

Capital Gains

How we ignore living systems — The resource riddle — Original quality provider — One teaspoon of good grassland — Nature's workers out of business — \$33 trillion and counting — Substitutes or complements — When the limiting factor changes — Subsidizing global loss — Taxing waste, not work — The first sustainable corporation

WASTE ELIMINATION IN INDUSTRY LEADS TO A CHAIN OF EVENTS AND PROCESSES that can form the basis for startling innovation in the business sphere. Ultimately, however, the chain leads back to biological systems, the sphere of life from which all prosperity is derived.

So far, the connection between industry and living systems has largely been ignored. The *Wall Street Journal* doesn't have a column devoted to the latest news about natural capital, because natural capital has been for the most part irrelevant to business planning. The exclusion of natural capital from balance sheets has been an understandable omission. There was so much of it available that it didn't seem worth taking into account. Throughout the Industrial Revolution, manufactured capital — money, factories, machinery — was the principal factor in industrial production, and natural capital was considered only a marginal input, one that rarely affected the economy save for during periods of war or famine, when scarcity could become a critical issue.

In 1972, a book commissioned by the Club of Rome entitled *The Limits to Growth* investigated the long-term consequences of existing patterns of consumption and production on factors like population growth, industrial capacity, food production, and pollution.¹ Using the system dynamics model created by engineer Dr. Jay Forrester, professor at the Sloan School of Management at MIT, the authors predicted that, sometime in the next hundred years, if then-current trends in population growth, industrialization, and resource depletion continued unchanged, the world would face actual physical limits to growth. The

shortages we would face would be tantamount to pouring sand into the gears of the industrial machine. Prosperity could be preserved, but only by changing the trends. Shortly after the publication of the book, it seemed as if its cautionary warnings were already coming true as the 1973 Arab oil embargo and subsequent energy crisis gripped the nation. Drivers fought to secure places in six-mile-long gas lines, while food prices rocketed. Overanxious survivalists hoarded toilet paper, light-bulbs, and nitrogen-packed containers of wheat and beans.

Nine million copies of *The Limits to Growth* were eventually sold in a total of thirteen languages. The book represents the very first systematic application of a comprehensive model to global futures. Although the methodology and terms used were not well understood, the book caused a furor. Businesspeople attacked it, arguing that the world had successfully adapted to previous shortages and that any future crises would be no exception. Robert Ayres, the inventor of the term “industrial metabolism,” criticized the model because he thought it did not take into account the role prices would play in signaling shortages far enough in advance to precipitate innovation.² Energy analysts like Daniel Yergin said that such innovations, especially energy efficiency measures, would offset shortages and correctly foresaw that the price of oil, over time, would come down instead of going up.

Twenty-seven years later, what many observers most remember of *The Limits to Growth* is that some of the more specific predictions of resource shortages that it was thought (wrongly) to have made have not occurred.³ Further, although the book described “present known reserves,”⁴ and how they increase over time through fuller exploration and better technology, it didn’t explicitly state that mining and oil companies have no financial incentive to prove out reserves much beyond the next thirty-odd years. Some readers therefore got the incorrect impression that the authors thought the reserves known in 1972 equaled the entire geological resource base. The authors didn’t think that. Sure enough, reserves in 1972 turned out to be only a part of the resource base, so exploration and discoveries continued routinely to expand them. In 1970, estimated proven world reserves of oil were 455 billion barrels; by 1996, the proven figure had risen to 1,160 billion barrels.⁵ For natural gas, the figures are even more dramatic. In 1970, reserves were 1,140 trillion cubic feet; by 1996, they had increased to 5,177 trillion cubic feet.⁶ Most important, the annual compound growth

in world demand for oil, which in 1972 was projected to stay around 4 percent a year indefinitely, turned negative in 1974 and then averaged only 0.9 percent for the next 20 years, greatly extending the reserves' useful life. In what will continue to be a durable equilibrium between price, availability, perception of scarcity, and energy efficiency, prices fell and stabilized. People now believe that there is no energy crisis, and Detroit now makes 8,000-pound-plus sport-utility vehicles for upper-middle-class suburbanites to pick their kids up at school. In other words, in the two and half decades that have passed since the publication of *The Limits to Growth*, we seem to have more “more” rather than less.

Because the book was widely perceived as an unfulfilled prediction of doom⁷ — which was emphatically not the intent of the authors, who sought rather to point out that using resources at a rate greater than they could be replenished would lead to trouble and could be advantageously avoided — the idea of resource limits is scoffed at today in many business and political circles and has fallen into disrepute. What has been lost, however, in that simplistic dismissal is the genuine understanding of what a resource really is. The word comes from the Latin *resurgere*, to rise *again*. A true resource, in other words, is something that returns over and over again, because it is part of a cyclical process. Of course, the definition has changed with time and now describes such nonrenewables as coal and oil. But even they could be recreated in a billion years or so, if we had the time to wait.

ECOSYSTEM SERVICES

Another way to assess the worth of ecosystem services is to consider the \$200-million Biosphere 2 experiment. In 1991, eight scientists entered a sealed, glass-enclosed, 3.15-acre structure near Oracle, Arizona, where they remained for two years. Inside was a diversity of ecosystems, each built from scratch, including a desert, a tropical rainforest, a savanna, a wetland, a field for farming, and an ocean with a coral reef. The “bionauts” were accompanied into their habitat by insects, pollinators, fish, reptiles, and mammals that were selected to maintain ecosystem functions. They were to live entirely off the land inside the dome. All air, water, and nutrient recycling took place within the structure.

Biosphere 2 was the most ambitious project ever undertaken to study life within a closed system. Never before had so many living organisms been placed in a tightly sealed structure. Inside the dome, air quality steadily declined. While a rise in carbon dioxide was expected, scientists were surprised at the drop in oxygen levels. While the ecosystems maintained life and, in some cases, flourished, there were many ecological surprises. Cockroaches multiplied greatly but fortunately took on the role of *de facto* pollinators as many other insects died off. Of the original 25 small vertebrate species in the Biosphere 2 population, 19 became extinct. At the end of 17 months, because of the drops in oxygen levels, the humans were living in air whose composition was equivalent to a 17,500-foot altitude.⁸ The lesson for nonscientists is that it required \$200 million and some of the best scientific minds in the world to construct a functioning ecosystem that had difficulty keeping eight people alive for 24 months. We are adding eight people to the planet every three seconds.

