Can We Survive?

The Changes Required to Deal Effectively with Global Warming

(Part 2)

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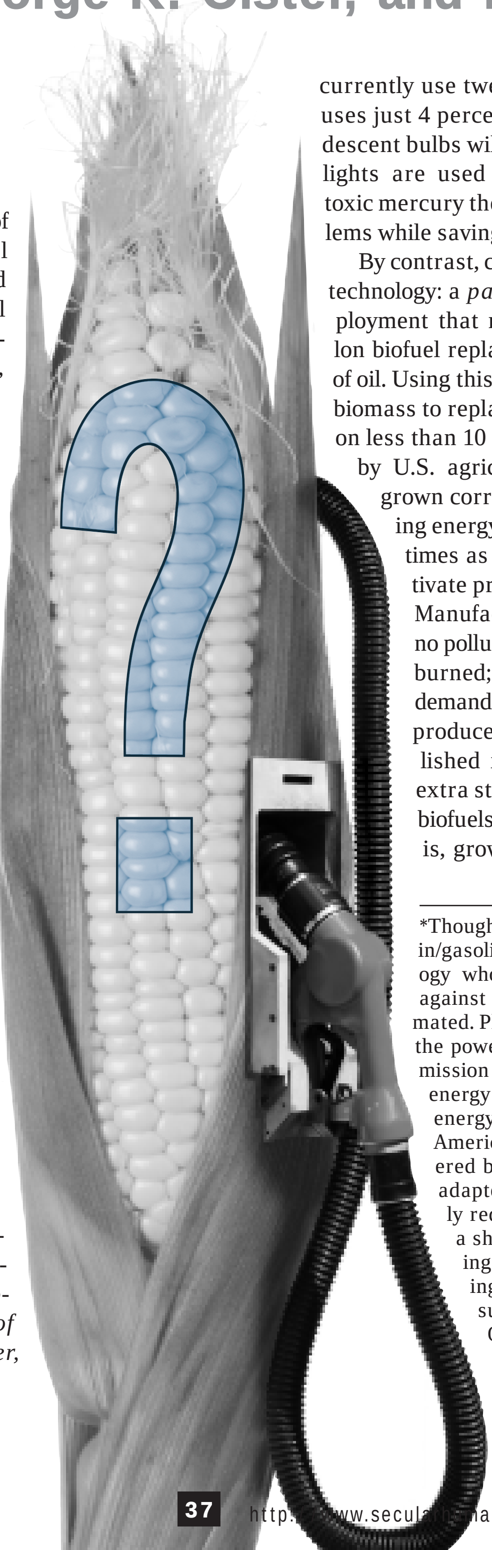

In Part 1 (*FI*, February/March 2008), we argued for the rapid deployment of what we called "first-round survival technologies." These technologies are designed to satisfy certain of mankind's fundamental needs while buying additional time to hold global warming within tolerable limits—long enough, it is hoped, to make other substantive changes that are required for humankind's survival. Without such technologies, many climate researchers believe that our opportunity to prevent intolerable climate change may evaporate in *fewer than ten years.*

Yet so far, climate change has been treated as just another political problem. Officials tend to choose politically acceptable remedies, which are often claimed to do more to solve a problem than they are capable of doing—and then to move such remedies' adoption dates well into the future, leaving time to suspend, weaken, or further delay them.

The energy bill just passed by the U.S. Congress displays both shortcomings. Increasing average auto fuel economy to thirty-five miles per gallon would save only one million barrels of oil per day (if achieved). We currently use twenty million barrels per day. Lighting uses just 4 percent of U.S. energy; phasing out incandescent bulbs will save only part of that. If fluorescent lights are used to replace incandescent bulbs, the toxic mercury they contain will multiply disposal problems while saving a relatively small amount of energy.*

By contrast, consider a genuine first-round survival technology: a *particular process* capable of rapid deployment that manufactures a seventy-cent-per-gallon biofuel replacement for most energy applications of oil. Using this process, enough of the proper kind of biomass to replace all U.S. oil imports could be grown on less than 10 percent of the acreage currently used by U.S. agriculture and would be sustainable if grown correctly. This process offers an astonishing energy gain of *11*; that is, it would release 11 times as much energy as was expended to cultivate proper biomass and change it to biofuel**.** Manufacture of this biofuel generates almost no pollution; it produces few particulates when burned; it is neither capital-intensive nor very demanding of nonrenewable resources; and it is produced by a low-tech process easily established in developing nations. By adding an extra step during manufacture, this and other biofuels can be rendered carbon-negative: that is, growing proper biomass and changing it

