CHAPTER 1

The Next Industrial Revolution

Emerging possibilities — A new type of industrialism — The loss of living systems — Valuing natural capital — The industrial mind-set — The emerging pattern of scarcity — Four strategies of natural capitalism — Radical resource productivity — Putting the couch potato of industrialism on a diet — An economy of steady service and flow — Restoring the basis of life and commerce

IMAGINE FOR A MOMENT A WORLD WHERE CITIES HAVE BECOME PEACEFUL and serene because cars and buses are whisper quiet, vehicles exhaust only water vapor, and parks and greenways have replaced unneeded urban freeways. OPEC has ceased to function because the price of oil has fallen to five dollars a barrel, but there are few buyers for it because cheaper and better ways now exist to get the services people once turned to oil to provide. Living standards for all people have dramatically improved, particularly for the poor and those in developing countries. Involuntary unemployment no longer exists, and income taxes have largely been eliminated. Houses, even low-income housing units, can pay part of their mortgage costs by the energy they *produce;* there are few if any active landfills; worldwide forest cover is increasing; dams are being dismantled; atmospheric CO_2 levels are decreasing for the first time in two hundred years; and effluent water leaving factories is cleaner than the water coming into them. Industrialized countries have reduced resource use by 80 percent while improving the quality of life. Among these technological changes, there are important social changes. The frayed social nets of Western countries have been repaired. With the explosion of family-wage jobs, welfare demand has fallen. A progressive and active union movement has taken the lead to work with business, environmentalists, and government to create "just transitions" for workers as society phases out coal, nuclear energy, and oil. In communities and towns, churches, corporations, and labor groups promote a new living-wage social contract as the least expensive way to ensure the growth and preservation of valuable social capital. Is this the

vision of a utopia? In fact, the changes described here could come about in the decades to come as the result of economic and technological trends already in place.

This book is about these and many other possibilities.

It is about the possibilities that will arise from the birth of a new type of industrialism, one that differs in its philosophy, goals, and fundamental processes from the industrial system that is the standard today. In the next century, as human population doubles and the resources available per person drop by one-half to three-fourths, a remarkable transformation of industry and commerce can occur. Through this transformation, society will be able to create a vital economy that uses radically less material and energy. This economy can free up resources, reduce taxes on personal income, increase per-capita spending on social ills (while simultaneously reducing those ills), and begin to restore the damaged environment of the earth. These necessary changes done properly can promote economic efficiency, ecological conservation, and social equity.

The industrial revolution that gave rise to modern capitalism greatly expanded the possibilities for the material development of humankind. It continues to do so today, but at a severe price. Since the mid-eighteenth century, more of nature has been destroyed than in all prior history. While industrial systems have reached pinnacles of success, able to muster and accumulate human-made capital on vast levels, *natural capital,* on which civilization depends to create economic prosperity, is rapidly declining,[1] and the rate of loss is increasing proportionate to gains in material well-being. *Natural capital* includes all the familiar resources used by humankind: water, minerals, oil, trees, fish, soil, air, et cetera. But it also encompasses living systems, which include grasslands, savannas, wetlands, estuaries, oceans, coral reefs, riparian corridors, tundras, and rainforests. These are deteriorating worldwide at an unprecedented rate. Within these ecological communities are the fungi, ponds, mammals, humus, amphibians, bacteria, trees, flagellates, insects, songbirds, ferns, starfish, and flowers that make life possible and worth living on this planet.

As more people and businesses place greater strain on living systems, limits to prosperity are coming to be determined by natural capital rather than industrial prowess. This is not to say that the world is running out of commodities in the near future. The prices for most raw materials are at a twenty-eight-year low and are still falling. Supplies are

cheap and appear to be abundant, due to a number of reasons: the collapse of the Asian economies, globalization of trade, cheaper transport costs, imbalances in market power that enable commodity traders and middlemen to squeeze producers, and in large measure the success of powerful new extractive technologies, whose correspondingly extensive damage to ecosystems is seldom given a monetary value. After richer ores are exhausted, skilled mining companies can now level and grind up whole mountains of poorer-quality ores to extract the metals desired. But while technology keeps ahead of depletion, providing what appear to be ever-cheaper metals, they only appear cheap, because the stripped rainforest and the mountain of toxic tailings spilling into rivers, the impoverished villages and eroded indigenous cultures — all the consequences they leave in their wake — are not factored into the cost of production.

It is not the supplies of oil or copper that are beginning to limit our development but life itself. Today, our continuing progress is restricted not by the number of fishing boats but by the decreasing numbers of fish; not by the power of pumps but by the depletion of aquifers; not by the number of chainsaws but by the disappearance of primary forests. While living systems are the source of such desired materials as wood, fish, or food, of utmost importance are the *services* that they offer,[2] services that are far more critical to human prosperity than are nonrenewable resources. A forest provides not only the resource of wood but also the services of water storage and flood management. A healthy environment automatically supplies not only clean air and water, rainfall, ocean productivity, fertile soil, and watershed resilience but also such less-appreciated functions as waste processing (both natural and industrial), buffering against the extremes of weather, and regeneration of the atmosphere.