One of the primary lessons of Biosphere 2 is that there are some resources that no amount of money can buy.⁹ Few if any human-made substitutes can truly supply the diverse array of benefits that flow from nature. We can't manufacture watersheds, gene pools, topsoil, wetlands, riverine systems, pollinators, or tropospheres, let alone create an entire ecosystem. Aldo Leopold's famous dictum to "think like a mountain" was not just a poetic device but a plea to think in terms of the integrity of systems, because we cannot interrupt or replace the complex interrelationships in ecosystems with good results. What we *do* know about nonlinear systems is that they can maintain dynamic equilibrium in the face of disruptions — but only up to a point. Then, even small shifts in their balance can cause critical changes that throw the system into disequilibrium and rapid perturbation from which it may never return to its original pattern.

For example, a slight global warming may actually precipitate a sudden ice age rather than, as one would expect, a hothouse. At present, the North Atlantic Current, a flow of warm water equivalent to the mass of one hundred Amazon Rivers, maintains Europe and its farms at temperatures nine to eighteen Fahrenheit degrees higher than would otherwise be the case. London is at the same latitude as Calgary, but thanks to the way the Atlantic organizes itself, there are no snowmobiles or sled dogs in Hyde Park. Increased flows of freshwater melting off the Greenland icecap, however, could simply stop the North Atlantic

Current in a matter of only a few years. When mixed with the current, the sweeter water of melted ice could prevent a downwelling, the process whereby the heavier North Atlantic Current sinks and returns eventually to the Equator. Such an event would be the equivalent of turning off the heat in Europe.¹⁰

The real possibility of sudden, dramatic system changes is something we should be able to understand. Our lives are full of mechanisms for which a slight nudge or force can cause rapid changes or “flip-flops,” from light switches to thermostats to fire sprinklers to gun triggers.¹¹ Experience has taught us that ecosystems are laced with similar trigger mechanisms, and before our fingers get too itchy, we would do well to heed science’s warnings about the possible outcomes of our actions.¹²

ENVIRONMENT AS SOURCE OF QUALITY

Science provides a necessary basis for business to comprehend the emerging economics of living systems and ecosystem services. In scientific terms, there is no phenomenon called production, only transformation. No matter how energy or resources are used, scattered, or dispersed, their sum remains essentially the same, as dictated by the Law of Conservation of Matter and Energy. This law is of more than passing interest because it means that the term “consumption” is the abstract figment of economists’ imagination — that it is physically impossible in all processes or transformations.¹³ What is consumed from the environment is not matter or energy but order or quality — the structure, concentration, or purity of matter.¹⁴ This is a critically important concept, because it is “quality” that business draws upon to create economic value. Instead of focusing on whether physical resources will run out, it is more useful to be concerned about the specific aspects of the quality that natural capital produces: clean water and air; healthy soil, food, animals, forests, pollination, oceans, rivers; available and affordable sources of energy; and more. If industry removes concentrated and structured matter from the system faster than it can be replaced, and at the same time destroys the means of its creation, namely ecosystems and habitats, it introduces a fundamental problem in production.

Humankind has a long history of destroying its environs, especially soil and forest cover. The entire Mediterranean region shows the effects of siltation, overgrazing, deforestation, and erosion or salinization caused by irrigation.¹⁵ In Roman times, one could walk North Africa’s

coast from end to end without leaving the shade of trees; now it is a blazing desert.¹⁶ Today human activities are causing global decline in all living systems. The loss of 750 metric tons of topsoil per second worldwide and 5,000 acres of forest cover per hour becomes critical. Turning 40,000 acres a day into barren land — the present rate of desertification¹⁷ — is not sustainable either. In 1997, more than 5 million acres of forest were destroyed by “slash-and-burn” industrialists in the Indonesian archipelago. The Amazon basin, which contains 20 percent of the world’s freshwater and the greatest number of plant and animal species of any region on earth, saw 19,115 fires in a six-week period in 1998, five times as many as in 1995.¹⁸ In the oceans, the losses are similar. Our ability to overfish oceans with 30-mile-long lines results in 20 million tons of annual bycatch — dead or entangled swordfish, turtles, dolphins, marlin, and other fish that are discarded, pushed overboard, tossed back, or definned for soup in the case of sharks. This bycatch that is thrown overboard is the equivalent of ten pounds of fish for everyone on Earth.¹⁹ By now almost all the world’s fisheries are being exploited at or beyond their capacity, and one-third of all fish species (compared with one-fourth of all mammal species) are threatened with extinction.²⁰ A 7,000-square-mile “dead zone” — that’s the size of New Jersey — is growing off the coast of Louisiana. No marine life can live there because nitrate runoff in the form of agricultural fertilizers borne by the Mississippi River has depleted supplies of oxygen. The growing marine desert threatens a \$26 billion-a-year fishing industry.²¹ Each fire, every degraded hectare of crop- and rangeland, and each sullied river or fishery reduces the productivity and integrity of our living planet. Each of them diminishes the capacity of natural capital systems to process waste, purify air and water, and produce new materials.

In the face of this relentless loss of living systems, fractious political conflicts over laws, regulations, and business economics appear petty and small. It is not that these issues are unimportant but that they ignore the larger context. Are we or are we not systematically reducing life and the capacity to re-create order on earth? This is the level on which our discourse should take place, for it is there that a framework for both understanding and action can be formulated. In spite of what such signals as the GDP or the Dow Jones Industrial Average indicate, it is ultimately the capacity of the photosynthetic world and its nutrient flows that determine the quality and the quantity of life on earth.

With human population doubling sometime in the next century, and per-capita availability of ecosystem services dropping significantly over that same period, no one can accurately predict when a limitation in a given resource or ecosystem service will affect commerce and society. Nevertheless, in the coming years and decades, it is clear that the value of natural capital will shift accordingly. Business does not need to reach a consensus on specific environmental problems, or regulatory analyses, to acknowledge that a basic shift in capital availability — scarcer natural capital — is inexorable.

