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CHAPTER 3

Rethinking Production

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In 1999, executives at DuPont boldly pledged to reduce the company's greenhouse gas (GHG) emissions 65 percent below their 1990 levels by 2010 as part of a companywide strategy to lighten its environmental impact. The plan, in part, was to diversify the product line—shedding divisions such as nylon and pharmaceuticals to focus on materials that reduce greenhouse gases, such as Tyvek house wraps for energy efficiency. The plan worked: by 2007 DuPont had cut emissions 72 percent below 1991 levels, reduced its global energy use 7 percent, and, in the process, saved itself $3 billion. DuPont now plans to go beyond mere efficiency improvements to make products that mimic nature, including plant-based chemicals like Bio-PDO that can replace petroleum in polymers, detergents, cosmetics, and antifreeze.[1]

DuPont's actions—and similar ones in dozens of other firms—reflect a recognition that the way goods and services are produced must be radically rethought in this sustainability century. Over the past 100 years, the way humans made and sold goods and services took a heavy toll. Now, smart companies recognize the need to move beyond business as usual to meet people's needs in sustainable ways.

Every year the world digs up, puts through various resource crunching processes, and then throws away over a half-trillion tons of stuff. Less than 1 percent of the materials is embodied in a product and still there six months after sale. All of the rest is waste. This pattern of production and the consumption it engenders now threaten every ecosystem on Earth. In March 2005, U.N. Secretary-General Kofi Annan observed that "the very basis for life on earth is declining at an alarming rate."[2]

By the time most human artifacts have been designed but before they have been built, 80–90 percent of their lifecycle eco-

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nomic and ecological costs have already become inevitable. For example, this book you are holding, the seat in which you are sitting, the airplane in which you may be flying, the terminal at which you will land, the vehicle in which you will continue your trip are all the result of myriad choices made by policymakers, designers, engineers, craftspeople, marketers, distributors, and so on. Each step represents opportunities to deliver the idea, the part, or the production process in ways that use more or fewer resources and result in a superior or suboptimal end-result. Thinking in a more holistic way and choosing more wisely at each step can reduce the impacts of these choices on the planet and its inhabitants.[3]

This is the foundation of Natural Capitalism, the framework of sustainability that describes how to meet needs in ways that achieve durable competitive advantage, solve most of the environmental and many of the social challenges facing the planet at a profit, and ensure a higher quality of life for all people. It is based on three principles:

- Buy the time that is urgently needed to deal with the growing challenges facing the planet by using all resources far more productively.
- Redesign how we make all products and provide services, using such approaches as biomimcry and cradle to cradle.
- Manage all institutions to be restorative of human and natural capital.[4]

The good news is that meeting human needs while using less stuff can be more profitable and can deliver a higher standard of living than continuing with current practices. Combined with efforts to lower consumption (see Chapter 4), practices that raise resource efficiency, circulate materials rather than dump them, and imitate nature offer a new model of prosperity for an environmentally degraded and poverty-stricken planet.

The Solid Foundation of Eco-efficiency

The ability to produce cheap goods and ship them around the planet derived in part from abundant supplies of cheap energy. Using this inexpensive oil, gas, and coal has polluted the planet and dangerously warmed the climate. In a carbon-constrained world, survival depends on finding ways to produce goods and services in dramatically more energy-efficient ways.

The concept of making things using fewer resources is far from new, but it remains the cornerstone in producing goods and services more sustainably. Critics such as William McDonough disparage eco-efficiency as simply doing less bad, but therefore still bad. Greater resource productivity alone will not deliver a sustainable society, but the criticism misses the significance of using as few resources as possible. The foundation of a building is far from sufficient to house a family, but without a solid underpinning no structure can long stand. Without eco-efficiency, no system of production can be said to be sustainable.[5]

More important, however, given the challenges facing the world, is the fact that using less stuff buys the critical time necessary to solve such daunting problems as climate change and to develop and implement production methods that meet humanity's needs in ways that do not cause more problems.

Eco-efficiency is the easiest component of the transition to sustainability to implement. It is increasingly profitable, and psychologically it is far more familiar to industrial engineers than are such concepts as biomimicry or the human dimensions of implementing the changes necessary. It is therefore a great place to start.