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*Though not mandated by the energy bill, plug-in/gasoline hybrid autos employ another technology whose potential contribution to the battle against global warming is drastically overestimated. Plug-in hybrids would draw electricity from the power grid; because of generation and transmission losses in coal-fired plants, 2.6 units of energy must be generated to impart 1 unit of energy to a hybrid's battery. Some 70 percent of America's electrical generating capacity is powered by coal. If plug-in hybrid technology were adapted on a large enough scale to significantly reduce the use of gasoline, it would require a sharp rise in coal-fired generation, increasing our output of carbon dioxide and promoting global warming, airborne mercury, and sulfur dioxide, which produces acid rain. Otherwise-avoidable expansions of the national electrical grid would also be required, with significant environmental impact.

into biofuel will pull more carbon dioxide out of the atmosphere than is released when the biofuel is burned. Finally, without using *any* land needed for growing food and fiber, a reasonable extension of this system may enable the sustainable production of sufficient biomass to replace all the oil used in most nations of the world with this biofuel.**

Science fiction? The stuff of wish lists? Not at all. *This technology exists.* This new process for making ethanol is ready for rapid deployment. In fact, it has been sitting on the shelf for several years. Imagine the impact of even one first-round survival technology that would help combat global warming, eliminate the costs, pollution, and politico-military consequences of the U.S.'s current dependence on foreign oil and, possibly soon thereafter, eliminate the whole world's need for oil as a fuel in favor of a carbon-negative replacement.

> "Making enough ethanol for one gas-tank fill-up consumes enough corn to feed a person for a year."

Sadly, that impact can only be imagined. Given the status quo (which we will describe in detail), and given that this technology was developed by a small high-tech company, chances are remote that this low-cost biofuel technology will ever be commercialized and deployed.

Congress's energy bill also encourages expansion of ethanol manufacture from corn, a technology the United Nations has declared a "crime against humanity." Why?

1. The world now needs all of its agricultural land to grow food and will need more as population expands and global warming reduces yields.

**If growth of algae or phytoplankton could be stimulated, harvested, and used as biomass in a practical, low-cost, and environmentally sound manner—something requiring only simple engineering techniques to determine—then all nations of the world, even those without land on which to grow biomass, could access the energy they need without turning to oil.

"I started wearin' this when I realized how much money there is in ethanol."

2. Corn ethanol demands too much land per unit of ethanol produced.
3. Making enough ethanol for one gas-tank fill-up consumes enough corn to feed a person for a year.
4. Making and transporting corn ethanol consumes more energy than we get back by burning it.
5. Diverting corn to ethanol production also drives up the cost of foods and feedstock. It has already doubled the price of tortillas in Mexico and substantially increased the price of eggs and milk. Soon the prices of hogs and corn-fed cattle will follow. Expanding corn-ethanol manufacture will only aggravate these problems.

Did legislators write corn-ethanol expansion into the energy bill as a political fillip for agricultural states? Or did they act out of ignorance? Perhaps both; but no matter their motivations, such promotion of "nonsurvival" energy technologies *reduces* our likelihood of containing global warming while enhancing the likelihood that we will fail to do so.

Innovation, a Game Just One Can Play

This crisis seems to call for breakthrough research—why has it been so slow in coming? One surprising cause lies with the large public and private research organizations—specifically, their failure to recognize that significant innovation is a *one-person game.* As a rule, major breakthroughs occur in the mind of a single individual. Group research becomes relevant only after defining the innovation and framing the approach for implementing it.

Organizational climates were once friendlier toward breakthrough research. Until the mid 1960s, innovative engineers and researchers at large organizations could frequently act on their own ideas. A classic example is the diversion (with management's approval) of a small amount of time by one researcher at Bell Labs to demonstrate his concepts for the first transistor, a feat that ultimately won him the Nobel Prize, after which the device was eventually made practical for wide use by years of team development.

Today's researchers or engineers enjoy far less support. By the time technical people become involved in most projects, both the project goal and the approach by which that goal is to be achieved have already been decided by managers who usually have little scientific or technical knowledge. It then falls to researchers to simply work out the details *within an established framework.* But what if that framework does not permit the creation of a survival technology?