NATURAL CAPITAL

Natural capital comes about not by singular miracles but as the product of yeoman work carried out by thousands upon thousands of species in complex interactions. While scientists can identify the organisms that provide such things as food, pharmaceuticals, spices, or fiber, no one fully understands their roles in the health of the ecosystem. The best example of this is the most complex ecosystem on earth — soil. Soil fertility is maintained by conversion processes carried out by an extremely large number of organisms, some of which are poorly understood and some of which are unknown. Fertilizers notwithstanding, nutrient flows cannot be maintained without these processes. Stanford University biologist Gretchen Daily calls the profusion of life forms in the soil “staggering.” “One teaspoon of good grassland soil,” explains gardener/biologist Evan Eisenberg, “may contain 5 billion bacteria, 20 million fungi, and 1 million protoctists.”²² Expand the census to a square meter and you will find, besides unthinkable numbers of the creatures already mentioned, perhaps 1,000 each of ants, spiders, wood lice, beetles and their larvae, and fly larvae; 2,000 each of earthworms²³ and large myriapods (millipedes and centipedes); 8,000 slugs and snails; 20,000 pot worms, 40,000 springtails, 120,000 mites, and 12 million nematodes.²⁴ These life forms belowground weigh more than those aboveground — the equivalent of a dozen horses per acre.²⁵

Besides providing fertility, the soil stores water, holding rain and runoff for later release, feeding streams while preventing flooding. The fine particles in a pound of clay-rich soil contain about 100 acres of surface area²⁶ on which to host biological and physicochemical interactions including buffering acidity from rain. Soils decompose waste and remove litter, transforming animal, plant, and many types of human waste to nutrients and growing mediums. Soils cleanse and filter

pathogens and toxins. Antibiotics were discovered in soil. Soil and soil organisms play an integral role in the cycling of nitrogen, carbon, and sulfur — the grand cycles that affect every aspect of climate.

The interaction between plants and animals, in conjunction with the natural rhythms of weather, water, and tides, provides the basis for the cycle of life, a cycle that is ancient, complex, and highly interconnected. When one of its components — say, the carbon cycle — is disrupted, it in turn affects oceans, soils, rainfall, heat, wind, disease, and tundras to name but some other components. Today, every part of the earth is influenced by human activity, and the consequences are unknowable. Since it may not be possible to determine precisely which species are needed to maintain soil or other living systems, there is no way to state with any confidence which organisms we can do without (if any). Charles Darwin both foretold and appreciated what biologists would discover when he wrote: “We cannot fathom the marvelous complexity of an organic being. . . . Each living creature must be looked at as a microorganism — a little universe, formed of a host of self-propagating organisms, inconceivably minute and as numerous as the stars in heaven.”²⁷ As biologist E. O. Wilson has commented, the multitudinous diversity of obscure species don’t need us. Can we say with certainty the same about them?²⁸

Natural capital can be viewed as the sum total of the ecological systems that support life, different from human-made capital in that natural capital cannot be produced by human activity. It is easy to overlook because it is the pond in which we swim, and, like fish, we are not aware we’re in the water. One can live perfectly well without ever giving a thought to the sulfur cycle, mycorrhizal formation, alleles, wetland functions, or why giant sequoia trees can’t reproduce without chattering squirrels. We need not know that 80 percent of the 1,330 cultivated species of plants that supply our food are pollinated by wild or semi-wild pollinators,²⁹ but we should be aware that we are losing many of those pollinators including half of our honeybee colonies in the past 50 years in the United States, one-fourth since 1990. As biologists Gary Paul Nabhan and Steven Buchmann write in their book *Forgotten Pollinators*, “Nature’s most productive workers [are] slowly being put out of business.”³⁰

Only when the services provided by ecosystem functions are unmistakably disrupted do we step back and reconsider. Virtually every fish caught and consumed in the Great Lakes region comes with some

amount of industrially produced contamination. When rain disappears and soil blows away in the Midwest, when towns are flooded downstream by clear-cutting upstream, the absence of natural capital services becomes more apparent. Sometimes we mourn the loss much later. Kelp has become an increasingly valuable commodity, producing a wide range of products from food additives to nutritional supplements and pharmaceuticals. But Russian trappers critically injured Pacific Coast kelp beds in the eighteenth and nineteenth centuries, when sea otters from Alaska to Baja were hunted to near extinction. The otters ate urchins that eat kelp. Without the otters, the urchin population soared, and the beds, described by early explorers as vast underwater forests, were decimated. The Russians wanted the otter because after the invention of the samovar, Russian appetite for Chinese tea soared and otter furs were the only currency the Chinese would accept. Worth as much as precious metals, the fur was desired as trim for ornate robes.³¹

Compared to the rest of the world, North Americans have been fortunate in not having suffered debilitating degradation of their ecosystem services. Many countries and regions, more densely and historically populated, face far more severe effects of natural capital depletion. Yet American ecosystems cannot long endure without the health of their counterparts around the world. The atmosphere does not distinguish whether CO₂ comes from U.S. oil or Chinese coal, nor do the record-breaking 240 mph winds recorded in Guam in 1997 lose force if you don't happen to believe in climate change.³²

SUBSTITUTES OR COMPLEMENTS?

Many economists continue to insist that natural and manufactured capital are interchangeable, that one can replace the other. While they may acknowledge some loss of living systems, they contend that market forces will combine with human ingenuity to bring about the necessary technological adaptations to compensate for that loss. The effort of creating substitutes, they argue, will drive research, promote spending, increase jobs, and create more economic prosperity. Hydroponics, for example, could theoretically replace farms, creating potential benefits. There are substitutes for many resource commodities, as is the case with copper, coal, and metals. And there may be other beneficial substitutes on the drawing boards or not yet invented. Nevertheless, look at this very human-oriented list and try to imagine the technologies that could replace these services:

- production of oxygen
- maintenance of biological and genetic diversity
- purification of water and air
- storage, cycling, and global distribution of freshwater
- regulation of the chemical composition of the atmosphere
- maintenance of migration and nursery habitats for wildlife
- decomposition of organic wastes
- sequestration and detoxification of human and industrial waste
- natural pest and disease control by insects, birds, bats, and other organisms
- production of genetic library for food, fibers, pharmaceuticals, and materials
- fixation of solar energy and conversion into raw materials
- management of soil erosion and sediment control
- flood prevention and regulation of runoff
- protection against harmful cosmic radiation
- regulation of the chemical composition of the oceans
- regulation of the local and global climate
- formation of topsoil and maintenance of soil fertility
- production of grasslands, fertilizers, and food
- storage and recycling of nutrients³³

Thus far there are precious few if any substitutes for the services that natural capital invisibly provides. If it took a \$200 million investment to minimally keep eight people alive for two years in Biosphere 2, how much would it cost to replicate functions in the preceding list?

In 1997 a group of highly respected scientists, primarily biologists, wrote a consensus paper on ecosystem services in an attempt to raise public awareness of their concern about this issue. Published in the Spring 1997 *Issues in Ecology*, it noted:

Based on available scientific evidence, we are certain that:

- Ecosystem services are essential to civilization.
- Ecosystem services operate on such a grand scale and in such intricate and little-explored ways that most could not be replaced by technology.
- Human activities are already impairing the flow of ecosystem services on a large scale.
- If current trends continue, humanity will dramatically alter or destroy virtually all of Earth's remaining natural ecosystems within a few decades.