It is now cost-effective to increase the efficiency with which the world's resources are used by at least fourfold—dubbed "Factor Four" in a 1997 book. The European Union has already adopted this as the basis for sustainable development policy and practice. Some countries like Australia have set this and even greater efficiency as a desirable national goal. The Environment Ministers of the Organisation for Economic Co-operation and Development, the government of Sweden, and various industrial and academic leaders in Europe, Japan, and elsewhere have gone even further, adopting Factor Ten improvements as their goal. The World Business Council for Sustainable Development (WBCSD) and the U.N. Environment Programme have called for Factor Twenty, which involves increasing efficiency 20-fold. There is growing evidence that even such ambitious goals are feasible and achievable in the marketplace. They may, in fact, offer even greater profits.[6]

One of the foremost proponents of eco-efficiency is the World Business Council for Sustainable Development, which introduced this term to the world right before the 1992 Earth Summit in Rio de Janeiro. WBCSD defines eco-efficiency as:

- reduction in the material intensity of goods or services,
- reduction in the energy intensity of goods or services,
- reduced dispersion of toxic materials,
- improved recyclability,
- maximum use of renewable resources,
- greater durability of products, and
- increased service intensity of goods and services.[7]

WBCSD is a CEO-led network of more than 200 companies promoting market-oriented sustainable development and greater resource productivity. It enables its members to share knowledge, experiences, and best practices on energy and climate, development, ecosystems, and the role of business in society. It maintains initiatives in sustainable value chains, capacity building, water, and energy use in buildings. WBCSD conducts sector-specific studies on how to reduce resource use in such areas as cement, electric utilities, mining and minerals, mobility, tires, and forestry. The group is led by an executive committee featuring leaders of such companies as Toyota, DuPont, Unilever, Lafarge, and Royal Dutch Shell.[8]

Member companies have implemented profitable resource productivity to lower their costs and reduce their environmental footprint. For example, AngloAmerican/ Mondi South Africa increased the production capacity of one of its pulp mills by 25 percent. This enabled it to accommodate a 40-percent increase in timber supply from more than 2,800 small growers, while increasing the efficiency of using waste wood to power the plant, decreasing the use of bleach chemicals, and reducing the use of coal from 562 to 234 tons per day—all while significantly cutting costs. The measures achieved reductions in:

- 2,177 tons of sulfur dioxide—a 50-percent reduction;
- 509 tons of nitrogen oxide (NO_X)—a 35-percent reduction;
- 297,121 tons of carbon dioxide (CO_2)—a 50-percent reduction; and
- total sulfur emissions—down approximately 60 percent.

Energy-efficient technologies also reduced water consumption and purchased energy. These enabled the pulp mill to use 44 percent less purchased energy in 2005 than in 2003. During 2005, one mill cut its energy and water costs by 27 percent.[9]

Increasingly, companies are implementing eco-efficiency to drive their innovation and enhance their competitiveness. STMicroelectronics (ST), a Swiss-based $8.7-billion semiconductor company, set a goal of zero net GHG emissions by 2010 while increasing production 40-fold. ST's GHG emissions were traced to facility energy use (45 percent), industrial process (perfluorocarbon and sulfur hexafluoride) emissions (35 percent), and transportation (15 percent). The company undertook to reduce on-site emissions by investing in cogeneration (efficient combined heat and electricity production) and fuel cells (efficient electricity production).[10]

By 2010 cogeneration sources should supply 55 percent of ST's electricity, with another 15 percent coming from fuel switching to renewable energy. ST will reduce the need for energy supply through improved efficiency and implement various projects to sequester carbon. This commitment has improved profitability. During the 1990s its energy efficiency projects averaged a two-year payback—a nearly 71 percent after-tax rate of return.[11]

Making and delivering on this promise has also driven ST's corporate innovation and increased its market share, taking the company from the twelfth to the sixth largest microchip maker by 2004. By the time ST meets its commitment, it expects to have saved almost $1 billion.[12]

What is true in microchip manufacturing holds true in consumer retailing as well: things can be done more efficiently. In October 2005, Wal-Mart, the world's largest retailer, announced a corporate commitment to cut greenhouse gas emissions and reduce waste, pledging to be supplied 100 percent by renewable energy, to create zero waste, and to sell products that sustain resources and the environment.[13]

To achieve this, Wal-Mart is working with its 60,000 plus suppliers to help them learn how to produce "affordable sustainability, and become more sustainable businesses in their own right." The company began by reducing waste, announcing a goal of a 5-percent reduction in overall packaging by 2013. It estimated that the impact would be the equivalent of removing 213,000 trucks from the road and saving about 324,000 tons of coal and 77 million gallons of diesel fuel a year.[14]

Reducing packaging in the company's Kid Connection line of toys let Wal-Mart use 427 fewer containers to ship the same number of items, saving $2.4 million in shipping costs, 3,800 trees, and 1,300 barrels of oil annually. The company estimates that a similar effort globally could save nearly $11 billion. Wal-Mart's supply chain alone could save $3.4 billon.[15]

Companies are implementing eco-efficiency to drive their innovation and enhance their competitiveness.

