NATURAL CAPITALISM: PATH TO SUSTAINABILITY?

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The late 20th century is witnessing two great intellectual shifts. The first is the fall of Communism, with the apparent triumph of market economics. The second, now emergent in a rapidly growing number of businesses, is the end of the war against the earth, with the eventual competitive victory of a new form of economics we call Natural Capitalism.

The term emphasizes that industrial capitalism, as it is now practiced, is unnatural–is an aberration. It is defying its own logic. It does not value, but rather is liquidating, the most important forms of capital, especially *natural* capital–the biological world whose resources and ecosystem services make possible all life. According to a pioneering analysis of the world's ecosystems prepared by the United Nations, the World Bank, and the World Resources Institute (released June 2000 at the World Exposition in Hannover), "There are considerable signs that the capacity of ecosystems, the biological engines of the planet, to produce many of the goods and services we depend on is rapidly declining."

Ecosystem services are the natural processes vital to the planet’s metabolism, such as cycling nutrients and water, regulating atmosphere and climate, providing pollination and biodiversity, controlling pests and diseases, and assimilating and detoxifying society’s wastes. These free and automatic services provide tens of trillions of dollars of worth each year–more than the global economy. Indeed, their value is nearly infinite, since without them there is no life and therefore no economic activity. But none of their value is reflected on anyone’s balance sheets.

Deficient logic of this sort can’t be corrected simply by monetizing natural capital. Many key ecosystem services have no known substitutes at any price. The $200-million Biosphere II project, despite a great deal of impressive science, was unable to provide breathable air for eight people. Biosphere I, our planet, performs this task daily at no charge for six billion of us.

The best technologies can’t substitute for water and nutrient cycling, atmospheric and ecological stability, pollination and biodiversity, topsoil and biological productivity, the ability to assimilate and detoxify society’s wastes. (We do know how to hand-pollinate plants, but doing it for all of agriculture would be tedious.) There is no longer any serious scientific dispute that every major ecosystem service in the world is in decline. With 10,000 new people arriving on earth every hour, more people are chasing after fewer resources. The limits to economic growth are coming to be set by scarcities to natural capital. These ecosystem services underpin all life and thus all economic activity.

This is not to say that commodities are scarce. Prices for such resources as oil (despite the recent price spike) and copper are low and will trend downwards for some time, in part because companies have gotten better at extracting these materials with very powerful technologies that look cheap, especially if their environmental cost are not counted. Increasingly, what is limited is the ability of deteriorating *living* systems to sustain a growing human population.

Sometimes the cost of destroying ecosystem services becomes apparent only when the services start to break down. In China's Yangtze basin in 1998, for example, upstream deforestation triggered flooding that killed 3,700 people, dislocated 223 million and inundated 60 million acres of cropland. That $30 billion disaster forced a logging moratorium and a $12 billion crash program of reforestation. Economic losses due to extreme weather have been rising since the 1950s, when there were 20 "great catastrophes" and steeply since the 1970s, when there were 47 disasters, to now $608 billion in 1990s, which suffered 87 weather related disasters. These costs arise because there is a gap in the ideology of the industrial economy, which (for example) harvests wood fiber in a way that prevents forests from properly regulating watersheds to prevent flooding, or provides energy in a way that damages the self-stabilization of the earth's climate.

Industrial capitalism was born a quarter-millennium ago in the first Industrial Revolution. Before that time, it was inconceivable that people could work more productively. If you needed two horsepower, you needed two horses, and if you wanted more cloth, you had to hire more skilled weavers–if you could find them. So it made sense to enable the relatively scarce people to do more work by substituting machines and abundant nature. The textile mills introduced in the late 1700s soon enabled one Lancashire spinner to produce the cloth that had previously required 200 weavers. These were only one of many technologies that increased the productivity of workers, and increased prosperity. As these technical and organizational innovations spread through sector after sector of the economy, affordable mass goods, purchasing power, a middle class, and everything we now call the Industrial Revolution emerged.

Profit-maximizing capitalists economized on their scarcest factor of production, skilled people. They substituted the use of the seemingly abundant resources and ability of the planet to absorb their pollution to enable people to do more work.