That the public does not understand the economic implications of declining ecosystem services has been frustrating to scientists. But in 1994, a group of Pew Scholars gathered in Arizona. Out of this meeting came the book *Nature's Services*, edited by Gretchen Daily, and a paper, whose lead author was economist Robert Costanza, entitled "The Value of the World's Ecosystem Services and Natural Capital," published in the British journal *Nature* on May 15, 1997. Both publications occasioned headlines, press conferences, and follow-up stories. The issues finally received proper attention because the scientists shrewdly put a price tag on the annual value of seventeen ecosystem services: \$36 trillion on average, with a high estimate of \$58 trillion (1998 dollars). Given that in 1998 the Gross World Product was \$39 trillion, the figures were surprising.³⁴

Most of the ecosystem values the scientists identified had never been economically measured. They included \$1.3 trillion a year for atmospheric regulation of gases, \$2.3 trillion for the assimilation and processing of waste, \$17 trillion for nutrient flows, and \$2.8 trillion for the storage and purification of water. The greatest contribution, \$20.9 trillion, was from marine systems, especially coastal environments. Terrestrial systems added \$12.3 trillion, with forests and wetlands each responsible for about \$4.7 trillion. The value of all terrestrial systems averaged just over \$466 per acre. Marine systems were lower, averaging \$234 per acre, but more highly concentrated in coastal environments, including the Continental Shelf, where the yield was \$1,640 per acre. The highest annual value per acre recorded was for estuaries, at \$9,240. The primary value of coastal estuaries is not as a food source but in their capacity to provide nutrient recycling services for 40 trillion cubic meters of river water every year. On land, the highest valued environments were wetlands and floodplains, at \$7,924 per acre. The greatest benefits derived from these systems are flood control, storm protection, waste treatment and recycling, and water storage.

At first glance, these numbers may seem unduly high. After all, many farmers have much more modest incomes per acre; U.S. annual gross farm income averages about \$200 per acre per year. But bear in mind that the values measured do not simply record resources extracted and sold. An acre of ocean or chaparral can't be conventionally monetized according to the standard economic point of view, which counts only what's taken away to market, not the service of supporting life itself.

In the United States, the decline in ecosystem services can be gauged in part by the loss of major ecosystems. These habitats or ecological communities, and many more, are all unique and are all under threat of destruction:

- California wetlands and riparian communities
- tallgrass prairies (which once nurtured nearly 100 million buffalo, elk, and antelope)
- Hawai‘ian dry forests
- longleaf pine forests and savannas
- forest wetlands in the South
- ancient ponderosa pine forests
- ancient eastern deciduous forests
- California native grasslands
- southern Appalachian spruce-fir forests
- midwestern wetlands
- marine coastal communities in all lower forty-eight states and Hawai‘i
- ancient redwood forests
- ancient cedar forests of the Northwest
- ancient pine forests of the Great Lakes
- eastern grasslands and savannas
- Southern California coastal sage scrub³⁵

If we capitalized the annual income of \$36 trillion for ecosystem services, using the going rate for U.S. Treasuries, it would mean that nature is roughly worth a little more than \$500 trillion — an absurdly low figure, as it is comparable to the next thirteen years of economic output.³⁶ What prices can do, however, is to illustrate vividly and concretely a relationship that is breaking down. Establishing values for natural capital stocks and flows, as rough as they may be, or — as natural capitalism does — *behaving as if* we were doing so, is a first step toward incorporating the value of ecosystem services into planning, policy, and public behavior. When a Philippine fisherman tosses a stick of dynamite into coral reefs, harvesting stunned fish for local markets and broken pieces of coral for the pharmaceutical industry, he pockets cash at market prices. He does not pay for the loss of the coral reef, but it should be obvious that the net present value of the coral reef habitat as

a future home of fish far outweighs the few pesos garnered by its destruction. Nevertheless, governments from developed and developing nations still use accounting methods that register the fish and coral harvest as net gains rather than net losses.

If the services provided by natural capital provide in effect annual “subsidies” to production worth tens of trillions of dollars, and these subsidies are declining while affluence and population growth are accelerating their depletion, at what point will civilization be affected? How will businesses all reliant on natural capital, and some especially so, prosper in the future? Given that all of the biomes studied in the *Nature* article are declining in area, viability, and productivity, perhaps a revision in economics is overdue. A reassessment of national and international balance sheets is needed in which the stock and flow of services from natural capital are at least partially if not fully valued.

Biologist Peter Raven, head of Missouri Botanic Garden, and one of the world’s foremost experts in biodiversity, writes that ecosystem services are not merely “a series of factors lying on the side of industrial processes, which added up could cause trouble, but rather an expression of the functioning of a healthy Earth. . . . [W]e’re disrupting that functioning to an incredible degree.” The cash estimate of their value commodifies the living world and says

nothing about our real place in nature, morality, or the simple joy of living in a richly diverse, interesting, living world. As a biologist, I always think about such broad subjects in the way the world functions, as if there were no people there; and then I think about the flow of energy from the Sun, and the activities of all the photosynthetic organisms, the food chains and communities that regulate the flow of the stored energy here on Earth, and the ways in which human beings impact or break that flow, or divert it for their own purposes — what are the actual biological limits. For me, it is always the centrality of those functions, within which we evolved and which are so essential to our continued existence, that keeps looming so large.³⁷

LIMITING FACTORS

Former World Bank economist Herman Daly believes that humankind is facing a historic juncture: For the first time, the limits to increased prosperity are due to the lack not of human-made capital but rather of natural capital.

Historically, economic development has periodically faced one or another limiting factor, including the availability of labor, energy

resources, and financial capital. A limiting factor is one that prevents a system from surviving or growing if it is absent. If marooned in a mountain snowstorm, you need water, food, and warmth to survive; the resource in shortest supply limits your ability to survive. One factor does not compensate for the lack of another. Drinking more water will not make up for lack of clothing if you are freezing, just as having more clothing will not satisfy hunger. Because limiting factors in a complementary system cannot be substituted one for the other, the complement in shortest supply is what must be increased if the enterprise is to continue. Increasingly, the limiting factor for humanity is the decline of the living systems, quintessentially complements. Remove any of the ecosystem services listed previously, and others start to break down and eventually disappear.