Wal-Mart has pledged to implement an "Ethical Supplier Initiative" and is seeking more long-term and sustainable partnerships with the factories that supply its stores. One such program in a candy factory in Brazil that lacked a system for processing, recycling, and disposing of waste enabled the factory to install a waste management program, which in turn let the supplier generate $6,500 a year in new profits.[16]

Wal-Mart is working with suppliers to design more-efficient products to offer to its customers. A partnership with the Eco-magination program of General Electric (GE) will produce light-emitting diodes (LEDs). LED lights last longer, produce less heat, contain no mercury, and use significantly less energy than other bulbs. Lighting accounts for about one third of Wal-Mart's electricity use. Since 2004 Wal-Mart has invested about $17 million in developing LED lighting systems for its own refrigerator cases in more than 500 stores. It projects that this will save about $3.8 million a year and reduce the company's CO_2 emissions by 65 million pounds. Wal-Mart's purchase will be sufficiently large that it will bring GE's production costs for LED lighting down to levels competitive with ordinary lamps.[17]

The company is also taking a closer look at how some of the products on its shelves are made, in line with WBCSD's emphasis on reducing the dispersion of toxic chemicals as one component of eco-efficiency. At the March 2007 quarterly meeting of senior management and major suppliers of Wal-Mart, CEO Lee Scott indicated that the company would begin phasing phthalates out of the plastics used in children's toys. By July, Wal-Mart announced that it would no longer ship infants' toys containing these endrocrine-disrupting compounds.[18]

A number of frameworks aim to help companies use resources more efficiently. Lean manufacturing arose from the Toyota Production System and was popularized in the 1996 book *Lean Thinking* by James Womack and Dan Jones. It emphasizes reduction in process variability as a way to identify and eliminate inefficiencies that reduce quality. Waste is eliminated as a byproduct of enhancing the smoothness of the process. Similarly, the Six Sigma system trademarked by Motorola and fanatically implemented by hundreds of companies seeks to cut waste by eliminating any variability in the production of items.[19]

These two systems are valuable approaches, but management needs to understand their limits. Manufacturers have found that both have the drawback of inhibiting creativity. The mental model that seeks to eliminate any defect or deviation from a given standard is inimical to the sort of intellectual curiosity, tolerance for ambiguity, spirit of experimentation, and appetite for risk that characterizes great invention. Many companies now insulate their creative staff from the salutary discipline of Six Sigma. But once the invention is conceived, lean manufacturing enables a company to deliver exceptional quality, squeeze out waste, and scale up production to efficiently deliver a predictable product.

Lean manufacturing, as implemented by Toyota, features an almost manic dedication to reducing the "seven wastes" as a way to enhance customer satisfaction. It identifies any part of an operation that does not contribute to customer satisfaction as waste, specifically targeting product design, supplier networks, and factory management. It seeks to eliminate the production of more items than are demanded by the customer, the movement of people or machines, any idle time of people or machines, the movement of material or product, inefficient processing (see Box 3–1), excess inventory of input or product, and the need to rework or throw out anything.[20]

As lean manufacturing caught on in the United States, it was logical that it would be combined with clean production, which is what the U.S. Environmental Protection Agency, the Chicago Manufacturing Center (CMC), and others did.

CMC sponsored the GreenPlants Sustainable Leadership Program to help a group of Chicago area manufacturers implement lean, clean, more-sustainable production, in order to enhance the competitiveness of manufacturing companies threatened by foreign companies. Working with Natural Capitalism Solutions, the program helps local manufacturers implement more-sustainable production techniques as the basis for retaining globally competitive manufacturers in the Chicago area. The 84 CMC clients surveyed in fiscal 2004 reported that they hired 194 people for newly created jobs, saved 527 jobs, and did not lay off anyone due to improvements.[21]

PortionPac Chemical Corporation is using

Box 3–1. The Robot Versus the Hair Dryer

A *Wall Street Journal* article exploring why Toyota was outcompeting Detroit and its suppliers stated that the Japanese manufacturer was able to "produce vehicles with one-third the defects of mass-produced cars using half the factory space, half the capital, and half the engineering time. Elements of lean production, such as 'just-in-time' shipments of supplies, are familiar to most U.S. manufacturers. But adapting the whole Toyota system, and the cultural changes that go with it, has proven difficult for many American companies."

