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Human Sustainability: Overview of Survival Technologies and Impediments to Their Development and Deployment

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1. Introduction

Four significant and interconnected physical problems are likely to reach critical stages over the next two decades:

(1) Global warming and environmental degradation;
(2) Depletion of key resources including oil, gas, and potable water;
(3) Pollution caused by use of fossil fuels with current technologies;
(4) A world population beyond Earth's carrying capacity—exacerbating the first three problems—that continues to increase.

Keeping these problems within tolerable limits will require defining the actions that we must take and the sequence in which we must take them, followed by rapid deployment of the largest set of integrated, knowledge-based changes the world has ever seen. Included in these changes is the deployment of "survival" technologies. In this chapter, we will discuss fundamental impediments to the creation, adoption, deployment, and proper use of those technologies.

The compartmentalization of knowledge, along with various cultural, economic, and business realities, has created a severely limited understanding of the changes necessary for our survival, and has delayed implementation of those changes. These realities are:

(1) Economic self-interest;
(2) Profit motive as the sole determinant of action;
(3) Lack of appropriate institutions to promote and manage required changes;
(4) Limitations on the range of practical solutions that experts are able to create because they possess only a narrow range of specialized knowledge in a particular field;
(5) Limitations associated with non-expert decision makers attempting to formulate decisions that require expert knowledge.

We suggest that we create an institution designed to orchestrate solutions to the first three of these four problems. Regarding the fourth, overpopulation, this institution would promote understanding of the need for population reduction as necessary for human survival and help create improved, long-term birth-control technology to facilitate population reduction.

2. The Nature of Survival Technologies

Because the physical problems listed above are interrelated, developing effective survival technologies is exceedingly difficult and not always achievable by those possessing only a narrow range of specialized knowledge. By "survival technologies," we mean those that are sustainable and which provide to a significant extent for:

(1) Human needs for energy, fresh water, food, and population reduction;
(2) Reduced human impact upon the environment;
(3) Restricting global warming to within tolerable limits; and
(4) Adjustment to negative environmental changes due to global warming.

Survival technologies must be sparing in their use of nonrenewable resources, must avoid producing much pollution, and avoid, as much as possible, harming the environment. The wish list of survival technology characteristics calls for them to be robust, relatively low-cost, rapidly deployable, and compatible with existing infrastructure. We will refer to a survival technology that exhibits these criteria as "practical." But even this formidable list is incomplete when discussion turns to energy technologies.

Practical energy technologies must also have a high "energy gain." Energy gain of a fuel is the ratio of energy produced by burning the fuel to the energy expended to manufacture it. For example, we can compare the energy obtained by burning a gallon of gasoline to the energy expended to obtain that gallon of gasoline. "Energy expended," in this case, includes but is not limited to that required to drill, produce, transport, and refine the oil and the energy (prorated) required for making pipes, erecting oil-drilling platforms, and constructing refineries.

For other forms of energy, such as electricity generated by wind power, we similarly need to compare the total energy generated by a wind turbine over its lifetime with the energy needed to mine and refine the metals, forge the blades, build the generator and the support structure of the turbine, and other factors requiring the expenditure of energy. Unless all of these parameters are favorable, the technologies upon which we depend for our survival will eventually fail us.

Finally, we must guarantee that in regions where climate change is most evident, the resources required by proposed survival technologies must be impervious to climate change.

As a case in point, during 2006, high temperatures and a summer drought in Western Europe increased the temperature of water supplies needed to cool nuclear reactors and reduced its volume. Consequently, reactor power levels (and the electricity they generate) had to be reduced, In one case, a reactor shut down; water used to cool reactors had to be discharged to rivers and lakes at higher temperatures than normally permitted, which, in turn, resulted in substantial damage to the environment (Goday, 2008). By our criteria, therefore, we must not consider water-cooled nuclear reactors as a future survival technology in any region susceptible to either higher temperatures or permanent freshwater shortages. In addition, existing reactors may have limited future use in areas that will become hotter or drier because of climate change.

Currently, freshwater shortages are occurring all over the world. Australia is presently suffering the worst drought in its history; a significant portion of its crops have failed. Commentators speculate that the drought is due to global warming and may represent a permanent climate change. Such a change may result in the need to relocate up to six million people, but no one has suggested where such a relocation could successfully occur (Tim Johnson, "Parched in Australia: Drought Changes Views on Warming," *International Herald Tribune*, Asia Pacific, 7 November, 2006; Marks, 2007). Some analysts have predicted that agricultural areas, which grow much of the world's food, will become hotter and drier due to global warming and potentially reduced precipitation (Michael McCarthy, "The Century of Drought," *The Independent/UK*, 4 October 2006; Steve Corner, "A Global Catastrophe of Our Own Making," *Independent/UK*, 31 October 2006). In North America, these areas include the American Midwest, Southwest, and far West. In the future, these regions may no longer be able to support high-yield agriculture because of a lack of water.

In addition to less precipitation, is the approaching depletion of the Ogallala Aquifer threatens agriculture in the Midwest and South Central region of the United States. Parts of the Southwest, including parts of California, gets 80 percent of its water from mountain snowmelt runoff, which is already in sharp decline, possibly because of global warming or very long-term (hundred-year) drought, which, historically, is common in this part of the country.

Residential development also competes with agriculture for water resources. For example, California's Imperial Valley, naturally a desert, has long been employed for production of fruits and vegetables. The success this industry depends on irrigation from diverted Colorado River water. In recent years, much of the water used to irrigate crops in the Imperial Valley has been transferred to cities in Southern California. This has resulted in reduction of agricultural production ("Building Bonanza: Growth and the Ag Industry," 2004).

Whatever the cause for reduced water supplies, we need to replace the water lost by drought and diversion to residential purposes if we are to maintain food production. The survival technology that could enable human beings to have adequate supplies of water to maintain food production would be a practical, extremely low-cost, energy-conserving method of desalinating vast quantities of ocean water. As we shall see, this, and other innovative solutions face serious impediments to their development and deployment. Before discussing those in more detail, let us turn our attention to reasons why timely adoption of new technologies is crucial.

3. Why Global Warming Requires Immediate Deployment of Survival Technologies

Normally, rational people desire solid proof of potential outcomes before acting on major issues. But some aspects of global warming require us to compromise this principle. Global warming is so critical that, if it becomes pronounced enough, it could jeopardize humankind's future on the planet. Given such a severe threat, we must address some aspects of global warming before we establish cause and effect with 100 percent certainty.

For example, major threats we need to address now without waiting to be "sure" global warming is occurring or to what degree it might advance include the quantity of greenhouse gases in the atmosphere, their rate of increase, and the potential for global warming to become self-sustaining. In simplest terms, global warming occurs when greenhouse gases (carbon dioxide, water vapor, nitrous oxide, and methane) trap heat in the earth's atmosphere. Light from the sun enters the atmosphere freely and gets absorbed within the atmosphere and at the earth's surface and changed into heat. The heat remains trapped by the greenhouse gases in the atmosphere, which act like a blanket. The greenhouse gases do not let the heat go back out into space as easily as light enters the atmosphere, which causes an increase in the earth's temperature. The greater the concentration of greenhouse gases, the greater will be the rate at which the earth's temperature increases.

