Ⅱ. Lectures and Essays by the Winners of the Blue Planet Prize (2007-2011)

Professor Joseph L. Sax
Dr. Amory B. Lovins
Dr. Claude Lorius
Professor José Goldemberg
Professor Hirofumi Uzawa
Lord (Nicholas) Stern of Brentford
Dr. James Hansen
Sir Bob Watson
Dr. Jane Lubchenco
Barefoot College

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The Winners of the Blue Planet Prize

2007

Professor Joseph L. Sax (USA)

Dr. Amory B. Lovins (USA)

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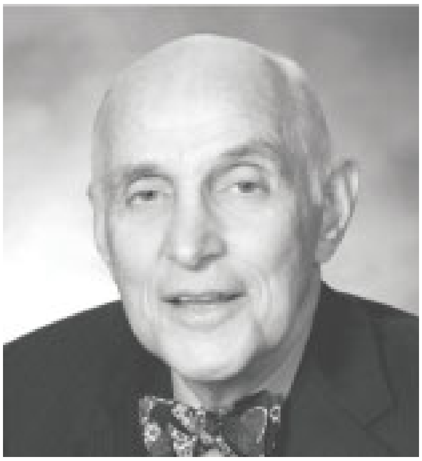
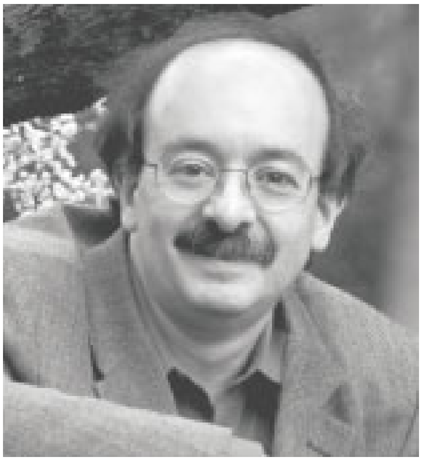
Blue Planet Prize

Professor Joseph L. Sax (USA)
Professor Emeritus,
University of California, Berkeley



Dr. Amory B. Lovins (USA)
Chairman and Chief Scientist,
Rocky Mountain Institute



SYMPOSION:
On this blue planet, The planet we live in Harmony of life so grandeur Plays the melody so deep in wisdom.

When have we human beings become so forgetful To listen to the wisdom of nature And negligent in caring for other lives. We a tiny member on this planet Needing care and affection, Became ignorant to join the chain of infinity To sustain to live together.

We hope this film Can play its part In reawakening people's awareness Of our planet, the blue planet That tells us the importance Of all the lives And to lend an ear To the tune of wisdom of nature.

Selected from the Slide Show Presented at the Opening of the Awards Ceremony

His Imperial Highness Prince Akishino congratulates the laureates

Their Imperial Highnesses Prince and Princess Akishino at the Awards Ceremony

Hiromichi Seya, Chairman of the Foundation delivers the opening address

Dr. Hiroyuki Yoshikawa, Chairman of the Selection Committee explains the rationale for the determination of the year's winners

Mr. J. Thomas Schieffer, Ambassador of the United States of America to Japan, congratulates the laureates

The prizewinners receive their trophies from Chairman Seya

Professor Joseph L. Sax

Dr. Amory B. Lovins

The prizewinners meet with the press prior to the awards ceremony

Blue Planet Prize Commemorative Lectures

Profile

Professor Joseph L. Sax

Professor Emeritus, University of California, Berkeley

Education and Academic and Professional Activities

1936	Born in Illinois
1957	A.B., Harvard University
1959	J.D. University of Chicago
1962-66	Professor of Law, University of Colorado
1966-86	Philip A. Hart Distinguished University Professor, University of Michigan
1976	Environmental Quality Award, U.S. E.P.A
1977	Elizabeth Haub Award, Free Univ. Brussels
1984	Wm. O. Douglas Legal Achievement Award, The Sierra Club
1985	Environmental Law Institute Award
1986-present	James H. House & Hiram H. Hurd Professor (emeritus), School of Law (Boalt Hall), University of California (Berkeley)
1994-96	Counselor to the Secretary of the Interior, Deputy Assistant Secretary of the Interior
2004	Distinguished Water Attorney Award

(As of June, 2007)

Professor Sax was born in Illinois, U.S.A. in 1936. After graduating from Harvard University, he earned the degree of Juris Doctor from the University of Chicago in 1959. He taught law at the University of Colorado from 1962 to 1966 and then he moved to the University of Michigan, where he became the Philip A. Hart Distinguished University Professor. He joined the Boalt faculty of the University of California at Berkeley in 1986, and at present is the House & Hurd Professor of Environmental Regulation, Emeritus.

In the mid-1960s, series of lawsuits were raised against pesticide spraying encouraged by Rachel Carson's "*Silent Spring*" although all lawsuits were wholly unsuccessful. Professor Sax observed that the laws themselves rarely contained environmental protections, and was drawn to the area and further engaged himself in the field of environmental law. In 1969, he learned of a lawsuit opposing the construction of an apartment building along the bank of the Potomac River in Washington, DC The basis for the suit was the public trust doctrine, and here he found the legal basis to advance environmental conservation causes.

Michigan Environment Protection Act which was adopted in 1970 and known as the "Sax Act" was drafted by Professor Sax and was groundbreaking in that it authorized environmental citizen suits and ensured standing in environmental litigation by stating "any person, partnership, corporation, association, organization or other legal entity may maintain an action in the circuit court for the protection of the air, water and other natural resources and the public trust therein from pollution, impairment or destruction." A primary feature of the law was its recognition that every person is legally entitled to the benefits of legal protection against pollution and other environmentally destructive activities, and that the courts were to be empowered to grant relief against such activities.

The "Sax Act" later became the model for similar statutes in more than a dozen other states.

In 1970, Professor Sax published "*The Public Trust Doctrine in Natural Resource Law: Effective Judicial Intervention.*" This landmark article argued that the U.S. courts has the authority and responsibility to prevent legislatures and administrative agencies from damaging, selling, or giving away environmental features, such as coastlines and wetlands, that were entrusted to the ownership of the people as a whole. More than any other work in the history of environmental law, this article has been cited countless times as the leading discussion of the public trust principle, and it has initiated an entire literature on the limits of governments in America to damage environmental resources held in trust for all people.

Professor Sax served as Deputy Assistant Secretary of the U.S. Interior Department and as legal counsel to the Secretary, Bruce Babbitt between 1994 and 1996, and internationally, he has been active and contributed in helping governments, and multilateral organizations (such as the U.N. agencies) improve the role of environmental law in contending with continuing ecological degradation, pollution, and diminishing water and natural resources stocks. He authored books on environmental law issues and is the author of about 150 law review articles. He has also published many magazine articles, newspaper essays, and reports emphasizing the need for improving environmental protection. He did more than write. He led the creation of the Environmental Law Institute, and the launch of the Environmental Law Reporter.

In seeking to explain the appropriate limits of private property, and the legitimate interests of the public, Professor Sax has in recent years sought to draw provocative analogies between the need to protect the natural world's treasures, and the well-accepted understanding of the need to protect cultural treasures, such as great works of art and historical and archaeological resources. He has therefore written about "cultural property" as another example of the need for a public trust concept, and to illustrate the importance of appreciating the limits of what can be claimed in the name of private property.

Professor Sax has been and still is the leading environmental law scholar in the United States and the world, and he has repeatedly created new legal innovations to expand the realms of environmental and natural resources protection laws, and has directly or indirectly influenced the ideas of scholars in many other countries. He has also been actively involved in public affairs as they relate to environmental protection and conservation issues, and contributed to the world.

Essay

An Environmental Agenda for Our Time

Professor Joseph L. Sax

Where do we go from here? If we are to make real advances in protecting the natural heritage that time has passed down to us, one central element of our agenda must necessarily be a re-conception of the meaning and content of landownership. A transformative legal change is required, and so long as courts and lawmakers, and the scholars who influence them, cling to the proposition, "what is the land but the profits thereof", we will not effect that transformation.

The need to re-conceive land law does not require a repudiation of the importance of using land to meet the needs and interests of human communities. So the question is what would an environmentally appropriate land system look like?

I suggest the following five approaches as an outline that can help move us toward a new way of thinking about land, landowners, and the public.

First, we have a theoretical legal precedent very close to hand that can be very helpful: the legal status of water. Nearly 100 years ago, the U.S. Supreme Court famously observed, "there [cannot] be said to arise any ownership of [a navigable] river. …Ownership of a private stream wholly upon the lands of an individual is conceivable; but that the running water in a great navigable stream is capable of private ownership is inconceivable." [1] The reason, of course, is that great rivers and the sea have always been understood to provide vital services that the community as a whole needed, and to which, therefore, the community as a whole must have an entitlement. The notion of the sea as common property traces at least back to Roman law, [2] and the idea that water as a vital resource cannot be privately owned but remains the property of the people, subject only to use-rights or usufructs. Water, since it is a vital resource, as the Supreme Court of Colorado observed as long ago as 1882, is governed by the law of "imperative necessity." [3]

As we now see land—in the context of climate change, as vital for biodiversity protection, as a continuum with other land and with its adjacent waters, rather than a collection of independent fenced squares—it looks much more like the waters that have earned universal recognition as incorporating an elemental public entitlement to which private uses must necessarily accommodate.