The article tells one of the classic Toyota stories of an engineer making wasteful reliance on expensive high technology look silly. Painting processes are one of the auto industry's more polluting activities.

> *Armed with a $12 dryer from a discount store, Mr. Oba proved to engineers from Michigan's Summit Polymers Inc. that their $280,000 investment in sleek robots and a paint oven to bake the dashboard vents they produce actually was undermining quality and pushing up costs. The fancy equipment took up to 90 minutes to dry the paint and in the bargain caused quality flaws because parts gathered dust as they crept along a conveyor.*
>
> *Mr. Oba's hair dryer did the job in less than three minutes. Chastened, Summit's engineers replaced their paint system with some $150 spray guns and a few light bulbs for drying and integrated the painting into the final assembly process. Family-owned Summit cut its defect rate to less than 60 per million parts from 3,000 per million.*

Source: See endnote 20.

CMC's program to develop sustainable cleaning systems. The cleaning industry has traditionally wasted energy in manufacturing, shipping, and disposing of cleaning formulations that were 90 percent water; these were shipped in steel pails and multigallon drums that were then discarded. Many cleaning formulations being used were extremely hazardous, and few janitors understood how to apply the solutions correctly. To address these problems, PortionPac Chemical Corporation was founded in 1964 to eliminate the water and instead ship small plastic packets of concentrated, portion-controlled solutions. PortionPac helped Boeing reduce costs and simplify its cleaning process by reducing a thousand different brands of cleaning products to just 10, with PortionPac products as 3 of those 10.[22]

PortionPac has gained market share because of its sustainability campaign. It has also shifted its business model to sell customers the service of a cleaner facility, in addition to selling chemicals that others can use. In 1999, the company helped schools in Tacoma, Washington, save 627,000 hours of labor, including moving drums around, and $102,000 in chemical purchases by implementing this system. Now more than 7,000 schools have signed on to PortionPac's set cost fee, which includes the cleaning products the schools need plus proper education on how to clean, proper mixing, and safe usage. PortionPac works with correctional facilities, schools, hotels, hospitals, and industrial plants to limit the number of products and ensure proper usage.[23]

The company has also helped such clients as Cornell University earn Leadership in Environmental and Energy Design (LEED) certification from the U.S. Green Building Council by using PortionPac's Green Seal–certified products. Dale Walters, General Manager of Facilities Operations at Cornell, notes that "over time, Cornell saved costs by using the right amount of product and going from twenty cleaning products to four. It also reduced safety risks involved with handling chemicals. When we sought to create LEED certified buildings, we worked with PortionPac to establish a green housekeeping strategy." Walters reports that "PortionPac products reduced chemical waste through both the proper use of cleaning chemicals and the sheer reduction of packaging (small packets versus large jugs or plastic containers). PortionPac products are a main component of our sustainable cleaning strategy." By helping organizations find better ways to motivate their janitors and clean their facilities, while reducing the use of chemicals, PortionPac is winning contracts and expanding its business.[24]

Cradle to Cradle: Extending a Product's Life

"Cradle to cradle" is a concept introduced by Walter Stahel more than 25 years ago in Europe. In 1976, as Director of a project on product life extension at Battelle research laboratories in Geneva, Stahel embarked on a program to return products to useful lives. He analyzed cars and buildings on microeconomic and macroeconomic bases and concluded that every extension of product life saved enormous amounts of resources in contrast with turning virgin material into a new product, and it also substituted the use of people for the expenditure of energy.[25]

Stahel found that 75 percent of industrial energy use was due to the mining or production of such basic materials as steel and cement, while only about 25 percent was used to make the materials into finished goods like machines or buildings. The converse relationship held for human labor: three times as much labor was used to convert materials into higher value-added products as in the original mining. He suggested that increasing the kinds of businesses that recondition old equipment as opposed to those that convert virgin resources into new goods would substitute labor for energy. And he pointed out that such work could be conducted in small workshops around the country where the products that needed rebuilding were located—something like car repair shops that are located in every village. This sort of job creation would address both unemployment and resource waste.[26]

In the early 1990s Walter Stahel, by then widely recognized in Europe as a founder of the new sustainability movement, proposed that sustainability rests on five pillars, each of which is essential for the survival of humans on Earth. None of these pillars is a higher priority, he observed, or subject to tradeoffs. Stahel's pillars roughly mirror the history of the sustainability movement.