Carbon dioxide is a relatively long-lived molecule and is emitted into the atmosphere as a byproduct of respiration or by burning organic fuels. While molecule for molecule, methane is a more effective greenhouse gas than carbon dioxide, its concentration is much smaller so that its total effect in trapping heat is only about a fourth of that of carbon dioxide.

Data for the years 2000 through 2006 reveal that carbon dioxide emissions during that time were the highest recorded since the beginning of continuous monitoring in 1959 and a significant increase over growth recorded in earlier decades. Global atmospheric carbon dioxide rose from 280 parts per million (ppm) at the start of the industrial revolution (taken to be approximately 1750 CE) to 381 ppm in 2006. The rate of annual rise during 2000–2006 has increased to over three times the rate of annual increase over the previous 250 years. The present concentration is the highest during the last 650,000 years and probably during the last 20 million years (Canadell, Le Que´ re´, Raupacha, et al., 2007). The rate at which carbon dioxide is being released into the atmosphere since 2006 continues to accelerate ("Increase in Carbon Dioxide Emissions Accelerating, Australian Research Shows," 2006). Reports such as this one have caused many to form the opinion that the advance of global warming is already out of control (Connor, 2006; Lean, 2007).

The time during which humankind can attempt to hold global warming to tolerable limits may be short: a commonly held view among three thousand climate researchers, who participated in a recent five-year international study of global warming, is that the time left for us to attempt effective action is shorter than ten years. This is not to say that global warming will be full-blown within a decade, but that within this ten-year timeframe, progressive and irreversible effects could exacerbate beyond the ability of human beings to sufficiently moderate them (Mary Millkin, "World Has 10 Year Window to Act on Climate Warming—NASA Expert," *Reuters*, 14 September 2006).

If rapid increase of greenhouse gases in the atmosphere and irreversible environmental damage are not threatening enough, even more disturbing is the prospect that global warming might become self-sustaining because of a feedback effect. As Earth's average temperatures rise, the rate at which some natural sources inject greenhouse gases into the atmosphere also increases.

Globally, crop soils alone currently supply about 25 percent of the total amount of carbon dioxide that enters the atmosphere from manmade sources (Soil Science Society of America, 2007). As temperatures rise, the amount of carbon dioxide released in to the atmosphere from soil increases (Trumbore, 1999). This, in turn, increases the Earth's temperature even further, further accelerating the rate at which natural sources of greenhouse gases enter the atmosphere. Such self-perpetuating processes, well known to physicists, are said to have "undamped positive feedback upon the input." Although they are not yet the largest contributors to global warming, such processes, quite varied and common in nature, represent potential sources that pushed too far, could continue to spontaneously drive environmental changes beyond the limits human beings can tolerate.

If natural sources of greenhouse gases continue to increase and become self-sustaining, then the biggest contributor to additional global warming will ultimately be global warming itself. Consider the following examples of positive feedback of greenhouse gases.

In the same time as the industrial revolution has transpired, permafrost, a layer of earth frozen since the last ice age, has been melting to an alarming degree (NASA, 2003; Borenstein, 2006; Deborah Zabarenko, "Thawing Permafrost Could Unleash Tons of Carbon," *Reuters*, 15 June 2006). Currently, one continuous area of permafrost in Asia is larger than the areas of France and Germany combined. Permafrost contains large quantities of the greenhouse gases methane and carbon dioxide, released into the atmosphere when the permafrost thaws (Borenstein, 2006; Zabarenko, 2006). This contributes to further global warming, which, in turn, contributes to more rapid melting of permafrost, and so on.

A second serious example of positive feedback in the environment is the melting of the ice covering the Arctic Ocean. Ice reflects 90 percent of the light falling upon it, but ocean water absorbs 80 percent of that light and changes it into heat. As the area of the ice cover deceases and is replaced by water, more light is absorbed and changed into heat, which causes the remaining ice to melt even faster (NASA, 2003).

Melting ice absorbs heat without causing a rise in ambient temperature, which may currently be retarding any temperature increase in the Arctic Ocean area. But after the ice is gone, we can expect the ocean's temperature to rise more quickly. The melting of the Arctic ice is already in an advanced stage: climatologists predict the summer ice covering the Arctic Ocean will disappear by 2013 enough to open up the Northwest Passage during summer months (Revkin, 2007). Contrary to the prima facie benefits for commerce of an open sea-lane through the Northwest Passage, a significant downside looms: the warming of the Arctic Ocean is expected to result in significant climate changes elsewhere on the planet. This, in turn, suggests that we must immediately prepare for climate change by, among other actions, deploying survival technologies needed to support fundamental human needs that enable adjustment to the negative environmental changes caused by global warming. We will look at low-cost, low energy desalination as an example of a practical solution to this sort of problem later in the chapter.

The above example of positive feedback of greenhouse gases and the numerous negative effects caused by their increase suggest that we must *immediately* address both manmade *and* natural sources of greenhouse gasses in the atmosphere. Furthermore, the percentage of carbon dioxide entering the atmosphere from manmade versus natural sources is irrelevant; we know enough about the carbon cycle to know that uninterrupted at its present rate of increase, atmospheric carbon dioxide can ultimately cause human extinction along with that of much of the biosphere.

In principle, two approaches to ameliorate the problem are available to us. One would be the use of techniques to reduce the output of some natural and manmade sources—difficult in the case of natural sources because most of them extend over large areas. The other approach would be to employ a practical survival technology that would remove and sequester greenhouse gases after they enter the atmosphere, irrespective of whether they came from manmade or natural sources.

In our opinion, a practical technology that enables the capture and long-term sequestration of carbon dioxide from the atmosphere is the most important survival technology we can presently deploy. But let us examine this intervention more closely: Although the build-up of greenhouse gases in the atmosphere is *currently* increasing global warming and a good place to intervene or compensate on a temporary emergency basis, the capture and long-term sequestration of atmospheric greenhouse gases is analogous to placing a human patient on life support. It may be necessary to keep the patient alive, but if you stop there without fixing the underlying causes, the patient will eventually die.

Some of the direct and indirect sources of increased atmospheric carbon dioxide are environmental destruction, population increase, conventional methods of energy generation and use, the increased rate of greenhouse gases released by natural sources into the atmosphere due to warming that has already occurred, and, replacement of planted areas by concrete and asphalt.

4. "First Round" Survival Technologies: An Initial Step toward Humankind's Survival

Creating and deploying most long-term survival technologies, and making many of the more or less permanent changes necessary for human sustainability, will require considerably more time than we have left to contain climate change. No time is left for further research and development of survival technologies.

A solution to this apparently hopeless situation is to *immediately* deploy certain "first round" survival technologies that can buy us more time. To meet this criterion of rapid deployment, these first round technologies must: (1) be those that *already exist* (or slight modifications of them); or (2) be optimized systems synthesized from such existing, rapidly deployable technologies. A low cost, low energy method for (net) large-scale capture of carbon dioxide from the atmosphere, using an existing technology, to produce carbon-negative ethanol followed by a simple method of long-term sequestration, is an example of such optimization of pre-existing technology for a new, originally unintended purpose. Another first round survival technology is use of 100-year-old physics and a slight modification of existing technology to achieve low energy, large scale desalination. We will discuss the production of carbon-negative cellulosic ethanol later in this chapter.