Second is the question what is need to assure that we do not continue to diminish biodiversity, to generate destructive rising sea levels, or to destroy a sustainable economy. But for a long time we believed—wrongly as it turned out—in the inexhaustibility of the globe's resources, and in a promise of technology to replace what was destroyed, a promise that it could not adequately fulfill. We also knew less once than we do now about resources such as wetlands (which we called swamps), and about the role of land as habitat, a word that was not even a part of our vocabulary until recent decades. What is new is our understanding that the existing system of laws about land and about ownership is not producing and protecting adequately what we need and are entitled to expect of it.

Third, the changes that are needed can and should be made in ways that facilitate the continued production of goods and services that are required to serve a prosperous human community. A first principle would be that the public holds an entitlement to the natural services provided by land, and that a landowner has no proprietary right to diminish or destroy those services, but that proprietary uses for human benefit are appropriate and lawful to the extent that they are compatible with minimization of loss of biodiversity, and with promotion of sustainable use of natural resources. This principle must underlie our system of land laws.

Fourth, we now know a good deal about how to shape land use to produce the goods and services we need, and simultaneously to protect our natural patrimony. There are many well-known practices that can and should be implemented in support of a land law suitable to an effective environmental agenda, and there is a substantial literature on the subject. [4] Among the most familiar practices are avoidance of development in wetlands, along shorelines, and in flood plains; identification and protection of wildlife corridors; identification of valuable undeveloped areas, and institution of land use practices that maintain such places to the maximum extent practicable, including clustering of development away from sensitive areas; forestry and agricultural management practices calculated to maximize sustainable use; restoration of mined areas to re-initiate natural services from those areas; and protection and restoration of instream flows and riparian areas. We know how to restore upstream eroded meadowlands to hold more spring waters, as an alternative to building new dams and reservoirs.[5] There are also well-established techniques for restoration of severely-altered ecosystems that can restore endemic species and, at least to a significant extent, natural processes—even in the most ecologically troubled places. [6]

In addition to restrictive practices, we should not hesitate to offer positive incentives to landowners to utilize environmentally appropriate methods—such as tax benefits and subsidies to encourage new practices that maintain or restore degraded terrain. Such incentives can be particularly valuable during transitional periods, and help to avoid unfairness or excessive burdens on owners who find themselves caught in transitional regulatory situations, using such devices as a more flexible and positive approach than using property doctrines to shape land use. [7] A mixture of public incentives along with regulation that incentivizes private actors to be innovative and to behave adaptively is the most productive approach.

Having said this, I want to emphasize the continued need for public funding to support and sustain restoration of already-degraded areas, the usefulness of private philanthropic purchases of critical tracts, and the central importance of public lands that embrace pristine or near-pristine areas, which, though not sufficient, have a vital role to play. Both extreme positions that only purchase of private rights, or only regulatory action without any payments or subsidies to landowners and water users are mistaken. We need both approaches.

Implementation of these approaches would go far toward encouraging disinvestment and non-investment by high-risk investors in sensitive areas, and instead encourage investment in lands and waters that can be utilized non-destructively.

Fifth, and finally, changing the rules is essential, but that change can only be fully effective as landowners move on to see themselves as custodians for the community, and for the future, as well as for their own benefit. This may seem a form of wishful thinking, but there is a parallel worth pondering, that of art collectors holding famous works who, though using the works for their own benefit and pleasure, also see themselves as participants in the safeguarding of a common heritage and routinely loan their property to public institutions, and make them available to students and scholars, so that they serve as private property imbued with a public interest.[8]

Moreover, there is no way to avoid a new way of thinking if we really intend to make biodiversity protection a serious goal of land use. If we look at land as habitat, we must then ask, who owns biodiversity? It's not a question our legal system is structured to ask. I suppose the answer is everybody and nobody. One way of thinking about it is as an unprotected common superimposed on privately owned land. We can all agree it's a good thing and it deserves as much protection as we can manage to provide it. We would then have to agree that its protection depends on the maintenance of adequate, viable habitat. And that such places consists very largely of privately owned land.

So we find ourselves in unfamiliar territory. There is something very important to us all collectively. But we don't own it. It inheres in, and depends on, something called habitat (which is also un-owned as such). Habitat inheres in land, which is owned, and which we have always believed owners could generally use as they wished, which largely involved destroying its value for that service. So it seems that the public has a legitimate stake in the way in which owners use land, even though the owner isn't doing anything that has traditionally been thought of as outside his private domain and therefore as unpermitted. These are thoughts honorable landowners will sometime have to ponder.

I close with two brief statements that I made in 2005 at the IUCN Academy meeting in Sydney in 2005:

First, "It is a chastening fact that the phrase 'rights of the public' is as rare as an endangered species in American environmental jurisprudence, as rare as the phrase 'rights of the private property owner' is commonplace."

And second, "That no one has a property right to destroy the benefits of a natural system" may seem obvious, yet its opposite has been the unarticulated watchword of the developmental economy's property system for some 300 years. It's time for a change.

References

1. United States v. chandler-Dunbar co. 229 U.S. 53,62,69 (1913); affirmed in United States v. Willow River Power Co., 324 U.S. 499, ___ (1945).
2. [cite Inst. Of Justinian].
3. Coffin v. Left Hand Ditch Co., 6 Colo. 443, ___ (1882).
4. E.g., Richard L. Knight & Courtney White, Conservation for a New Generation: Redefining Natural Resource Management (2009); Joshua H. Goldstein et al., Business Strategies for Conservation on Private Lands: Koa Forestry as a Case Study, 103 Proced. U.S. Nat'l. Acad. Sci. 10, 140 (2006); Stacy M. James, *Bridging the Gap between Landowners and Conservationists*, 16 CONSERV. BIOL. 269 (2002); Mari N. Jensen, *Can Cows and Conservation Mix?* 51 BIOSCIENCE 85 (2001).
5. Dana M. Nicholds, "Meadow Restoration May Be Inexpensive Method for Water Storage", Stockton, CA Record, Mar. 14, 2011. This is a project of the National Fish and Wildlife Foundation, a quasi-private

organization created by Congress.

6. In the U.S., a good example is California's Bay-Delta ecosystem. See, e.g., Ellen Hanak, et al, Managing California's Water: From Conflict to Resolution (Public Policy Institute of California, 2011), ch. 5, "Reconciling Ecosystems: Reversing Declines in Native Species". See generally, Michael Rosenzweig, Win-Win Ecology, "How The Earth's Species Can Survive in the Midst of Human Enterprise" (Oxford Univ. Press, 2003).
7. Joseph L. Sax,"Land Use Regulation: Time to Think About Fairness", 50 Nat.Res.J. 455 (No. 2, Spring, 2010).
8. I have tried to draw this parallel in a book entitled Playing Darts With A Rembrandt (University of Michigan Press, 1999).

Lecture

The Unfinished Agenda of Environmental Law

Professor Joseph L. Sax

The field of environmental law is young. Not even four decades have passed since the basic laws for protection of air and water, and for environmental assessment, began to be enacted in the industrialized nations. Obviously much has been accomplished in that relatively short time. Today I would like to talk about what remains to be done in terms of the law's role in safeguarding our environmental heritage. Before turning to that matter, however, and because many of you are not specialists in this field, I would like to make a few preliminary observations about the role of the legal system more generally.

The primary tasks of the law are basically three-fold:

(1) to establish rules to govern daily social intercourse in commercial areas such as contract, and to protect property and bodily security against unwanted intrusions;
(2) to replace anarchy and self-help with the rule of law; and
(3) to articulate and safeguard basic human rights in order to protect the individual against over-reaching by the state. In this latter category we find essential individual rights like free speech, freedom of religion, and basic protections for those accused of wrongdoing. More recently, there has been growing recognition of what are sometimes called positive human rights, such as the right to an education, to decent housing, to a living wage and healthful working conditions, and to basic medical care.

Where in this pantheon does one find the role of environmental law? In its formative stages, it developed primarily to bring certain traditional protections such as nuisance and trespass law to bear on hazards generated by modern industrial society. For example, though law had always protected the physical integrity of the individual against unwanted invasions, contamination of rivers and the ambient air presented new harms in new forms. Pollution was often caused by many different dischargers, and its damages frequently did not appear until many years later.