The first pillar is the conservation of nature as the underpinning of a prosperous economy. This involves the need to preserve intact ecosystems as the basis of all life-support systems. It applies to such planetary systems as a stable climate or the ability of the oceans to support life, as well as to local carrying capacities and the ability of regions to assimilate waste. The second pillar is the need to preserve individual health and safety that may be jeopardized by economic activities. This seeks to limit toxicity and pollution by such things as heavy metals and endocrine disruptors.

The first two pillars form the domain of the original environmental movement. They are characterized by command-and-control legislation and by minimalist compliance by industry. They tend to be dominated by technical experts and agency bureaucrats. This approach to protecting the environment costs money and created the belief that environmental protection, actually the basis of durable prosperity, is incompatible with economic success.

The third pillar adds resource productivity, innovation, and entrepreneurship to the sustainability approach. It assumes a Factor

Ten increase in efficiency as the way to forestall such threats as climate change and the loss of ecosystems. This is the approach of eco-efficiency in industrial as well as developing countries.

Stahel argues that implementing the first three pillars is the basis of a sustainable economy. But, he says, "a sustainable economy is only part of the objective to reach a sustainable society. A distinct border-line exists therefore after these first three pillars, which separates techno-economic issues from societal ones. The coming 'Quest for a Sustainable Society' must be much broader and include social and cultural issues."[27]

Thus the fourth pillar adds social ecology to the mix. This is the first element of the human dimension of sustainability and includes, in Stahel's words, "peace and human rights, dignity and democracy, employment and social integration, security and safety, the constructive integration of female and male attitudes. Key words here are: the commons, 'prisoners' dilemma', sharing and caring, barter economy."[28]

The fifth pillar Stahel calls cultural ecology. This encompasses how different cultures view the concept of sustainability and how to achieve it. It includes attitudes toward risk-taking and a sense of national heritage. For example, American engineers may see a good business case for eliminating waste, but the Japanese have an almost visceral distaste for waste. It offends them. The fifth pillar includes the critical aspects of corporate culture, whereby, for example, in 1995 DuPont called for 100-percent yield rather than zero waste. This pillar also considers the human part of the equation, such as whether people should be retrained rather than fired.

The First Industrial Revolution, the forerunner of modern manufacturing, arose at a time in history when there were relatively few skilled people to run the new machines that were revolutionizing production. There was an apparent abundance of nature and its services. Profit-maximizing capitalists "economized on their scarce resource" (people) and substituted the use of natural resources and ecosystem services (the ability to spew pollution into the air that everyone breathes and pour wastes into rivers) to drive profits. From this the modern world was born. This transformation enabled a Lancashire weaver to spin 200 times as much fabric on the new machines as his predecessor did on a spinning wheel.[29]

The Holy Grail of prosperity was believed to be labor productivity, and indeed still today people believe that increasing labor productivity will increase well-being—as if the goal of the economy is one person doing all the work and everyone else out of work. But in today's world of relative scarcity, the tables are turned. About 10,000 more people arrive on Earth every hour, and every major ecosystem is in peril. Greater use of ecosystem services impoverishes everyone, and people need work. Yet the whole mental model of how to run the economy is based on the 200-year-old perception of the basis of prosperity: penalize the use of people, subsidize the use of resources, and increase labor productivity.[30]

Stahel describes how in 1993, as U.S. companies faced hard times, the corporate world made heroes of such restructurers as Al Dunlap and Jack Welch. Dunlap, in the name of "creating shareholder value" gained the nickname Chainsaw Al: in 20 months as CEO of Scott Paper, he devastated the 115-year-old company by terminating 11,000 people—35 percent of the labor force—including 71 percent of the staff at corporate headquarters. He, of course, made enormous personal gain. His counterpart at GE, dubbed Neutron Jack Welch, cut GE employment from 380,000 to 208,000.[31]

The logic of capitalism, the greatest known system in human history for the creation of wealth, has not changed. But the relative scarcities have. In today's world, the recipe for prosperity is to encourage, as Stahel has outlined, the use of people and to penalize the use of resources.

Stahel describes how, also in the early 1990s, Honda used its workers to maintain and repair its own machines rather than suffer layoffs that would damage worker morale and lead to work stoppages. Increasingly, European and Japanese policymakers are considering the approach of tax shifting: eliminating taxes on employment and income, things people want more of, and replacing them with taxes on pollution and depletion of resources, things the world wants less of.[32]

Stahel cautions that of the five pillars, social and cultural ecology are the weakest underpinnings. To the extent that the social fabric breaks down, the other pillars soon collapse. The current focus on eco-efficiency, clean production, green products, and the use of technology to implement sustainability are necessary, but it is equally important to consider the human dimension, including such issues as meaningful employment, sustainable development, and enabling people to achieve their full potential.