The fact that innovation is a one-person enterprise has other consequences, too. Although some individuals are responsible for more than one significant innovation, and in more than one specialty, innovation is inherently unpredictable. *One can never be sure from whom—or from where—a specific, significant innovation will come.* Thus, significant innovations cannot be planned, which means that they may not come from specific university or government labs funded and designated for particular kinds of applied research.

Survival requires that we change the system so that important innovations *from any source* can be safely revealed and verified, while fully protecting the innovation's commercial potential. However, existing government or university labs are unlikely to cooperate in this process. Breakthroughs in any field usually result in research funding being cut or eliminated—after all, a breakthrough means a problem is solved. Established labs would rather make progress slowly to keep research funds flowing. This is actually occurring in some survival-critical research areas at a time when we may have less than ten years in which to widely deploy first-round solutions.

Finding the Skills to Create Survival Technologies

Iconic innovators like Alexander Bell, Thomas Edison, Guglielmo Marconi, and George Eastman were successful one-man shows simply because few national markets and large national corporations existed. Edison actually had the best of both worlds. A talented innovator in his own right, he had numerous assistants to carry out the various aspects of his development programs under his close direction. He is credited with inventing the modern development team, and his operation at Menlo Park is an excellent example of the many innovations that can be generated when a highly innovative individual *is in charge and able to closely guide the development effort.* (The converse is true today, when people who know little or nothing about science and technology are ultimately in charge and frame research and development.)

World War II saw a huge increase in applications of science and technology. Because the survival of Western democracies was at stake, engineers and scientists were significantly freer to develop the technologies that won the war. Some of the companies for which they worked would become major defense contracting firms.

During the postwar transition to civilian technologies and products, large numbers of innovators learned their skills within large corporations. At RCA—for example, at the Morristown, New Jersey, location that developed color television—as much as 10 percent of the technical and scientific workforce was able to develop such skills. They became "technologists"—an under-recognized multidisciplinary specialty. These tech-savvy *generalists* learned their skills by bootstrap trial and error just after the war; by the early 1950s, however, such knowledge was transmitted by apprenticeship. Under either system, certain characteristics of the work environment long gone from today's organizations enabled technologists to learn and pass on their skills. Principal among these was an atmosphere that encouraged interaction among scientists and engineers, so that each could extend his or her knowledge and understanding into the disciplines of others and learn to make practical (system) compromises between elements of technology involved in the project.

By the mid 1960s, this culture of technologist training was in decline. It was replaced by the compartmentalization of technology development—first begun in the defense industry as protection against espionage. As this system became the norm in large corporations and government programs, there were fewer places that taught technologists' skills. Also in recent years, the number of defense contractors has shrunk by a factor greater than 10; at the same time, much commercial research and development has been outsourced to groups in foreign countries. America has lost the critical mass of scientists and engineers and program architectures within which the technologists' skills could be preserved. Because few new technologists were trained, the relevant skill set became nearly extinct. The capacity to function *as a technologist* remains mostly in a small number of individuals, most of whom are now beyond retirement age. Fortunately, some of them have joined small high-tech companies in which they have developed survival technologies.

This disappearance of knowledgeable generalists greatly complicates the implementation of survival technologies. Such scientific and technical expertise as remains is organized almost exclusively according to the *principle of specialization*. Specialization is simultaneously powerful and limiting in terms of the range of solutions that an expert is able to generate. When an expert is assigned a particular problem, the solution he or she develops usually falls within his or her area of expertise. If an *optimum* solution does not exist within the expert's area of expertise, we end up with a technology that is less than optimum—not acceptable for survival technologies that must satisfy many diverse criteria (see Part 1 of this article).

There is another important contrast between the specialist skills of basic researchers and the generalist skills of technologists as far as rapid deployment of *first-round* global warming solutions is concerned. Basic research often takes decades before it can be translated into practical technologies; such time frames are long gone for first-round solutions. Some technologists have used their generalist skills to join *existing technologies* to create first-round solutions, and, at best, this is all we have time for. We do not get to try additional solutions unless *immediate deployment* of certain first-round solutions buys humankind the additional time. Given today's dearth of generalists, the next-best solution might be a development program in which specialist experts can interact easily and often. Not only is such communication discouraged today by the culture and structure of most organizations, but in some research and development programs (in large oil companies, for example), it is actually forbidden.