Humankind has inherited a 3.8-billion-year store of natural capital. At present rates of use and degradation, there will be little left by the end of the next century. This is not only a matter of aesthetics and morality, it is of the utmost practical concern to society and all people. Despite reams of press about the state of the environment and rafts of laws attempting to prevent further loss, the stock of natural capital is plummeting and the vital life-giving services that flow from it are critical to our prosperity.

Natural capitalism recognizes the critical interdependency between the production and use of human-made capital and the maintenance

and supply of natural capital. The traditional definition of capital is accumulated wealth in the form of investments, factories, and equipment. Actually, an economy needs four types of capital to function properly:

- human capital, in the form of labor and intelligence, culture, and organization
- financial capital, consisting of cash, investments, and monetary instruments
- manufactured capital, including infrastructure, machines, tools, and factories
- natural capital, made up of resources, living systems, and ecosystem services

The industrial system uses the first three forms of capital to transform natural capital into the stuff of our daily lives: cars, highways, cities, bridges, houses, food, medicine, hospitals, and schools.

The climate debate is a public issue in which the assets at risk are not specific resources, like oil, fish, or timber, but a life-supporting system. One of nature's most critical cycles is the continual exchange of carbon dioxide and oxygen among plants and animals. This "recycling service" is provided by nature free of charge. But today carbon dioxide is building up in the atmosphere, due in part to combustion of fossil fuels. In effect, the capacity of the natural system to recycle carbon dioxide has been exceeded, just as overfishing can exceed the capacity of a fishery to replenish stocks. But what is especially important to realize is that there is no known alternative to nature's carbon cycle service.

Besides climate, the changes in the biosphere are widespread. In the past half century, the world has a lost a fourth of its topsoil and a third of its forest cover. At present rates of destruction, we will lose 70 percent of the world's coral reefs in our lifetime, host to 25 percent of marine life.[3] In the past three decades, one-third of the planet's resources, its "natural wealth," has been consumed. We are losing freshwater ecosystems at the rate of 6 percent a year, marine ecosystems by 4 percent a year.[4] There is no longer any serious scientific dispute that the decline in every living system in the world is reaching such levels that an increasing number of them are starting to lose, often at a pace accelerated by the interactions of their decline, their assured ability to sustain the continuity of the life process. We have reached an extraordinary threshold.

Recognition of this shadow side of the success of industrial production has triggered the second of the two great intellectual shifts of the

late twentieth century. The end of the Cold War and the fall of communism was the first such shift; the second, now quietly emerging, is the end of the war against life on earth, and the eventual ascendance of what we call natural capitalism.

Capitalism, as practiced, is a financially profitable, nonsustainable aberration in human development. What might be called "industrial capitalism" does not fully conform to its own accounting principles. It liquidates its capital and calls it income. It neglects to assign any value to the largest stocks of capital it employs — the natural resources and living systems, as well as the social and cultural systems that are the basis of human capital.

But this deficiency in business operations cannot be corrected simply by assigning monetary values to natural capital, for three reasons. First, many of the services we receive from living systems have no known substitutes at any price; for example, oxygen production by green plants. This was demonstrated memorably in 1991–93 when the scientists operating the $200 million Biosphere 2 experiment in Arizona discovered that it was unable to maintain life-supporting oxygen levels for the eight people living inside. Biosphere 1, a.k.a. Planet Earth, performs this task daily at no charge for 6 billion people.

Second, valuing natural capital is a difficult and imprecise exercise at best. Nonetheless, several recent assessments have estimated that biological services flowing directly into society from the stock of natural capital are worth at least $36 trillion annually.[5] That figure is close to the annual gross world product of approximately $39 trillion — a striking measure of the value of natural capital to the economy. If natural capital stocks were given a monetary value, assuming the assets yielded "interest" of $36 trillion annually, the world's natural capital would be valued at somewhere between $400 and $500 trillion — tens of thousands of dollars for every person on the planet. That is undoubtedly a conservative figure given the fact that anything we can't live without and can't replace at any price could be said to have an infinite value.

Additionally, just as technology cannot replace the planet's life-support systems, so, too, are machines unable to provide a substitute for human intelligence, knowledge, wisdom, organizational abilities, and culture. The World Bank's 1995 *Wealth Index* found the sum value of human capital to be three times greater than all the financial and manufactured capital reflected on global balance sheets.[6] This, too,

appears to be a conservative estimate, since it counts only the market value of human employment, not uncompensated effort or cultural resources.

It is not the aim of this book to assess how to determine value for such unaccounted-for forms of capital. It is clear, however, that behaving as though they are valueless has brought us to the verge of disaster. But if it is in practice difficult to tabulate the value of natural and human capital on balance sheets, how can governments and conscientious businesspersons make decisions about the responsible use of earth's living systems?