Sustainability, Stahel notes, has little application in the short term. Its value is as a vision. He tells the story of the three stonecutters who are asked what they are doing. One says that he is putting in his eight hours. The second replies that he is cutting this limestone into blocks. The third answers that he is building a cathedral. Sustainability, says Stahel, is the cathedral we are all creating.[33]

Following Nature's Lead

Biomimicry, the conscious emulation of life's genius, is an even more profound approach to making manufacturing sustainable. Janine Benyus, author of the groundbreaking book *Biomimicry*, asks the simple question, How would nature do business? She points out that nature delivers a wide array of products and services, but very differently from the way humans do. Nature, for example, runs on sunlight, not high flows of fossil energy. It manufactures everything at room temperature, next to something that is alive. It makes very dangerous substances, as anyone who has been in proximity to a rattlesnake knows well, but nothing like nuclear waste, which remains deadly for millennia. It creates no waste, using the output of all processes as the input to some other process. Nature shops locally and creates beauty. Buckminster Fuller once pointed out that "When I am working on a problem I never think about beauty. I only think about how to solve the problem. But when I have finished, if the solution is not beautiful, I know it is wrong."[34]

The discipline of biomimicry takes nature's best ideas as a mentor and then imitates these designs and processes to solve human problems. Dozens of leading industrial companies—from Interface Carpets and AT&T to 3M, Hughes Aircraft, Arup Engineers, DuPont, General Electric, Herman Miller, Nike, Royal Dutch Shell, Patagonia, SC Johnson, and many more—use the principles of biomimicry to drive innovation, design superior products, and implement production processes that cost less and work better. (See Box 3–2.)[35]

Biomimicry invites innovators to turn to the natural world for inspiration, then evaluate the resulting design for adaptiveness in the manufacturing process, the packaging, all the way through to shipping, distribution, and take-back decisions. It ensures that the energy used, production methods chosen, chemical processing, and distribution are part of a whole system that reduces materials use, is clean and benign by design, and eliminates

Box 3–2. Biomimicry and Carpets

Industrialist Ray Anderson, chair of the billion-dollar-a-year carpet company Interface, tells the story of the creation of his product Entropy. David Oakey, the head product designer of Interface, sent his design team into the forest with the instruction to find out how nature would design floor covering. "And don't come back," he instructed, "with leaf designs—that's not what I mean. Come back with nature's design principles."

So the team spent a day in the forest, studying the forest floor and streambeds until they finally realized that it is total chaos there: no two things are alike, no two sticks, no two stones, no two anything....Yet there is a pleasant orderliness in this chaos.

They returned to the studio and designed a carpet tile such that no two tiles have the same face design. All are similar but all are different. Interface introduced the product into marketplace as Entropy, and in 18 months the design was at the top of best-seller list. This was faster than any other product in the company's history. How different is that from the prevailing industrial paradigm of every mass-produced item? A typical industrial product must be cookie-cutter the same.

The advantages of Entropy were astonishing: almost no waste and off quality in production. The designers could not find defects in the deliberate imperfection of having no two tiles alike. Installers could put the carpet in quickly without having to take time to get the pile net all running uniformly. They could take tiles from the box as they came and lay them randomly, the more random the better—like a floor of leaves. The user can replace individual damaged tiles without the "sore thumb effect" that comes with precision perfection and uniformity and can rotate tiles just like tires on cars in order to extend useful life. Moreover, dye lots now merged indistinguishably, which means sellers do not have to maintain an inventory of individual dye lots waiting to be used.

Yet one wonders: could there be more to explain the success of entropy? Perhaps there is.

A speaker on an environment lecture circuit begins every speech by having her audience close their eyes and picture that ideal comfort zone of peace and repose, of solitude, creativity, security—that perfect place of comfort. She then asks, how many of you were somewhere indoors? Almost no one ever raises their hand. This quality has a name, biophilia—humans gravitate to nature for the perfect comfort zone.

And somehow, subliminally, Entropy seems to bring the outdoors indoors. That is its real appeal.

Entropy is made with recycled content in a climate-neutral factory; 82 of Interface's products are now designed on the principle of no two alike. These represent 52 percent of Interface's sales. Using principles like waste minimization and biomimicry has enabled Interface to bring the company's CO_2 emissions to roughly 10 percent of their 1996 levels.

