ecosystems in which infrastructure, building, products and services are designed to function cyclically.
Companies participating in an eco-industrial network can benefit from a wide range of potential cost savings. The appeal of EINs for tenant businesses and industrial development is the increased profitability and cost savings brought through economies of scale and added value to outputs. Value is added to by- products as they cycle back into the production cycle as raw materials for another firm or process.
EIN can be achieved through direct, physical linkages, such as one business supplying its by-products to other businesses, to be used as their feedstock; or through more

"virtual" linkages such as the formation of a purchasing network so that a group of businesses can get special rates on green fuels or office supplies.
Evidently, networks contain critical linkages, both lateral and transverse, formed from the flow of materials. These linkages add life to the system to which they belong and make them more environmentally benign. Therefore, material flow patterns within the network, the sector and the geographical region assume highest importance in their establishment as eco-industrial network.
The recent growth of eco-industrial networks stems from the wide range of economic, environmental and social benefits gained by businesses and communities alike. These benefits include turning 'wastes' (also known as under-utilized by-products), into useable by-products, improving human resource training, reducing infrastructure costs and maximizing the efficient use of energy flows – all for improved competitiveness, investment attraction, business retention, community and ecosystem health.

CONCLUSION

Eco-industrial development adds value to businesses and communities by optimizing the use of energy, materials and resources. It draws from pollution prevention approaches and focuses on the efficiency of individual firms, its unique contribution lies in its emphasis on inter-firm resource linkages. Waste byproducts, water and energy are cycled back into the overall production stream of an industrial park or region. What was formerly considered waste can be used as raw materials for another product or firm.
The links between economic development and sustainable industrial activity are a means of simultaneously retaining and expanding businesses towards a healthy and sustainable community. Eco-industrial networking opportunities were identified that would help make the region more economically, socially and environmentally sustainable.
The symbiotic networks between businesses, community, and the public sector are expected to create synergy among participants. This is the broadest view of industrial ecology. It focuses on developing networks to manage energy, water, and material resources in a sustainable fashion. This approach considers interconnections between labor force, industry clusters, ecosystems, institutional, and community resources.
By partnering to exchange byproducts, businesses in some area could accomplish two important goals: first, they could lower waste disposal costs and become more competitive; second, they could reduce their impact on the natural environment. Lowering business costs and protecting the environment would help ensure the longevity of local businesses, which would in turn provide much needed jobs and a pleasant living environment.

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