CONVENTIONAL CAPITALISM

Following Einstein's dictum that problems can't be solved within the mind-set that created them, the first step toward any comprehensive economic and ecological change is to understand the mental model that forms the basis of present economic thinking. The mind-set of the present capitalist system might be summarized as follows:

- Economic progress can best occur in free-market systems of production and distribution where reinvested profits make labor and capital increasingly productive.
- Competitive advantage is gained when bigger, more efficient plants manufacture more products for sale to expanding markets.
- Growth in total output (GDP) maximizes human well-being.
- Any resource shortages that do occur will elicit the development of substitutes.
- Concerns for a healthy environment are important but must be balanced against the requirements of economic growth, if a high standard of living is to be maintained.
- Free enterprise and market forces will allocate people and resources to their highest and best uses.

The origins of this worldview go back centuries, but it took the industrial revolution to establish it as the primary economic ideology. This sudden, almost violent, change in the means of production and distribution of goods, in sector after economic sector, introduced a new element that redefined the basic formula for the creation of material products: Machines powered by water, wood, charcoal, coal, oil, and eventually electricity accelerated or accomplished some or all of the work formerly performed by laborers. Human productive capabilities

began to grow exponentially. What took two hundred workers in 1770 could be done by a single spinner in the British textile industry by 1812. With such astonishingly improved productivity, the labor force was able to manufacture a vastly larger volume of basic necessities like cloth at greatly reduced cost. This in turn rapidly raised standards of living and real wages, increasing demand for other products in other industries. Further technological breakthroughs proliferated, and as industry after industry became mechanized, leading to even lower prices and higher incomes, all of these factors fueled a self-sustaining and increasing demand for transportation, housing, education, clothing, and other goods, creating the foundation of modern commerce.[7]

The past two hundred years of massive growth in prosperity and manufactured capital have been accompanied by a prodigious body of economic theory analyzing it, all based on the fallacy that natural and human capital have little value as compared to final output. In the standard industrial model, the creation of value is portrayed as a linear sequence of extraction, production, and distribution: Raw materials are introduced. (Enter nature, stage left.) Labor uses technologies to transform these resources into products, which are sold to create profits. The wastes from production processes, and soon the products themselves, are somehow disposed of somewhere else. (Exit waste, stage right.) The "somewheres" in this scenario are not the concern of classical economics: Enough money can buy enough resources, so the theory goes, and enough "elsewheres" to dispose of them afterward.

This conventional view of value creation is not without its critics. Viewing the economic process as a disembodied, circular flow of value between production and consumption, argues economist Herman Daly, is like trying to understand an animal only in terms of its circulatory system, without taking into account the fact it also has a digestive tract that ties it firmly to its environment at both ends. But there is an even more fundamental critique to be applied here, and it is one based on simple logic. The evidence of our senses is sufficient to tell us that all economic activity — all that human beings are, all that they can ever accomplish — is embedded within the workings of a particular planet. That planet is not growing, so the somewheres and elsewheres are always with us. The increasing removal of resources, their transport and use, and their replacement with waste steadily erodes our stock of natural capital.

With nearly ten thousand new people arriving on earth every hour, a new and unfamiliar pattern of scarcity is now emerging. At the beginning of the industrial revolution, labor was overworked and relatively scarce (the population was about one-tenth of current totals), while global stocks of natural capital were abundant and unexploited. But today the situation has been reversed: After two centuries of rises in labor productivity, the liquidation of natural resources at their extraction cost rather than their replacement value, and the exploitation of living systems as if they were free, infinite, and in perpetual renewal, it is people who have become an abundant resource, while *nature* is becoming disturbingly scarce.

Applying the same economic logic that drove the industrial revolution to this newly emerging pattern of scarcity implies that, if there is to be prosperity in the future, society must make its use of *resources* vastly more productive — deriving four, ten, or even a hundred times as much benefit from each unit of energy, water, materials, or anything else borrowed from the planet and consumed. Achieving this degree of efficiency may not be as difficult as it might seem because from a materials and energy perspective, the economy is massively inefficient. In the United States, the materials used by the metabolism of industry amount to more than twenty times every citizen's weight per day — more than one million pounds per American per year. The global flow of matter, some 500 billion tons per year, most of it wasted, is largely invisible. Yet obtaining, moving, using, and disposing of it is steadily undermining the health of the planet, which is showing ever greater signs of stress, even of biological breakdown. Human beings already use over half the world's accessible surface freshwater, have transformed one-third to one-half of its land surface, fix more nitrogen than do all natural systems on land, and appropriate more than two-fifths of the planet's entire land-based primary biological productivity.[8] The doubling of these burdens with rising population will displace many of the millions of other species, undermining the very web of life.