The knowledge that shortages of ecosystem services will not lead to substitutions causes a different kind of anguish on both sides of the environmental debate. Eminent scientists and economists including Peter Raven, Herman Daly, J. Peterson Myers, Paul Ehrlich, Norman Myers, Gretchen Daily, Robert Costanza, Jane Lubchenco, and thousands more are trying to reach business, academic, and political audiences with this message. On the other hand, business acts as if scientists have either been unduly pessimistic or simply wrong in the past, and, in the case of climate change, will buy full-page ads in the *Wall Street Journal* arguing for, ironically, more studies and science, little of which they offer to fund. In the meantime, the loss of living systems is accelerating worldwide, despite huge capital spending on environmental cleanup by industrial nations and responsible corporations. The gap in understanding would be comical were it not potentially tragic. It's as if you are intent on cleaning your house, which is situated on a floodplain whose river is rising. Cleaning house is an admirable activity, but it's not an appropriate response to the immediate problem.

Whenever the economy has faced limiting factors to development in the past, industrial countries were able to continue to grow by maximizing the productivity or increasing the supply of the limiting factor. These measures sometimes came at a high cost to society. "From this foul drain the greatest stream of human industry flows out to fertilize the whole world," as de Tocqueville wrote.³⁸ Labor shortages were "satisfied" shamefully by slavery, as well as by immigration and high birthrates. Labor-saving machinery was supplied by the industrial revolution. New energy sources came from the discovery and extraction of

coal, oil, and gas. Tinkerers and inventors created steam engines, spinning jennies, cotton gins, and telegraphy. Financial capital became universally accessible through central banks, credit, stock exchanges, and currency exchange mechanisms. Typically, whenever new limiting factors emerged, a profound restructuring of the economy was the response. Herman Daly believes we are once more in such a period of restructuring, because the relationship between natural and human-made capital is changing so rapidly.

As natural capital becomes a limiting factor, we ought to take into consideration what we mean by the concept of “income.” In 1946, economist J. R. Hicks defined income as the “maximum amount that a community can consume over some time period and still be as well off at the end of the period as at the beginning.”³⁹ Being well-off at the end of a given year requires that some part of the capital stock is used to produce income, whether that capital is a soybean farm, semiconductor factory, or truck fleet. In order to continue to allow people to be well-off, year after year, that capital must either increase or remain in place. In the past, this definition of income was applied only to human-made capital, because natural capital was abundant. Today, the same definition should also apply to natural capital. This means that in order to keep our levels of income stable, much less increase them, we must sustain the original stocks of both types of capital. The less able we are to substitute artificial for natural capital, the more *both* forms of capital must be safeguarded from liquidation.

To maintain income, we need not only to maintain our stock of natural capital but to increase it dramatically in preparation for the possible doubling of population that may occur in the next century. This fourth principle of natural capitalism, investing in natural capital, is a matter of common sense. The only way to maximize natural capital’s productivity in the near term is by changing consumption and production patterns. Since today 80 percent of the world receives only about 20 percent of the resource flow, it is obvious that this majority will require more consumption, not less. The industrialized world will need radically improved resource productivity, both at home and abroad, and then begin to reverse the loss of natural capital and increase its supply. This is the only way to improve the quality of life everywhere in the world at once, rather than merely redistributing scarcity.

As economist Herman Daly explains, “[W]hen the limiting factor changes, then behavior that used to be economic becomes uneconomic.

Economic logic remains the same, but the pattern of scarcity in the world changes, with the result that behavior must change if it is to remain economic.”⁴⁰ This proposition explains the despair and excitement on both sides of the issue of resource management. On the environmental side, scientists are frustrated that many businesspeople do not yet understand the basic dynamics involved in the degradation of biological systems. For business, it seems unthinkable if not ludicrous that you shouldn’t be able to create the future by using the same methods that have been successful in the present and past. In this transitional phase, however, business is gradually coming to realize that economic activities that were once lucrative may no longer lead to a prosperous future. That realization is already fueling the next industrial revolution.

INVESTING IN NATURAL CAPITAL

The most fundamental policy implication of the resource productivity revolution is simple to envision but difficult to execute. We need, incrementally but firmly, to transform the sticks and carrots that guide and motivate business. That means, in essence, revising the tax and subsidy system — the mechanism that is most responsible for the constant rearrangement of monetary flows and that determines social, economic, and ecological outcomes by applying politically selected subsidies and penalties. In the world today, there are powerful incentives to “disinvest” in natural capital. While governments, NGOs, land trusts, and other agencies strive mightily to conserve and restore living systems, they are not keeping up with the rate of destruction. It is our belief that we already know how to “invest” in natural capital — thousands of groups are doing it around the world. What we haven’t learned is how to conduct our economy so that degradation first stops, and then reverses.

Today, abusers of ecosystem services are imposing costs on the rest of society, because everyone depends on those services and is harmed by their decrease. Drivers of cars pollute everyone’s air; paper mills pollute rivers that flow for miles into the surrounding countryside; chemical companies’ pesticides are found in creatures large and small from the Arctic to remote Pacific atolls. The minority is profiting at the expense of the majority. Not only do users of ecosystem services get a free ride, but everyone else is forced to subsidize the resulting resource depletion and loss, at an estimated expense to taxpayers, as we shall see in

a moment, of around \$1.5 trillion per year.⁴¹ A very large, money-saving, cost-free investment in natural capital can be made by eliminating both the perverse subsidies now doled out regularly by governments to industries and the practices, encouraged by those subsidies, that are heedless of the environment.

In a groundbreaking work of research and collaborative sleuthing, Dr. Norman Myers undertook an approximate accounting of the world's perverse subsidies in six sectors: agriculture, energy, transportation, water, forestry, and fisheries. Ideally, subsidies are supposed to exert a positive outcome by helping people, industries, regions, or products that need to overcome cost, pricing, or market disadvantages. For example, education is subsidized so that parents don't have to pay the full cost of their children's schooling. Microprocessor development was heavily subsidized by the U.S. Defense Department for over a decade, and still is in specialized areas. Today, that looks like a brilliant investment.

Perverse subsidies do the opposite. They function as disinvestments, leaving the environment and the economy *worse* off than if the subsidy had never been granted. They inflate the costs of government, add to deficits that in turn raise taxes, and drive out scarce capital from markets where it is needed. They confuse investors by sending distorting signals to markets; they suppress innovation and technological change; they provide incentives for inefficiency and consumption rather than productivity and conservation. They are a powerful form of corporate welfare that benefits the rich and disadvantages the poor.

