Attachment One

Concepts and Definitions associated with Sustainable Industrial Development

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Compiled and modified from various sources

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Clean Production takes advantage of opportunities to reduce and even eliminate the reliance on toxic materials in manufacturing, to prevent air and water pollution, and to avoid hazardous waste generation. This often involves moving away from a "cradle-to-grave" industrial model, where raw materials are extracted and processed and the substances not directly useful to a factory become unwanted waste, to "closed-loop" systems in which the byproducts of one factory become the feedstock of another. As a part of clean production, **"dematerialization"** aims to reduce the amount of raw materials needed to create a product by, for example, making vehicles lighter and cutting the energy needed to operate products.

Another strategy to achieve clean production is **design for the Environment (DFE).** DFE is the systematic consideration during design of issues associated with environmental safety and health over the entire product life cycle. DfE can be thought of as the migration of traditional pollution prevention concepts upstream into the development phase of products before production and use. The objective is to minimize or eliminate, during design, the anticipated waste generation and resource consumption in all subsequent life cycle phases: construction, operation, and closure (or production, use, and disposal).

Clean Technology includes wind power, solar power, biomass, hydropower, biofuels, information technology, electric motors, lighting, and many other appliances that are now more energy efficient. It is a means to create electricity and fuels with a smaller environmental footprint. While there is no standard definition of "clean technology," it has been described by Clean Edge, a clean-tech research firm, as "a diverse range of products, services, and processes that harness renewable materials and energy sources, dramatically reduce the use of natural resources, and cut or eliminate emissions and wastes." It notes that "Clean technologies are competitive with, if not superior to, their conventional counterparts. Many also offer significant additional benefits, notably their ability to improve the lives of those in both developed and developing countries.

Cleantech is a term used to describe knowledge-based products or services that improve operational performance, productivity, or efficiency while reducing costs, inputs, energy consumption, waste, or pollution. Its origin is the increased consumer, regulatory and industry interest in clean forms of energy generation—specifically, perhaps, the rise in awareness of global warming and the impact on the natural environment from the burning of fossil fuels

Cluster-based Industry clusters are geographic concentrations of interconnected companies, specialized suppliers, service providers, and associated institutions in a particular field that are present in a nation or region. In recent years, states such as Arizona, California, Connecticut, Minnesota and Utah have adopted clusters as a new approach to economic development.

Clusters arise because they increase the productivity with which companies can compete. Clusters usually include companies that do business inside and outside of their particular region and will support firms that supply them with raw materials, finished components and business services. Clusters greatly enhance a particular industry's competitiveness in several ways. First, clusters help improve productivity by providing ready access to specialized suppliers, skills, information, training and technology. Second, clusters help to foster innovation by increasing opportunities for new products, new processes and meeting new needs with a full range of local suppliers and research institutions. Lastly, clusters can facilitate the commercialization of innovation through the creation of new firms via start-ups, spin-offs, and new business lines with needed inputs such as banks and venture capital. (Wisconsin Department of Commerce)

Distributed Generation also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy, generates electricity from many small energy sources.

Distributed generation reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building. This also reduces the size and number of power lines that must be constructed.

Typical distributed power sources in have low maintenance, low pollution and high efficiencies. In the past, these traits required dedicated operating engineers, and large, complex plants to pay their salaries and reduce pollution. However, modern embedded systems can provide these traits with automated operation and clean fuels, such as sunlight, wind and natural gas. This reduces the size of power plant that can show a profit. (From Wikipedia)

Eco-Efficiency as defined by the World Business Council on Sustainable Development, is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity. Key aspects of eco-efficiency are:

- De-materialization: Companies are developing ways of substituting knowledge flows for material flows
- Closing production loops: The biological designs of nature provide a role model for sustainability
- Service extension, moving from a supply-driven economy to a demand-driven
- Functional extension: companies manufacturing smarter products with new and enhanced functionality and services to enhance the products' functional value.