The resulting ecological strains are also causing or exacerbating many forms of social distress and conflict. For example, grinding poverty, hunger, malnutrition, and rampant disease affect one-third of the world and are growing in absolute numbers; not surprisingly, crime, corruption, lawlessness, and anarchy are also on the rise (the fastest-growing industry in the world is security and private police protection); fleeing refugee populations have increased throughout the

nineties to about a hundred million; over a billion people in the world who need to work cannot find jobs, or toil at such menial work that they cannot support themselves or their families;[9] meanwhile, the loss of forests, topsoil, fisheries, and freshwater is, in some cases, exacerbating regional and national conflicts.

What would our economy look like if it fully valued *all* forms of capital, including human and natural capital? What if our economy were organized not around the lifeless abstractions of neoclassical economics and accountancy but around the biological realities of nature? What if Generally Accepted Accounting Practice booked natural and human capital not as a free amenity in putative inexhaustible supply but as a finite and integrally valuable factor of production? What if, in the absence of a rigorous way to practice such accounting, companies started to act *as if* such principles were in force? This choice is possible and such an economy would offer a stunning new set of opportunities for all of society, amounting to no less than the *next industrial revolution.*

CAPITALISM AS IF LIVING SYSTEMS MATTERED

Natural capitalism and the possibility of a new industrial system are based on a very different mind-set and set of values than conventional capitalism. Its fundamental assumptions include the following:

- The environment is not a minor factor of production but rather is "an envelope containing, provisioning, and sustaining the entire economy."[10]
- The limiting factor to future economic development is the availability and functionality of *natural capital,* in particular, life-supporting services that have no substitutes and currently have no market value.
- Misconceived or badly designed business systems, population growth, and wasteful patterns of consumption are the primary causes of the loss of natural capital, and all three must be addressed to achieve a sustainable economy.
- Future economic progress can best take place in democratic, market-based systems of production and distribution in which *all* forms of capital are fully valued, including human, manufactured, financial, and natural capital.
- One of the keys to the most beneficial employment of people, money, and the environment is radical increases in resource productivity.
- Human welfare is best served by improving the quality and flow of desired services delivered, rather than by merely increasing the total dollar flow.
- Economic and environmental sustainability depends on redressing global inequities of income and material well-being.

- The best long-term environment for commerce is provided by true democratic systems of governance that are based on the needs of people rather than business.

This book introduces four central strategies of natural capitalism that are a means to enable countries, companies, and communities to operate by behaving as if all forms of capital were valued. Ensuring a perpetual annuity of valuable social and natural processes to serve a growing population is not just a prudent investment but a critical need in the coming decades. Doing so can avert scarcity, perpetuate abundance, and provide a solid basis for social development; it is the basis of responsible stewardship and prosperity for the next century and beyond.

1. **RADICAL RESOURCE PRODUCTIVITY.** Radically increased resource productivity is the cornerstone of natural capitalism because using resources more effectively has three significant benefits: It slows resource depletion at one end of the value chain, lowers pollution at the other end, and provides a basis to increase worldwide employment with meaningful jobs. The result can be lower costs for business and society, which no longer has to pay for the chief causes of ecosystem and social disruption. Nearly all environmental and social harm is an artifact of the uneconomically wasteful use of human and natural resources, but radical resource productivity strategies can nearly halt the degradation of the biosphere, make it more profitable to employ people, and thus safeguard against the loss of vital living systems and social cohesion.

2. **BIOMIMICRY.** Reducing the wasteful throughput of materials — indeed, eliminating the very idea of waste — can be accomplished by redesigning industrial systems on biological lines that change the nature of industrial processes and materials, enabling the constant reuse of materials in continuous closed cycles, and often the elimination of toxicity.

3. **SERVICE AND FLOW ECONOMY.** This calls for a fundamental change in the relationship between producer and consumer, a shift from an economy of goods and purchases to one of *service* and *flow.* In essence, an economy that is based on a flow of economic services can better protect the ecosystem services upon which it depends. This will entail a new perception of value, a shift from the acquisition of goods as a measure of affluence to an economy where the continuous receipt of quality, utility, and performance promotes well-being. This concept offers incentives to put into practice the first two innovations of natural capi-

talism by restructuring the economy to focus on relationships that better meet customers' changing value needs and to reward automatically both resource productivity and closed-loop cycles of materials use.

4. INVESTING IN NATURAL CAPITAL. This works toward reversing worldwide planetary destruction through reinvestments in sustaining, restoring, and expanding stocks of natural capital, so that the biosphere can produce more abundant ecosystem services and natural resources.

All four changes are interrelated and interdependent; all four generate numerous benefits and opportunities in markets, finance, materials, distribution, and employment. Together, they can reduce environmental harm, create economic growth, and increase meaningful employment.