Traditional legal notions, such as causation and proof of harm, all had to be revised to take account of the complex nature of contemporary environmental contamination. Among these revisions, one of the most important was the recognition that a preventive strategy was necessary, since the law usually provided only money damages after harm had been done. This meant a need to set emission standards, to deal with scientific uncertainty about risk, and to engage with the perplexing issues raised by what is now called the "precautionary principle." The adaptations made to traditional legal concepts such as nuisance, to take account of these new elements, were among the first important achievements of environmental law.

But environmental law has also had to pioneer in another much less conventional area. The most familiar example is biodiversity protection. This problem does not arise in the form of an invasion of any individual's established legal right, and it does not involve any conduct traditionally viewed as wrongful. For example, farmers cultivating their fields to produce agricultural products may be destroying valuable habitat, and contributing to the decline in species diversity. Moreover, unlike health-endangering pollution, many people (even today) do not see diminishing biodiversity as a serious problem for the planet, and sometimes especially where obscure species with strange-sounding names are involved-do not perceive it as a problem at all.

When conduct involves neither familiar rights or wrongs, and presents no imminently obvious peril, controlling it presents a distinctive challenge for the legal system: How does one bring such a problem within the ambit of rights that people can understand, and that the system can accommodate.

As we began to grapple with issues like loss of biodiversity, we sought out a precedent based on something that has virtually disappeared from the modern world: the law of the commons[1], where everyone in a community had a stake, for example, in the maintenance of a forest's productivity for the collection of firewood, or for hunting, but no one bore individual responsibility for protecting the forests' continued capacity to be productive. In such settings, both the rights and the benefits were collective; they belonged to people not as individuals but as members of a community. Of course, commons were a feature of traditional societies, where people thought more of themselves as members of a community than as autonomous individuals. Moreover, in such relatively stable societies people knew what was required of them; they did what had been done traditionally, what their forbears did going back countless generations.

The maintenance or restoration of habitat is obviously a commons problem, but with some unique features in the contemporary world. For one thing, the land that comprises habitat is no longer held in common; it has been divided up into separately owned tracts. And the notion of common responsibility for maintaining productivity (traditional uses and limitations known to all, and incumbent on all) has virtually disappeared from our consciousness. In its place has arisen individually-owned property and the entitlements that go with it. And, of course, modern property law was devised not to assure the maintenance of biodiversity, but to promote productivity in the sense of maximizing the economic benefit that could be achieved by an individual proprietor.

The case of species loss is illustrative. Species require habitat. But habitat fits no conventional legal concept. Landownership bears no relation to the essential habitat of any species. Wildlife species are usually unowned and un-possessed, and endemic plant species are often competitors with more immediately profitable crops. Most species have no economic value to those who own the lands that are their habitat, though they may be of extraordinary value for research that ultimately generates important scientific and technological advances.
Moreover, indigenous species are often seen as obstacles to conventional land uses: wolves or bears as predators on domestic livestock; wetlands denizens as a problem for land filling and

development; prairie or forest as an impediment to modern agriculture.

This history has generated a particularly difficult jurisprudential challenge for modern environmental law. It has been obvious for some time that we were losing biological diversity at a rapid and increasing rate, and on a number of fronts. As rivers were dammed up for hydro power and for irrigation and municipal water supply, spawning grounds and habitat for indigenous species of fish were extirpated. The demand for wood products saw the decimation of forests, first in the temperate zones, and then in tropical areas. Mineral exploitation had similar impacts, and population growth and urban development, like agriculture before it, has converted vast areas of habitat, both uplands and wetlands, and generated a steady decline in biological diversity. All this, of course, is very well known. What is perhaps less well understood is how poorly prepared our legal system was to address these issues: we faced a commons problem in a non-commons world.

In an article some years ago[2], I noted that our laws relating to natural resources such as land and water have evolved over the past several centuries almost exclusively to promote what I called the transformative economy. That economy, I said, "builds on the image of property as a discrete entity that can be made one's own by working it and transforming it into a human artifact. A piece of iron becomes an anvil, a tree becomes lumber, and a forest becomes a farm. The law treats undeveloped land as essentially inert. The land is there, it may have things on it, or in it, but it is in a passive state, waiting to be put to use. Insofar as it is 'doing' something for example harboring wild animals or indigenous plants-the conventional law considers such functions expendable. Indeed, getting rid of the natural, or at least domesticating it, was a primary task of modern society. For most of the modern era, land and water have been employed essentially to end the existence of natural systems. Land has been fenced to exclude or extirpate wildlife so it could support domesticated grazing animals, agriculture, mining, and human settlements.

By contrast, any notion of the importance of protecting biodiversity builds on what may be thought of as the economy of nature, as contrasted with the transformational or developmental economy. In the economy of nature, land is not a passive entity waiting to be transformed by an owner. Nor is the world composed of distinct tracts of land. Rather the ecological perspective views land as a system defined by function, not by man-made boundaries. Land is already at work performing important functions in its unaltered state. Forests regulate global climate, marshes sustain marine fisheries, and prairie grass holds the soil in place. In the economy of nature, wetlands would be governed by laws based on their ecological role, not on lines drawn on a map. And their protection would be the responsibility of all those whose activities wherever carried on adversely affected them. If today we are seriously to protect what remains of our biological heritage, to restore degraded rivers and landscapes, and to redeploy forests to play a positive role in controlling human-induced climate change, we need a legal system that is as well-attuned to achieving those goals as the conventional legal system we have inherited was attuned through transformation of nature to achieving the goals of the industrial revolution.

This history helps explain why the law has had so difficult a time in dealing with the most profound of modern environmental problems, such as biodiversity protection and climate change. When it works best, law creates incentives that encourage people to behave in ways that promote society's goals. Our legal system structured on separately owned tracts of land was designed, and works efficiently, to achieve the goals of the transformative society: to produce houses and cars and wheat and steel, etc. It is quite ill-suited to meet the goals of an economy of nature, such as biodiversity maintenance and restoration. We have collective needs, but no collective rights. Moreover, as I shall illustrate shortly, the mentality of many of us, including lawmakers and judges, continues to perceive of the natural world solely through the lens of the transformative economy.

It is, of course, possible that the interest in protecting the services provided by natural systems could be protected by sovereign states outside the category of ordinary legal rights, and we have done that to some extent by setting aside parks, wildlife refuges, marine reserves, and wilderness areas. These were the primary techniques of the 19th Century conservation movement, and they continue to be necessary elements of any strategy for biodiversity protection, but they are demonstrably not sufficient. The vast majority of the world's land, including much of its most important and sensitive habitat, is in private ownership or control, and is vulnerable to private economic exploitation by owners whose conception of property rights and of ownership responsibility contains little or no notion of any common rights or of responsibility to the commons. In light of traditional concepts of landownership (and usufructuary rights in water as well), that is hardly surprising.

It is a sobering thought that while virtually every other interest that we consider vital has been made the subject of enforceable legal rights, our heritage of biodiversity stands largely outside the framework of established jurisprudential theory, and thus, except to the extent governments find it in their interest to act protectively, exposed to the ravages of human activity. We would not think of leaving individuals to the discretion or current policies of the government to safeguard their private property, or their contractual rights, or their inheritances. We view all these things as essentials and we have enshrined them as legal entitlements. They can be invoked even if government officials at a given time decided to take no initiative on their behalf. It is not that we do not, and should not, rely on public officials. It is simply that we should not rely solely on them; and where fundamental rights are in question, we never do rely solely on them. We want and need the state to be vigilant on our behalf, but we treasure our rights, and we know the value of being able to invoke the machinery of the law to protect those rights.

To be sure, the notion of rights held in common among us all that are real and serious enough to be as well protected as our individual rights, is not the way most of us are accustomed to thinking about what is "ours." If someone asked you to list your assets, in addition to your house and your bank account and your jewelry, you would not likely list the polar bear or the eagle, to say nothing of freshwater mollusks or primaeval forests, yet our biological patrimony is among the most precious of our assets. In the United States, we *do* think of places like our national parks as common possessions that belong to us and that we are entitled to have protected, but such publicly owned places embrace only a tiny fraction of the creatures, plants and habitats that constitute the stock of our remaining biodiversity.

The task of protecting adequately our remaining biological patrimony demands a robust development of the idea of common heritage, of things that belong to us as members of the world community, and that are entitled to protection at our behest in whatever particular ownership patterns they are held. As some of you know, I have written quite a bit in recent years about what is called "cultural property," such as great works of art, important antiquities, and objects of historical and scientific importance[3]. This has puzzled many people, who wonder what all this has to do with environmental law. The answer is that I became interested in studying cultural property because it has some of the same characteristics and presents some of the same problems of preservation and protection as does our biological inheritance.

