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"Eco-efficiency," the current industrial buzzword, will neither save the environment nor foster ingenuity and productivity, the authors say. They propose a new approach that aims to solve rather than alleviate the problems that industry makes

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The NEXT Industrial Revolution

In the spring of 1912 one of the largest moving objects ever created by human beings left Southampton and began gliding toward New York. It was the epitome of its industrial age—a potent representation of technology, prosperity, luxury, and progress. It weighed 66,000 tons. Its steel hull stretched the length of four city blocks. Each of its steam engines was the size of a townhouse. And it was headed for a disastrous encounter with the natural world.

This vessel, of course, was the Titanic—a brute of a ship, seemingly impervious to the details of nature. In the minds of the captain, the crew, and many of the passengers, nothing could sink it.

One might say that the infrastructure created by the Industrial Revolution of the nineteenth century resembles such a steamship. It is powered by fossil fuels, nuclear reactors, and chemicals. It is pouring waste into the water and smoke into the sky. It is attempting to work by its own rules, contrary to those of the natural world. And although it may seem invincible, its fundamental design flaws presage disaster. Yet many people still believe that with a few minor alterations, this infrastructure can take us safely and prosperously into the future.

During the Industrial Revolution resources seemed inexhaustible and nature was viewed as something to be tamed and civilized. Recently, however, some leading industrialists have begun to realize that traditional ways of doing things may not be sustainable over the long term. "What we thought was boundless has limits," Robert Shapiro, the chairman and chief executive officer of Monsanto, said in a 1997 interview, "and we're beginning to hit them."

The 1992 Earth Summit in Rio de Janeiro, led by the Canadian businessman Maurice Strong, recognized those limits. Approximately 30,000 people from around the world, including more than a hundred world leaders and representatives of 167 countries, gathered in Rio de Janeiro to respond to troubling symptoms of environmental decline. Although there was sharp disappointment afterward that no binding agreement had been reached at the summit, many industrial participants touted a particular strategy: eco-efficiency. The machines of industry would be refitted with cleaner, faster, quieter engines. Prosperity would remain unobstructed, and economic and organizational structures would remain intact. The hope was that eco-efficiency would transform human industry from a system that takes, makes, and wastes into one that integrates economic, environmental, and ethical concerns. Eco-efficiency is now considered by industries across the globe to be the strategy of choice for change.

What is eco-efficiency? Primarily, the term means "doing more with less"—a precept that has its roots in early industrialization. Henry Ford was adamant about lean and clean operating policies; he saved his company money by recycling and reusing materials, reduced the use of natural resources, minimized packaging, and set new standards with his timesaving assembly line. Ford wrote in 1926, "You must get the most out of the power, out of the material, and out of the time"—a credo that could hang today on the wall of any eco-efficient factory. The linkage of efficiency with sustaining the environment was perhaps most famously articulated in Our Common Future, a report published in 1987 by the United Nations' World Commission on Environment and Development. Our Common Future warned that if pollution control were not intensified, property and ecosystems would be threatened, and existence would become unpleasant and even harmful to human health in some cities. "Industries and industrial operations should be encouraged that are more efficient in terms of resource use, that generate less pollution and waste, that are based on the use of renewable rather than non-renewable resources, and that minimize irreversible adverse impacts on human health and the environment," the commission stated in its agenda for change.

The term "eco-efficiency" was promoted five years later, by the Business Council (now the World Business Council) for Sustainable Development, a group of forty-eight industrial sponsors including Dow, Du Pont, Con Agra, and Chevron, who brought a business perspective to the Earth Summit. The council presented its call for change in practical terms, focusing on what businesses had to gain from a new ecological awareness rather than on what the environment had to lose if industry continued in current patterns. In Changing Course, a report released just before the summit, the group's founder, Stephan Schmidheiny, stressed the importance of eco-efficiency for all companies that aimed to be competitive, sustainable, and successful over the long term. In 1996 Schmidheiny said, "I predict that within a decade it is going to be next to impossible for a business to be competitive without also being 'eco-efficient'—adding more value to a good or service while using fewer resources and releasing less pollution."