RESOURCE PRODUCTIVITY

Imagine giving a speech to Parliament in 1750 predicting that within seventy years human productivity would rise to the point that one person could do the work of two hundred. The speaker would have been branded as daft or worse. Imagine a similar scene today. Experts are testifying in Congress, predicting that we will increase the productivity of our resources in the next seventy years by a factor of four, ten, even one hundred. Just as it was impossible 250 years ago to conceive of an individual's doing two hundred times more work, it is equally difficult for us today to imagine a kilowatt-hour or board foot being ten or a hundred times more productive than it is now.

Although the movement toward radical resource productivity has been under way for decades, its clarion call came in the fall of 1994, when a group of sixteen scientists, economists, government officials, and businesspeople convened and, sponsored by Friedrich Schmidt-Bleek of the Wuppertal Institute for Climate, Environment, and Energy in Germany, published the "Carnoules Declaration." Participants had come from Europe, the United States, Japan, England, Canada, and India to the French village of Carnoules to discuss their belief that human activities were at risk from the ecological and social impact of materials and energy use. The Factor Ten Club, as the group came to call itself, called for a leap in resource productivity to reverse the growing damage. The declaration began with these prophetic words: "Within one generation, nations can achieve a ten-fold increase in the efficiency with which they use energy, natural resources and other materials."[11]

In the years since, Factor Ten (a 90 percent reduction in energy and materials intensity) and Factor Four (a 75 percent reduction) have

entered the vocabulary of government officials, planners, academics, and businesspeople throughout the world.[12] The governments of Austria, the Netherlands, and Norway have publicly committed to pursuing Factor Four efficiencies. The same approach has been endorsed by the European Union as the new paradigm for sustainable development. Austria, Sweden, and OECD environment ministers have urged the adoption of Factor Ten goals, as have the World Business Council for Sustainable Development and the United Nations Environment Program (UNEP).[13] The concept is not only common parlance for most environmental ministers in the world, but such leading corporations as Dow Europe and Mitsubishi Electric see it as a powerful strategy to gain a competitive advantage. Among all major industrial nations, the United States probably has the least familiarity with and understanding of these ideas.

At its simplest, increasing resource productivity means obtaining the same amount of utility or work from a product or process while using less material and energy. In manufacturing, transportation, forestry, construction, energy, and other industrial sectors, mounting empirical evidence suggests that radical improvements in resource productivity are both practical and cost-effective, even in the most modern industries. Companies and designers are developing ways to make natural resources — energy, metals, water, and forests — work five, ten, even one hundred times harder than they do today. These efficiencies transcend the marginal gains in performance that industry constantly seeks as part of its evolution. Instead, *revolutionary* leaps in design and technology will alter industry itself as demonstrated in the following chapters. Investments in the productivity revolution are not only repaid over time by the saved resources but in many cases can *reduce* initial capital investments.

When engineers speak of "efficiency," they refer to the amount of output a process provides per unit of input. Higher efficiency thus means doing more with less, measuring both factors in physical terms. When economists refer to efficiency, however, their definition differs in two ways. First, they usually measure a process or outcome in terms of expenditure of money — how the market value of what was produced compares to the market cost of the labor and other inputs used to create it. Second, "economic efficiency" typically refers to how fully and perfectly market mechanisms are being harnessed to minimize the monetary total factor cost of production. Of course it's important to

harness economically efficient market mechanisms, and we share economists' devotion to that goal. But to avoid confusion, when we suggest using market tools to achieve "resource productivity" and "resource efficiency," we use those terms in the engineering sense.

Resource productivity doesn't just save resources and money; it can also improve the quality of life. Listen to the din of daily existence — the city and freeway traffic, the airplanes, the garbage trucks outside urban windows — and consider this: The waste and the noise are signs of inefficiency, and they represent money being thrown away. They will disappear as surely as did manure from the nineteenth-century streets of London and New York. Inevitably, industry will redesign everything it makes and does, in order to participate in the coming productivity revolution. We will be able to see better with resource-efficient lighting systems, produce higher-quality goods in efficient factories, travel more safely and comfortably in efficient vehicles, feel more comfortable (and do substantially more and better work)[14] in efficient buildings, and be better nourished by efficiently grown food. An air-conditioning system that uses 90 percent less energy or a building so efficient that it needs no air-conditioning at all may not fascinate the average citizen, but the fact that they are quiet and produce greater comfort while reducing energy costs should appeal even to technophobes. That such options save money should interest everyone.

As subsequent chapters will show, the unexpectedly large improvements to be gained by resource productivity offer an entirely new terrain for business invention, growth, and development. Its advantages can also dispel the long-held belief that core business values and environmental responsibility are incompatible or at odds. In fact, the massive inefficiencies that are causing environmental degradation almost always cost more than the measures that would reverse them.