The logic of economizing on the scarcest resource, because that is what limits human progress, remains perennially true. What has changed–indeed, reversed–is the pattern of scarcity. *Today we have abundant people and scarce nature*, not the other way around. Now, as the economic gurus call for even greater efforts to increase labor productivity, as if people were still scarce and nature still abundant, a completely different approach is needed.

Today's patterns of relative scarcity and abundance dictate using more people and more brains to wring four, ten or even 100 times as much benefit from each unit of energy, water, materials, or anything else borrowed from the planet. Success at this will be the basis of competitiveness in the decades to come. Increased resource productivity will be the hallmark of what Paul Hawken calls the Next Industrial Revolution.

Radically increased resource efficiency is the first principle of Natural Capitalism. It offers not only increased profits, but also the solution to most of the environmental dilemmas facing the world today. It greatly slows depletion of resources at one end of the economic process, and the discharge of pollution–resources out of place–at the other end. It creates profits from not having to pay for either. And it also buys time, forestalling the threatened collapse of natural systems.

That time should then be used to implement the other three principles of Natural Capitalism. These are:

- Eliminate the concept of waste by redesigning the economy on biological lines that close the loops of materials flows;
- Shift the structure of the economy from focusing on the processing of materials and the making of things to the creation of service and flow; so as to reward resource productivity and loop-closing; and
- Reverse the planetary destruction now underway with programs of restoration that invest in natural capital.

Together the four principles of Natural Capitalism enable businesses to behave as if ecosystem services were properly valued. Behaving in this way will begin to reverse the loss of such services, while increasing profits.

INCREASING RESOURCE PRODUCTIVITY

It is relatively easy to profit by using resources more efficiently because they are used incredibly wastefully now. The stuff that drives the metabolism of industry currently amounts to more than 20 times your body weight every day, or more than a million pounds per American per year. The corresponding figures for Europe and Japan are not very different.

Globally, the economy mobilizes a flow of half a trillion tons per year. But only about 1% of that huge flow ever gets embodied in a product and is still there six months after sale. The other 99% is waste. Cutting such waste represents a vast business opportunity.

No where are the opportunities for savings easier to see than in energy. The U.S. has already cut its annual energy bill by $200 billion since the first oil shock in 1973, but still wastes $300 billion worth of energy each year. Just the energy thrown away by U.S. power stations as waste heat equals the total energy used by Japan for everything. Moreover, the efficiency of converting fuel at the power station into incandescent light in the room is only 3%. Modern cars use only 1% of their fuel energy to move the driver.

But many companies have shown how to reduce such waste and increase profits.

Southwire Corporation, an energy intensive maker of cable, rod and wire, halved its energy per pound of product in six years. The savings roughly equaled the company's profits during that period when many competitors were going bankrupt. The energy efficiency effort probably saved 4,000 jobs at ten plants in six states. The company then went on to save even more energy, still with two-year paybacks.

Dow Chemical's Louisiana Division implemented more than 900 worker-suggested energy-saving projects during 1981—93, with average annual returns on investment in excess of 200%. Both returns and savings tended to *rise* in the latter years, even after the annual savings had passed $100 million, because the engineers were learning new ways to save faster than they were using up the old ones.

State-of-the-shelf technologies can make old buildings three- to four-fold more energy-efficient, new ones nearer 10-fold–and cheaper to build. Examples include large and small buildings in climates ranging from well below freezing to sweltering. For example

1. In our own house, at 7,100 ft in the Rocky Mountains of Colorado, we grow bananas despite a severe outdoor climate that has gone as low as —40ºF. The house cost less than normal to build, because the superwindows, superinsulation, and ventilation heat recovery that let us eliminate the furnace cost less than the furnace would have cost to install. We also saved 90% of the household electricity (the average usage is only ~110 W, equivalent to one light-bulb), 99% of the water-heating energy, and half the water, with extra investments that paid for themselves in the first ten months with 1983 technologies; today's are much better.
2. Other houses we helped to design have achieved normal or better comfort with no air-conditioning equipment at outdoor temperatures up to 115ºF, yet they too cost less than normal to build.
3. Architecture Professor Suntoorn Boonyatikarn built a delightful house in Bangkok that uses only 10% the normal amount of air-conditioning, yet maintains superior comfort and cost nothing extra to build.
4. An existing California office building was cost-effectively improved to save more than 90% of its air-conditioning energy while improving comfort.