We tend to think of things like the Parthenon Marbles or Old Master Paintings or the temple at Angkor Wat as part of our common cultural heritage, and to recognize that they need to be cared for and protected, regardless of their location or their formal ownership status. Many great works of art are in private collections, yet we expect them to be cared for, and ultimately to be made accessible to the public. The great English Monument of Stonehenge was once part of a private landed estate, but that did not make it any less worthy of preservation to humankind, both to present and future generations. Nor does national sovereignty or asserted national ownership, as in the tragic case of the Bamiyan Bhuddas of Afghanistan recently mutilated by the Taliban-bestow rights of neglect or destruction, a point that has been made against political iconoclasm at least since the destructive frenzies experienced at the time of the French Revolution[4]. The ideas, and the protective techniques, that have been established in the field of cultural property provide some useful precedents and analogies as we work to enlarge public understanding and to assure the safeguarding of our biological birthright.

The distinctive character of biodiversity, as I have noted in these remarks, presents a novel challenge to our legal system, not simply in the technical task of formulating laws, but even in understanding of the nature of the problem. A few moments ago I noted that the presuppositions of the transformative society were so dominant in the thinking of many that they made it difficult even to perceive the real nature of biodiversity issues. Several recent cases in the U.S. Supreme Court are depressingly illustrative of the problem.[5]

The case involved implementation of the Endangered Species Act[6], and the question was whether the environmentally concerned citizens who had initiated the case had a sufficient stake in the matter to be allowed to come to court. (The general principle is that I can only sue to protect some interest of my own, as where my contract is breached, or my property is trespassed on; and the question in this case was who had a sufficient interest in protecting an endangered species from illegal activities that were jeopardizing its continued existence, to sue to stop that activity). In this case, the justices characterized the sole legitimate interest of the public in the safeguarding of endangered species as "use," in the sense that people use the animals when they come as tourists to see and photograph them, or use them for scientific study. The Court refused to allow the environmental plaintiffs to seek enforcement of the endangered species law because they had not proven that they personally were going to re-visit the site where the animals lived in order to see them, and thus their personal "use" of the species was not being affected. This appalling misconception of what biodiversity is about, and what the stake of each of us is in that enterprise, is unfortunately demonstrative of how far we have yet to go.

Nor is the case I just cited as exceptional as one might wish. In another more recent case[7], a number of the Justices showed themselves unable or unwilling to see the scope of our water protection law in terms of ecological connections, and voted to deny protection under the law to wetlands unless they were physically adjacent to a river, apparently on some notion that wetlands are land, and not water, and therefore don't come within the ambit of a law designed to protect "the chemical, physical and biological integrity of [the] Nation's waters[8]." The opinion says it "rejected the notion that ...ecological considerations....provide[d] an independent basis for including entities like wetlands or ephemeral streams within the phrase "the waters of the United States." Whether decisions such as these are read as purposeful anti-environmental sentiment, or as a more innocent incapacity to see how modern environmental problems can be fitted into the pre-existing legal system, the conclusion is inescapable that the notion of a common heritage that vitally needs legal protection is still woefully under-developed.

Obviously, we cannot and should not simply replace the structure of the existing transformative economy, and its legal system, with a structure built solely on the restoration of natural systems. No sensible person wants to return to a state of nature. We need the positive benefits of the industrial and post-industrial economy, but our inherited legal structure cannot stand unaltered if we want to protect what we have, and to restore what we can, of our biological patrimony. There are many workable adaptive mechanisms that can produce a desirable level of protection and restoration. But we need a legal system that permits and promotes such adaptations.

One aspect of such a system requires an understanding of property rights as being adaptive to changing public needs and to new technological and scientific knowledge. This is well accepted at some levels. Everyone understands that if new knowledge demonstrates something to be hazardous to health, though it was previously a valuable property, it can no longer be used as it was previously. Industrial waste water, once discharged without control or limit, is a familiar example. That principle needs to be more widely appreciated. For example, as we have discovered the adverse impacts on fish spawning grounds of traditional water diversions for agriculture, industry and urban use, it must be recognized that there is no property right to destroy a fishery or other valuable aquatic habitat, even though that means a reduction in traditional economic uses.

This is simply one example of the proposition that a river is a common, and must be used to secure common rights in its productivity as an aquatic system, and isn't simply a source of private proprietary diversionary rights. The same sort of re-conception is possible in the context of forest management, or land development for residential and commercial use, if previously-recognized developmental rights are moderated to promote maintenance and restoration of habitat, and the duty to do so is acknowledged as a legally cognizable public entitlement.

While any such re-configuration of rights will necessarily require changes in the way business is done, and will sometimes be costly, we should not require such changes to be compensated. The reason is that we need a system that encourages human adaptation and ingenuity. The familiar precept that necessity is the mother of invention is a necessary component of a well-functioning legal system. For example when we articulated air emission standards as legal requirements, it stimulated the development of new technologies and new industrial practices. Often, it is possible to implement such transitions without serious adverse consequences to those who must undergo change. For example, in the arid western United States, where agricultural irrigation (which uses the great bulk of all the available water, averaging as much as 80%) must limit its diversions in order to restore instream ecosystem values, newly developed efficiency gains in the use of water, or shifting to less water-intensive crops, can significantly offset losses attributable to reduced diversions.

In either event, whether costly or not, property exists in a social context, and like all rights, its limits are described by the social exigencies of its time. For example, at one time married women could not own property; what they owned went to their husbands upon marriage, reflecting a societal view about women's status in society. When that value changed, we enacted what are called Married Women's Property Acts, which revised the property rights of husbands to their disadvantage. This same principle must govern contemporary societal values about the responsibilities of owners to protect our environmental heritage.

The need to revise our conception of rights in the earth and its waters in order to re-invigorate the conception of the world as a commons, and of rights held in common, has a long way to go before it can flower fully. So far, we have made just a modest amount of progress. The public trust doctrine, drawn from the ancient Roman law recognizing the sea and the seashore as the common inheritance of humankind, open to all for navigation and fishery, has been one of the most useful adaptations of traditional legal doctrines for bringing the notion of public rights and responsibilities into the modern era[9]. So far its application has been limited to waters, but the underlying principle will, I am confident, find even broader application. Two important contemporary cases in the United States are illustrative of the way the law needs to evolve if we are to get an adequate grip on protecting the natural values that constitute our biological inheritance.

In the first such case[10], the City of Los Angeles was diverting water for municipal use from streams tributary to a large lake known as Mono Lake, which is located directly east of Yosemite National Park in California. The result of these diversions was steadily to diminish the elevation of the lake, severely impacting its capacity to sustain its indigenous marine organisms, and its use as bird habitat. In response to concerns expressed that the enforcement of common rights under the public trust doctrine would either deprive a major city of its needed water supply, or simply drive it to another location where it might do even more harm, the government authorized the appropriation of funds to install a variety of water-conservation programs in the city, so as effectively to replace the lost supply by reducing demand. In the ensuring years, the elevation of Mono Lake has risen, and its biological values have been largely restored with no discernible adverse impact on Los Angeles. The case stands for the proposition that the natural values in the Mono Lake ecosystem are an entitlement of the public, and that any uses of the resources of that system, even though for a perfectly legitimate use, must be made in a way that respects the protection and sustained productivity of that system. Notably, nothing in the case suggests that absolute preservation is required, or that the system cannot be impacted by human use. The legal constraint is only that use must be made in a way that does not destroy the functioning ecosystem of the lake.

A more recent Hawaii case[11] is also illustrative of how common rights in the form of the public trust can be effectively implemented. Early in the 20th Century, in order to irrigate plantations on the dry (southern) side of the island of Oahu, tunnels were drilled through the mountains, and water diverted from streams on the northern (wet) side of the island. The result was harm to ecosystem values in those streams and to the traditional agriculture of Native Hawaiian people who lived near those streams. In recent years, as the plantations were retired, diversions through the tunnels were sharply reduced, and water again flowed in the streams. In a notable example of the resilience of natural systems (and, incidentally, of the positive potential of restoration efforts), there was a resurgence of life in the streams and revived opportunities for traditional agriculture. While those who had owned the use-rights in the water for plantation irrigation wanted to retain those rights, presumably for planned future residential development, an environmental case was initiated to restore ecosystem and Native values under the rubric of the public trust in water as a common right, rather than a merely private, perpetual property right. The Supreme Court of the State of Hawaii issued a most interesting and important decision recognizing public trust rights in Hawaii, and ordering the restoring of substantial flows to implement those rights. The case is of special interest because it not only elucidates the familiar public trust doctrine with its roots in Roman Law, but it sets out principles of traditional Hawaiian law that lead to similar mandates for restoration. In addition, the case is instructive because it shows that certain moments of opportunity arise (in this case the closing of the sugar plantations on Oahu) where environmental restoration can be effectuated without adverse impacts on existing economic activity.