Source: See endnote 35.

the costs that last century's technologies imposed on society and the living world.[36]

EcoCover Limited of New Zealand used the concept that in nature there is no waste—the output of all processes is food for some other process—to develop an organically certified, biodegradable mulch mat to substitute for black plastic sheeting used in agriculture to prevent moisture loss and weed growth. Using shredded waste paper that would otherwise have gone to landfill, bound together with fish waste, the material is produced by previously unemployed people.[37]

The product uses waste to improve soil productivity, conserve soil moisture, and cut water use. It cuts the use of chemical fertilizers, pesticides, and herbicides that contaminate soil and groundwater. It reduces weeds; increases plant growth, quality, and yield; and keeps paper and fish waste out of landfills. The cover is left in the soil as improved organic and nutrient content. This is not recycling. It is "upcycling" waste back into productive soil.[38]

The humble abalone sits in the Pacific Ocean and in seawater and creates an inner lining immediately next to its body that is twice as strong as the best ceramics that humans can make using very high temperature kilns. The overlapping brick-like structure of the seashell makes it very hard to crack, protecting the abalone from sea otters and the like. Dr. Jeffrey Brinker's research group at Sandia Labs found out that the iridescent mother-of-pearl lining of the abalone self-assembles at the molecular level when the animal excretes a protein that causes sea water to deposit out the building blocks of the abalone's beautiful shell.[39]

The researchers mimicked the manufacturing process of the mollusk to create mineral/polymer layered structures that are optically clear but almost unbreakable. This evaporation-induced, low-temperature process enables the liquid building blocks to self-assemble and harden into complex "nano-laminate" structures. The bio-composite materials can be used as coatings to toughen windshields, airplane bodies, or anything that needs to be lightweight but fracture-resistant.[40]

Companies are using biomimicry to match not only the form of natural products but also the function of larger ecosystems. In July 2007, Toyota Motor Corporation announced plans to increase the sustainability of its production operations. The Tsutsumi Prius production plant will add a 2-megawatt solar electric array. It will also paint some of its exterior walls and other surfaces with a photo-catalytic paint that breaks down airborne NO_X and sulfur oxides. This will do as much to clean the air as surrounding the plant with 2,000 poplar trees would have.[41]

The plant's impressive biomimicry program is coupled with a strong foundation of eco-efficiency. The plant is installing innovative assembly-line technology and further streamlining current production systems such as the Global Body Line and Set Parts System to greatly improve both productivity and energy efficiency. By 2009, the plant is expected to achieve an annual CO_2 reduction effect of 35 percent.[42]

The practice of using nature as model, measure, and mentor lies at the heart of the change in the industrial mental model that will be essential if humans are to survive. Nature runs a very rigorous, 3.8-billion-year-old testing laboratory in which products that do not work are recalled by the manufacturer. As Janine Benyus says: "Failures are fossils, and what surrounds us is the secret to survival."[43]

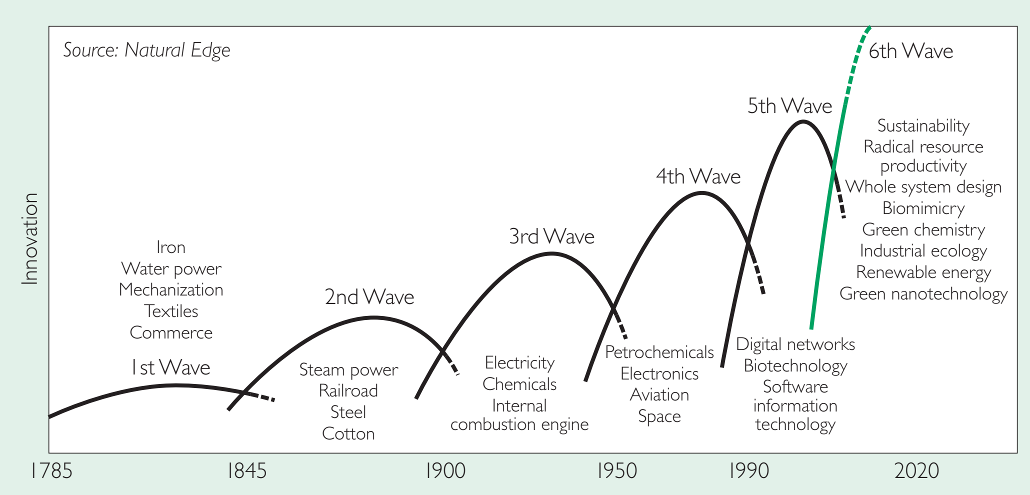
The First Industrial Revolution was based on brute force manufacturing processes that inefficiently heat, beat, and treat massive amounts of raw materials to produce a throwaway society. The next Industrial Revolution will rise upon the elegant emulation of life's genius, a survival strategy for the human race, and a path to a sustainable future. "The more our world looks and functions like the natural world," Benyus notes, "the more likely we are to endure on this home that is ours, but not ours alone."[44]