Humanity could use the additional time bought through rapid deployment of first round survival technologies to develop and deploy more long-term technologies and changes that, we cannot, by virtue of their nature, accomplish quickly. As crucial as we see this approach to be, though, some major impediments to the creation and deployment of such technologies exist. A primary goal of this chapter is to discuss some of these impediments.

Some of these impediments will come as no surprise: Some large companies may have purchased rights to innovative technologies and then suppressed their further development to protect their profit interests. For example, some evidence exists to suggest that Enron-AMOCO-British Petroleum may have suppressed photovoltaic's deployment after its possibly fraudulent takeover of Solarex Corporation during the 1980s (Berger, 1998). Multinational corporations have been able to earn sizable profits for decades without their products conforming to the many requirements of a practical survival technology—a major reason for our current environmental crisis. The nature of our economic system is that corporations distribute the economic benefits of some technologies among different groups and subsidiaries so the full benefits may not appear on the balance sheet of any one company or institution that purchases them. For example, solar cells, which generate energy without atmospheric pollution, may have appeared far more economically attractive decades ago if an accurate accounting of the economic benefits appeared on the balance sheets of the companies that purchased them.

Other significant impediments may be less familiar: As we will discuss, skills different from those of basic research and germane to creating first-round survival technologies are almost extinct. Changes have occurred in multinational corporations, defense contractors, and government labs, which make alternative development and utilization of the skills necessary to create survival technologies nearly impossible. The culture of freedom and flexibility prevalent in many smaller, high technology companies has enabled some of them to create such technologies. But, as we will also discuss, such companies—some with solutions pivotal in the battle to contain global warming—have little or no access to sufficient capital with which to deploy these technologies.

As we will show, not every survival technology will yield immediate financial gains, and production costs may be more than that required to produce "dirty" fuels. Companies motivated only by profit will not be interested. Instead, some crucial technologies will result in additional expenses to their manufacturers without the opportunity for additional profit. If we are to deploy such technologies, government intervention to mandate or pay for them will be necessary.

Finally, as we will discuss, a fundamental obstacle exists that we authors have labeled the "knowledge barrier." It often accompanies the above-listed impediments and arises when economic, financial, industrial or political decision makers, who have little or no firsthand knowledge of technology, attempt to make decisions concerning technology. Fundamental limitations arise when such decision makers attempt to utilize, in a "secondhand" fashion, the knowledge of science and technology experts. These limitations result in decisions that are usually far from optimal. If this flawed decision-making process continues, based on past performance, it will significantly reduce the likelihood of creating, recognizing, and deploying the optimal technologies required for humanity's survival at the very time we may have only one last chance to achieve and deploy them.

5. The Potential Effectiveness of Survival Technologies Versus Currently Proposed Solutions

So far, United States congressional legislators appear to have treated climate change as merely another political problem. They have tended to choose politically acceptable remedies, often with exaggerated claims implied about their predicted degree of successful solution. They move such remedies' adoption date so far into the future as to effectively suspend or fatally weaken them. HR 6, Energy Independence and Security Act of 2007 displays both shortcomings.

Increasing average auto fuel economy to thirty-five miles per gallon, mandated by HR 6, would save approximately one million barrels of oil per day. We currently use twenty million gallons per day to fuel vehicles. Similarly, lighting utilizes 4 percent of United States' energy consumption; phasing out incandescent bulbs in favor of a more efficient alternative, as also mandated by the bill, would save only a fraction of that. If we replace incandescent bulbs with fluorescent bulbs, the toxic mercury they contain will multiply disposal problems to save a relatively small percentage of the energy we use.

By contrast, consider the much greater and shorter-term benefits of a genuine first round survival technology capable of rapid deployment: the manufacture of a $0.70 per gallon, biofuel replacement for most energy applications of petroleum: a *particular* (microorganism-mediated) process for making "cellulosic" ethanol. While many processes for making cellulosic ethanol exist, using this process, enough of the required kind of biomass to replace all United States' oil imports could be grown on less than 10 percent of the acreage currently used by United States agriculture, and would be sustainable if grown correctly. This process also offers an *astonishing* energy gain of *11 units* of energy contained in the biofuel *per unit* of energy expended to grow proper biomass and change it into the biofuel. By contrast, corn ethanol, at best, has an energy gain of only about 10 percent that of cellulosic ethanol. Some argue that of corn is lower due to the energy intensive nature of growing corn.

In addition, manufacture of ethanol using this process generates almost no pollution, produces few particulates when burned, is neither capital-intensive nor very demanding of nonrenewable resources, and is produced by a non-critical low-tech process easily established in developing nations. Even more beneficial, by adding an extra step—one that uses existing technology—during manufacture, the process can be rendered *carbon-negative*—growing proper biomass and changing it into biofuel will pull more carbon dioxide out of the atmosphere than is released when the biofuel is burned. (Even without rendering the ethanol carbon negative, the high-energy gain and the very small amount of energy required to make a unit of ethanol using this process, means that the ethanol will be only slightly carbon positive—must less carbon positive than other fuels or ethanol made by other processes.)

Finally, a reasonable extension of this system may enable sustainable production of sufficient biomass to replace, with ethanol made by this process, energy applications of oil worldwide without requiring *any* agricultural land, forest or grassland, to grow it. Science fiction? The stuff of wish lists? Not at all.

This carbon-negative process already exists and has ready for rapid deployment for years, but due to some of the impediments mentioned and others we will discuss, its inventors have been unable to deploy the technology.

Imagine the initial impact of just this one first-round survival technology in helping to combat global warming, reducing fuel costs and pollution, and alleviating the politico-military consequences of the United States' current dependence on foreign oil in favor of a carbon negative (or low carbon positive) replacement. Given the status quo, which we will subsequently describe in detail, and given that a small high-tech company invented this technology, chances are remote that it—as with most developed by small companies today—will ever be recognized for its potential benefits, commercialized, or deployed.

HR 6 also encourages expansion of ethanol manufactured from corn, a technology (along with other biofuels) the United Nations has declared a "crime against humanity" (Lederer, 2007) based on the following premises:

(1) The world now needs all of its agricultural land to grow food, and this need will only be aggravated as population increases and global warming reduces yields;
(2) Corn ethanol and other current biofuels demand too much land per unit of ethanol produced;
(3) Making enough ethanol for one SUV car tank fill-up consumes enough corn to feed a person for a year;
(4) More energy is consumed in making and transporting corn ethanol than we get back by burning it; and
(5) Diverting corn to ethanol production also drives up the cost of foods for which corn is an ingredient or feedstock. It has already doubled the price of tortillas in Mexico and substantially increased the price of eggs and milk; soon prices of hogs and corn-fed cattle will follow. Expanding the manufacture of corn ethanol and other conventional biofuels will only aggravate these problems.

Did legislators write corn ethanol expansion into the energy bill as a political earmark for agricultural states? Did they act out of technological or environmental ignorance? Perhaps, but regardless of their motivations, such promotion of "non-survival" energy technologies *reduces* the likelihood of containing global warming and related problems, and of achieving survival.

6. Significant Innovation: A Game Just One Can Play

The four crises previously discussed call, in part for breakthrough research that has not yet emerged from conventional, established sources. One surprising reason for this is that large research organizations, public and private, fail to recognize that significant innovation is a *one-person game.* Major breakthroughs occur in the mind of a single individual (Bower, 2008). Group research becomes relevant only after planners define the innovation and frame the approach for implementing it.