These are just two specific illustrative instances of adaptive behavior mandated by the legal system, providing examples of the practicality of bringing about needed change in favor of biodiversity protection and restoration. Broadly stated, what we need is a more robust notion of common rights and responsibilities, legally recognized and enforceable, that we all hold as stewards of the earth, no less important than the effort we expend to protect our stock of common scientific knowledge, or our literary and artistic heritage. We need a more fully developed conception of land as habitat (and not solely as an object to be transformed and exploited for privatized benefit). Such changes call for an increased focus on land in terms of function, rather than in terms of boundaries. Such an approach is the antithesis of the perception I described earlier, in which it was thought important to decide whether a wetland is 'land' or is 'water'. And it is antithetical to the way in which some laws still formally treat surface water and ground water as separate legal entities, even when they are demonstrably elements of a single geo-hydrological system.

In addition, we need increasingly to come to terms with the need for proactive protective laws, as contrasted with the traditional legal practice of focusing on after-the-fact remedies. We have made some considerable progress in this respect in our modern air pollution and water pollution laws. But the urgent issues of climate change that are at the forefront of today's environmental agenda indicate how remiss we have often been in getting in front of problems before they reach crisis proportions. This is in part due to a traditional mind-set about the standards of proof needed to set the protective machinery of the law in motion, and our traditional use of the law largely to provide after-the-fact remedies. Whether it goes by the name of a precautionary principle, or of simple prudence in adapting away from the excesses of the transformative economy, these are the some of the vital tasks that remain before us. They constitute the unfinished agenda of environmental law.

I would like to end with a brief quotation from the American scientist Edward O. Wilson, who in my opinion clearly and elegantly sets out the nature of the task before us. He said[12]:

> "...it is reckless to suppose that biodiversity can be diminished indefinitely without threatening humanity itself.....The ethical imperative should therefore be, first of all, prudence..... We should not knowingly allow any species or race to go extinct. And let us go beyond mere salvage to begin the restoration of natural environments, in order to enlarge wild populations and stanch the hemorrhaging of biological wealth. There can be no purpose more enspiriting than to begin the age of restoration, reweaving the wondrous diversity of life that still surrounds us."

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Profile

Dr. Amory B. Lovins

Chairman and Chief Scientist, Rocky Mountain Institute

Education and Academic and Professional Activities

1947	Born in Washington DC
1964-1967	Harvard University
1967-1969	Magdalen College, Oxford, England
1968-present	Consulted for governments and the industries in the U.S. and worldwide
1969-1971	Junior Research Fellow, Merton College, Oxford, England Received a master of arts (M.A.) degree1971
1982	Co-founded Rocky Mountain Institute; currently Chairman & Chief Scientist
1982	Mitchell Prize
1983	Right Livelihood Award
1989	Delphi Prize
1993	Nissan Prize, ISATA; MacArthur Fellow
1997	Heinz Award for the Environment
1998	Lindbergh Award
1999	World Technology Award
1999	Established Hypercar, Inc. (Chairman 1999-2007), now Fiberforge, Inc.
2000	*Time* Heroes for the Planet Award
2001	Shingo Prize
2005	Jean Meyer Award
2006	Benjamin Franklin Medal and Life Fellow, Royal Society of Arts (London)
2007	Honorary Member, American Institute of Architects

(As of June, 2007)

Dr. Lovins was born in Washington, DC in 1947. From his high-school days, he showed talent in physics, music, classics and mathematics. He entered Harvard College, and transferred to Magdalen College, Oxford, England. He became a Junior Research Fellow of Merton College, Oxford in 1969, receiving a master of arts (M.A.) degree in 1971.

During his stay in the U.K., Dr. Lovins was fascinated by Snowdonia National Park in North Wales, and wrote a book about these endangered Welsh wildlands. Dr. Lovins then served for ten years as British Representative for Friends of the Earth. While taking interest in nature and environment, he became involved increasingly in energy strategy, initially through his research on climate. He wrote his first books on energy "*World Energy Strategies*" in 1974.

The energy crisis in 1973 drew more people to Dr. Lovins's ideas, and in 1976, he published a groundbreaking essay "*Energy Strategy*: The Road Not Taken?" It redefined the energy problem from "how to supply more energy" to how to provide just the amount, type, and scale of energy that would do each task in the cheapest way, and there he put forward the concept of the "soft energy path." The concept points out to a new system with efficient use of energy and the use of "soft energy technologies" based on such resources as solar, wind force, bio-fuel and geothermal heat. This is opposite to the "hard energy path" which points out to an existing huge centralized power generation system utilizing fossil fuel and nuclear power. He envisaged this approach as a "master key" to unlock the intertwined puzzles of energy, environment, resources, development, and security. Dr. Lovins suggested that soft energy paths are possible, profitable, environmentally benign, and supportive of fair global development without the hard path's prohibitive costs and risks.

The soft-path concept initially attracted huge criticism from traditional energy suppliers. But nowadays, efficient use and soft energy technologies are being adopted worldwide through competition in the marketplace, and it can be said that his pioneering views have been proven.

Dr. Lovins continued to write books and consulted widely to industry, and was active in energy affairs in some 15 countries as a policy advisor. He and his first wife L. Hunter Sheldon co-founded Rocky Mountain Institute in 1982 to foster the efficient and restorative use of resources. They built their home and the original headquarters of Rocky Mountain Institute, still one of the world's most efficient buildings. The essence of its construction is that in order to thoroughly utilize the solar heat, it uses high performance insulation and glass, and takes notice on the heat intake and prevention of its dissipation, and through integrative design optimizing the whole building as a system for multiple benefits rather than isolated components for single benefits.

Radical energy efficiency has always been a key goal at Rocky Mountain Institute, examining in great detail nearly every use and emphasizing the most important ones. In 1991, Dr. Lovins invented the Hypercar , integrating two known and demonstrated techniques in a radically simplified, software-rich vehicle design. Compared to then-existing cars, Hypercar-class vehicles could triple fuel economy with equal or better performance, safety, and affordability.

In 1997, the Lovinses and Prof. E.U. von Weizsaecker wrote "*Factor Four: Doubling Wealth Halving Resource Use,*" and in 1999, with Paul Hawken, the Lovinses published the book "*Natural Capitalism: Creating the Next Industrial Revolution.*" In 2004, Dr. Lovins published "*Winning the Oil Endgame*" which provided a detailed roadmap for eliminating U.S. oil use by the 2040s.

Dr. Lovins with his remarkable foresight has consistently proposed and implemented pioneering concepts since the 1970s in the energy field and many others. Inefficient energy use has created many economic and security issues and most of the world's environmental problems, so he has designed compelling technological, business, and policy innovations to solve them. At the same time, he has shown how to achieve a society where high energy efficiency and sustainable energy supplies can lead to a safer, environmentally healthier, climate-stabilized, and more rewarding future.

Essay

Applied Hope

Dr. Amory B. Lovins

The early bioneer Bill McLarney was stirring a vat of algae in his Costa Rica research center when a brassy North American lady strode in. What, she demanded, was he doing stirring a vat of green goo when what the world really needs is *love*? "There's *theoretical* love," Bill replied, "and then there's *applied* love" and kept on stirring.

Many of us here stir and strive in the spirit of applied *hope*. We work to make the world better, not from some airy theoretical hope, but in the pragmatic and grounded conviction that starting with hope and acting out of hope can cultivate a different kind of world worth being hopeful about, reinforcing itself in a virtuous spiral. Applied hope is not about some vague, far-off future but is expressed and created moment by moment through our choices.

Hope, said Frances Moore Lappé, "is a stance, not an assessment." But applied hope is not mere glandular optimism. The optimist treats the future as fate, not choice, and thus fails to take responsibility for making the world we want. Applied hope is a deliberate choice of heart and head. The optimist, says David Orr, has his feet up on the desk and a satisfied smirk knowing the deck is stacked. The person living in hope has her sleeves rolled up and is fighting hard to change or beat the odds. Optimism can easily mask cowardice. Applied hope requires fearlessness.

Fear of specific and avoidable dangers has evolutionary value. Nobody has ancestors who weren't mindful of saber-toothed tigers. But pervasive dread, lately promoted by some who want to keep us pickled in fear, is numbing and demotivating. When I give a talk, sometimes a questioner details the many bad things happening in the world, all the suffering in the universe, and asks how dare I propose solutions: isn't resistance futile? The only response I've found is to ask, as gently as I can, "I can see why you feel that way. Does it make you more effective?"

In a recent college class, one young woman bemoaned so many global problems that she said she'd lost all hope and couldn't imagine bringing a child into such a world. But discussion quickly revealed to us both that she hadn't lost hope at all; she knew exactly where she'd left it.

The most solid foundation for feeling better about the future is to improve it tangibly, durably, reproducibly, and scalably. So now is the time to be practitioners, not theorists; to be synthesists, not specialists; to do solutions, not problems; to do transformation, not incrementalism. Or as my mentor Edwin Land said, "Don't undertake a project unless it is manifestly important and nearly impossible." It's time to shift our language and action, as my wife Judy says, from "Somebody should" to "I will," to do real work on real projects, and to go to scale. As that early activist St. Francis of Assisi said, "Preach the Gospel at all times. If necessary, use words."