For example, Germany pays \$6.7 billion, or \$73,000 per worker, every year to subsidize the Ruhr Valley coal regions.⁴² The high-sulfur coal produced there contributes to air pollution, acid rain, lung disease, the die-off of European forests (*Waldsterben*), and global warming. For less money, the German government could pay all workers their full wages for the rest of their lives and shutter every coal company. In the mid-1990s, Bulgaria was still spending over 7 percent of its entire GDP on subsidies to make energy look cheaper than it really was so people would be encouraged to use it even more wastefully.⁴³ Perverse subsidies can also be involuntary. In past decades, the Swedes indirectly subsidized the electrical industry in the U.K. because their forests are unintentionally but heavily damaged by the sulfur-dioxide emissions of British coal-burning power plants. Perverse subsidies can even be

embedded in taxes. For example, by taxing drivers for ownership of vehicles rather than their use, governments reduce the owner's marginal cost of driving while raising it for society as the number of people driving increases.

Dr. Myers found that governments are loath to cooperate to reveal their transfer payments to protected industries. Oligarchies, corruption, and/or lobbying can all contribute to discouraging full disclosure, much less interference. Subsidies are not regularly and officially tallied by any government in the world, including that of the United States.⁴⁴ They are euphemized, concealed, or brazenly defended as pro-growth and pro-jobs by the powerful interests who benefit but are seldom revealed clearly or directly to the taxpayers who finance them. That concealment is not surprising, since the sums of money are enormous: \$1.5 trillion a year represents twice the money spent on defense and weapons, and is a sum larger than the GDP of all but five countries in the world — larger, indeed, than the total GDP of the world's seventy-four smallest countries. If even a third of these subsidies were transfer payments to the world's poor, the income of 1.3 billion people with the lowest incomes could double.

In the United States, automobile companies and related industries have effectively been on welfare for most of the twentieth century. Hidden automobile costs total nearly \$464 billion annually, from the expense of taxpayer-funded road construction to the cost of Persian Gulf forces earmarked to protect America's access to "its" oil. But roads may be the most insidious of these beneficiaries because they are so often seen as vital for growth and jobs. Subsidizing them has led to suburban sprawl, urban decay, and highways to nowhere. Even a publication as conservative as *The Economist* has acknowledged the perversity of subsidies in this realm, perhaps influenced by the fact that in one-third of all European cities, traffic moves at less than nine miles per hour at peak times, and even slower in London:

If roads continue to be operated as one of the last relics of a Soviet-style command economy, then the consequence will be worsening traffic jams and eventual Bangkok-style gridlock. If, on the other hand, roads were priced like any other scarce commodity, better use would be made of existing space and the revenues raised would be used to improve public transport. The mere fact of making motorists pay their way would free capacity to such an extent that bus travel would become easier and faster, and subsidies could be reduced.⁴⁵

Not only did the magazine's editorial come out squarely for road pricing and taxes for road use, but it suggested that governments could borrow against the stream of future revenue from such taxes, thus accelerating financing to improve public transportation. This is a useful and practical principle and one that can be applied elsewhere: Once perverse subsidies are eliminated, the stream of income from realized savings can be reinvested in further savings. Tunneling through the subsidy barrier creates a multiplier effect that starts to compound the investment and finance the restoration of natural capital.

In some cases, the word "perverse" is too innocuous a description for the ways that various businesses are underwritten. Take, for example, the subsidies for agriculture provided by the twenty-nine member nations of the Organization for Economic Cooperation and Development (OECD). They total \$300 billion per year, and are designed to suppress or restrain surplus production. In contrast, raising agriculture to Western standards in developing countries where food is not in surplus would cost only \$40 billion per year. Similarly bizarre, while U.S. gasoline prices fall to their lowest levels in history, American subsidies to fossil-fuel industries exceed \$20 billion per year.⁴⁶ Between May 1994 and September 1996, the U.S. government honored an 1872 mining law by transferring land containing \$16 billion worth of minerals to private parties for the sum of \$19,190 — nearly a millionfold less. Any downstream damage to streams and rivers will be paid by taxpayers, who will not receive a single penny of royalties. Already, an estimated \$33–72 billion of cleanup at abandoned mining sites must be underwritten by those same taxpayers.⁴⁷ In all, polluting American industries, according to the Congressional Joint Committee on Taxation, will get \$17.8 billion *more* in tax breaks over the next five years.⁴⁸ Fifteen direct subsidies to virgin resource extraction and waste disposal industries will account for another \$13 billion in the same period.⁴⁹

In farming, the U.S. government has set up a veritable universal sprinkler system for subsidies. It subsidizes agricultural production, agricultural nonproduction, agricultural destruction, and agricultural restoration, and for good measure, it subsidizes crops that cause death and disease, by giving over \$800 million a year to tobacco farmers. American taxpayers heavily subsidize the 3,400 gallons of water it takes to produce one dollar's worth of California sugar beet.⁵⁰ Taxpayers paid to drain the Everglades, subsidize sugar producers with price supports, and cover the damage to wetlands and the Gulf from phosphate runoff

and pesticide poisoning — and are now spending \$1.5 billion to buy back some of the 700,000 acres that they had paid to drain and sell at below-market prices in the first place.⁵¹ We subsidize cattle grazing on public lands (\$200 million), and then pay for soil conservation services to try to repair the damage. And most notoriously, even wealthy landowners are paid to keep their land out of production. (The Conservation Reserve Program pays out \$1.7 billion a year, meant to reduce soil loss but apparently structured partly to subsidize the rich.)⁵²

The irrationality of agricultural subsidies is confirmed by many World Bank studies. Three examples suffice. Indonesia heavily subsidized pesticides, resulting in massive use and equally serious side effects. Starting in 1986, the government banned many pesticides and adopted Integrated Pest Management as official policy. By 1989, the subsidies were gone; pesticide production plummeted nearly to zero and imports by two-thirds; yet rice production *rose* by another 11 percent during the years 1986–90, thanks to the ecosystem’s recovering health. Bangladesh’s removal of fertilizer subsidies, which had amounted to 4 percent of the national budget, made food prices *drop* through increased competition. Throughout the developing countries that subsidize irrigation with some \$22 billion a year, “massive underpricing of irrigation water has resulted in substantial overuse” and is a “major factor behind the waterlogging and salinization problems being experienced in many countries,” yet has benefited mainly medium-sized and rich farmers.⁵³ U.S. agricultural subsidies teach precisely the same lessons.