Eco-efficiency is a management strategy that links financial and environmental performance to create more value with less ecological impact, gains can be achieved through: (Source Nolan 2007)

- Optimized processes—moving from costly end-of-pipe solutions to approaches that prevent pollution in the first place.
- Waste recycling - using the by-products and wastes of one industry as raw materials and resources for another, thus creating zero waste.
- Eco-innovation—manufacturing "smarter" by using new knowledge to make old products more resource-efficient to produce and use.
- New services—such as, leasing products rather than selling them, changing perceptions and spurring a shift to product durability and recycling.
- Networks and virtual organizations - shared resources increase the effective use of physical assets.

Eco-Industrial Development provides a pragmatic application of industrial ecology concepts. It involves a network of businesses that cooperate to improve resource productivity, restore the local environment, eliminate pollution and associated costs, and capture new economic opportunities and growth. EID offers an alternative approach to many current economic development models. A network of relationships is fostered between core businesses within a selected industrial development, those core businesses and the community or region, and the core eco-industries and other regional materials, energy, or component suppliers. This approach may result in facilities "collocated" in an industrial park or an "industrial cluster" in a defined geographic area. Building green infrastructure systems is a way to support and catalyze eco-industrial development.

Eco-Industrial Park is "a community or network of companies and other organizations in [a physical park] who choose to interact by exchanging and making use of byproducts and/or energy in a way that provides one or more... benefits over traditional, non-linked operations." These benefits include: reduction in natural resources use for inputs, reduction in pollution, reduction in energy use, reduction in disposal of wastes, and increase in value of non-product outputs. (Gertler 1995, 16).

Ecosystems are communities of plants, animals and microbes interacting with one another and with their physical and chemical environment (e.g. soil, water, nutrients). Ecosystem interactions result in the capture and transformation of energy and nutrients that drive all life processes. Humans are part of ecosystems, as well, and depend on and impact the services ecosystems supply.

Green Building, also called "sustainable or "high-performance" building, means having a significantly reduced impact on the Earth's resources compared to conventional building. It also means creating a building that is healthier and more comfortable for its occupants, consequently enhancing productivity.

We define a "sustainable building" as one that is healthy and comfortable for its occupants and is economical to operate. It conserves resources (including energy, water, raw materials and land) and minimizes the generation of toxic materials and waste in its design, construction, landscaping, and operation. A green building also considers historic preservation and access to public infrastructure systems, as well as the entire life cycle of the building and its components. (Source Minnesota Pollution Control Agency's Green Building Program 2008)

Green Business involves businesses that produce goods or services that result in an environmental performance advantage over equivalent goods and services within that specific industry. Core business activities of a so called green industry should result in quantifiable advantages to measure, prevent, limit, correct, restore, or enhance water, air, land, and ecosystem problems and improve environmental quality. Included under the rubric of green industries are innovative clean technologies, sustainable production processes, and products and services that significantly improve environmental quality. (Source Nolan 2008)

- Implement an Environmental Management System (EMS)
- Participate in National Environmental Performance Track Programs
- Produce products with significant green performance attributes
- Practice product design for the environment
- Adopt pollution prevention best practices reduce or eliminate pollution at the source
- Implement clean production processes
- Adopt eco-efficiency approaches
- Utilize renewable energy or purchase green power
- Select suppliers that provide environmentally superior materials, products, and practices
- Integrate green design approaches in facilities and sites
- Minimize waste and energy in product distribution and end-use
- Share responsibility for best product end-of-life practices
- Provide a service (e.g. construction, business, etc.) categorized as green

- Employ people with specific green production, process or business skills
- Implement environmental corporate social responsibility into company policies and decisions
- Support low-impact employee transportation; carpooling, mass transit, telecommuting

Green Chemistry is the use of chemistry for pollution prevention. More specifically, green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. By offering environmentally benign alternatives to the more green chemistry is promoting pollution prevention at the molecular level. Principles of green chemistry are:

1. Prevent waste
2. Design safer chemicals and products (little or no toxicity)
3. Design less hazardous chemical syntheses
4. Use renewable feed stocks
5. Use catalysts, not stoichiometric reagents
6. Avoid chemical derivatives
7. Maximize atom economy
8. Use safer solvents and reaction conditions
9. Increase energy efficiency
10. Design chemicals and products to degrade after use
11. Analyze in real time to prevent pollution
12. Minimize the potential for accidents

Green Infrastructure consists of *natural* green infrastructure – forests, grasslands, wetlands, and surface waterways that provide ecological services resulting in cleaner water and air – and *engineered* green infrastructure – human-designed that protect, restore, and regenerate, to reduce impacts on ecological systems and function. It also includes more innovative approaches or techniques (advanced) not limited to traditional systems. Both forms of green infrastructure can be complementary to achieve superior levels of energy and resource efficiency, preserve and enhance natural resources, and apply designs that soften the footprint of development and resource use. To be considered green infrastructure, superior performance should result. Performance objectives include, but are not limited to: (Nolan 2009)

- Reduced impact and footprint of development
- Mitigated green house gas generation
- Enhanced competitive advantage
- Increased economic development and job creation
- Reduced system-wide energy consumption
- Increased energy and resource efficiency
- Reduced waste
- Enhanced water supplies
- Improved local environmental quality and health
- Cleaner Surface and ground water
- Reduced capital, operational, or future costs
- Increased long-term sustainability

Green Manufacturing is a method of manufacturing that minimizes waste and pollution achieved through product and process design. It is a philosophy rather than an adopted process or standard and integrates sustainability as a core principle. Green manufacturing requires a shift from traditional end-of-pipe control methods to new technologies and process improvements that adopt: (Source Nolan 2008)

- Eco-efficiency and design for the environment (DFE) approaches
- Product responsibility in end-of-life management
- Waste and energy reduction upfront
- Reusing and recycling byproducts
- Production efficiency improvements rather than pollution control technologies
- Manufacturing systems innovation including lean manufacturing and greening supply chains

- Green design and construction in facilities
- Renewable resource substitution
- Progression toward zero waste and emissions strategies
- Elimination of all environmentally damaging byproducts from the production process

Green Products or Services should have the primary purpose of achieving superior environmental performance beyond equivalent products and services. The green attributes should be demonstrated and provide quantifiable advantages. A green product or service should be applied to measure, correct, prevent, limit, improve, or eliminate – water, air, land, and ecosystem – impacts and improve environmental quality. (Source Nolan 2007)

High Performing "Green" Industries adopt sustainable production practices and are distinguished by their systemic approach to resource utilization which results in minimal environmental impacts throughout their supply chain while positively affecting local and global socioeconomic concerns. Such industries apply lifecycle costing methods to internalize the costs of environmental degradation and shift away from using polluting processes, technologies, and products. The results are less generation of wastes, air and water pollution, land degradation and release of toxic materials to the environment which need to be controlled, mitigated, treated or managed at costs born by the business or local community.

A high performance industrial system occurs when existing and new industrial facilities, production processes, and supply chains are designed to and operate symbiotically as networks and in ways that achieve high levels of material, energy and water efficiencies with optimal use of resource inputs and minimal discharges of emissions and waste outputs. In this system not only is environmental performance improved but so is economic performance. Economic benefits include: (Source Nolan 2005)

- Reduced costs of environmental compliance and reduced liabilities
- Increased return on capital investments and asset value
- Energy security
- Access to eco-product markets (capitalizes on the growing consumer demand for environmentally sound products)
- Decreased operating costs such as waste disposal and pollution control
- Reduced future costs
- Quality job creation
- Socially responsible performance brand identity

Industrial Ecology involves designing businesses and groups of businesses as if they were a series of interlocking ecosystems, which interface benignly with the environment. Industrial ecology takes the pattern of the natural environment as a model for solving environmental problems and creating the most efficient industrial processes. Achieving this is often referred to as "**industrial symbiosis",** when the supply chain components within an industrial system are integrated to be symbiotic, rather than independent, each contributing to an efficient system that generates minimal byproducts and pollutants. Materials, energy, and water resource inputs are optimized, emissions and wastes are minimized. Wastes that remain are recovered for use as feedstocks by other businesses within the system.