In a world short of both hope and time, we need to practice Raymond Williams's truth that "To be truly radical is to make hope possible, not despair convincing." Hope becomes possible, practical—even profitable—when advanced resource efficiency turns scarcity into plenitude.

David Whyte's poem "Loaves and Fishes" captures that goal thus:

This is not the age of information.
This is not
the age of information.

Forget the news,
and the radio,
and the blurred screen.

This is the time
of loaves
and fishes.

People are hungry,
and one good word is bread
for a thousand.

So with the world so finely balanced between fear and hope, with the outcome in suspense and a whiff of imminent shift in the air, let us choose to add the small stubborn ounces of our weight on the side of applied hope. As Zen master Gôtô-roshi put it, "Infinite gratitude toward all things past; infinite service to all things present; infinite responsibility to all things future."

This mission is challenging. It requires you to combine sizzle in your brain, fire in your belly, perseverance rooted like a redwood, and soul as light as a butterfly. According to the Internet, one Michael C. Muhammad said: "Everything works out right in the end. If things are not working right, *it isn't the end yet*. Don't let it bother you—relax and keep on going."

So in this tranquil but unwavering spirit of applied hope, let me tell you a story.

In the early 1950s, the Dayak people in Borneo had malaria. The World Health Organization had a solution: spray DDT. They did; mosquitoes died; malaria declined; so far, so good. But there were side-effects. House roofs started falling down on people's heads, because the DDT also killed tiny parasitic wasps that had previously controlled thatch-eating caterpillars. The colonial government gave people sheet-metal roofs, but the noise of the tropical rain on the tin roofs kept people awake. Meanwhile, the DDT-poisoned bugs were eaten by geckoes, which were eaten by cats. The DDT built up in the food chain and killed the cats. Without the cats, the rats flourished and multiplied. Soon the World Health Organization was threatened with potential outbreaks of typhus and plague, which it would itself have created, and had to call in RAF Singapore to conduct Operation Cat Drop—parachuting a great many live cats into Borneo.

This story—our guiding parable at Rocky Mountain Institute—shows that if you don't understand how things are connected, often the cause of problems is solutions. Most of today's problems are like that. But we can harness hidden connections so the cause of solutions is solutions: we solve, or better still avoid, not just one problem but many, without making new ones, before someone has to go parachuting more cats. So join me in envisioning where these linked, multiplying solutions can lead if you apply and extend what you've learned and take responsibility for creating the world you want. Details of this business-led future will be described this autumn in a book my team and I are now finishing, called *Reinventing Fire*.

Imagine a world, a few short generations hence, where spacious, peppy, ultrasafe, 125- to 260-mpg cars whisper through revitalized cities and towns, convivial suburbs, and fertile, prosperous countryside, burning no oil and emitting pure drinking water or nothing; where sprawl is no longer mandated or subsidized, so stronger families eat better food on front porches and kids free of obesity, diabetes, and asthma play in thriving neighborhoods; where new buildings and plugged-in parked cars produce enough surplus energy to power the now-efficient old buildings; and where buildings make people healthier, happier, and more productive, creating delight when entered, serenity when occupied, and regret when departed.

Imagine a world where oil and coal and nuclear energy have all been phased out, all vanquished by the competitors whose lower costs and risks have already enabled them to capture most of the world's market for new electrical services, energy efficiency, distributed renewables, combined heat and power and optionally by small amounts of advanced biofuels that use no cropland and move carbon from air to tilth; where resilient, right-sized energy systems make major failures impossible, not inevitable; where the collapse of oil's demand and price has defunded enemies, undermined dictatorship and corruption, and doused the Mideast tinderbox; where our advanced economy is no longer fueled at all by the rotted remains of primeval swamp goo and dinosaur droppings; where energy policy is no longer a gloomy multiple-choice test-do you prefer to die from (a) climate change, (b) oil wars, or (c) nuclear holocaust? We choose (d) none of the above.

Imagine, therefore, a world where carbon emissions have long been steadily declining at a handsome profit, because saving fuel costs less than buying fuel; where global climate has stabilized and repair has begun; and where this planetary near-death experience has finally made antisocial and unacceptable the arrogance that let cleverness imperil the whole human prospect by outrunning wisdom.

Imagine a world where the successful industries, rather than wasting 99.98% of their materials, follow Ray C. Anderson's lead: they take nothing, waste nothing, and do no harm; where the cost of waste is driving *un*natural capitalism extinct; where service providers and their customers prosper by doing more and better with less for longer, so products become ever more efficient to make and to use; where integrative engineering and biomimicry create abundance by design; and where elegant frugality turns scarcities and conflicts about energy, water, land, and minerals into enough, for all, for ever.

Imagine a world where the war against the Earth is over; where we've stopped treating soil like dirt, forests are expanding, farms emulate natural ecosystems, rivers run clean, oceans are starting to recover, fish and wildlife are returning, and a stabilizing, radically resource-efficient human population needs ever less of the world's land and metabolism, leaving more for all the relatives who give us life.

Imagine a world where we don't just know more—we also know better; where overspecialization and reductionism have gone from thrillingly fashionable to unaffordably foolish; where Darwin finally beat Descartes; where vision across boundaries triumphs, simply because it works better and costs less.

Imagine a world secure, free from fear of privation or attack: where conflict prevention is as normal as fire prevention; where conflicts not avoided are peacefully resolved through strengthened international laws, norms, and institutions; where threatened aggression is reliably deterred or defeated by nonprovocative defense that makes others feel and be more secure, not less; where all people can be nourished, healthy, and educated; and where all know Dr. King's truth that "Peace is not the absence of war; it is the presence of justice."

Imagine a world where reason, diversity, tolerance, and democracy are once more ascendant; where economic and religious fundamentalism are obsolete; where tyranny is odious, rare, failing, and dwindling; and where global consciousness has transcended fear to live and strive in hope.

This is the astonishing world we are all gradually creating together. It's being built before our eyes by many of you and a myriad other world-weavers. Brains, as Gifford and Libba Pinchot note, are evenly distributed, one per person. Thus most of the world's brains are in the South, half are in the heads of women, and most are in the heads of poor people. As an emerging global nervous system and millions of new civil-society organizations start to knit together that collective intelligence, the most powerful thing we know in the Universe-innovation and collaboration, are starting to overcome stagnation and squabbles. The search for intelligent life on Earth continues, but as we all strive to become much higher primates, some promising specimens are turning up just in time: each of you here today.

In their many ways, they're mobilizing society's most potent forces, businesses in mindful markets and citizens in vibrant civil society, to do what is necessary at this pivotal moment, the most important moment since we walked out of Africa: the moment when humanity has *exactly enough time, starting now*.

Each of you can choose to be one of those unusual people who with humor and courage, *chutzpah* and humility, eager enthusiasm and relentless patience are composing their lives and combining their efforts to make it so.

Here we are. And now imagine the power of *all of us together* to make it so.

Lecture

Profitable, Business-Led Solutions to the Climate, Oil, and Proliferation Problems

Dr. Amory B. Lovins

I appreciate the great honor of suggesting here some integrated and profitable solutions to three of the world's biggest challenges—climate change, oil dependence, and the spread of nuclear bombs—in the spirit of Raymond Williams's remark that "To be truly radical is to make hope possible, not despair convincing."

Until my "*Foreign Affairs*" article in 1976, the energy problem was generally thought to be where to get *more energy*-more, from any source, at any price, increasingly in the costliest and highest-quality form (electricity), made from depletable resources in ever bigger facilities. Instead, I redefined the energy problem around "end-uses"-the tasks that we want energy *for*, like hot baths, cold beer, comfort, mobility, cooked food, and smelted alumina. I asked how much energy, of what quality, at what scale, from what source, would do each end-use task in the cheapest way. This question reveals what happens when all ways to save or produce energy can compete fairly, at honest prices, no matter which kind they are (savings or supply), what technology they use, how big they are, where they are, or who owns them. Of course, that hypothetical world is far from today's actual energy policies in any country, but it remains a sound goal.

Slide 1* - The end-use/least-cost question led to a different answer about the energy future of, say, the United States over the next half-century. In 1975, all government and industry forecasts of U.S. energy use pointed to the upper right, along the red curve. I heretically suggested that this red curve could be flattened and then decreased, as in the dashed blue curve, by wringing more work from our energy-by substituting technology and brains for energy and money. That curve was within 4% of actual U.S. energy use in 2000, although the takeoff of "soft technologies"-diverse, renewable sources the right size and quality for their task-was delayed a quarter-century by largely hostile government policies that suppressed competition and even exported to Japan and Europe the fledgling solar industries that U.S. innovation had hatched. But now we can to do far better than my 1976 soft-path blue curve,especially in saving electricity and oil.