5. We showed how to modify a 200,000-ft2 glass office tower in Chicago to save three-quarters of its energy, while making the people more comfortable, healthy, and productive–at no more cost than the normal 20-year renovation that would have saved nothing.

Industries can achieve similarly surprising savings:

1. Thirty-five improvements can save about half the energy in typical existing industrial motor systems (which use three-fourths of industrial electricity) with returns on investment approaching 200% per year. The improvements are so profitable because only seven of the improvements must be paid for; the other 28 are free byproducts.
2. Radical changes in process technology can, for example, often condense a big chemical plant into the size of a watermelon, via the practice of microfluidics.
3. Revolutions in product lifetime, design and manufacturing with a minimum of materials, and elimination of waste can enable far less manufacturing to produce the same desired flow of products and services.

How can such savings big be captured?

Inventor Edwin Land once remarked that "People who seem to have had a new idea have often just stopped having an old idea."

You've all seen the mental exercise that calls for finding the solution that connects the 9 dots with four interconnecting lines, drawn without lifting the pencil. The cliched solution is to "think outside the box".

A friend of ours who posed this problem for his class was amazed the next day when a student said she could solve it in three lines. Because these are not mathematical dots of zero diameter, if the lines are long and slim enough and the dots fat enough, the lines can skim the edges of the dots in a big "Z". Our friend realized that asking the class to "find *the* solution" had artificially limited the students' creativity. Thus liberated, the students then devised a multitude of ways to do it with one line. There is the origami solution, the geographer's solution, the mechanical engineer's approach, the statistician's answer. My favorite came from a ten-year old girl, who said, "I used a fat line. You never said it had to be a skinny line.

Inventor Edwin Land once remarked that "People who seem to have had a new idea have often just stopped having an old idea." The world's leading interiors company, Interface, recently experienced what Land called "a sudden cessation of stupidity" when redesigning a standard industrial pumping loop for installation in a new Shanghai factory. The original, supposedly optimized, design needed 70.8 kW for pumping. Interface engineer, Jan Schilham, made two simple design changes that cut that 70.8 to only 5.3 kW, a 92% reduction. Yet the redesigned system cost *less* to build, and worked better in all respects. This required no new technology (though that could save even more energy and money), but only two changes in the design mentality. These changes were not "rocket science" but merely a rediscovery of the traditional wisdom of century-old holistic engineering.

First, Engineer Schilham chose big pipes and small pumps rather than small pipes and big pumps. The friction in a pipe falls as nearly the fifth power of its diameter. Normal engineering practice balances the higher capital cost of a fatter pipe against the present value of the pumping energy that the pipe's lower friction will save over time.

But this textbook optimization is wrong, because it ignores the capital cost of the pumping equipment–the pump, motor, variable-speed electronic control, and electrical supply–that must be big enough to overcome the pipe friction. Ignoring the potential to make that equipment much smaller, and optimizing one component (the pipe) in isolation, pessimizes the system. Optimizing the *whole system* instead, and counting savings in capital cost as well as in energy cost, makes the whole system cost less but work better.

Engineer Schilham's second innovation was to lay out the pipes first, *then* the equipment. The normal sequence is the opposite: install the equipment in traditional positions (far apart, at the wrong height, facing the wrong way, with other things in between), then tell the pipefitter to hook it all up. The resulting long, crooked pipes have about 3—6 times as much friction as short, straight pipes.

The pipefitters like this approach: they're paid by the hour, they mark up a profit on the extra fittings, and they don't pay for your larger pumping equipment and its inflated electric bills. But using short, straight pipes instead of long, crooked pipes cuts both capital and operating costs. In this case, it also saved 70 kilowatts of heat loss, with a 3-month payback, because straight pipes are easier to insulate, and it had many other benefits.

So why does this matter? Pumping is the biggest user of electricity worldwide. Electric motors use 3/5ths of all electricity. Every unit of friction saved in the pipe saves about ten units of fuel, cost, pollution, and climate change at the power station. Most importantly, the thought process of whole-systems thinking, and of optimizing for multiple benefits, applies to almost every technical system that uses energy and resources. Optimizing a whole pumping system, a whole building, a whole factory, a whole economy, can typically yield resource savings of 3- to 10-fold, yet cost less to build.