Industrial Metabolism deals with the integration of physical processes which convert raw material, energy, and labor into finished products and wastes. Labor input and consumer output act as the human components or stabilizing controls of the processes.

The word metabolism "refers to the internal processes of a living organism that are necessary for the maintenance of life". There are many similarities between the biological and industrial processes both described with this word. They are both examples of "dissipative systems" which are self-stabilizing in a stable state.

A manufacturing enterprise or firm may also be described as a self-organizing entity, and the concept of industrial metabolism again applies. The industry may be described as a "balanced, quasi-stable collection of interdependent firms belonging to the same economy". (Eblen and Eblen, 1994)

Industrial Symbiosis is a way of achieving industrial ecology, when the supply chain components within an industrial system are integrated to be symbiotic, rather than independent, each contributing to an efficient system that generates minimal byproducts and pollutants. Materials, energy, and water resource inputs are optimized, emissions and wastes are minimized. Wastes that remain are recovered for use as feedstocks by other businesses within the system.

Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity. *(M. Chertow 2000 Annual Review of Energy and Environment)*

Industrial symbiosis involves linking separate companies so that the byproduct of one company may be used as a feedstock to the other company. With a network of these linkages, you can, in theory, achieve a closed loop system where waste is eliminated or drastically reduced. The other main element to industrial symbiosis is energy cascading. "Energy cascading involves the use of residual heat in liquids or steam from one process to provide heating, cooling, or pressure for another process" (Gertler 1995). Gertler points out that this approach is most suited for large-scale industrial processes only.

Integrated Bio-Systems Today, many efforts to move toward more sustainable agricultural practices are based on the theory of integrated bio-systems (IBS). According to the Zero Emissions Research and Initiatives (ZERI) Foundation, an IBS is a system that:

> ...[I]ntegrates at least two [biological] sub-systems so that the wastes generated by the first system are used by the next biological sub-system to produce a value-added product(s). The general aim of an IBS is to turn a material flow with losses that contribute to pollution into a closed and integrated one where nutrients are recovered by plants and animals.

The cyclical structure of these dynamic systems is not revolutionary. In fact, the fundamental composition of the IBS represents a return to the highly integrated agricultural systems that preceded industrialization.
The IBS concept closely resembles that of industrial symbiosis, an area of industrial ecology that "engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products" (Chertow 1999). As is true of industrial symbiosis, the key factors in IBS are the interdependence or collaboration between component systems, and the synergistic possibilities offered by geographic proximity. Unlike industrial symbiosis, however, IBS is focused on biological, not industrial systems (UNU/IAS 2000).

Linear (Open) Versus Cyclical (Closed Loop) Systems Applied industrial ecology involves the evolution of industrial systems from linear systems, where resources are consumed and damaging wastes are dissipated into the environment to a more closed systems like that of ecological systems. In a linear process, materials and energy enter one part of the system and then leave either as products or by-products/wastes. Unless the supply of materials and energy is infinite and the carrying capacity of the natural systems can assimilate the wastes and emissions, this system is unsustainable. In most of our current industrial systems, some wastes are recycled or reused within the system while others leave it. In a more evolved and integrated industrial system, there is a dynamic equilibrium with ecological systems, where energy and wastes are constantly recycled and reused in closed loops by other processes within the system.

Material and Energy Flows and Transformations as a primary part of industrial ecology requires an analysis of material and energy flows and their transformation into products, byproducts, and wastes throughout industrial systems. The consumption of resources is inventoried along with environmental releases to air, water, land and biota. One strategy of industrial ecology is to reduce the amount of waste material and waste energy that is produced and that leaves the industrial system, subsequently impacting ecological systems adversely. Instead, the system is designed to utilize waste as a material input or energy source in another process within the industrial system and thus improve the overall efficiency of the industrial system while reducing negative environmental impacts.