While Americans subsidize environmental degradation, cars, the wealthy, corporations, and any number of technological boondoggles, the clean technologies that will lead to more jobs and innovation are often left to the “market.” Free markets for sound investments are advocated in the same breath as corporate socialism for unsound investments — if they benefit the advocates. Between 1946 and 1961, the Atomic Energy Commission spent \$1.5 billion to develop a plutonium-powered airplane; it was so laden with lead shielding that the vehicle could not get off the ground.⁵⁴ Tax-free bonds enrich owners of sports franchises who build stadiums, and then build the requisite roads and highways so that fans can leave games quickly (\$9.1 billion a year is the lost federal revenue from tax-free municipal bonds).⁵⁵

Then there is the money donated to dying industries, federal insurance provided to floodplain developers, cheap land leases to ski resorts, bailouts to felons controlling savings and loans (\$32 billion a year for 30

years),⁵⁶ roads into National Forests so private forest-products companies can buy wood at a fraction of its replacement cost (\$427 million a year) while taxpayers make up the losses to the Forest Service, long the world's largest socialist road builder.⁵⁷

Those are some of the activities that our tax policies encourage. What they discourage, apparently, is jobs and well-being. In 1996, the federal government raised \$1.587 trillion in taxes, over 80 percent of which came from taxes on individuals, in the form of either personal income taxes or Social Security levies. Another 11 percent was from corporate income tax.⁵⁸ Two-thirds of personal income tax is derived from the sale of labor, while one-third is from taxing dividends, capital gains, and interest. By taxing labor heavily in the United States (and even more in Europe), the system encourages businesses not to employ people. The system works, and taxpayers then have to pay the social costs for unemployment. German businesses are especially adept at not employing people because German social taxation nearly doubles the cost of each worker. Taxpayers then have to pay the social costs for unemployment, further raising taxes. Germany has just begun to reduce employment taxes by raising gasoline taxes.

Taxes and subsidies are, in essence, a form of information. At the most basic level, they cause change. Everybody in the world, whether rich or poor, acts on price information every day. Taxes make something more expensive to buy, subsidies artificially lower prices. Thus, when something is taxed, you tend to buy less of it, and when you subsidize, you reduce prices and stimulate consumption. A practical step in moving toward radical resource productivity would be to shift taxes away from labor and income, and toward pollution, waste, carbon fuels, and resource exploitation, all of which are presently subsidized. For every dollar of taxation that is added to the cost of resources or waste, one dollar is removed from taxes on labor and capital formation.

A tax shift is not intended to redefine *who* pays the taxes but only *what* is taxed. Work is freed from taxation as is business and personal income. Waste, toxins, and primary resources make up the difference. As the cost of waste and resources increases, business can save money by hiring now-less-expensive labor and capital to save now-more-expensive resources. As business saves by increasing resource productivity, higher resource taxes may ensue, because there will be a smaller base of resources and waste to tax. That, in turn, will spur further research and innovation in resource productivity. A positive feedback

loop develops that incrementally generates more demand for labor while reducing demand for resources — and, important, less need for taxes in the first place, because the tax shift will reduce many of the environmental and social problems that government budgets seek to address. Economist Robert Ayres writes:

I believe many of the problems with slow economic growth, growing inequity, unemployment, and environmental degradation in the western world could be solved, in principle, by restructuring the tax system. The fundamental cause of under-employment is that labor has become too productive, mostly as a result of substituting machines and energy for human labor. The underlying basic idea of the change would be to reduce the tax burden on labor, so as to reduce its market price — relative to capital and resources — and thus encourage more employment of labor vis-à-vis capital and especially fossil fuels and other resources. If there is any implication of neo-classical economics that seems to be beyond challenge it is that shifting the relative prices of factors of production (i.e. labor, capital resources) will eventually induce the economy to substitute the cheaper factor (labor) for the more expensive one (resources). For the same reason, I want to increase the tax burden on activities that damage the social or natural environment, so as to discourage such activities and reduce the resulting damage.⁵⁹

A tax shift of this nature has to be steadily implemented over time, so that business has a clear horizon over which to make strategic investments. Further, the time span must be long enough — at least fifteen to twenty years — so that existing capital investments can continue to be depreciated over their useful lives. This provides a window wherein gradual changes can occur (such as the use of and reliance on fossil fuels) but also a clear long-term signal that allows for acceleration of progress through innovation. In the end, the goal is to achieve zero taxation on employees, whether on wages, income, or employer contribution. Except for lower-income workers, a tax shift should leave the tax burden on different income groups roughly where it is now, and there are numerous means to accomplish this. (The Social Security tax is the most regressive and punitive tax of all, requiring the lowest-income worker to pay the highest rate as a proportion of total income.) Though it sounds elitist if not outlandish to shift taxes away from personal investments or corporate income, the purpose is to lower the rate of return required to make an investment worthy. When there are high taxes on investment income, the rate of return must be correspondingly higher to justify investment. In part, that is why more money can

be made by rapidly exploiting resources rather than by conserving them. The higher the rate of return demanded on investments, the greater the likelihood of natural capital's liquidation. When lower rates of return are coupled with higher resource taxes, incentives shift dramatically toward restoration and regeneration of natural capital.⁶⁰ The important element to change is the purpose of the tax system, because the Internal Revenue Code, with its more than nine thousand sections, has no mission or goal.

It is easier, as the saying goes, to ride a horse in the direction it is going. The inevitable increases in the costs of natural capital should motivate us to get ahead of the curve. Shifting taxes toward resources creates powerful incentives to use fewer of them now. Simultaneously removing personal and employer taxes on labor creates new arenas of employment opportunity, since the cost of employment is reduced without lowering income. This in turn encourages many resource-saving activities, like closing the loops on material flows, disassembling products, and remanufacturing and repairing products, that currently look costlier than virgin resource use. This illusion is caused by keeping labor artificially expensive and raw materials artificially cheap.⁶¹

Many economists would say, let the markets dictate costs; taxation is interventionist. True, tax systems are by their very nature interventionist, but unless we abolish government, the question for society is *how* to intervene. A tax shift attempts to match price to cost. The present system is dissociative. People now know the price of everything but the true cost of nothing. Price is what the person pays. Cost is what society pays, here, now, elsewhere, and into the future. A pesticide may sell for thirty-five dollars a gallon, but what does it cost society as it makes its way into wells, rivers, and bloodstreams? Just because markets do not address value, goodness, justice, and morals does not mean that such concerns can be safely ignored.

To be clear, let's look at what would *not* be taxed. You would receive your whole paycheck. The only deductions would be discretionary contributions to a retirement plan such as a 401(k) or to a charity. If you were an independent contractor, such as a plumber, graphic designer, or consultant, you would pocket all billable income. Small businesses would not pay income taxes, nor would corporations. And there would be no taxes on interest received on savings or bonds, or on retirement plans, or on savings for college tuition.