Consider another example of design integration, from real-estate development. Typical U.S. tract home developments drain storm water away in costly underground pipes. Village Homes, an early solar housing development near Sacramento, California, instead installed natural water-catchment channels in the landscaping. After a storm, the channels would fill with rainwater; most would soak into the ground, recharging the groundwater, while the rest would run off one day faster than mosquito larvae could hatch. Not needing the big pipes in the ground saved $800 per house. The developer then used the saved money to pay for extensive edible landscaping that provided shade, nutrition, beauty, community focus, and crop revenues to support more amenities. The landscaping, plus people-centered site planning (pedestrian/bike greenways in front of the houses, cars around the back on narrow, tree-shaded streets), saved more land and money. It also cooled off the micro-climate, yielding better comfort with little or no air-conditioning, and it created safe and child-friendly neighborhoods that cut crime by 90%. Real-estate agents once described the project as weird. It is now the most desirable place to live in the whole town, with market values averaging $11/sq.ft above normal, and sales three times faster than average. As usual, the same integrative design that improved environmental, resource, and human performance also improved market and financial performance.

Combining many new technologies with the new design thinking can yield unexpected breakthroughs. For example, Rocky Mountain Institute's Hypercar℠ design synthesis for automobiles and other road vehicles can produce a large sport-utility vehicle that gets 100 miles per gallon-equivalent, powering its electric propulsion motors with an onboard fuel cell using compressed gaseous hydrogen. (A smaller version–an ordinary 4—5-passenger family car–could achieve roughly 120 MPG.) Made of advanced polymer composites like carbon fiber, the sport-utility vehicle would be ultra-light, weighing only 1,700 pounds, but could carry the same up a 30º slope. It could carry six adults and 140 ft3 of cargo with Mercedes comfort and safety, even if it hits one, yet with the performance of a BMW. Its body materials wouldn't dent, rust, or fatigue. It would be ultra-reliable and emit no pollution, producing only hot drinking water. Its hydrogen could be profitably produced without harming the climate. The car could also be plugged back into the electric grid when parked, becoming a mini-power-plant on wheels and selling back to the grid enough power to earn its owner up to half the cost of buying the car.

This combination of technologies–to which roughly $10 billion has already been committed by automakers and potential new market entrants–will ultimately save about as much oil as OPEC now sells. Indeed, it probably spells the end of the car, oil, steel, aluminum, nuclear, coal, and electricity industries as we know them, and the beginning of successor industries that are cleaner and more profitable. Ford Motor Company Chairman William Clay Ford, Jr., has predicted that hybrid-electric cars and trucks could account for 20% of vehicle sales by 2010. (President Okuda of Toyota even envisaged 33% by 2005.) Mr. Ford, like the Chairman of General Motors, also predicted that both engine-driven hybrids and traditional cars will eventually be replaced by fuel-cell vehicles. At least eight major automakers have announced volume production of fuel-cell cars in model years 2004—05, and two (Honda and Toyota) intend to do so in 2003. Hypercars with the sorts of advanced characteristics mentioned above should be available within five years, dominant in ten; the old car industry will be toast in about 20 years.

All of these ways of saving energy mean that global climate change can be prevented at a profit, because saving fuel costs less than buying fuel. Leading companies are starting to capture this potential. DuPont recently announced that by 2010, it will reduce its CO2 emissions by 65% from 1990 levels, raise its revenues 6% a year with no increase in energy use, and get a tenth of its energy and a quarter of its raw materials from renewables–all in the name of increasing shareholder value. STMicroelectronics, the world's sixth-largest chipmaker, has set a goal of zero net carbon emissions by 2010 despite a 40-fold increase in production from 1990, again in pursuit of commercial advantage.

This is why the European Union has already adopted at least a fourfold ("Factor Four") gain in resource productivity as the new basis for sustainable development policy and practice. . Some countries, like Holland and Austria, have declared this a national goal. The OECD Environment Ministers, the government of Sweden, and distinguished industrial and academic leaders in Europe, Japan, and elsewhere have gone even further, adopting Factor Ten improvements as their goal. The World Business Council for Sustainable Development and the United Nations Environment Programme have called for Factor Twenty. There is growing evidence that even such ambitious goals are feasible and achievable in the marketplace. They may, in fact, offer even *greater* profits.