In today's organizations, three principal elements essential for the creation of survival technologies are missing:

1. technical people and management possessing the knowledge and skills needed to create survival technologies;
2. internal development programs organized in a manner that encourages their creation; and
3. institutional goals, mandates, and self-interests that promote their creation.

If large organizations are so hostile to the creation of survival technologies, we might hope for a better outcome among small high-tech companies. After the invention of a technology, such companies are often able to further its development. Such companies often avoid the barriers large organizations present to the creation of survival technologies. This is especially true if a small company includes an influential, innovative technologist, preferably the one who invented the technology. Unfortunately, small companies are almost invariably unable to access capital sufficient to commercialize, successfully deploy, and disseminate their technologies.

We conclude that so long as the status quo persists, there are few places left to create and deploy survival technologies.

Case Studies

Let us examine a cluster of survival technologies developed and perfected in selected small, high-technology companies. Full disclosure: we will discuss two technologies we have developed and a third to which we have added an important feature—the ability to render some biofuels carbon-negative. We

Multitalented innovators like Henry Ford (left) and Thomas Edison revolutionized American engineering and manufacturing. In recent decades, America's large corporations have grown inhospitable to innovative technologists whose skills span specialties.

> "By the time technical people become involved in most projects today, both the project goal and the approach . . . have already been decided by managers who usually have little scientific or technical knowledge."

wish to be able to accurately discuss survival technologies with which we have firsthand familiarity. To eliminate any suspicion of self-interest, we pledge that if we deploy our technologies it will be within the framework of a nonprofit corporation and/or licensed to all parties who agree to utilize the technologies in an environmentally sound fashion that promotes human survival. (In addition, we have freely published our concepts for rendering biofuels carbon-negative.)

Below, we briefly discuss three perfected survival technologies that continue to await deployment:

1. a *particular* process of microorganism-mediated production of celluosic ethanol;
2. an inexpensive, large-scale, energy-conserving method of desalinating large quantities of seawater; and
3. a sensing and information technology that could enable significant reductions in energy-intensive inputs to agriculture while simultaneously increasing yields in some crops. (Commercialized, but badly undercapitalized, this technology could not stay in place long enough to develop the market.)

1. A particular *microorganism-mediated process for the production of cellulosic ethanol.* This is the "new biofuel" process previously discussed in this paper. Its unique advantages eliminate several fatal drawbacks of corn ethanol as a replacement for oil-based fuels. In producing corn ethanol, the sugars and starches within corn kernels are fermented, but most of the corn plant remains unused. In cellulosic-ethanol production, the cellulose of the *entire plant*—most of the plant's mass—is broken down into sugars. Then these along with the naturally occurring sugars are fermented into ethanol. Thus, fewer plants are needed to make a given quantity of ethanol. And fewer plants means less acreage required to grow them.

Several known processes produce cellulosic ethanol. Some break cellulose into sugars by using enzymes. But enzymes are expensive, and different enzymes are needed for different kinds of plant material. The new process does not use enzymes; it uses inputs of very small amounts of energy, and a different microorganism is used in each step of the process to break biomass up into small pieces, to change cellulose into sugars, to ferment the sugars into ethanol, and so on. This particular microorganism-mediated process produces ethanol at very low cost: $0.70 per gallon compared to well over $2 per gallon for enzyme (and other) processes. It generates almost no pollution and can make ethanol from mixtures of different sources of cellulose—crops grown as biomass, leftover straw or stubble from food or fiber crops, wood or sawdust, switch grass, prairie grasses, old newspapers, etc. The resulting fuel offers a very high energy gain of 11. Like other biofuel processes, some cellulosic-ethanol production processes can now be made carbon-negative.

2. Large scale, low cost, low-energy desalination. Another survival technology is a process (based on hundred-year-old science) for large-scale water desalination. It requires a very small input of energy and produces fresh water at a cost of about ten mils (one hundredth of a U.S. cent) per gallon, low enough that it can be used economically for irrigated agriculture. The current technology used for large-scale desalination, mostly in desert regions, is based on reverse osmosis through membranes. However, it is energy-intensive, and the water it produces is too costly for irrigated agriculture, about three hundred mils per gallon.