What *would* be taxed? For starters, gases that cause climatic change. The atmosphere is not “free” when there are 6 billion other people who have to share it in the near term, and untold generations after them. If you want to put gases there, you have to pay. Nuclear power would be heavily taxed, as would all forms of electricity nonrenewably generated. Diesel fuels, gasoline, motor oils, nitrogen oxides, and chlorine would all pay their share. Air traffic of all kinds, from commercial to light aircraft, would be taxed (their fuel is now tax-exempt worldwide), along with all vehicular use and public roads. Motor vehicle insurance premiums would be collected at the gas pump, eliminating government subsidies of uninsured drivers. Pesticides, synthetic fertilizers, and phosphorus would join tobacco and alcohol as heavily taxed commodities. Piped-in water would be taxed, as would old-growth timber, harvests of free-run salmon and other wild fisheries, grazing “rights,” irrigation water from public lands, and depletion of topsoil and aquifers. From the ground, coal, silver, gold, chromium, molybdenum, bauxite, sulfur, and many other minerals. Any waste sent to a landfill or incinerator would be taxed (“pay-as-you-throw”), at such interesting rates that most landfills would cease to exist. Some, like those in Japan, may even be excavated for “resources.”⁶²

The result of the partial listing is that every individual and business can “avoid” taxes by changing behavior, designs, processes, and purchases. This works. Many a municipality has greatly extended the life of a nearly full landfill by taxing unnecessary inputs to it and using the proceeds to reward reduction, reuse, and recycling. Denmark’s landfill taxes increased the reuse of construction debris from 12 to 82 percent in less than a decade, twenty times greater than the 4 percent average rate seen in most industrial countries.⁶³ Holland’s green taxes have cut heavy-metal leaks into lakes and canals by up to 97 percent since 1976.⁶⁴

Thermal insulation and superwindows in such a world will have a bigger payout than Microsoft stock. You will be able to make Warren Buffet returns by simple investments in hardware-store technologies. When you save money, you will also be saving the environment for yourself and your children. For those who say that such a shift is regressive, bear in mind that it is the poor who bear the greatest burdens from environmental degradation. They cannot afford water filters, to live in the clean suburbs, to vacation in the mountains, or to obtain military deferments from Persian Gulf oil wars. They get the low-wage,

high-risk jobs in solvent-laden dry cleaners, pesticide-laced farms, and dust-filled coal mines. In addition, the \$1.5 trillion in annual subsidies previously outlined go almost entirely to business and the rich.

The intellectual inevitability of such a tax shift increases with time. Jacques Delors, former chairman of the European Commission, is urging its adoption there. Inquiries and small trial shifts are already under way in Sweden, Britain, Germany, the Netherlands, and Norway. Europe will lead because the solution offered by a tax shift addresses two key problems: environmental degradation and high structural unemployment coupled with jobless growth. The tax issue is alive in the United States, but the arguments are primarily ideological ones, chiefly conservative and libertarian, rather than constructive ones about aligning tax signals with social needs. Regardless, as Europe and other countries move toward tax shifting, it will force the United States to follow, for the very simple reason that it will lower our competitors' labor costs while spurring their innovation.⁶⁵ It will also help to ensure that the economic vitality stimulated will moderate, not worsen, the burden on natural capital.

These concepts are a startling reversal from the response to the environment that has been offered by the thousands of trade organizations, 60,000 lawyers, and 90,000 lobbyists clustered in Washington, D.C., who spend \$100 million a month in direct lobbying expenses.⁶⁶ Not liquidating natural capital means that business will not only have to conserve existing natural capital but will have to forgo corporate welfare and find ways to invest in increasing the supply of its limiting factor. The good news is that one of the most economical ways to do that is to reduce the amount of materials required by industry to provide the services needed by its customers. Is it possible? Ray Anderson, the CEO of Interface, Inc., believes so. In a message to his customers and employees published in the *Interface Sustainability Report* in 1997, he offered the following:

As I write this, there is not an industrial company on earth that is sustainable in the sense of meeting its current needs without, in some measure, depriving future generations of the means of meeting their needs. When Earth runs out of finite, exhaustible resources or ecosystems collapse, our descendants will be left holding the empty bag. But, maybe, just maybe, we can change this.

At Interface, we are on a quest to become the first sustainable corporation in the world, and then we want to keep going and become the first restorative company. We know, broadly, what that means for us. It's daunting. It's a moun-

tain to climb that's higher than Everest. It means creating the technologies of the future — kinder, gentler technologies that emulate nature. That's where I think we will find the model. For example, when we understand how a forest works and apply its myriad of symbiotic relationships analogously to the design of industrial systems, we'll be on the right track. A tree operates on solar energy. The right track will lead us to technologies that will enable us to operate our factories on renewable energy. A half-way house for us may be fuel cell or gas turbine technologies; but ultimately, I believe we have to learn to operate off current income the way a forest does, and, for that matter, the way we do in our businesses, not off of capital — stored natural capital — but off current income; *i.e.*, the sun.

The technologies of the future will enable us to feed our factories with closed loop, recycled raw materials that come from harvesting the billions of square yards of carpets and textiles that have already been made — nylon face pile recycled into new nylon yarn to be made into new carpet; backing material recycled into new backing materials for new carpet; and in our textile business, Guilford of Maine, polyester fabrics recycled into polyester fiber, then to be made into new fabrics — closing the loop; using those precious organic molecules over and over in cyclical fashion, rather than sending them to landfills or downcycling them (into lower value forms) by the linear processes of the first industrial revolution. Linear must go; cyclical must replace it. That's nature's way. In nature, there is no waste; one organism's waste is another's food. For our industrial process, so dependent on petro-chemical, man-made raw materials, this means technical "food" to be reincarnated by recycling into the product's next life cycle. Of course, the recycling operations will have to be driven by solar energy, too. Otherwise we will consume more petro-material for the energy to recycle than we will save in virgin raw materials by recycling in the first place.

We look forward to the day when our factories have no smokestacks and no effluents. If successful, we'll spend the rest of our days harvesting yesteryear's carpets, recycling old petro-chemicals into new materials, and converting sunlight into energy. There will be zero scrap going into landfills and zero emissions into the ecosystem. Literally, it is a company that will grow by cleaning up the world, not by polluting or degrading it.⁶⁷

Impractical? Four years after Interface began this quest in 1994, its revenues had doubled, its employment had nearly doubled, and its profits had tripled.