ELIMINATING THE CONCEPT OF WASTE

Resource efficiency is Natural Capitalism's cornerstone, but is only its beginning.

Natural Capitalism doesn't mean merely reducing waste; it means eliminating the entire *concept* of waste by adopting biological patterns, processes, and often materials. This implies eliminating any industrial output that represents a disposal cost rather than a saleable product. There should be none of what in the 20th Century were called "wastes and emissions" but are properly called "unsaleable production." If we can't sell it, we shouldn't produce it; we should design it out.

DesignTex, a subsidiary of Steelcase (the world's largest maker of office furniture), commissioned the architect Bill McDonough to design a "green" textile for upholstering office chairs. The fabric it was to replace used such toxic chemicals to treat and dye the cloth that the Swiss government had declared its edge trimmings to be a hazardous waste (so what's in the cloth that you sit on?). McDonough's team screened more than 8,000 chemicals, rejecting any that were persistently toxic, built up in food chains, or caused cancer, mutations, birth defects, or endocrine disruption. They found only 38 that weren't harmful. From these, however, they could make every color. The cloth looked better, felt better in the hand, and lasted longer, because the natural fibers weren't damaged by harsh chemicals. The new fabric won design awards. Production also cost *less*, because it required fewer and cheaper feedstocks and caused no health and safety concerns: there was nothing that could harm the workers or the neighbors.

When the Swiss environmental inspectors tested the new plant, they thought that their equipment was malfunctioning: the water coming out was cleaner than the Swiss drinking water going in, because the cloth itself was acting as an additional filter. But what had really happened was that the redesign of the process had eliminated any waste and toxicity. As architect McDonough put it, the redesign took "the filters out of the pipes and put them where they belong, in the designers' heads."

Professor Hanns Fischer noticed that the University of Zürich's basic chemistry lab course was turning pure, simple reagents into mainly hazardous wastes, incurring costs at both ends. The students were also learning once-through, linear thinking. So the instructional design was partly reversed: in some of the lessons, the students turned the toxic wastes back into pure, simple reagents. Waste production declined 99%, costs fell by about $20,000 a year and the students learned the closed-loop thinking that must ultimately save the chemical industry. The only problem was that they kept volunteering vacation time to repurify the wastes, because it was so much fun. Demand for wastes soon outstripped supply.

Closing the loops in the flow of toxic materials can also be a good way to encourage better design that eliminates toxicity altogether. For example, how clean would you design a car to be if the exhaust pipe were plumbed into the passenger compartment instead of being aimed at people on the streets? How clean would you make the discharge from your factory if the water intake were upstream of the water intake? (The first Environmental Minister of Australia made many factories do exactly that.) How safe would you make your explosives factory if you built your house next to it? (That's what Mr. DuPont did; his company has been the world leader in industrial safety ever since.)

Ultimately, companies that need environmental regulation will not be around, however, because they will not be profitable. They will have wasted money to make things that nobody wants. In such a biological world, the design lessons of nature will improve business–as well as health, housing, mobility, community, and national security. In this coming world, companies will take their values from their customers, their designs from nature and their discipline from the marketplace. Companies that ignore this will do so at their peril.

THE SOLUTIONS ECONOMY

A further key element of Natural Capitalism is to shift the structure of the economy from focusing not on matter and things but on service and flow; from the episodic acquisition of goods to the continual flow of value and performance.

This change in the business model incentivizes a continuous improvement in the elimination of waste, because it structures the relationships so that *the provider and customer both make money by finding more efficient solutions that benefit both.* That contrasts sharply with the sale or leasing of physical goods, where the vendor wants to provide more things more often–increasing waste–and at a higher price, while the customer has the opposite interests. But in a "solutions economy," both the provider and the customer are rewarded for doing more and better, with less, for longer.

For example, in Europe and Asia, the Schindler company leases vertical transportation services instead of selling elevators, because it believes that its elevators use less energy and maintenance than others. By owning the elevators and paying their running cost, Schindler can provide to customers, at higher profit and lower cost, what they really want, which is not an elevator but the service of being moved up and down. Similarly, Electrolux/Sweden leases the performance of professional floor-cleaning and commercial food-service equipment rather than the equipment itself, and is experimenting with leasing household "washing services" charged by the weight of clothes washed–like the way many photocopier services are charged by the page. Dow leases dissolving services rather than selling solvents; now the whole American chemical industry has a working party exploring this business model. Most French commercial buildings are heated by *chauffagistes*–"heat contractors" who provide the service of thermal comfort. In all these cases, both customer and provider profit from minimizing the flow of energy and materials.