Organizational climates were once much 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 complete freedom management gave to the two physicists, John Bardeen and Walther Brattain, who were tasked with developing what was later to be known as the transistor, a feat that ultimately won them and the manager of the project, William Shockley (who took no active role in development), the 1956 Nobel Physics Prize (Augenbraum and Hammer, 1999). After its inventor demonstrated the first transistor, others eventually made the device more practical by virtue of many years of team development. Brattain, the theoretician, even spent much of his productive time working at home, an action today's company management is not likely to sanction.

Having been in industry and defense research and development since just after World War II, one of us authors has first-hand experience that researchers and engineers today enjoy far less freedom to demonstrate new concepts or suggest how to implement a project goal. By the time technical people become involved in most projects today, 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. Obviously, this is not conducive to creation of survival technologies, which must satisfy many diverse criteria.

Innovation being a one-person enterprise has other consequences, too. Although some individuals have generated significant innovations more than once, and in more than one specialty, innovation is inherently unpredictable. *One can never be sure from whom—or from where—a significant innovation will come.* A corollary is that significant innovation cannot be planned with any certainty which means, in turn, that it may or may not come from any one university or government laboratory funded and designated as a center for applied research in some crucial area.

Reasons for this unpredictability relate to the backgrounds of the technologists who develop innovative solutions. Often, someone trained in one special field may invent a technology traditionally considered to be part of a different discipline. Aside from what we might consider the disadvantages of not having trained in the target field, "outsiders" possess two significant advantages regarding their ability to provide an innovative solution to problems in the new field. Coming from a different technical or scientific background, they may possess different knowledge, *or be aware of a different approach* relevant to solving the problem at hand: they can "think outside the box." This is consistent with the most recent research on the process of innovation (Bower, 2008). In addition, they will not suffer from "the conventional way of thinking" of people trained in that particular field because they never went through the same training.

One of the most notable examples of this sort of innovation is Paul A. M. Dirac, who put quantum theory, one of the most significant advances in modern physics, on a sound theoretical and axiomatic basis. When he entered the field, Dirac was a mathematician much more than a physicist. In a somewhat similar, if not as grandiose a vein, one of us authors, who had no academic credentials or training in biofuels or any allied field, developed the concepts for carbon negative biofuels described above. Based on his background and training in a different field, he would never have been hired for work in biofuels research or development. His insight, in this case, had more to do with his knowledge of systems from technical areas quite different from biofuels than with his knowledge of chemistry, biology, or biochemistry.

Another well-known example of individuals who, based on their backgrounds and formal training, would never have been hired to work, in this case on aircraft development, were the Wright brothers. By contrast, the foremost "expert" in the developing field of aviation at that time was Samuel Langley, whose calculations for flight turned out to be incorrect.

Survival requires that we change the system so that significant innovations *from any source* can be safely revealed and verified, while aspects of the innovation with commercial potential are fully protected against their unauthorized disclosure to, or misappropriation by, others. Existing government-sponsored or university labs are unlikely to cooperate in this process without new incentives.

7. Finding the Skills and Organizations to Create First Round Survival Technologies

Iconic innovators like Alexander Graham Bell, Thomas Edison, Marchese Guglielmo Marconi, and George Eastman were *successful* one-man enterprises because during their time, few national markets and few large national corporations existed. Edison actually had the best of both worlds. A talented innovator in his own right, he had many assistants to carry out 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 often true today: administrative people with little knowledge of science and technology are in charge of, and frame research and development.)

During World War II, we saw a huge increase in applications of science and technology. Because the survival of Western democracies was at stake, engineers and scientists had significant freedom to develop the technologies that won the war. Some of the companies for which they worked, or their offshoots, would ultimately become major defense contracting firms.

During the postwar transition to civilian technologies and products, large numbers of innovators learned their skills within large United States' corporations. For example, one of us authors worked at Radio Corporation of America (RCA) at their Morristown, New Jersey, location, where color television was refined after CBS had introduced it on a limited basis in 1940. At that location, as much as 10 percent of the technical and scientific workforce developed general technological skills. They became "technologists," an under-recognized multidisciplinary specialty. These tech-savvy *generalists* initially learned their skills by bootstrap trial and error.

By the early 1950s, enough technologists worked throughout industry that workers learned technologist's skills by apprenticeship. Whether learned by trial and error or under the tutelage of established experts, characteristics of the work environment, long gone from today's organizations, enabled technologists to learn and pass on their skills. Principal among these were high quality development programs, a relatively small number of engineers and scientists doing the entire project, and working in an atmosphere that encouraged interaction among scientists and engineers so that each could extend their knowledge and understanding into the disciplines of others. This atmosphere enabled them to learn, among other skills, how to make practical (system) compromises among different elements of technology involved in the products, processes, or systems they were developing.

By the mid 1960s, this culture of technologist training was in decline because industries had instituted a new system of technology development requiring compartmentalization of knowledge—first begun in the defense industry as a protection against espionage. As compartmentalization became the norm in large corporations and government programs, the number of places where technologists could teach and learn their skills dwindled. In recent years, the number of defense contractors has decreased by a factor greater than ten; at the same time, companies have outsourced much commercial research and development to groups in foreign countries. America has lost the critical mass of scientists, engineers, and program architectures within which technologists' skills could be preserved. Because we could train fewer new technologists, the relevant skill set has become nearly extinct over time. The capacity to function *as a technologist* remains mostly in a small number of aging individuals, most of whom are now beyond retirement age. Fortunately, some of them have joined small high-tech companies in which some have developed survival technologies; we authors are part of this small group.

This disappearance of technologists greatly complicates the development and implementation of survival technologies. Such scientific and technical expertise as America retains is organized almost exclusively according to the *principle of specialization in which scientists and engineers know a single area of science or engineering in great depth or detail but have much less knowledge in other areas.* This leaves us nuclear physicists, solid-state physicists, and structural engineers, with relatively narrow specialties.

Specialization is simultaneously powerful and limiting in terms of the range of solutions that an expert in a any discipline is able to generate. When experts receive assignments of particular problems, the solutions at which they arrive usually fall within their area of expertise. If an *optimum* solution does not exist within that area of expertise, we end up with a less than optimum technology—not acceptable for survival technologies that must satisfy many diverse criteria.

Another disadvantage of specialization is that technologies based upon the specialization inherent in basic research can often take decades before they can be made practical—as far as survival technologies are concerned, we cannot wait that long. Specialization of knowledge, which originally gave civilization a jump-start, may now be one of the key factors that limits its advance or even brings it to a close, *if it prevents the timely creation and adoption of survival and first-round survival technologies*.

Creation of first-round survival technologies ideally calls for technologists who are generalists versed in many different areas of science and technology but who need not know any particular area to the same degree as an expert who specializes in that area would. Given today's dearth of technologists, the next-best solution might be a development program within which technical specialists can collaborate easily, informally, and often. Unfortunately, to the contrary, the culture and structure of most large, complex, multi-tiered organizations today make regular intercommunications among different work groups quite difficult if not practically impossible.

Today's organizations are missing three essential elements for creation of survival technologies:

(1) Technologists and members of management who possess the knowledge and skills needed to create survival technologies *and policies that allow them to be created*;
(2) Internal development programs organized in a manner that encourages the creation of survival technologies; and
(3) Institutional goals, mandates, and self-interests that promote creation of survival technologies.