Slide 2 - Of course, there are many important differences between energy systems in America and Japan, most obviously in prices, climates, and land-uses. But in many key ways, the similarities seem to me more important than the differences. Energy intensity-the energy used to make a dollar of GDP-is two to three times higher in America than in Japan, due substantially to bigger houses and travel distances and to more and bigger appliances. In some uses,

* There are supplement slides *at the back of* the section.

especially in certain industries, Japanese industry is famously #1 in technical efficiency. But energy efficiency is improving much faster in America than in Japan, and some sectors in Japan, especially building, appear to be lagging. Japan is more conscious of the dangers of oil dependence, but America is catching up quickly. Of course, Japan never had its own oil resources; America had abundant oil, but its output peaked in 1970, has since fallen by half, to only two-fifths of U.S. supply; the rest is cheaper imports. Both countries have large and diverse renewable energy potential: Japan's is the largest per person of any major industrial nation. But this potential is badly underused and poorly understood in both countries. America's national energy policy is weak and fragmented (many states do far better); Japan's is strong and coherent but is less transparently formed and, as in America, sometimes reflects factional interests more than the national interest. Both countries have powerful engines of innovation-America's driven mainly by small businesses and independent inventors, Japan's mainly by giant companies and *keiretsus.* America's great strength is wildly diverse and chaotic entrepreneurship; Japan's is social cohesion and the wisdom of a long history. America's main energy weakness is its utterly dysfunctional national policy, but there are many ways to get around those roadblocks, mainly through the private sector. Japan's main energy handicap is the unfounded belief that the nation is poor in energy and can't become much more efficient than it already is.

Slide 3 - A new McKinsey study reflects the growing official realization that global energy efficiency can be greatly and profitably improved beyond its normal spontaneously achieved levels. The potential energy savings costing less than the energy they save can nearly pay for all the costlier ways to reduce greenhouse gas emissions. Thus reductions totaling 46% of the total emissions projected for the world in 2030 would have an average cost of only about two Euros, or ¥325, per tonne of CO_2-equivalent avoided. I believe this encouraging result is still very conservative because it understates the amount and overstates the cost of available energy efficiency improvements, some of which I'll summarize here.

Slide 4 - In Japan, a fascinating study is emerging from the National Institute of Environmental Studies thanks to support from the Ministry of the Environment. About 60 diverse experts have constructed two plausible scenarios for Japan in 2050-one busy and urban, the other more traditional, serene, and community-centered. Both are consistent with the basic assumptions of government policy; both have growing wealth and technology; both have an extremely high standard of living and, in their different styles, quality of life. Strikingly, both scenarios reduce national CO_2 emissions by 70% below 1990 levels.

Slide 5 - This is achieved through a mixture of better land-use or societal organization, returning per-capita steel and cement production to Western norms (they're now twice that high due to exaggerated infrastructure investments), and switching to lower-carbon energy sources and more efficient end-use technologies. The extra cost of all these improvements in 2050 is estimated at roughly ¥1 trillion per year, or about 0.1% of GDP at that time. This is already a very impressive and encouraging result. But I'd like to explore whether, even in already rather energy-efficient Japan, end-use efficiency might be improved *even more* than the assumed 24-41%, and at even *lower* cost than assumed, thus making even bigger reductions in greenhouses gases both feasible and profitable. If Japanese people can do this, then others who are now less efficient can save even more.

It may seem odd to talk about "profitable" climate protection, because the whole political discourse is about how this will be costly, requiring us all to forego wealth, crimp lifestyles, bear burdens, and make sacrifices. But climate protection is actually like the Hubble Space Telescope. How? Both got messed up by a sign error-a confusion between a plus sign and a minus sign. In fact, climate protection is *not costly but profitable*, because saving fuel costs less than buying fuel. Every practitioner understands this; only some politicians and journalists, and therefore many citizens, do not. But once they do, especially in the United States, political resistance to protecting the climate will melt even faster than glaciers.

Many companies do understand this, so whether or not they worry about climate change, they are buying energy efficiency just to make money. For example:

- Two of the world's biggest chipmakers have been cutting their CO_2 emissions by 6% every year by improving their factories, recovering their investments in ~2-3 years.
- DuPont set an ambitious goal to cut its energy use per dollar of output by 6% a year, switch toward renewable fuels and feedstocks, and cut its greenhouse gas emissions by 2010 to 65% less than in 1990. By 2006, DuPont was 80% below 1990 emissions and had made $3 billion profit by substituting efficiency for fuel.
- Dow made an even bigger profit by cutting its energy intensity by 42% in 15 years.
- BP met its operational carbon-reduction goals 8 years early at a net profit of $2 billion.
- General Electric has promised to raise its energy efficiency 30% in 7 years to enhance shareholder value.
- Interface, a carpet and textile maker, has cut its greenhouse gas emissions by 60% in a decade (an average rate of over 9% per year) at a third of a billion dollars' profit. By 2020, the firm intends to eliminate *all* waste and all fossil-fuel input. Already it has the industry's strongest, least oil-dependent cost structure and much stronger profits.
- Texas Instruments is commissioning a new chip fab in Texas, not China, because my team was able to help reduce its capital cost by $230 million, or 30%, while saving a fifth of the energy and a third of the water. The next design should save over 50% via two additional energy-saving methods.

So while politicians keep lamenting the "costs" of climate protection, such smart firms are racing to grab the profits before their competitors do!

Slide 6 - Yet the whole climate problem is caused by one percentage point. Here's what that means. Professor Youichi KAYA notes that how fast the global economy emits carbon by burning fossil fuel is the product of four terms: population, times per-capita GDP, times the rate of using primary energy per unit of GDP, times how much carbon each unit of energy supply releases. Economic theorists normally assume certain rates of change for these variables. Their net effect is a 1% annual increase in carbon emissions-enough to triple emissions by 2100. Those promoting their favorite forms of energy supply generally debate the rather small, green term showing carbon reductions per unit of energy. But the red term showing energy intensity-energy used per dollar of GDP-is normally assumed to change four times faster, even though that's only 1% per year. If we could double that modest pace, to 2% per year, it would offset population and economic growth, stabilizing global carbon emissions. If we could increase the rate of cutting energy intensity further, to 3% per year, we'd reduce carbon emissions and rather quickly stabilize the earth's climate, to the extent irreversible changes aren't already underway. So it is plausible that we could raise the world's energy productivity by 2-3% per year, whether by using energy more efficiently, making the mix of outputs less energy-intensive, or changing behaviors?

Some major countries already do this without even paying attention. The United States normally saves about 3% of its energy use per dollar of GDP each year; in 2006, that reached 4% per year, and total U.S. energy use went *down* 0.8% while GDP rose 3.3%. California generally saves energy about one percentage point faster than the whole United States-around 4% a year. China saved more than 5% a year for over 20 years, then nearly 8% a year for 5 years (until coming off the rails during 2001-06-this is now being fixed); energy efficiency is China's top strategic priority for national development, which otherwise becomes impossible. Attentive companies, some of which I've just named, routinely and profitably cut their energy intensity or even their absolute energy use or carbon emissions by 6-9% a year. So why should it be so hard for the world to achieve 3% a year? and since everyone who saves energy also makes money at it, why should this be costly?

Japan, having saved energy so inspiringly in the 1970s and early 1980s, then slowed down; the pace of saving energy per yen of GDP averaged only 0.7 per year from 1977 to 2004. The government's New National Energy Strategy calls for doubling that pace, and the National Institute of Environmental Studies' scenarios would speed it a little further, though nowhere near, say, the U.S. rate. Even so **[Slide 7]**, the equitable vision of "contraction and convergence," where all countries have the same carbon emission rights per person and everyone continues to get richer (especially in developing countries), could head for carbon reductions around 90% over the next century. Could that grand vision of a richer, fairer, cooler, and safer world actually be feasible and profitable? And could Japan lead the way?

Slide 8 - Some think not. *Yomiuri Shimbun* spoke for many when it remarked that "Japan's energy efficiency level is unlikely to improve much, since it is already the best in the world." Hmmm. Is that how Toyota thinks about making cars? Is it how Japan became such a mighty industrial power? Doesn't continuous improvement apply to energy as much as to manufacturing? Isn't Japan still the best in the world at this *kaizen*? As an admirer of Japan's scientific and technical genius as much as of its unique contributions to world culture, I believe Japan can lead this global leapfrog. And I know frogs leap also in Japan, because Bashô tells us so:

furu ike ya
kawazu tobikomu
mizu no oto

To see how this Japanese frog can leap ahead of the world, let's focus on oil and electricity, each of which is responsible for two-fifths of the world's CO_2 emissions.

First let's see where we're starting. Many of Japan's leading firms have already made impressive and exciting contributions to saving the climate: Toyota, Nissan, Honda, Ricoh, Kirin, and many more. But outside such pioneering companies, challenges have emerged.