Carrier, the world's largest manufacturer of air-conditioners, is experimenting with leases of comfort instead of sales of air-conditioners. Making the equipment more efficient or more durable could give Carrier greater profits and its customers better comfort at lower cost. So, however, will making the building itself more efficient so that less cooling yields the same comfort. Carrier could team up with firms that can improve lighting, glazings, and other building systems. Providing a more systemic solution, creating a relationship that aligns interests, is obviously better for customers, shareholders and the earth than selling air-conditioners.

Or consider the Films Division of DuPont. Once nearly defunct, it now leads its 59-firm market because it is able to make films ever thinner, stronger, and better matched to customers' needs. The higher-performance film is more valuable to customers and hence fetches a higher price, but it contains fewer molecules and hence costs less to make. Moreover, rather than using virgin raw materials, DuPont recycles nearly a billion dollars of used film per year, recovered from customers using a process called "reverse logistics," a new topic of study in business schools. Jack Krol, past Chair of DuPont, has remarked that he sees no end to DuPont's ability to profit from this loop-closing and "dematerialization," doing ever more and better with less material–until ultimately the company is selling almost nothing but ideas.

REINVESTING IN NATURAL CAPITAL

The fourth principle of Natural Capitalism is to reinvest to reverse the planet-wide destruction of ecosystems by reinvesting profits, achieved by eliminating waste, in the most productive way. Typically this means restoring natural capital, to produce more abundantly the biotic resources and ecosystems services that are scarce.

If natural capital is the most important, valuable, and indispensable form of capital, then a wise society will reinvest in restoring it where degraded, sustaining it where healthy, and expanding it wherever possible–the better to create wealth and sustain life. This is tending to occur first in the industries of forestry, farming, and fishing, whose success depends directly on the health of the natural systems around them. But it is starting to spread to other industries as the primary inputs to manufacturing come to be grown, not mined. If living nano-technologies replace factories *vastly* fewer materials would be used.

Such transitions, however will place a premium on learning to understand biological models, and on using nature as model and mentor rather than as a nuisance to be evaded. Nano-technologies especially pose profound challenges and concerns.

Restoring ecosystem services might sound expensive. But whole-system solutions can be restorative in low-cost and often even profitable ways. They enable life to flourish, creating more life and hence more value. Production is carried out automatically by nature; people need only create hospitable conditions and do no harm. In this exciting sphere of innovation lie such opportunities as these:

- Allan Savory, a wildlife biologist from Africa, has redesigned ranching to mimic the migration of large herds of native grazers that co-evolved with grasslands. This can greatly improve the carrying capacity even of arid and degraded rangelands, which turn out to have been not overgrazed but undergrazed, out of ignorance of how brittle ecosystems co-evolved with graziers;
- The California Rice Industry Association partnered with environmental groups to switch from burning rice straw to flooding the ricefields after harvest. They now flood 30% of California's rice acreage, harvesting a far more profitable mix of wildfowl, free cultivation and fertilization by millions of wild ducks and geese, lucrative hunting licenses, high-silica straw, groundwater recharge, and other benefits, with rice as a byproduct;
- Dr. John Todd's biological "Living Machines" make sewage treatment plants that look like a garden–because they are. They make sewage into exceptionally clean water, plus valuable flowers, an attractive tourist venue, and other byproducts, with no toxicity, no hazard, no odor, and lower capital costs. The plant can easily be small enough to serve an urban neighborhood or even a single building,

avoiding the diseconomies of excessively centralized collection and treatment systems. Such "Bioneers" are also using living organisms to "bioremediate" toxic pollutants into forms that are harmless or salable or both.

Some of the most exciting developments are modeled on nature's low-temperature, low-pressure assembly techniques, whose products rival anything manmade. Janine Benyus's book *Biomimicry* points out that spiders make silk, strong as Kevlar but much tougher, from digested crickets and flies, without needing boiling sulfuric acid and high-pressure extruders.