Sometimes goals, publicly stated or implied (for example, in television commercials), are the opposite of the hidden agendas of large organizations. Some oil companies, for example, claim to be environmentally responsible while they cause significant environmental damage brought about by careless operation or extraction of oil and improper waste disposal in developing nations (Environmental News Service, 2005; Epstein, 2003).

Until recently, some corporations claimed in commercials that they were attempting to develop alternate energy sources. Their claims created an illusion of commitment to progress and falsely suggested that, if large corporations with their vast resources cannot accomplish the goal, no one can. This façade was recently shattered when Shell Oil Company sold its solar energy division during 2007 and positioned itself, along with virtually all other multinational oil companies, to extract oil from Canadian tar sands—a project shaping up to be one of the biggest environmental disasters that the planet has seen so far (Baker, 2007; Terry Macalister, "Big Oil Lets Sun Set on Renewables: Shell Has Quietly Shed Most of its Solar Power, while BP Is Buying into Dirty Tar Sands," *The Guardian/UK*, 11 December 2007; Cahal Milmo, "The Biggest Environmental Crime in History," *The Independent/UK*, 10 December 2007).

If large organizations are hostile to the creation of survival technologies, we might hope for better among small high-tech companies. Such companies are often set up to develop a technology after its invention, precluding the barriers erected by large organizations to creation of survival technologies. This is especially true if the small company retains the innovative technologists who invented the technology as influential members of the organization. Unfortunately, small companies are almost invariably unable to access capital sufficient to commercialize and successfully deploy their technologies. So long as the status quo persists, few places will remain in which survival technologies can be created and then deployed. We will return to this point.

8. Cases Studies

To illustrate the sort of survival technologies we have been discussing, let us examine a cluster of survival technologies developed and perfected in selected small, high-technology companies. We will discuss two technologies that we authors have developed and a third in which we have no financial stake but to which we have added an important feature—the ability to render some biofuels carbon-negative. We have chosen technologies with which we have first-hand experience to be able to accurately discuss the issues with regard to particular examples. The three survival technologies are as follows:

A particular process of microorganism-mediated production of cellulosic ethanol is the "new biofuel process" to which we alluded earlier in the chapter. Infinitely Renewable Energy, Inc., near Mac Allen, Texas, developed this process. It uniquely eliminates several fatal drawbacks of corn ethanol as a replacement for oil-based fuels and eases and potentially eliminates competition between using agricultural land for growing food crops versus biomass for making ethanol in addition to other objections to biofuels raised by the United Nations and other organizations.

In producing corn ethanol, the sugars and starches within corn kernels are fermented, but most of the rest 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. These, along with the naturally occurring sugars, are fermented into ethanol. Fewer plants are needed to make a given quantity of cellulosic ethanol; 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. Microorganism-mediated production does not use enzymes. This particular process of microorganism mediated cellulosic ethanol is also a low pressure and low temperature process able to use input of extremely small amounts of energy and a different microorganism for each step: to break biomass up into small pieces, to change cellulose into sugars, and, to ferment the sugars into ethanol. This process produces ethanol at a very low cost, approximately $.70 USD per gallon compared to well over $2.20 USD per gallon for enzyme (and other) cellulosic ethanol processes.

This process generates almost no pollution and, unlike other cellulosic ethanol processes, 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, even old newspapers. This process of ethanol production, because of the very low energy input required, has an unprecedented high energy gain of 11. Corn ethanol, at best, has an energy gain of 1.3 and it may be closer to breakeven since growing corn is energy intensive.

The additional step during the manufacturing process, which can produce ethanol that is "carbon negative" uses an existing "bubbler" device, consisting of transparent tubes exposed to sunlight and containing algae, can capture the large quantities of carbon dioxide that are produced during this (and other) biofuel manufacturing processes. The carbon dioxide is turned into solid carbon compounds within the tubes—within the algae—as the algae feed and multiply using photosynthesis to consume the carbon dioxide that is fed into the tubes. This algae technology is now being tested on a full-sized power plant to capture carbon dioxide emissions (Sheehy, 2005; MSNBC Staff and News Service, 2006; Paley and Oister, 2006; Bielli, 2007).

The carbon dioxide captured and turned into solid forms of carbon within the algae can be sequestered for millennia through deep ocean disposal of the algae from the bubbler after they die. Provided this sequestering is done, then a life cycle analysis of the growing biomass and changing it into ethanol shows that more carbon dioxide will be pulled out of the atmosphere by biomass photosynthesis than is put back by burning the ethanol. The steps are as follows:

Photosynthesis pulls carbon dioxide out of the atmosphere. Cultivating the biomass—to the extent that it requires the use of fuel and energy intensive material—puts some carbon dioxide back into the atmosphere. We thus grow biomass that requires little fuel or energy intensive material to cultivate. Fortunately, we can accomplish this in a practical sense while satisfying all other requirements.

The carbon dioxide from the fuel required to run the ethanol production process, along with the carbon dioxide produced by the process itself, is captured by the algae in the bubbler and permanently disposed in deep ocean. Finally, some carbon dioxide is returned into the atmosphere when the ethanol is burned.

Examining the inputs and outputs of carbon dioxide to the atmosphere, and permanent deep ocean disposal of much of it, more carbon dioxide is pulled from the atmosphere by biomass photosynthesis than is put back by burning the ethanol. The ethanol has been rendered "carbon negative."

A problem does exist in getting slow-falling algae to drop below the initial three thousand feet of ocean. Within this zone, up to half the algae are consumed and recycled, short-term, back into the atmosphere as carbon dioxide. To compensate, we propose to compress the dead algae (with a small amount of binder) and increase its aggregate density to a point greater than that of ocean water. (We can do this, if necessary, by simply adding stones to the compressed algae bundle.) Once the density of the bundle is greater than that of ocean water it will fall rapidly though the initial 3,000 feet of ocean with little consumption and recycling of the carbon in the dead algae back into the atmosphere.

We understand that we must also do studies of the environmental impact of this sort of carbon sequestration in the ocean so that we can make the improvements without dire unexpected consequences. But to ignore even the possibility of using this innovative approach is short-sighted foolhardiness.

The reduction of atmospheric carbon dioxide that accompanies manufacture and use of carbon negative biofuels has two sources. One is direct: The production and use of the carbon negative biofuels themselves. To the extent that carbon negative biofuels replace fossil fuels, we can also rid ourselves of the largest manmade carbon positive enterprise on earth, burning fossil fuels and their support technologies and industries (drilling, transporting, and refining oil; building pipelines and oil-drilling platforms and mining and refining that amount of metals that go into building them).

Because of the quantities of biomass required in the cellulosic ethanol production process, optimal manufacturing must take place within twenty miles of the biomass source, which minimizes transportation costs and the amount of energy required to transport it. The inherently local nature of the production process thereby minimizes the energy-input requirements and resulting amounts of carbon dioxide returned to the atmosphere.

Furthermore if suitable biomass crops can be locally grown, then both production and use of the ethanol can become local or nearly so, thereby further reducing the amount of carbon dioxide released into the atmosphere. Forage sorghum may be a suitable crop for cellulosic ethanol production throughout much of the United States, but if the preferred process of ethanol production is used, the crops can vary locally because of the ability of the preferred process to utilize a variety of biomass or even mixtures thereof.