3. Airborne remote sensing of plant health. A third survival technology is a set of breakthroughs in the field of remote sensing from low-flying aircraft, which could significantly reduce energy-intensive inputs to agriculture such as fertilizer, protective chemicals, and also water, at the same time enabling increased yields in some crops. Problems including nutrient deficiencies, crop diseases, insect infestations, and many other conditions are easily detectable in very early stages, even before they become visible to the human eye, such as when an insect infestation affects a circle of plantings only six feet across. Pesticides, fertilizer, and water can then be applied where needed, only when needed, and often in far smaller quantities than the whole-field applications that are often done according to a pre-established schedule.

Other examples could be provided, but these are typical of survival technologies developed by small companies in that *they have virtually no chance of being recognized for what they are and successfully commercialized and deployed.* Their poor prospects all relate to lack of adequate capital.

Why Can't Small Companies Secure Funding for Survival Technologies?

Small high-tech companies command little inherent credibility among venture capitalists and other external decision-makers—with the possible exception of companies in which one or more of the principals is a researcher at a prestigious university. As noted above, university researchers are generally specialists and unlikely to be technologists who can innovate a survival technology. Consequently, the decision to fund a small company's survival technology usually hinges on nontechnical decision-makers attempting to evaluate something that they have no idea how to evaluate.

For example, the microorganism-mediated ethanol process was demonstrated to nontechnical potential investors on multiple occasions. Invariably, they were either unsure of what was being demonstrated or they suspected trickery. The company's business plan could not persuade them, because it had meaning only if the technology were real and unflawed, precisely the thing they could not judge. Couldn't potential investors hire someone with the proper knowledge to evaluate the technology for them? Over several decades, we have seen this happen only once. In order for an investor group to choose a person with the correct knowledge, its members must already know something about the subject. In the case of a technology drawn from a unique blend of disciplines, the small company seeking funding may already know the only people qualified to evaluate it. However, prospective investors fear collusion when offered a list of individuals alleged to be capable of making a proper evaluation.

If one cannot assure others on the basis of knowledge presented to them and the situation is one in which trust is not possible, then there is really no way of assuring others that the conclusions presented to them are valid.

Neither venture capital nor initial public offerings (IPOs) can fund small companies at the point when they need to commercialize their technology. Using the microorganism-mediated ethanol technology as an example, current investment criteria would require the firm to *first* build a commercial-scale plant using its new process (demonstrating that its technology was sound) and then sell its product successfully for about a year (demonstrating a sound business model). What small company can afford to invest millions of dollars to do that, simply to reach the point where it might be *considered* for venture capital? And IPOs are only available to companies with *established* technologies, which does not initially include new survival technologies.

Three other serious problems arise when decision-makers must deal with unfamiliar information:

1. *The solutions they propose are often improperly framed.* That is, a solution within the framework they have chosen will not be optimal, practical, effective, sustainable, or even possible. Richard Branson, the billionaire Englishman behind Virgin Airlines, offered a prize to anyone who could come up with a *machine* to capture and sequester large amounts of carbon dioxide from the atmosphere. Those familiar with such processes realized that a practical approach might be to exploit a natural process under specific and carefully monitored conditions. (This is how we were able to render some biofuel processes carbon-negative.) It proved impossible to communicate to Branson that although his goal was valid, he had framed the problem in a manner that rendered a practical and effective solution (a biological reactor, rather than a machine) unlikely. This illustrates the need for society to have a means of first *recognizing the best solutions,* irrespective of their origin, then being able to communicate them with credibility to leadership whose responsibility is to make decisions.

In most large American organizations today, managers lack the technical expertise to frame and develop survival technology.

2. Decision makers often view strong statements in areas that they do not understand as being exaggerated. "Everyone knows" that extreme descriptions and strong conclusions are almost invariably wrong or exaggerated; in most situations, the real world doesn't work that way. But what of the rare situations in which an accurate description of an important problem requires a forcefully stated description or conclusion? For example, if it is true that we have fewer than ten years in which to do the things necessary to contain global warming within tolerable limits, then forceful statements are necessary to express the crisis and present its solutions. Such robust arguments can be made *with maximum impact* only to those with the knowledge and background to understand the arguments fully. To others, including most of our technologically unenlightened leadership, forceful conclusions and strong recommendations will sound exaggerated. This may limit their understanding of the need for urgent, timely responses, such as the deployment of first-round survival technologies as quickly as possible.

This knowledge limitation, together with short-term economic self-interest, may explain the behavior of industrial and financial leaders who deny or downplay the consequences of global warming in order to continue using fossil fuels without the cost of carbon capture and long-term sequestration for as long as possible.