As Schmidheiny predicted, eco-efficiency has been working its way into industry with extraordinary success. The corporations committing themselves to it continue to increase in number, and include such big names as Monsanto, 3M, and Johnson & Johnson. Its famous three Rs—reduce, reuse, recycle—are steadily gaining popularity in the home as well as the workplace. The trend stems in part from eco-efficiency's economic benefits, which can be considerable: 3M, for example, has saved more than $750 million through pollution-prevention projects, and other companies, too, claim to be realizing big savings. Naturally, reducing resource consumption, energy use, emissions, and wastes has implications for the environment as well. When one hears that Du Pont has cut its emissions of airborne cancer-causing chemicals by almost 75 percent since 1987, one can't help feeling more secure. This is another benefit of eco-efficiency: it diminishes guilt and fear. By subscribing to eco-efficiency, people and industries can be less "bad" and less fearful about the future. Or can they?

Eco-efficiency is an outwardly admirable and certainly well-intended concept, but, unfortunately, it is not a strategy for success over the long term, because it does not reach deep enough. It works within the same system that caused the problem in the first place, slowing it down with moral proscriptions and punitive demands. It presents little more than an illusion of change. Relying on eco-efficiency to save the environment will in fact achieve the opposite—it will let industry finish off everything quietly, persistently, and completely.

We are forwarding a reshaping of human industry—what we and the author Paul Hawken call the Next Industrial Revolution. Leaders of this movement include many people in diverse fields, among them commerce, politics, the humanities, science, engineering, and education. Especially notable are the businessman Ray Anderson; the philanthropist Teresa Heinz; the Chattanooga city councilman Dave Crockett; the physicist Amory Lovins; the environmental-studies professor David W. Orr; the environmentalists Sarah Severn, Dianne Dillon Ridgley, and Susan Lyons; the environmental product developer Heidi Holt; the ecological designer John Todd; and the writer Nancy Jack Todd. We are focused here on a new way of designing industrial production. As an architect and industrial designer and a chemist who have worked with both commercial and ecological systems, we see conflict between industry and the environment as a design problem—a very big design problem.

Many of the basic intentions behind the Industrial Revolution were good ones, which most of us would probably like to see carried out today: to bring more goods and services to larger numbers of people, to raise standards of living, and to give people more choice and opportunity, among others. But there were crucial omissions. Perpetuating the diversity and vitality of forests, rivers, oceans, air, soil, and animals was not part of the agenda.

If someone were to present the Industrial Revolution as a retroactive design assignment, it might sound like this:

Design a system of production that

*puts billions of pounds of toxic material into the air, water, and soil every year

* measures prosperity by activity, not legacy

* requires thousands of complex regulations to keep people and natural systems from being poisoned too quickly

* produces materials so dangerous that they will require constant vigilance from future generations

* results in gigantic amounts of waste

* puts valuable materials in holes all over the planet, where they can never be retrieved

* erodes the diversity of biological species and cultural practices

Eco-efficiency instead

*releases *fewer* pounds of toxic material into the air, water, and soil every year

*measures prosperity by *less* activity

**meets* or *exceeds* the stipulations of thousands of complex regulations that aim to keep people and natural systems from being poisoned too quickly

*produces *fewer* dangerous materials that will require constant vigilance from future generations

*results in *smaller* amounts of waste

*puts *fewer* valuable materials in holes all over the planet, where they can never be retrieved

*standardizes and homogenizes biological species and cultural practices

Plainly put, eco-efficiency aspires to make the old, destructive system less so. But its goals, however admirable, are fatally limited.

Reduction, reuse, and recycling slow down the rates of contamination and depletion but do not stop these processes. Much recycling, for instance, is what we call "downcycling," because it reduces the quality of a material over time. When plastic other than that found in such products as soda and water bottles is recycled, it is often mixed with different plastics to produce a hybrid of lower quality, which is then molded into something amorphous and cheap, such as park benches or speed bumps. The original high-quality material is not retrieved, and it eventually ends up in landfills or incinerators.

The well-intended, creative use of recycled materials for new products can be misguided. For example, people may feel that they are making an ecologically sound choice by buying and wearing clothing made of fibers from recycled plastic bottles. But the fibers from plastic bottles were not specifically designed to be next to human skin. Blindly adopting superficial "environmental" approaches without fully understanding their effects can be no better than doing nothing.

Recycling is more expensive for communities than it needs to be, partly because traditional recycling tries to force materials into more lifetimes than they were designed for—a complicated and messy conversion, and one that itself expends energy and resources. Very few objects of modern consumption were designed with recycling in mind. If the process is truly to save money and materials, products must be designed from the very beginning to be recycled or even "upcycled"—a term we use to describe the return to industrial systems of materials with improved, rather than degraded, quality.