The logistical significance of developing carbon negative biofuels cannot be overstated. An 80 percent reduction in manmade sources of carbon dioxide in the atmosphere will be required to keep global warming within limits humankind can tolerate. To accomplish that degree of reduction with continued use of fossil fuels would require capturing carbon dioxide at most of the places where fossil fuels are burned, a logistical nightmare. After capture, a practical, low-cost, energy-efficient technique must be available to sequester the carbon dioxide for millennia, either on-site or byf transporting it elsewhere for long-term disposal and sequestration. That would be energy intensive and constitute another logistical nightmare.

With carbon negative ethanol, the only place where carbon dioxide needs to be captured is at the manufacturing plants where the ethanol is produced. After that, this biofuel can be burned anywhere without capturing the carbon dioxide produced by burning it, yet a net overall carbon dioxide reduction in the atmosphere is effected.

A process of large scale, low-energy desalination produces fresh water at a cost of about 0.01 cents, USD per gallon, low enough so 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 plastic ion exchange membranes. That process is energy-intensive and the water it produces is thirty times as expensive as the process we have been exploring.

Airborne remote sensing of plant health can be accomplished due to a set of breakthroughs in the field of remote sensing from low-flying aircraft (flying at 3,000 feet), which could significantly reduce energy-intensive inputs to agriculture such as fertilizer, protective chemicals, and water, while at the same time enabling increased yields in some crops. Our advances in airborne sensors consistently detect, in their early and even pre-visible stages, problems such as nutrient deficiencies, crop diseases, insects and many other adverse conditions that degrade crop yield. The resolution of our detection equipment enables us to detect problem areas in the field as small as six feet in diameter. In response to weekly data gathering, field inputs can then be applied exactly where needed, only when needed, and often in far smaller quantities than the traditional whole-field application often done "blindly," today, according to a pre-established schedule. We had commercialized this technology for a time but could continue operation long enough to develop a sustainable market because the company was thinly capitalized.

These examples are typical of survival technologies developed by small companies that all suffer poor prospects for successful deployment related to lack of adequate capital to commercialize and deploy these innovations.

9. Why Small Companies Cannot Secure Funding: The Difficulties Non-Technically Trained Decision Makers Have Dealing with Technology

In the United States, unlike most of the rest of the world, newly formed small high technology companies, historically played a major role in bringing economically major innovative technologies to the marketplace—technologies such as air conditioning, the automatic transmission, stereoscopic sound, instant photography, and the photocopier. According to the United States Department of Commerce, two-thirds of the pioneering inventions made in the United States during the first half of the twentieth century came from individuals and small, high tech companies (Harvey, 1977).

Because non-technical, financial leadership lacks the knowledge to judge technological innovations developed by small companies , such companies command little inherent credibility among venture capitalists and other external decision makers—with the possible exception of companies one or more of whose principals is a researcher at a prestigious university. Consequently, the decision to fund a survival technology created by most small companies today usually hinges on non-technical decision makers attempting to evaluate a technology that they have no competence to evaluate.

There is usually no way around this lack of credibility. Most technologies do not function as simply or with an easily demonstrated result (such as a light bulb being switched on and off). For example, the technologist who created the microorganism-mediated ethanol process demonstrated it, with appropriate measurements, to non-technical potential investors on many occasions. Invariably they were either unsure of what it was they were viewing or they suspected deception. The company's business plan could not persuade them because it had meaning only if the technology was real and unflawed, precisely what they could not judge.

Readers may ask why potential investors do not hire someone with the proper technical knowledge to evaluate the technology for them. Over several decades, we have seen a person with the correct knowledge and experience to make a reliable judgment chosen only once. For an investor group to choose a person with the correct knowledge, its members must already know something about the subject to make a wise selection of a candidate. But prospective investors usually fear collusion when offered a list of individuals alleged to be capable of making a proper evaluation. If investors cannot be persuaded based on knowledge presented to them because they cannot understand it, and absent trust, then no way exists to assure potential investors that the conclusions drawn are valid.

Neither venture capital nor initial public offerings (IPOs) can fund small companies at the point that capital is required to move their technology toward initial commercialization. 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 the many millions of dollars required to do all that, simply to reach the point where it *might be considered* for venture capital? As a practical matter, IPO'S are available only to technology companies with *established* technologies, which exclude new survival technologies. Brokerages will not provide an IPO for a new technology that they cannot judge because these institutions are legally required to act as fiduciaries.

Other problems arise when decision makers try to deal with knowledge in which they are not well versed in the science they are evaluating: *Technology* solutions *proposed by non-technical decision makers are often improperly framed for creating survival technologies.*

As an example, 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 with the prerequisite knowledge realized that a more practical approach to this goal might instead be the exploitation of an appropriate natural process (such as the carbon-negative process we have described here). Knowledgeable critics found it impossible to communicate to Branson that although his goal was valid, he had framed the problem of atmospheric carbon dioxide capture and sequestration in a manner that rendered a practical technology to accomplish this goal unlikely. (One objection to machines on the scale required is that they would require input of significant amounts of energy thus producing unacceptable amounts of carbon dioxide when operated.) At one juncture, a lower echelon employee told us that, "It was Branson's money and he could spend it any way he wanted."

The current state of affairs in American industry is unlikely to result in survival and first round survival technologies because it has too many criteria that must be satisfied. But continuing to develop, manufacture, and deploy non-optimum commercial technologies and products uses up nonrenewable resources and contributes to pollution—one of the reasons we find ourselves in the present environmental crisis.

As another example of these difficulties, contrast the early commercialization of reverse osmosis membranes for water desalination by DuPont (Oklejas, Moch, and Nielsen, 1995), an excellent job of product development for its time, with our recent development of an alternative, very low cost, energy-conserving method of water desalination.

Someone at DuPont, probably in marketing, realized that if reverse osmosis films could be perfected, they could be used for large-scale desalination of seawater. DuPont would then have a new ongoing product to sell—membranes that periodically needed replacement that could not immediately be manufactured by competitors, because of DuPont's proprietary technology and the patents that it was likely to acquire.

This development required professionals with state-of-the-art knowledge of reverse osmosis films and backgrounds in inorganic, polymer, and physical chemistry, and other specified areas of expertise that were either hired or transferred internally to the project.

Large companies usually operate with no one presented the goal of large-scale desalination to engineers and scientists and asked them how they would achieve it. Management framed the desired solution, reverse osmosis films, before scientists and engineers got involved with the project.

By contrast, one of the technologists in our company proposed a process to achieve large-scale desalination in a simpler, much lower cost, and much more energy conserving way than DuPont's process. Unlike the way desired solutions are assigned with preconceived parameters to technical workers in large companies, our technologist asked himself the question "What is the best (sustainable, energy-conserving, low cost, and, having the least environmental impact) way to achieve large scale desalination?" By virtue of the creative process, this technologist's practical experience, and way of thinking, he developed in areas completely different from desalination and reverse osmosis, he devised a simple method based on quite old science that was practically feasible with only a slight modification to existing technology.

This alternate desalination technology meets our criteria for a survival technology because it requires input of very small amounts of energy per unit of water produced, at a cost low enough to use the water for irrigated farming. Unfortunately, our method may not be patentable and would not have established a marketing advantage based on proprietary expertise and patents for DuPont. It is also sufficiently simple that others can readily copy it. We will discuss patent issues later.