But even as Factor Ten goals are driving reductions in materials and energy flows, some governments are continuing to create and administer laws, policies, taxes, and subsidies that have quite the opposite effect. Hundreds of billions of dollars of taxpayers' money are annually diverted to promote inefficient and unproductive material and energy use. These include subsidies to mining, oil, coal, fishing, and forest industries as well as agricultural practices that degrade soil fertility and use wasteful amounts of water and chemicals. Many of these subsidies are vestigial, some dating as far back as the eighteenth century, when European powers provided entrepreneurs with incentives to find and

exploit colonial resources. Taxes extracted from labor subsidize patterns of resource use that in turn displace workers, an ironic situation that is becoming increasingly apparent and unacceptable, particularly in Europe, where there is chronically high unemployment. Already, tax reforms aimed at increasing employment by shifting taxes away from people to the use of resources have started to be instituted in the Netherlands, Germany, Britain, Sweden, and Denmark, and are being seriously proposed across Europe.

In less developed countries, people need realistic and achievable means to better their lives. The world's growing population cannot attain a Western standard of living by following traditional industrial paths to development, for the resources required are too vast, too expensive, and too damaging to local and global systems. Instead, radical improvements in resource productivity expand their possibilities for growth, and can help to ameliorate the polarization of wealth between rich and poor segments of the globe. When the world's nations met in Brazil at the Earth Summit in 1992 to discuss the environment and human development, some treaties and proposals proved to be highly divisive because it appeared that they put a lid on the ability of nonindustrialized countries to pursue development. Natural capitalism provides a practical agenda for development wherein the actions of both developed and developing nations are mutually supportive.

BIOMIMICRY

To appreciate the potential of radical resource productivity, it is helpful to recognize that the present industrial system is, practically speaking, a couch potato: It eats too much junk food and gets insufficient exercise. In its late maturity, industrial society runs on life-support systems that require enormous heat and pressure, are petrochemically dependent and materials-intensive, and require large flows of toxic and hazardous chemicals. These industrial "empty calories" end up as pollution, acid rain, and greenhouse gases, harming environmental, social, and financial systems. Even though all the reengineering and downsizing trends of the past decade were supposed to sweep away corporate inefficiency, the U.S. economy remains astoundingly inefficient: It has been estimated that only 6 percent of its vast flows of materials actually end up in products.[15] Overall, the ratio of waste to the *durable* products that constitute material wealth may be closer to one hundred to one. The whole

economy is less than 10 percent — probably only a few percent — as energy-efficient as the laws of physics permit.[16]

This waste is currently rewarded by deliberate distortions in the marketplace, in the form of policies like subsidies to industries that extract raw materials from the earth and damage the biosphere. As long as that damage goes unaccounted for, as long as virgin resource prices are maintained at artificially low levels, it makes sense to continue to use virgin materials rather than reuse resources discarded from previous products. As long as it is assumed that there are "free goods" in the world — pure water, clean air, hydrocarbon combustion, virgin forests, veins of minerals — large-scale, energy- and materials-intensive manufacturing methods will dominate, and labor will be increasingly marginalized.[17] In contrast, if the subsidies distorting resource prices were removed or reversed, it would be advantageous to employ more people and use fewer virgin materials.

Even without the removal of subsidies, the economics of resource productivity are already encouraging industry to reinvent itself to be more in accord with biological systems. Growing competitive pressures to save resources are opening up exciting frontiers for chemists, physicists, process engineers, biologists, and industrial designers. They are reexamining the energy, materials, and manufacturing systems required to provide the specific qualities (strength, warmth, structure, protection, function, speed, tension, motion, skin) required by products and end users and are turning away from mechanical systems requiring heavy metals, combustion, and petroleum to seek solutions that use minimal inputs, lower temperatures, and enzymatic reactions. Business is switching to imitating biological and ecosystem processes replicating natural methods of production and engineering to manufacture chemicals, materials, and compounds, and soon maybe even microprocessors. Some of the most exciting developments have resulted from emulating nature's life-temperature, low-pressure, solar-powered assembly techniques, whose products rival anything human-made. Science writer Janine Benyus points out that spiders make silk, strong as Kevlar but much tougher, from digested crickets and flies, without needing boiling sulfuric acid and high-temperature extruders. The abalone generates an inner shell twice as tough as our best ceramics, and diatoms make glass, both processes employing seawater with no furnaces. Trees turn sunlight, water, and air into cellulose, a sugar stiffer and stronger than

nylon, and bind it into wood, a natural composite with a higher bending strength and stiffness than concrete or steel. We may never grow as skillful as spiders, abalone, diatoms, or trees, but smart designers are apprenticing themselves to nature to learn the benign chemistry of its processes.