The reduction of potentially harmful emissions and wastes is another goal of eco-efficiency. But current studies are beginning to raise concern that even tiny amounts of dangerous emissions can have disastrous effects on biological systems over time. This is a particular concern in the case of endocrine disrupters—industrial chemicals in a variety of modern plastics and consumer goods which appear to mimic hormones and connect with receptors in human beings and other organisms. Theo Colborn, Dianne Dumanoski, and John Peterson Myers, the authors of *Our Stolen Future* (1996), a groundbreaking study on certain synthetic chemicals and the environment, assert that "astoundingly small quantities of these hormonally active compounds can wreak all manner of biological havoc, particularly in those exposed in the womb."

On another front, new research on particulates—microscopic particles released during incineration and combustion processes, such as those in power plants and automobiles—shows that they can lodge in and damage the lungs, especially in children and the elderly. A 1995 Harvard study found that as many as 100,000 people die annually as a result of these tiny particles. Although regulations for smaller particles are in place, implementation does not have to begin until 2005. Real change would be not regulating the release of particles but attempting to eliminate dangerous emissions altogether—by design.

Ancient nomadic cultures tended to leave organic wastes behind, restoring nutrients to the soil and the surrounding environment. Modern, settled societies simply want to get rid of waste as quickly as possible. The potential nutrients in organic waste are lost when they are disposed of in landfills, where they cannot be used to rebuild soil; depositing synthetic materials and chemicals in natural systems strains the environment. The ability of complex, interdependent natural ecosystems to absorb such foreign material is limited if not nonexistent. Nature cannot do anything with the stuff *by design*: many manufactured products are intended not to break down under natural conditions.

If people are to prosper within the natural world, all the products and materials manufactured by industry must after each useful life provide nourishment for something new. Since many of the things people make are not natural, they are not safe "food" for biological systems. Products composed of materials that do not biodegrade should be designed as technical nutrients that continually circulate within closed-loop industrial cycles—the technical metabolism.

In order for these two metabolisms to remain healthy, great care must be taken to avoid cross-contamination. Things that go into the biological metabolism should not contain mutagens, carcinogens, heavy metals, endocrine disrupters, persistent toxic substances, or bio-accumulative substances. Things that go into the technical metabolism should be kept well apart from the biological metabolism.

If the things people make are to be safely channeled into one or the other of these metabolisms, then products can be considered to contain two kinds of materials: *biological nutrients* and *technical nutrients*.

Biological nutrients will be designed to return to the organic cycle—to be literally consumed by microorganisms and other creatures in the soil. Most packaging (which makes up about 50 percent by volume of the solid-waste stream) should be composed of biological nutrients—materials that can be tossed onto the ground or the compost heap to biodegrade. There is no need for shampoo bottles, toothpaste tubes, yogurt cartons, juice containers, and other packaging to last decades (or even centuries) longer than what came inside them.

Technical nutrients will be designed to go back into the technical cycle. Right now anyone can dump an old television into a trash can. But the average television is made of hundreds of chemicals, some of which are toxic. Others are valuable nutrients for industry, which are wasted when the television ends up in a landfill. The reuse of technical nutrients in closed-loop industrial cycles is distinct from traditional recycling, because it allows materials to retain their quality: high-quality plastic computer cases would continually circulate as high-quality computer cases, instead of being downcycled to make soundproof barriers or flowerpots.

Customers would buy the *service* of such products, and when they had finished with the products, or simply wanted to upgrade to a newer version, the manufacturer would take back the old ones, break them down, and use their complex materials in new products.

FIRST FRUITS: A BIOLOGICAL NUTRIENT

A few years ago we helped to conceive and create a compostable upholstery fabric—a biological nutrient. We were initially asked by Design Tex to create an aesthetically unique fabric that was also ecologically intelligent—although the client did not quite know at that point what this would mean. The challenge helped to clarify, both for us and for the company we were working with, the difference between superficial responses such as recycling and reduction and the more significant changes required by the Next Industrial Revolution.

For example, when the company first sought to meet our desire for an environmentally safe fabric, it presented what it thought was a wholesome option: cotton, which is natural, combined with PET (polyethylene terephthalate) fibers from recycled beverage bottles. Since the proposed hybrid could be described with two important eco-buzzwords, "natural" and "recycled," it appeared to be environmentally ideal. The materials were readily available, market-tested, durable, and cheap. But when the project team looked carefully at what the manifestations of such a hybrid might be in the long run, we discovered some disturbing facts. When a person sits in an office chair and shifts around, the fabric beneath him or her abrades; tiny particles of it are inhaled or swallowed by the user and other people nearby. PET was not designed to be inhaled. Furthermore, PET would prevent the proposed hybrid from going back into the soil safely, and the cotton would prevent it from re-entering an industrial cycle. The hybrid would still add junk to landfills, and it might also be dangerous.