We cannot fault DuPont, fueled by the profit motive, as are all large companies, for discarding our method—had it been aware of it—when it chose to pursue the reverse osmosis solution.

The requirement for companies to earn a profit, in some cases, conflicts with the world's present need for survival technologies. In such cases, we have no institutions capable of carrying out their deployment. The example we have offered is not an isolated cases. When small high tech companies are able to create survival technologies, they usually do so in a simple but innovative manner because they lack the resources to do it in any other way.

Another factor, that postpones deployment of survival technologies, is *decision makers, who often view strong statements in areas that they do not understand, as being exaggerated.* Most of us are suspicious of extreme descriptions and strong conclusions because we usually believe them to be wrong or exaggerated; in most situations, the real world does not 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?

If true, for example, that we have fewer than ten years to do the things necessary to hold global warming within tolerable limits, then forceful statements are necessary to express the crisis and present its solutions. On the other hand, we can make such robust arguments with maximum impact only to those with the knowledge and background to understand the arguments. To others, including most of our technologically unknowledgeable leadership, forceful conclusions and strong recommendations in the areas of science or the environment may sound exaggerated. This, in turn, may limit understanding of the need for urgent, timely responses, such as deployment of first-round survival technologies.

Inability to understand technical data concerning environmental problems, together with short-term economic self-interest, may explain the behavior of those industrial and financial leaders who deny or downplay the consequences of global warming or continue to espouse the use of fossil fuels without requiring carbon dioxide capture and its long-term sequestration.

Non-technical management, and most United States leadership tends to allow and can effectively manage only those functions that it understands and with which it feels comfortable. One of us authors christened this phenomenon the "knowledge barrier" during the 1970s, when its apparent primary effect was economic. It was an important but a little recognized contributing factor to the loss of many American industries to foreign competition.

Consider, for example, the American 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—functions its postwar management understood and with which it felt comfortable. By contrast, executives whose initial backgrounds were in engineering and manufacturing headed foreign competitors like Toyota. The CEO of Toyota for many years, for example, was a world-class engine designer. In these foreign companies, practical innovation relevant to market share continued, such as mileage-enhancing hybrids.

The knowledge barrier regarding technology is ubiquitous. One of us authors sent a published paper on the practical consequences of microorganism-mediated cellulosic ethanol, that also contained a description of how to render this and some other biofuels carbon negative, to Albert "Al" Gore, Jr.'s office in Tennessee. The paper described the process as a carbon-negative, low-cost, practical replacement for all imported oil, compatible with existing infrastructure, and with no significant negative tradeoffs. The paper included a simplified version of the paper written for nonprofessionals that avoided jargon used in the field of biofuels. The author called one of Gore's assistants to flag the importance of the paper and request that it not be lost in the large volume of mail that they receive.

After receiving a form letter acknowledging receipt of the material but subsequently failing to hear back for several months, the author called again. He learned that they had already processed all mail beyond the date that they had received his paper. The author learned that his paper had been "thrown away" because they "had no one capable of evaluating it." (Gore, who also has no ability to judge these technologies, is now a venture capitalist making decisions about which environmental technologies to commercialize.)

We do not mean, by recalling this anecdote, to diminish Al Gore's commitment to sounding the alarm about the seriousness of global warming—for which he won the Noble Prize—but he, as most of our other political leaders, is unqualified to understand and choose correct solutions from those that are presented to him. It is but another illustration of our belief that not possessing technical knowledge also means that our political leaders cannot choose the right expert to explain the problems to them or recommend the proper actions. This is one of the reasons that American science policy is generally ineffective.

Many of the proposed so-called solutions for global warming we hear being touted to Congress nowadays are simplistic, improperly framed, incomplete, impractical, and would be only be marginally effective if adopted—occasionally (as described above) some may be destructive to the environment.

The grant and patent traps: Government grants were once useful for a small high-tech company 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 government departments handing over small companies' research results to multinational corporations "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 knowledge or technology.

Patents are also effectively denied to small companies that have developed survival technologies. Even though the patent office does not judge the validity of the science or technology involved in the patent application, patents are nevertheless a significant source of credibility to prospective investors. Unfortunately, recent changes in patent law make the process of applying for a patent extremely risky for any small company whose technology might threaten the markets of a large corporation or multinational corporation—including markets for survival technologies. Under the current process, review of patent applications by an examiner takes between six and eighteen months after the patent application is made. During that time, the application is posted publicly on the Internet where the stated date of invention is displayed. Any large corporation has the resources to create a false history of invention (predating the displayed date of invention) and jump the claim by applying for a patent that predates the first. To avoid misappropriation, small companies whose technologies might be detrimental to the markets of a large company or a multinational corporation are obliged to hold them as trade secrets and forgo pursuing patents that would make their technology more credible to investors.

Not being able to safely apply for a patent, in turn, prevents the small, high tech company from having its innovation published in a peer-reviewed journal, another source of credibility to investors. To publish in a peer-reviewed journal, the author needs to provide enough detail for experimental results to be replicated, thereby revealing the innovation.

One final factor can suppress technologies of small companies that threaten a multinational if they appear able to succeed in the marketplace; the multinational can sometimes purchase the small company. We know of one small biotech firm that recently developed an artificial version of high-density cholesterol. In early tests, it showed promise of being able to sweep 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 much more profitable than the new technique would have been, since patients must take statin drugs indefinitely. A manufacturer of one of the primary statin drugs purchased the smaller biotech company for twice its then-current value and never developed the new technique. For these and other reasons beyond the scope of this chapter, few institutions now exist that can develop and deploy survival and first-round survival technologies.

We have explored some of the reasons why impediments to creation and deployment of survival technologies exist, but we must not lose sight of the forest through the trees. The absence of a mechanism to objectively evaluate claims about survival technologies should serve as a warning that our present system of research, development, and deployment is dysfunctional and unlikely to fulfill our needs for survival.

10. Significant Barriers to the Deployment and Proper Use of Survival Technologies

Despite the importance of atmospheric greenhouse gas capture and sequestration, no profit motive is associated with technologies to accomplish it. Rendering biofuels carbon negative, for example, and then sequestering the carbon on a long-term basis, would add expense to biofuel production without providing additional profit. Therefore, we suspect that we will not see these innovations adopted unless the federal government finances or mandates them.

Even if we were to deploy survival technologies, we have no guarantee that they will be used in the intended way to promote survival without regard to profit motive. In general, when any technology is commercially successful, it is at risk for dissemination without limits and without regard to the effect it may have on the environment.

In some parts of South America, for example, the cheapest initial source of biomass for cellulosic ethanol production would be what remains of the Amazon rainforest. Similarly, forests and grasslands are currently and indiscriminately being cleared and turned into fields to grow biomass for conventional biofuel production, or to grow natural oils to blend with petroleum-based fuels to lessen air pollution when the fuels are burned. A recent study has shown that the net result of these activities is to increase the amount of greenhouse gases entering the atmosphere to a greater extent than if the acreage had never been cleared to grow biomass; use of gasoline was expanded instead (Juliet Eilperin "Biofuels a Bigger Climate Risk than other Fuels, Studies Say," *Washington Post*, 8 February 2008). No institutions currently exist that can prevent indiscriminate clearing of acreage for growing biomass and expansion of biofuel production to the point where it is environmentally destructive.