Pharmaceutical companies are becoming microbial ranchers managing herds of enzymes. Biological farming manages soil ecosystems in order to increase the amount of biota and life per acre by keen knowledge of food chains, species interactions, and nutrient flows, minimizing crop losses and maximizing yields by fostering diversity. Meta-industrial engineers are creating "zero-emission" industrial parks whose tenants will constitute an industrial ecosystem in which one company will feed upon the nontoxic and useful wastes of another. Architects and builders are creating structures that process their own wastewater, capture light, create energy, and provide habitat for wildlife and wealth for the community, all the while improving worker productivity, morale, and health.[18] High-temperature, centralized power plants are starting to be replaced by smaller-scale, renewable power generation. In chemistry, we can look forward to the end of the witches' brew of dangerous substances invented this century, from DDT, PCB, CFCs, and Thalidomide to Dieldrin and xeno-estrogens. The eighty thousand different chemicals now manufactured end up everywhere, as Donella Meadows remarks, from our "stratosphere to our sperm." They were created to accomplish functions that can now be carried out far more efficiently with biodegradable and naturally occurring compounds.

SERVICE AND FLOW

Beginning in the mid-1980s, Swiss industry analyst Walter Stahel and German chemist Michael Braungart independently proposed a new industrial model that is now gradually taking shape. Rather than an economy in which *goods* are made and sold, these visionaries imagined a *service economy* wherein consumers obtain *services* by leasing or renting goods rather than buying them outright. (Their plan should not be confused with the conventional definition of a service economy, in which burger-flippers outnumber steelworkers.) Manufacturers cease thinking of themselves as sellers of products and become, instead, deliverers of service, provided by long-lasting, upgradeable durables. Their goal is selling results rather than equipment, performance and satisfaction rather than motors, fans, plastics, or condensers.

The system can be demonstrated by a familiar example. Instead of purchasing a washing machine, consumers could pay a monthly fee to obtain the *service* of having their clothes cleaned. The washer would have a counter on it, just like an office photocopier, and would be maintained by the manufacturer on a regular basis, much the way mainframe computers are. If the machine ceased to provide its specific service, the manufacturer would be responsible for replacing or repairing it at no charge to the customer, because the washing machine would remain the property of the manufacturer. The concept could likewise be applied to computers, cars, VCRs, refrigerators, and almost every other durable that people now buy, use up, and ultimately throw away. Because products would be returned to the manufacturer for continuous repair, reuse, and remanufacturing, Stahel called the process "cradle-to-cradle."[19]

Many companies are adopting Stahel's principles. Agfa Gaevert pioneered the leasing of copier services, which spread to the entire industry.[20] The Carrier Corporation, a division of United Technologies, is creating a program to sell coolth (the opposite of warmth) to companies while retaining ownership of the air-conditioning equipment. The Interface Corporation is beginning to lease the warmth, beauty, and comfort of its floor-covering services rather than selling carpets.

Braungart's model of a *service economy* focuses on the nature of material cycles. In this perspective, if a given product lasts a long time but its waste materials cannot be reincorporated into new manufacturing or biological cycles, then the producer must accept responsibility for the waste with all its attendant problems of toxicity, resource overuse, worker safety, and environmental damage. Braungart views the world as a series of metabolisms in which the creations of human beings, like the creations of nature, become "food" for interdependent systems, returning to either an industrial or a biological cycle after their useful life is completed. To some, especially frugal Scots and New Englanders, this might not sound a novel concept at all. Ralph Waldo Emerson once wrote, "Nothing in nature is exhausted in its first use. When a thing has served an end to the uttermost, it is wholly new for an ulterior service."[21] In simpler times, such proverbial wisdom had highly practical applications. Today, the complexity of modern materials makes this almost impossible. Thus, Braungart proposed an Intelligent Product System whereby those products that do not degrade back into natural nutrient cycles be designed so that they can

be deconstructed and completely reincorporated into *technical nutrient* cycles of industry.[22]

Another way to conceive of this method is to imagine an industrial system that has no provision for landfills, outfalls, or smokestacks. If a company knew that nothing that came into its factory could be thrown away, and that everything it produced would eventually return, how would it design its components and products? The question is more than a theoretical construct, because the earth works under precisely these strictures.

In a *service economy,* the product is a means, not an end. The manufacturer's leasing and ultimate recovery of the product means that the product remains an asset. The minimization of materials use, the maximization of product durability, and enhanced ease of maintenance not only improve the customer's experience and value but also protect the manufacturer's investment and hence its bottom line. *Both* producer and customer have an incentive for continuously improving resource productivity, which in turn further protects ecosystems. Under this shared incentive, both parties form a relationship that continuously anticipates and meets the customer's evolving value needs — and meanwhile rewards both parties for reducing the burdens on the planet.