The team decided to design a fabric so safe that one could literally eat it. The European textile mill chosen to produce the fabric was quite "clean" environmentally, and yet it had an interesting problem: although the mill's director had been diligent about reducing levels of dangerous emissions, government regulators had recently defined the trimmings of his fabric as hazardous waste. We sought a different end for our trimmings: mulch for the local garden club. When removed from the frame after the chair's useful life and tossed onto the ground to mingle with sun, water, and hungry microorganisms, both the fabric and its trimmings would decompose naturally.

The team decided on a mixture of safe, pesticide-free plant and animal fibers for the fabric (ramie and wool) and began working on perhaps the most difficult aspect: the finishes, dyes, and other processing chemicals. If the fabric was to go back into the soil safely, it had to be free of mutagens, carcinogens, heavy metals, endocrine disrupters, persistent toxic substances, and bio-accumulative substances. Sixty chemical companies were approached about joining the project, and all declined, uncomfortable with the idea of exposing their chemistry to the kind of scrutiny necessary. Finally one European company, Ciba-Geigy, agreed to join.

With that company's help the project team considered more than 8,000 chemicals used in the textile industry and eliminated 7,962. The fabric—in fact, an entire line of fabrics—was created using only thirty-eight chemicals.

The director of the mill told a surprising story after the fabrics were in production. When regulators came by to test the effluent, they thought their instruments were broken. After testing the influent as well, they realized that the equipment was fine—the water coming out of the factory was as clean as the water going in. The manufacturing process itself was filtering the water. The new design not only bypassed the traditional three-R responses to environmental problems but also eliminated the need for regulation.

In our Next Industrial Revolution, regulations can be seen as signals of design failure. They burden industry, by involving government in commerce and by interfering with the marketplace. Manufacturers in countries that are less hindered by regulations, and whose factories emit more toxic substances, have an economic advantage: they can produce and sell things for less. If a factory is not emitting dangerous substances and needs no regulation, and can thus compete directly with unregulated factories in other countries, that is good news environmentally, ethically, and economically.

A Technical Nutrient

Someone who has finished with a traditional carpet must pay to have it removed. The energy, effort, and materials that went into it are lost to the manufacturer; the carpet becomes little more than a heap of potentially hazardous petrochemicals that must be toted to a landfill. Meanwhile, raw materials must continually be extracted to make new carpets.

The typical carpet consists of nylon embedded in fiberglass and PVC. After its useful life a manufacturer can only downcycle it—shave off some of the nylon for further use and melt the leftovers. The world's largest commercial carpet company, Interface, is adopting our technical-nutrient concept with a carpet designed for complete recycling. When a customer wants to replace it, the manufacturer simply takes back the technical nutrient—depending on the product, either part or all of the carpet—and returns a carpet in the customer's desired color, style, and texture. The carpet company continues to own the material but leases it and maintains it, providing customers with the service of the carpet. Eventually the carpet will wear out like any other, and the manufacturer will reuse its materials at their original level of quality or a higher one.

The advantages of such a system, widely applied to many industrial products, are twofold: no useless and potentially dangerous waste is generated, as it might still be in eco-efficient systems, and billions of dollars' worth of valuable materials are saved and retained by the manufacturer.

Selling Intelligence, Not Poison

Currently, chemical companies warn farmers to be careful with pesticides, and yet the companies benefit when more pesticides are sold. In other words, the companies are unintentionally invested in wastefulness and even in the mishandling of their products, which can result in contamination of the soil, water, and air. Imagine what would happen if a chemical company sold intelligence instead of pesticides—that is, if farmers or agro-businesses paid pesticide manufacturers to protect their crops against loss from pests instead of buying dangerous regulated chemicals to use at their own discretion. It would in effect be buying crop insurance. Farmers would be saying, "I'll pay you to deal with boll weevils, and you do it as intelligently as you can." At the same price per acre, everyone would still profit. The pesticide purveyor would be invested in not using pesticide, to avoid wasting materials. Furthermore, since the manufacturer would bear responsibility for the hazardous materials, it would have incentives to come up with less-dangerous ways to get rid of pests. Farmers are not interested in handling dangerous chemicals; they want to grow crops. Chemical companies do not want to contaminate soil, water, and air; they want to make money.