As another example, currently, a hole in the ozone layer exists around the South Pole, possibly due to the bootleg manufacture of chlorofluorocarbons (CFCs) in Mainland China for use in South America. We propose that international negotiators must address such problems as soon as possible if we are to survive, yet no institutions currently exist to address the problem.

Without a systems approach, piecemeal adoption of technologies and other solutions is unlikely to assure survival. Consider, for example, the recent development and likely dissemination of a battery /gasoline-powered hybrid, which require battery charging from a traditional electric power source. Half of all electric power generated in the United States, and more than half in China, comes from burning coal ("Industry Statistics," 2008). Only about one-third of the energy produced by burning coal is left by the time the electricity reaches the home or office to charge an automobile battery (Andrew C. Revenkin, "A Shift in the Debate over Global Warming," *The New York Times*, 6 April 2008). If the battery is 85 percent efficient—another 15 percent of the energy is lost at the socket in charging the battery—then 72 percent of the energy from burning coal is lost by the time that the car's batteries are charged. Put another way, each unit of energy used to charge the car's battery requires the generation of 3.6 units of energy by burning coal. If the car's batteries are only 75 percent efficient—a more realistic number—then each unit of energy used to charge the car's batteries require of 4.0 units of energy by burning coal.

If plug-in/gasoline hybrids become common, we would have to dramatically increase our use of coal to generate enough electricity to charge their batteries and build more electric infrastructure to deliver the additional electricity. This increased use of coal would dramatically increase our (and China's) output of carbon dioxide, which promotes global warming, increases airborne mercury, and increases sulfur dioxide that produces acid rain if high sulfur coal is burned.

To determine which technology is better for the environment and for our survival we would have to compare the total efficiency of each system starting with the mining of coal or oil, its transportation, refining] and its direct use in a conventional auto in the case of gasoline versus the conversion of the energy of burning of coal into electricity and its use to charge the batteries of the plug-in hybrid.

The building of fixed infrastructure such as oil pipelines or tankers or extra infrastructure to carry more electricity complicates the calculation. But these calculations are necessary before deploying any technology. Noting that the utilization of oil and coal cause pollution, and neither is a sustainable technology, we simply cannot afford to replace one with another that may be better but still not good enough with respect to environmental requirements and our survival. "Relatively better" is no longer good enough. The awful possibility exists that if we replace the use of much of our oil with coal (via the plug-in hybrid for example) that oil producers may sell the amount we save in this country for use elsewhere. Then, on a worldwide basis, we will not have reduced carbon dioxide emissions at all.

Most people appear to be unaware of these complexities. Several reporters and spokespersons for a national auto show, as well as NPR (National Public Radio) have reported this development as a way for the United States to become less dependent on foreign oil—which it is—and/or as also good for the environment (Abuelsamid, 2007; Kahn, 2008). Adding to the possibility of unjustified enthusiasm, California air quality regulators have ordered six major car companies to have 60,000 of these hybrids operating in California by the year 2014 (Kahn, 2008; "Plug-in Hybrid Cars Ready to Roll in California," 2008).

All of these institutions ignored, or perhaps were unaware, of how much the widespread use of plug-in hybrids would cost in our attempt to keep global warming within tolerable limits. This is a typical but crucial example of the technologically-illiterate-blind leading the blind. It illustrates why humankind's attempt to survive global warming must be a coordinated effort by those with appropriate knowledge who, additionally, represent no special economic or political interests.

Instead of a knowledgeable systems approach, we currently we have technology (and other recommendations) determined piecemeal by those with a particular economic or political agenda who often possess neither the knowledge to advance humankind's' attempt to survive climate change nor the assignment to do so.

11. A Proposal for Creating, Recognizing, and Deploying Survival Technologies and Enabling 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 fully correcting them before human sustainability is irreparably damaged is unlikely. As an alternative, we believe that, a most practical approach, given the time constraints, is to try to work around these impediments to buy precious time to develop more long-term solutions and funding sources to deploy them. We therefore propose formation of a not-for-profit 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, and new ones, created internally or in cooperation with other organizations. The mandate would extend to funding the initial commercialization of these technologies if no other sources of capital were available. The technology would be kept proprietary ("owned" by the innovator), with resulting technologies offered for use to all who can deploy them on the condition that they agree to observe control parameters approved by the institute regarding environmental requirements and constraints.
(2) Study the four major physical problems set forth in this article to specify practical, integrated ways of dealing with them—develop 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 proposed function would constitute "Humanity's Survival Lobby."
(4) Assist legislators and other leaders to hire technology aides to keep them abreast of new developments and to interface effectively with institute personnel.
(5) Serve a teaching role to make science and technology professionals and other interested parties aware of the criteria required for survival.
(6) Survival will require system changes. A single company, however, is usually unable to introduce all of the changes that are necessary. Thus, the institute would work with other involved groups to educate them concerning the changes requested of them, and, where applicable, show how the changes would enhance their profit margin.

How might we secure funding for such an institute? After Niels Bohr first described nuclear fission in 1939, immigrant scientiest like Leo Szilard and Eugene Wigner attempted to persuade the American government that this might provide the answer for a weapon that could defeat Nazi Germany. The government ignored their supplications until Szilard convinced Albert Einstein to sign a letter to Franklin Delano Roosevelt outlining the theoretical possibility of building the first atom bomb. At that time, the government was not in the practice of funding research, but Roosevelt released six thousands dollars to investigate the possibilities. This research became the Manhattan project, and the rest, as the saying goes, is history (Goldberg, 1995).

This precedent might furnish a template for obtaining seed capital. The apparent reason Einstein was successful where others had failed was his previously established credibility and renown. The institute would employ one or more credible academics from prestigious institutions to approach philanthropists to obtain initial funding for the institute.

Another route might be for a philanthropist to underwrite a demonstration project to commercialize one first-round survival technology. The long-range goal would be to have the institute become self-sustaining, perhaps through agreements obligating companies whose technologies it helps disseminate to make later contributions to the institute's financial support.

12. Summary and Conclusions

Whatever time we have left to keep global warming within tolerable limits, our response must take into account that human existence and much of the biosphere is at stake. Global warming is highly interrelated with three other major problems, any one of which, by itself, poses a significant threat to humankind. Therefore, if we are to err, prudence dictates that it be on side of caution regarding actions with the potential to keep 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. But our current systems discourage this; the entire category of skills required to create such multidisciplinary, first round innovations is on the verge of extinction.

As we have learned more about global warming in recent years, 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 never anticipated. One reason for these unpleasant surprises is the highly coupled nature of elements within the environment (and between the environment and the other three physical problems.) When one significant element of the environment becomes perturbed, it invariably affects others.

Because of this significant interrelatedness of these issues, the likelihood that adequate solutions will emerge in piecemeal fashion is slim. This is the most powerful argument than can be made to argue for an institute that can take a systematic approach to charting the integrated changes necessary for survival. The other argument is the need for an organization that can find a way around the impediments to creating or deploying survival, and in particular, first round technologies, in a manner that will promote survival.

The time for urgency—and action—is now. If estimates of only a short time remaining to contain global warming are accurate, then a systematic program for survival would be starting with precious little time left to achieve its goals.