The abalone makes an inner shell twice as tough as ceramics, and diatoms make seawater into glass; neither need furnaces. Trees turn sunlight and soil into cellulose, a sugar stiffer and stronger than nylon but much less dense. Then they bind it into wood, a natural composite with a higher bending strength and stiffness than aluminum alloy, concrete, or steel. Yet trees don't need smelters, kilns, or blast furnaces.

We may never be as skillful as spiders, abalone, diatoms, or trees, but such benign natural chemistry may be a better model than industrialism's primitive approach of "heat-beat-and-treat." These practices adopt the design experience of nearly four billion years of evolutionary testing in which products that don't work are recalled by the Manufacturer. Though many details of such nature-mimicking practices are still evolving, the broad contours of the lessons they teach are already clear.

PUTTING IT ALL TOGETHER

What would a company that used Natural Capitalism as its strategic paradigm look like? A striking example is emerging at Atlanta carpetmaker Interface. Most broadloom carpet is replaced every decade because it develops worn spots. An office is shut down, furniture removed, carpet torn up and sent to landfill. (The millions of tons deposited each year will last for up to 20,000 years.) New carpet is laid down, the office restored, operations resumed, and workers possibly sickened from the carpet-glue fumes.

Its visionary chair, Ray Anderson, committed Interface to becoming the first company of the Next Industrial Revolution. Interface has been systematically implementing each of the principles of Natural Capitalism. First, its staff has sought to increase the productivity with which they use energy and materials. They implemented the QUEST program to identify and eliminate waste in its worldwide operations. From 1994 to mid-2001, this added $167 million to the bottom line, and now provides 27% of the company's operating profit.

Second, Interface has sought to close the loops of materials flows. It is implementing a program to recycle carpet virtually completely. Other companies that claim to recycle carpet actually "downcycle" it, taking used carpet, chopping it up and reusing it in lower-grade products such as carpet backing. But this wastes the embodied energy in the nylon "face" of the carpet, and uses more oil to make new nylon for the new "face". In contrast, Interface's new "Solenium" product, released in 1999, is almost completely remanufacturable into identical carpet. The face is a new type of polyester that can be separated from the backing and remade into new face, while the old backing becomes new backing. This severs the connection to the oil well at the front of the production cycle and to the landfill at the back end.

Solenium also provides better service. The new floor-covering, which may be leased or sold, is nontoxic, virtually stainproof, easy to clean with water, four times as durable, one-third less materials-intensive, climate neutral (the climate impacts of making and shipping it have all been offset), and in appropriate applications, superior in every respect. It also turns the avoided waste into profit.

Interface implements the third principle by preferring to sell floor-covering services rather than new carpet. People want to walk on and look at carpet, not own it. Under Interface's Evergreen Service Contract, the company will install carpet tiles, which Interface will own and remain responsible for keeping clean and fresh.

As needed, Interface will replace the 10 - 20% of the carpet-tiles that show 80 - 90% of the wear. This provides better service at lower cost. It also increases net employment, eliminates disruption (worn tiles are seldom under furniture), and turns a capital expenditure into a tax-deductible operating lease.

Solenium's quadrupled durability and one-third lower materials intensity, coupled with the four-fifths lower materials flow from replacing only the worn parts, will cut Interface's net flow of materials and embodied energy by 97% even *before* the remanufacturing of the Solenium begins. When these attributes are *combined* with the remanufacturing, the continuing use of virgin materials will fall by more than 99.9%.

Finally, Interface is initiating a program to grow its feedstocks, mindful that this will require them to ensure that their suppliers practice sustainable farming, so that they don't just substitute one form of unsustainability for another. This will put them in the forefront of making a steady market for organic farmers who restore the land through their practices–and will ultimately free this once petrochemical-intensive firm entirely from its dependence on oil. It will then take nothing from the planet, do no harm, and provide a better service at lower cost and higher profit.

Interface's first four years on this systematic quest returned doubled revenues, tripled operating profits, and nearly doubled employment. Its latest quarter-billion dollars of revenue have been produced with no increase in energy or materials inputs, just from mining internal waste, closing the loops, eliminating toxics, and shifting to a service model. (In the fifth year, external circumstances unrelated to Interface's sustainability work hurt the company, but it stayed profitable and is now coming back strongly.)