3. Nontechnical management, *and most leadership in general,* can effectively manage or deal with only those functions that it understands and with which it feels comfortable. One of us christened this phenomenon the "knowledge barrier" in the 1970s. Its primary effects then were economic: the commercialization of "nonsurvival" technologies (that subsequently contributed to pollution and our current environmental crisis) and the gradual decline and loss of many American industries to foreign competition. Consider the U.S. auto industry: at the end of World War II it was the world's *only* intact auto industry. Yet it threw away its primacy by focusing almost exclusively on marketing, finance, and sales—*the functions its postwar management understood and with which it felt comfortable*—while executives, many with backgrounds in engineering and manufacturing, led foreign competitors like Toyota. In the latter company, practical innovation continued.

Thus, the specialization that once jump-started civilization may now be limiting its advance. It may even end it if it prevents the timely creation and adoption of survival technologies.

The Grant and Patent Traps

Grants were once useful for small high-tech companies seeking to develop proprietary knowledge or a new technology. Because of recent changes to the laws that govern them, federal grants now have two significant drawbacks for small companies. All details of the research must be disclosed to the granting agency, which takes no responsibility for protecting it except on a "best efforts" basis—legally almost meaningless. In addition, any federal agency, even one not involved in the grant, has the right to "co-use" the fruits of supported research without compensation. This has resulted in small companies' research results being handed over to multinationals to apply on the government's behalf. For these reasons, government grants are no longer useful to small companies as vehicles for generating and retaining proprietary technology or knowledge.

What about patents? Holding one or more patents is a significant source of credibility for prospective investors. Unfortunately, recent changes in patent law make the process of applying for a patent extremely risky for any small company whose technology may threaten a large corporation or multinational, and most survival technologies meet this standard. Under the current process, six to eighteen months before review the application is posted on the Internet for everyone to see. The date of invention is clearly displayed. But, any large corporation has the resources to create a false history of invention and jump the claim. As a result, small companies whose technologies might be detrimental to a multinational are obliged to hold them as trade secrets and forgo pursuing patents that would make their technology more credible to investors.

Some Obstacles to Our Survival

It is now easy to understand how small high-tech companies can create survival and first-round survival technologies and the reasons they go unrecognized.

1. There is general technological ignorance on the part of decision-makers throughout our society.
2. There is a lack of credibility among technologists, scientists, and engineers who are associated with most small, high-tech companies, no matter where they were previously employed and irrespective of their prior accomplishments.
3. We lack a widely credible institution with the knowledge to judge these technologies, review them, and establish their validity for the rest of us.

> "We . . . propose the formation of an institute . . . that can take a systematic approach to recommending the changes necessary for survival."

4. There is a danger to a small company that it will have the technology stolen by large multinationals if it applies for a patent.

One final factor can suppress technologies of small companies whose products or technologies threaten a multinational: a multinational may purchase or take over the small company. This is not solely the stuff of conspiracy theories and urban legends. We know of one small biotech firm that recently developed an artificial version of high-density cholesterol. In early tests, it showed the promise of sweeping clogged arteries free of plaque after a small number of treatments, thereby reversing or even curing cardiovascular disease. This posed a threat to manufacturers of cholesterol-lowering statin drugs, which are of course much more profitable than the new technique would have been, since statin drugs must be taken indefinitely. A manufacturer of one of the primary statin drugs purchased the small biotech company for twice its then-current value, and the new technique has "disappeared."

For these and other reasons space does not permit us to cover, there now exist few institutions from which survival and first-round survival technologies can be created and deployed. We have explored some of the reasons why these impediments exist, but we must not lose sight of the forest for the trees. The fact that *claims for the existence of survival technologies made in this essay have no way of being evaluated* should serve as a warning that our present system is dysfunctional and unlikely to fulfill our survival needs.

The Limitations of Survival Technologies and Additional Major Barriers to Their Deployment and Proper Use

The buildup of greenhouse gases in the atmosphere is the *immediate* cause of greenhouse warming and a good place for emergency intervention through the practical, low-cost capture, and long-term sequestration of atmospheric greenhouse gases, as with our carbon-negative biofuels. But the buildup of greenhouses gases is not the fundamental cause. Greenhouse-gas capture and sequestration is analogous to placing a critically ill patient on life support. It must be done, but if we stop there, the patient is going to die.

