# 13.5: Attributes Required by an Industrial Ecosystem

Under the heading of "Response of Life Systems to Stress" in section 12.6, is a discussion of the *inertia* of biological communities, which is their resistance to alteration and damage. The key factors involved in inertia were mentioned as *productivity* of basic food materials, *diversity* of species, *constancy* of numbers of various organisms and *resilience* in the ability of populations to recover from loss. Industrial ecosystems likewise have key attributes that are required for their welfare. These include **energy**, **materials**, and **diversity**. One big difference between biological and industrial ecosystems is the time scale involved. In the evolution of organisms, a time period of several thousand years is very brief, whereas in industrial systems several decades may be a very long time.

## Energy

With enough energy, almost anything is possible (see Chapter 15, "Sustainable Energy: The Essential Basis of Green Systems"). Therefore, the provision of adequate amounts of energy that can be used without damaging the environment too much is essential for the function of industrial ecosystems. And the energy that is available has to be used as effectively and efficiently as possible. It was once believed that the world's vast coal resources would provide enough energy to meet human needs for several centuries. Now it is apparent that consuming most of these energy resources would cause unacceptable global warming effects. Solar energy and wind energy, which derives from solar energy, come about as close as any energy source to offering ideal renewable sources of energy. But there are major problems with the intermittent nature of these sources and the need that they present for short-term energy storage. Furthermore, they both require vast areas of land in order to provide a significant share of energy needs. Then there are unexpected problems, such as the one arising from the accumulation of dead insects on windmill blades, spoiling their finely tuned aerodynamic characteristics and reducing power output by about half in strong winds. Properly run nuclear power facilities can provide abundant energy for many decades, but this source comes with its own set of problems and is strongly opposed by many.

**Cogeneration** represents the most efficient energy use within an industry or within an industrial ecosystem. The two major reasons that an industrial plant uses energy are (1) for steam used in processing, such as heating chemical reaction mixtures to cause a reaction to go faster, and(2) to generate electricity. Traditionally, industrial operations, such as petroleum refineries, have bought electricity from external power plants to run pumps and compressors, for lighting, and other purposes that consume electricity. Steam, which can only be shipped economically for relatively short distances, is normally generated by burning fossil fuels in boilers on the site. Since a maximum of only approximately 40% of the heat generated in burning a fuel in a power plant can be converted to electricity, and because of losses in electrical transmission lines, obtaining electricity from an external source is a relatively inefficient means of getting power. Much greater efficiencies can be attained by burning fuels, such as natural gas, in large turbines connected to an electrical generator and using the hot exhaust from the turbine to raise steam. This approach can double the overall efficiency of energy utilization.

## Materials

There are several approaches to providing materials. These can be classified as **dematerialization** in which less material is used for a specific purpose, **substitution** of abundant materials for scarce ones, **recycling** materials, and **waste mining** in which needed materials are extracted from wastes.

Examples abound of areas in which the need for materials has been reduced in recent decades. Higher voltage electrical transmission carries more power over thinner copper or aluminum wires, the switch from 6-volt to 12-volt electrical systems in automobiles has enabled lighter wiring in automotive electrical systems, modern photographic film uses much less silver than in years past(and the almost complete switch to digital photography has virtually eliminated the use of silver in photography), and the switch from biased-ply to radial tires has greatly extended tire life, so that much less rubber is required (as well as saving fuel by lowered rolling resistance). Dematerialization has been spectacular in the electronics area. The popular laptop computer has far more computing power than did the earliest vacuum-tube-equipped computers that each required an entire air conditioned building for housing.

Material substitution is an area in which green chemistry has made a significant contribution and will continue to do so at an accelerating pace in the future. The most spectacular advances have been made in electronics where material substitution, which enabled dematerialization to occur, has provided electronic circuits with many orders of magnitude more capability than the circuits that they replaced. The glowing, electricity-consuming vacuum tubes, capacitors, resistors, and transformers of the receiver circuit of a 1950s table-top radio have been replaced with a tiny circuit almost invisible to the human eye. The huge numbers of copper wires that carried telegraph and telephone messages in the 1940s have now been replaced by fiber optic signal conductors that carry unimaginably more information per unit mass of carrier. Polyvinylchloride (PVC) pipe, synthesized from inexhaustible world resources of chlorine and potentially from biomass hydrocarbon sources, has replaced copper and steel for water and wastewater transmissions. Toxic liquid sulfur dioxide and ammonia used in early refrigerator models were replaced by nontoxic, nonflammable chlorofluorocarbons (CFCs). When the CFCs were found to deplete stratospheric ozone, substitutes were developed containing at least one bound H atom per molecule (HCFCs) that break down in the troposphere before reaching stratospheric altitudes. Many more similar examples could be cited.

Recycling is of course one of the major objectives of a system of industrial ecology and one in which significant progress is being made. There are some consumable items that are not practical to recycle and for which the raw materials are abundant enough that recycling is not required. Household detergents are in this category. A second group of recyclables are those that are not particularly scarce, but for which recycling is feasible and desirable. Wood and paper fall into this category. A third category of recyclable materials consists of metals, particularly the more valuable and scarce ones, such as chromium, platinum, and palladium. These metals definitely should be recycled. A fourth category of recyclables consists of parts and apparatus that can be refurbished and reused.

Waste mining, the extraction of useful materials from wastes, provides more materials while benefitting the environment. One of several important examples of waste mining is the extraction of combustible methane gas, a low-polluting premium fossil fuel, from municipal refuse landfills in which the biodegradation of organic matter in the absence of oxygen generates the gas. Sulfur in sulfur dioxide extracted from the flue gases generated in burning coal that contains sulfur can be reclaimed and used to make sulfuric acid. Methods have been developed to extract aluminum from finely divided coal fly ash generated in coal combustion. In this case, the finely divided, homogeneous, dry nature of the fly ash is a definite advantage in processing it. It is anticipated that growing scarcity of resources combined with the need to dispose of a variety of wastes will lead to the development of additional waste mining processes in the future.

## Diversity

Diversity in industrial ecosystems, tends to impart a **robust** character to them, which means that if one part of the system is diminished, other parts will take its place and keep the system functioning well. Many communities that have become dependent upon one or just a few major enterprises have suffered painful economic crises when a major employer leaves or cuts back. The fouling of beaches in Louisiana, Mississippi, Alabama, and Florida from the 2010 BP Deepwater Horizon has devastated the tourist trade and forced painful economic adjustments. In many parts of the world, water supply from a single vulnerable source threatens diversity.

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