BEYOND PROFITS: WHAT'S IN IT FOR US

Implementing the elements of Natural Capitalism tend to create an extraordinary outpouring of energy, initiative, and enthusiasm at all levels of a company. It removes the contradiction between what people do at work and what they want for their families when they go home. This makes natural-capitalist firms the most exciting places in the world to work.

Civilization in the 21st Century is imperiled by three problems: the dissolution of civil societies into lawlessness and despair; weakened life support systems; and the dwindling public purse needed to address these problems and reduce human suffering. All three share a common cause–waste. Its systematic correction is a common solution, equally unacknowledged yet increasingly obvious, the reduction of this waste and the implementation of the principles of Natural Capitalism.

This is perhaps best illustrated by the city of Curitiba, Brazil, whose population of 2.5 million has quadrupled in the past 20 years. The city has a per-capita municipal budget roughly 15 times smaller than that of Detroit, Michigan. Yet Curitiba, though not free of problems, has solved its problems better than any American city we know. It has achieved remarkable success by substituting brilliantly integrative design for wealth. In a community-based process run largely by architects and largely by women, the city has treated its formidable economic, social, and ecological needs not as competing priorities to be traded off, but as interlinked design elements with synergies to be captured. Hydrology was integrated with physiography, nutrient flows with waste flows, transport with land-use, education with health, participation with dignity. As described in Chapter 14 of our book *Ideology of Natural Capital,* Curitiba has built one of the world's great cities–by design.

Most of the biggest tasks in Curitiba's development were carried out by private companies, often in partnership with their communities, and working under simple rules that rewarded the desired results. For example, the city has probably the world's best public transport system, based on a safe, fast, clean, cheap, and radically redesigned bus service. It carries three-fourths of all commuters and serves all neighborhoods fairly, because the ten competing private bus companies are rewarded not for how many people they carry but for how many kilometers of route they serve.

Worldwide, too, the leaders in eliminating waste will be companies. But there remains a vital role for governments, and for civil society. It is important to remember markets' purposes and limitations. Markets make a splendid servant but a bad master and a worse religion. Markets produce value, but only communities and families produce values. A society that substitutes markets for politics, ethics, or faith is dangerously adrift. Commerce must be in the vanguard of creating a durable system of production and consumption by applying sound market principles. Yet not all value is monetized; not every priceless thing is priced. Nor is accumulating money the same thing as creating wealth or improving people. Many of the best things in life are not the business of business. And as the Russians and Somalis are finding under "gangster capitalism", unless there are democratic ways to establish and maintain a level playing field, only the most ruthless can conduct business.

One powerful tool that governments use is tax policy. Such taxes as FICA and other penalties on employment that grew out of the First Industrial Revolution, encourage companies to use more resources and fewer people. Groups like Redefining Progress have shown how gradual and fair tax shifting and desubsidization can provide more of what we want, jobs and income, and less of what we don't want, environmental and social damage.

But governments, though vitally important, cannot solve all our problems. Today over half the world's 100 largest economic entities are not countries, they're companies. Corporations may well be the only institution in the world today with the size, skills, resources, agility, organization, and motivation to solve the toughest problems. Such business leaders as Ray Anderson of Interface, Mark Moody-Stuart of Royal/Dutch Shell, and Pasquale Pistorio of STMicroelectronics are redefining what corporate responsibility means. As we cross the threshold into the next industrial revolution, many changes will beset us: technological and institutional. E-commerce alone will revolutionize business. In this turbulent time, companies seeking stability and profit are turning to Natural Capitalism.

Companies–and countries–that conscientiously pursue the four principles of Natural Capitalism, profiting from advanced resource productivity, closing materials loops and eliminating waste, providing their customers with efficient solutions, and reinvesting in natural capital, will gain a commanding competitive advantage. (Hundreds of such cases are documented in our book and at the website www.natcap.org.). They'll be behaving *as if* natural and human capital were properly valued. But they'll also be making a profit today, when these values are set at zero. And as Ed Woollard remarked, companies that take these opportunities seriously will do very well. Those that don't …won't be a problem, because they won't be around.

Perhaps the only problem with capitalism–a system of wealth creation built on the productive flow and expansion of all forms of capital–is that it is only now beginning to be tried.

For more information on these ideas, please see our latest book, *Natural Capitalism, Creating the Next Industrial Revolution,* published in 1999 by Little, Brown, written with the business author, Paul Hawken.

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