Greenhouse-gas capture and sequestration, however, are not profitable. For example, rendering biofuels carbon-negative and sequestering the carbon long-term adds expense to biofuel production without providing additional profit. Such initiatives will not be pursued unless paid for or mandated by the federal government.

Even upon the deployment of survival technologies, there is no guarantee that they will be used to promote survival rather than be circumvented for the sake of profit. In some parts of South America, for example, the cheapest initial source of biomass for the preferred microorganism-mediated process of cellulosic ethanol is cutting down what's left of the Amazon rain forest! Similarly, forests and grasslands are being indiscriminately cleared and turned into fields to grow biomass for conventional biofuel production. A recent study has shown that the net result of these activities is to actually increase the quantity of greenhouse gases entering the atmosphere to a greater extent than the continued use of gasoline. As another example, the hole in the ozone layer around the South Pole is still present and may be due to the bootleg manufacture of CFCs in mainland China and their use in South America. International negotiators must also rapidly address such problems if we are to survive.

A Proposal for Recognizing, Creating, and Deploying Survival Technologies (and Other Necessary Changes)

It is our opinion that impediments to creating and deploying survival technologies are so complex, extensive, and infused with self-interest that removing them in time is unlikely. In our opinion, the most practical approach is to try to work around the impediments.

We, therefore, propose the formation of an institute staffed by selected academic scientists, engineers, and technologists with the following mandates:

1. Verify and actively promote deployment and dissemination of existing first-round survival technologies as well as new ones, whether created internally or in cooperation with other organizations. The mandate would extend to funding these technologies if no other sources of capital were available. Regardless of development costs, resulting technologies would be offered to all who can deploy them effectively in accordance with environmental requirements and constraints.
2. Study the four major physical problems we set forth in Part 1 of this article (global warming/environmental degradation, resource depletion, pollution caused by fossil fuels and current technologies, and population growth) to specify practical, integrated ways of dealing with them—in other words, a systematic plan for humankind's survival.
3. Communicate with legislators and other political leaders regarding actions necessary to enable some survival technologies to be deployed and, once deployed, to ensure that all are utilized in the manner intended. This function would constitute "Humanity's Survival Lobby."

4. Assist legislators and other leaders in hiring technology aides to keep them abreast of new developments and to interface effectively with institute personnel.
5. Provide a teaching function to make science and technology professionals and other interested parties aware of the criteria required for survival.
6. Consult companies and institutions to support them in choosing and implementing technologies more consistent with survival.

How would an institute be funded? Einstein's appeal to Franklin Delano Roosevelt regarding the possibility of building the first atom bomb might furnish a template for the project of obtaining seed capital. One or more highly credible academics could approach one of the world's philanthropists for the institute's initial funding. Another route might be for a philanthropist to underwrite a demonstration project to commercialize one first-round survival technology—not necessarily one of our own. Ideally, this would be done through a nonprofit corporation, which would license the technology to all who want to use it commercially in ways that promote human survival. Eventually, the institute might become self-sustaining, perhaps through agreements obligating companies whose technologies it helps disseminate to make later contributions to the institute's financial support.

Summary and Conclusion

Whatever time we have left to contain global warming within tolerable limits, our response must take into account that human existence and much of the biosphere are at stake. As noted, global warming is linked to three other major problems (resource depletion, pollution, and population growth), any one of which, by itself, poses a significant threat to humankind. Therefore, if we are to err, prudence dictates we err on the side of keeping global warming and associated problems within tolerable limits.

Part of the solution is to create and deploy what we have called "first-round survival technologies." However, our current system of technology development discourages this; moreover, the entire category of skills required to create such multidisciplinary innovations is on the verge of extinction.

As we learn more about global warming, our understanding of the severity of the threat has increased. Some known effects have dramatically accelerated. Other effects, not expected for many decades, have already arrived, as have still others that were never anticipated. One reason for these unpleasant surprises is the linked nature of elements within the environment and between the environment and the other three problems. When one significant element of the environment or the other physical problems is impacted, it invariably affects others.

Einstein's letter to Franklin D. Roosevelt suggesting development of the first atom bomb might furnish a template for obtaining the institute's initial funding.

Because of this relationship, it is unlikely that adequate solutions will emerge piecemeal. This is the most powerful argument that can be made for creating an institute that can take a systematic approach to recommending the changes necessary for survival. The other argument is the need for an organization that can make an end run around the impediments to creating and deploying survival technologies.

The time for urgency—and action—is now. It's already very late in the survival game. fi