The service paradigm has other benefits as well: It increases employment, because when products are designed to be reincorporated into manufacturing cycles, waste declines, and demand for labor increases. In manufacturing, about one-fourth of the labor force is engaged in the fabrication of basic raw materials such as steel, glass, cement, silicon, and resins, while three-quarters are in the production phase. The reverse is true for energy inputs: Three times as much energy is used to extract virgin or primary materials as is used to manufacture products from those materials. Substituting reused or more durable manufactured goods for primary materials therefore uses less energy but provides more jobs.[23]

An economy based on a service-and-flow model could also help stabilize the business cycle, because customers would be purchasing flows of services, which they need continuously, rather than durable equipment that's affordable only in good years. Service providers would have an incentive to keep their assets productive for as long as possible, rather than prematurely scrapping them in order to sell replacements. Over- and undercapacity would largely disappear, as business would no longer have to be concerned about delivery or backlogs if it is contract-

ing from a service provider. Gone would be end-of-year rebates to move excess automobile inventory, built for customers who never ordered them because managerial production quotas were increased in order to amortize expensive capital equipment that was never needed in the first place. As it stands now, durables manufacturers have a love-hate relationship with durability. But when they become service providers, their long- and short-term incentives become perfectly attuned to what customers want, the environment deserves, labor needs, and the economy can support.[24]

INVESTING IN NATURAL CAPITAL

When a manufacturer realizes that a supplier of key components is overextended and running behind on deliveries, it takes immediate action lest its own production lines come to a halt. Living systems are a supplier of key components for the life of the planet, and they are now falling behind on their orders. Until recently, business could ignore such shortages because they didn't affect production and didn't increase costs. That situation may be changing, however, as rising weather-related claims come to burden insurance companies and world agriculture. (In 1998, violent weather caused upward of $90 billion worth of damage worldwide, a figure that represented more weather-related losses than were accounted for through the entire decade of the 1980s. The losses were greatly compounded by deforestation and climate change, factors that increase the frequency and severity of disasters. In human terms, 300 million people were permanently or temporarily displaced from their homes; this figure includes the dislocations caused by Hurricane Mitch, the deadliest Atlantic storm in two centuries.)[25] If the flow of services from industrial systems is to be sustained or increased in the future for a growing population, the vital flow of life-supporting services from living systems will have to be maintained and increased. For this to be possible will require investments in natural capital.

As both globalization and Balkanization proceed, and as the per-capita availability of water, arable land, and fish continue to decline (as they have done since 1980), the world faces the danger of being torn apart by regional conflicts instigated at least in part by resource shortages or imbalances and associated income polarization.[26] Whether it involves oil[27] or water,[28] cobalt or fish, access to resources is playing an ever more prominent role in generating conflict. In addition, many social instabilities and refugee populations — twelve million

refugees now wander the world — are created or worsened by ecological destruction, from Haiti to Somalia to Jordan. On April 9, 1996, Secretary of State Warren Christopher gave perhaps the first speech by an American cabinet officer that linked global security with the environment. His words may become prophetic for future foreign policy decisions: ". . . [E]nvironmental forces transcend borders and oceans to threaten directly the health, prosperity and jobs of American citizens. . . . [A]ddressing natural resource issues is frequently critical to achieving political and economic stability, and to pursuing our strategic goals around the world."

Societies need to adopt shared goals that enhance social welfare but that are not the prerogatives of specific value or belief systems. Natural capitalism is one such objective. It is neither conservative nor liberal in its ideology, but appeals to both constituencies. Since it is a means, and not an end, it doesn't advocate a particular social outcome but rather makes possible many different ends. Therefore, whatever the various visions different parties or factions espouse, society can work toward resource productivity now, without waiting to resolve disputes about policy.

The chapters that follow describe an array of opportunities and possibilities that are real, practical, measured, and documented. Engineers have already designed hydrogen-fuel-cell-powered cars to be plug-in electric generators that may become the power plants of the future. Buildings already exist that make oxygen, solar power, and drinking water and can help pay the mortgage while their tenants work inside them. Deprintable and reprintable papers and inks, together with other innovative ways to use fiber, could enable the world's supply of lumber and pulp to be grown in an area about the size of Iowa. Weeds can yield potent pharmaceuticals; cellulose-based plastics have been shown to be strong, reusable, and compostable; and luxurious carpets can be made from landfilled scrap. Roofs and windows, even roads, can do double duty as solar-electric collectors, and efficient car-free cities are being designed so that men and women no longer spend their days driving to obtain the goods and services of daily life. These are among the thousands of innovations that are resulting from natural capitalism.

This book is both an overview of the remarkable technologies that are already in practice and a call to action. Many of the techniques and methods described here can be used by individuals and small busi-

nesses. Other approaches are more suitable for corporations, even whole industrial sectors; still others better suit local or central governments. Collectively, these techniques offer a powerful menu of new ways to make resource productivity the foundation of a lasting and prosperous economy — from Main Street to Wall Street, from your house to the White House, and from the village to the globe.

Although there is an overwhelming emphasis in this book on what we do with our machines, manufacturing processes, and materials, its purpose is to support the human community and all life-support systems. There is a large body of literature that addresses the nature of specific living systems, from coral reefs to estuarine systems to worldwide topsoil formation. Our focus is to bring about those changes in the human side of the economy that can help preserve and reconstitute these systems, to try and show for now and all time to come that there is no true separation between how we support life economically and ecologically.