Pollution Prevention involves changing the existing or planned operations so that the volume and/or toxicity of wastes are minimized, so that waste generation is prevented all together. Pollution Prevention (P2) is the reduction or elimination of pollution at the source (source reduction) instead of at the end-of-the-pipe or stack. Pollution prevention occurs when raw materials, water, energy and other resources are utilized more efficiently, when less harmful substances are substituted for hazardous ones, and when toxic substances are eliminated from the production process. By reducing the use and production of hazardous substances, and by operating more efficiently we protect human health, strengthen our economic well-being, and preserve the environment.

Renewable Energy The most common definition is that renewable energy is from an energy resource that is replaced by a natural process at a rate that is equal to or faster than the rate at which that resource is being consumed. Renewable energy resources may be used directly, or used to create other more convenient forms of energy. **Renewable energy sources (RES)** capture their energy from existing flows of energy, from on-going natural processes, such as sunshine, wind, wave power , flowing water (hydropower), biological processes such as anaerobic digestion, and geothermal heat flow.

Sustainable Industrial Development requires that industries and communities support *economic, social, and environmental* quality in a community or region. In business terms this is often referred to as the **"triple bottom line"**. To be sustainable, industrial development must do more than create jobs and tax base while meeting minimum compliance standards for environmental protection, wages, and employee welfare. Industrial development should be cleanly integrated into the community to efficiently utilize resources sustainably within the local environment and commercial economy while enhancing community prosperity. Such development addresses the full economic costs of associated environmental impacts by achieving higher levels of environmental performance as a fundamental way of doing business. The inherent benefits resulting from this higher level of performance results in competitive advantages for the enterprises and communities involved. (Source Nolan 2005)

Systems Analysis is integral to industrial ecology, which requires a systems view of the relationship between human activities and environmental problems. Central to the systems approach is an inherent recognition of the interrelationships between industrial and natural systems. In an industrial production system, applying a systems view enables manufacturers to develop products in a sustainable fashion by understanding the life cycle impacts throughout each stage of production. Applying industrial ecology requires that the industrial system be viewed not in isolation from surrounding ecological systems but in concert with them. As a result, a manufacturer throughout their supply chain will seek to optimize the total materials cycle from virgin material, to finished material, to component, to product, to waste product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital.

Supply Chain is the all inclusive set of links from raw materials to customer, including extraction, transportation, fuels, manufacturing, and use, i.e., the network of retailers, distributors, transporters, storage facilities and suppliers that participate in the sale, delivery and production of a particular product (Investorwords.com 2003).

Sustainable Design The concept of sustainable design has a long-term focus and considers the life cycle of a building or larger development from the planning stage to demolition. The key is understanding before we build how things are interrelated while striving to integrate the building with the surrounding natural environment resulting in low and perhaps enhancing environmental impacts. We think whole systems and the process of building becomes integrated throughout the planning, predesign, design, construction and occupancy phases. The building itself is designed and built not as many separate parts but rather as a system that must be balanced to achieve the highest level of resource efficiency and a healthy productive indoor environment.

Triple Bottom Line captures an expanded spectrum of values and criteria for measuring organizational (and societal) success - economic, environmental and social. For some a commitment to Corporate Social Responsibility brings with it a need to institute triple bottom line reporting. The triple bottom line is rapidly gaining recognition as a framework for measuring business performance. In practical terms, triple bottom line accounting usually means expanding the traditional company reporting framework to take into account not just financial outcomes but also environmental and social performance.

Zero Waste is a philosophy that aims to guide the redesign of resource-use system with the aim of reducing waste to zero. It is a concept to extend beyond recycling to form a circular system where as much waste as possible is reused, similar to the way it is in nature. Practicing zero waste strategies is not just another form of recycling; it involves changing things at the production level. Zero waste depends on the redesign of industrial, commercial and consumer goods.