Consider the unintended design legacy of the average shoe. With each step of your shoe the sole releases tiny particles of potentially harmful substances that may contaminate and reduce the vitality of the soil. With the next rain these particles will wash into the plants and soil along the road, adding another burden to the environment.

Shoes could be redesigned so that the sole was a biological nutrient. When it broke down under a pounding foot and interacted with nature, it would nourish the biological metabolism instead of poisoning it. Other parts of the shoe might be designed as technical nutrients, to be returned to industrial cycles. Most shoes—in fact, most products of the current industrial system—are fairly primitive in their relationship to the natural world. With the scientific and technical tools currently available, this need not be the case.

RESPECT DIVERSITY AND USE THE SUN

The leading goal of design in this century has been to achieve universally applicable solutions. In the field of architecture the International Style is a good example. As a result of the widespread adoption of the International Style, architecture has become uniform in many settings. That is, an office building can look and work the same anywhere. Materials such as steel, cement, and glass can be transported all over the world, eliminating dependence on a region's particular energy and material flows. With more energy forced into the heating and cooling system, the same building can operate similarly in vastly different settings.

The second principle of the Next Industrial Revolution is "Respect diversity." Designs will respect the regional, cultural, and material uniqueness of a place. Wastes and emissions will regenerate rather than deplete, and design will be flexible, to allow for changes in the needs of people and communities. For example, office buildings will be convertible into apartments, instead of ending up as rubble in a construction landfill when the market changes.

The third principle of the Next Industrial Revolution is "Use solar energy." Human systems now rely on fossil fuels and petrochemicals, and on incineration processes that often have destructive side effects. Today even the most advanced building or factory in the world is still a kind of steamship, polluting, contaminating, and depleting the surrounding environment, and relying on scarce amounts of natural light and fresh air. People are essentially working in the dark, and they are often breathing unhealthful air. Imagine, instead, a building as a kind of tree. It would purify air, accrue solar income, produce more energy than it consumes, create shade and habitat, enrich soil, and change with the seasons. Oberlin College is currently working on a building that is a good start: it is designed to make more energy than it needs to operate and to purify its own wastewater.

EQUITY, ECONOMY, ECOLOGY

The Next Industrial Revolution incorporates positive intentions across a wide spectrum of human concerns. People within the sustainability movement have found that three categories are helpful in articulating these concerns: equity, economy, and ecology.

Equity refers to social justice. Does a design depreciate or enrich people and communities? Shoe companies have been blamed for exposing workers in factories overseas to chemicals in amounts that exceed safe limits. Eco-efficiency would reduce those amounts to meet certain standards; eco-effectiveness would not use a potentially dangerous chemical in the first place. What an advance for humankind it would be if no factory worker anywhere worked in dangerous or inhumane conditions.

Economy refers to market viability. Does a product reflect the needs of producers and consumers for affordable products? Safe, intelligent designs should be affordable by and accessible to a wide range of customers, and profitable to the company that makes them, because commerce is the engine of change.

Ecology, of course, refers to environmental intelligence. Is a material a biological nutrient or a technical nutrient? Does it meet nature's design criteria: Waste equals food, Respect diversity, and Use solar energy?

The Next Industrial Revolution can be framed as the following assignment: Design an industrial system for the next century that

*introduces no hazardous materials into the air, water, or soil

*measures prosperity by how much natural capital we can accrue in productive ways

*measures productivity by how many people are gainfully and meaningfully employed

*measures progress by how many buildings have no smokestacks or dangerous effluents

*does not require regulations whose purpose is to stop us from killing ourselves too quickly

*produces nothing that will require future generations to maintain vigilance

*celebrates the abundance of biological and cultural diversity and solar income

Albert Einstein wrote, "The world will not evolve past its current state of crisis by using the same thinking that created the situation." Many people believe that new industrial revolutions are already taking place, with the rise of cybertechnology, biotechnology, and nanotechnology. It is true that these are powerful tools for change. But they are only tools—hyperefficient engines for the steamship of the first Industrial Revolution. Similarly, eco-efficiency is a valuable and laudable tool, and a prelude to what should come next. But it, too, fails to move us beyond the first revolution. It is time for designs that are creative, abundant, prosperous, and intelligent from the start. The model for the Next Industrial Revolution may well have been right in front of us the whole time: a tree.