Riding the New Wave of Innovation

Business success in a time of technological transformation demands innovation. Since the First Industrial Revolution, there have been at least six waves of innovation (see Figure 3–1), each shifting the technologies that underpin economic prosperity. In the late 1700s textiles, iron mongering, water-power, and mechanization enabled modern commerce to develop.[45]

The second wave saw the introduction of steam power, trains, and steel. In the 1900s, electricity, chemicals, and cars began to dominate. By the middle of the twentieth century

Figure 3–1. Waves of Innovation



it was petrochemicals and the space race, along with electronics. The most recent wave of innovation brought computers and ushered in the digital or information age. As the Industrial Revolution plays out and economies move beyond iPods, older industries will suffer dislocations unless they join the increasing number of companies implementing the array of sustainable technologies that are making up the next wave of innovation.[46]

Perhaps the tipping point in corporate movement to greener production came when General Electric announced Eco-magination. As part of the initiative, GE board chairman Jeffrey Immelt promised to double the company's investment in environmental technologies to $1.5 billion by 2010. He also announced that GE would reduce the company's greenhouse gas emissions 1 percent by 2012; without action, emissions would have risen 40 percent. Immelt stated: "We believe we can help improve the environment and make money doing it."[47]

Critics charged that GE was greenwashing, simply labeling some of its existing products as green and changing very little. Hypocrisy, however, is often the first step to real change. A little less than a year after the campaign's launch, Immelt announced that his green-badged products had doubled in sales over the prior two years, with back orders for $50 billion more, blowing away his initial prediction of $12 billion in sales by 2010. Over the same time frame, the rest of GE products had increased in sales only 20 percent. GE also announced that it had reduced its GHG emissions by 4 percent in 2006, dwarfing its 2012 target of 1 percent.[48]

Companies that increase resource productivity and implement sustainable production strategies such as biomimicry and cradle to cradle, especially in the context of a broader whole-system corporate sustainability strategy, improve every aspect of shareholder value. What constitutes shareholder value? What enhances it?

Traditionally, the "bottom line" measured whether a company was profitable. More recently, a company's profits and stock value had to increase over the next quarter or the firm was considered unworthy of investment. This highly questionable metric is so incompatible with management of an enterprise for long-term value that even the Financial Accounting Standards Board has undertaken to rewrite financial reporting to encourage alternatives to such short-sighted behavior. (See also Chapter 2.)[49]

Sustainability advocates have urged companies to manage a "triple bottom line": achieve profit but also protect people and the planet. While this is a tempting formulation, it has had the effect of bolting concern for the environment and social well-being onto companies as cost centers that reduce the traditional measure of profit. A much more useful approach is that of the "integrated bottom line." This recognizes that profit is a valid metric, but only one of many that give a company enduring value.[50]

Other aspects of shareholder value include enhanced financial performance from energy and materials cost savings in industrial processes, facilities design and management, fleet management, and operations. Reduced risk is another key point to consider, tied to insurance access and cost containment, legal compliance, reduced exposure to increased carbon regulations and price, and reduced shareholder activism. Finally, core business value is enhanced through:

- sector performance leadership;
- greater access to capital;
- first-mover advantage;
- improved corporate governance;
- the ability to drive innovation and retain competitive advantage;
- enhanced reputation and brand development;
- increased market share and product differentiation;
- ability to attract and retain the best talent;
- increased employee productivity and health;
- improved communication, creativity, and morale in the workplace;
- improved value chain management; and
- better stakeholder relations.

The validity of this management approach is borne out by a recent report from Goldman Sachs, which found that companies that are leaders in environmental, social, and good governance policies have outperformed the MSCI world index of stocks by 25 percent since 2005. Seventy-two percent of the companies on the list outperformed their industry peers.[51]

It is daunting to realize that achieving a sustainable society will require changing how we manufacture and deliver all our products and services. But the evidence increasingly shows that companies taking a leadership role in using resources more efficiently, in redesigning how they make products, and in managing their operations to enhance people and intact ecosystems have found a better way to make a bigger profit. Solving the challenges of implementing a transition to a sustainable society can unleash the biggest economic boom since the space race. There has never been a greater opportunity for entrepreneurs to do well by doing good and for communities to enhance energy security, improve the quality of life, and enable people to join the transition to a more sustainable future.

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