Slide 9 - The per-capita use of electricity is the most important indicator of climate progress, because classical power plants use roughly three or four units of fuel to make and deliver one unit of electricity, and worldwide, most of their fuel is coal, the most carbon-intensive kind. Notice how, since 1965, the orange line, for Japan, has been rising about as steeply as the purple line, for Texas, or the green line, for the whole United States. There are many causes: strong industrial growth until recent years, a reversal of previously falling energy intensity in some big industries since 1990, a 45% increase in household electricity per person. That rise in turn is due to more and bigger appliances and to a huge increase in lighting, which operates for much longer hours in Japanese homes than anywhere else, partly because of long commutes. Meanwhile, too, houses became a little better insulated, but indoor temperatures, traditionally around 15 °C, rose even faster, the *kotatsu* gave way to bigger room heaters, and air conditioners to cool inefficient buildings continued to displace traditional architecture, attitudes, and customs.

Now compare the red line, California, where (as in New York State) the average citizen's total electricity use in all sectors is now slightly below that of the average Japanese person. In the past 30 years, while the average Japanese person's total electricity use doubled, the average Californian's total electricity use stayed flat even though her real income rose by 79%. Half of this dramatic efficiency gain came from strong and early efficiency standards for buildings and appliances. The other half came from rewarding utilities for cutting your bill, not for selling you more energy (as Japan and nearly all of the United States still do). Using electricity far more efficiently has saved California from building 65 billion watts of power stations, which with their grid investments would have cost upwards of $100 billion. Since Japan has 3.4 times more people than California, this implies that if Japanese people had held *their* electricity use flat for 30 years rather than doubling it, they wouldn't have needed tens of trillions of yen worth of electricity supply investments that help make Japanese electricity some of the costliest in the world.

Slide 10 - But don't those doubled-efficiency hybrid cars pioneered in Japan, not to mention those amazing Japanese mini-cars, make Japan a leader in oil efficiency? Not exactly. If we compare different countries' household vehicles (cars, vans, SUVs, and pickup trucks) using the same test procedures, we're surprised to find that in the late 1990s, the average Japanese light-duty vehicle became as inefficient as its American counterpart, pulling only slightly ahead in the past two years.

These broad facts, plus the technical literature and my decades of observations of how energy is used in Japan, suggest that there are surprising parallels between our two countries' potential for further profitable gains in energy efficiency. My team's very detailed studies and practical experience illustrate that potential to be in the United States.

There, if we fully adopted today's best efficiency techniques, we'd save over half the oil at a sixth of its price, half the gas at an eighth of its price, and three-fourths of the electricity at an eighth of its price. Implementing these radical efficiency gains would require extra investments equal to only one-sixth of the current direct price of the energy they'd save (at prices far below Japan's). This shift would also make energy cheaper, stabilize prices and keep them lower for longer, dramatically cut CO_2, enhance security, and buy time to learn more, choose better, and develop and deploy better techniques. While many details differ between the U.S. and Japan, I believe the Japanese potential for *percentage* reduction in energy use is not fundamentally different. The distinguished engineer KOMIYAMA Hiroshi-sensei, President of Tokyo University, agrees that about two-thirds of Japanese energy can be advantageously saved.

Slide 11 - To illustrate what can be done in buildings, which in Japan are particularly underinsulated, let's visit my own house, indoor farm, and office high in the Colorado Rockies at 2200 meters (7100 feet) above sea level. There we have seen temperatures as low as -44°C (-47°F), 39 days of continuous midwinter cloud, and frost on any day of the year. Yet if you come in out of the snowstorm into the central atrium, you're in a jungle where I've already harvested 28 banana crops and the new banana trees are growing 2 cm per day-and then you realize there's no furnace. The superinsulated house is 99% heated by the solar gain through the superwindows (which insulate as well as 12 to 19 sheets of glass, but look like 2 and cost less than 3), plus the heat from people, lights, and appliances. These heat-saving techniques *reduced* total construction cost by $1100, because they added less capital cost than I saved by not installing a heating system. I then reinvested that money, plus a further $6000-a net total of about ¥1900/m^2-in saving also 99% of the water-heating energy, half the water, and 90% of the household electricity. If I bought my home's electricity rather than making it with solar panels, it would cost only about ¥600 per month for 372 m^2. All these efficiencies together repaid their extra cost in ten months with 1983 technologies; today we can do much better.

In a hot climate, up to 46°C (115 °F), this ordinary-looking California tract house, with the obligatory stupid dark roof, was designed to use one-tenth the normal U.S. amount of energy. It provided excellent comfort with no air-conditioner, yet if built in quantity, would have cost about $1800 less than normal to build and $1600 less over time to maintain, because it had no heating or cooling equipment. Or in steamy Bangkok, architecture Professor Soontorn BOONYATIKARN built this modern house, at exactly normal cost, providing superior comfort with one tenth the normal amount of air-conditioning energy.

These three houses, spanning the range of the earth's climates, show how integrative design-getting multiple benefits from single expenditures-can make very large energy savings cost *less* than small savings!

Slide 12 - That sounds odd to economic theorists who believe in "diminishing returns": the more energy you save, the more and more steeply the cost of the next unit of savings keeps rising, until it gets too expensive and you must stop. Insulation does work this way. If, like most engineers, you buy only as much insulation as will repay its extra cost from saved heating fuel over the years, then you will have thin insulation and a big furnace burning costly fuel.

But if you remember to minimize *total* cost-construction cost as well as operating cost-then you'll discover a new part of the curve: **[Slide 13]** you can add so much insulation that you eliminate the whole heating system-furnace, pipes, pumps, ducts, fans, wires, controls, and fuel-supply arrangements! This makes the capital cost come down to *less* than you started with, just as my house saves 99% of its heating energy, at a lower construction cost than if I'd tried to save little or nothing.

Slide 14 - And rather than getting there the long way around, we can "tunnel through the cost barrier" directly to that design destination-*muda nashi* (no waste). (For details on how to do this, www.rmi.org/stanford posts my five new Stanford University lectures on advanced energy efficiency.) And this isn't just some magic we do in Colorado. Central and northern Europe already have more than ten thousand "Passive Houses" that are comfortable with no heating systems, with zero extra construction cost.

Surprisingly, we can tunnel through the cost barrier not only in new buildings but also in retrofits (fixing up old buildings) if we properly coordinate with other major renovations that are happening anyway, such as renewing the façade or the mechanical equipment. For example, in 1994 we designed a retrofit for a 19,000m^2 curtainwall office building in Chicago, which has both a hot and a cold climate. The 20-year-old window units had failing edge seals, so the whole curtainwall needed reglazing. But rather than replacing the dark heat-absorbing glass with the same kind, we found superwindows that would be nearly perfect in letting in light without heat. They'd admit nearly six times more visible light and a tenth less unwanted heat, and would block the flow of heat and noise 3-4 times better, at a slightly higher cost. But adding glare-free daylight distribution all the way through the building, plus very efficient and well-controlled lights and office equipment, would cut the peak cooling load by 77%. Then replacing the cooling system with a new one four times smaller and nearly four times more efficient would cost $200,000 less than renovating the big old system (for age and to eliminate its CFCs [chlorofluorocarbons]). That capital saving could then pay for the superwindows and the lighting and daylighting retrofits, yielding a 75% energy saving with a payback of *minus* five months-that is, a lower capital cost-compared with the normal 20-year renovation that saves nothing.

We can tunnel through the cost barrier not just in buildings but also in vehicles and factories. For example, a loop to pump a heat-transfer fluid around a factory was designed by a noted European engineering firm to use 70.8 kW of pumping power. A Dutch engineer using our methods reduced this by 92%, to 5.3 kW, at lower construction cost and with better performance, via two changes in design mentality that resulted in using fat, short, straight pipes rather than thin, long, crooked pipes. This is not rocket science; it's just Victorian integrative design rediscovered.

Slide 15 - I've offered you a pumping example because power plants release 40% of the world's CO_2, three-fifths of electricity runs motors, and pumps and fans, which have similar physics, are the two biggest uses of motors. If you feed ten units of coal into a classical power station, nine units get lost in the compounding losses of conversion, distribution, and then the motor and pumping systems. Only one unit of energy comes out of the pipe as flow. But if we reverse those compounding losses into compounding *savings*, then each unit of flow or friction saved in the pipe saves ten units of coal, climate change, and cost at the power plant. It also makes the motor about 2.5 units smaller (hence cheaper). All the upstream components become smaller, simpler, and cheaper. That's why we should always start saving at the downstream end.

Slide 16 - For example, often a big pump, meant to send fluid up a pipe, has an adjacent helper pump or identical in-place spare pump. They're drawn and then built so that the flow must always go through two 90°bends (friction) and two valves. A new design mentality could make the flow go through no bends and no valves (or one valve).

Slide 17 - When my colleague, engineer Peter RUMSEY, did this in retrofitting a pumping loop, his odd-looking piping layout saved 75% of the pumping energy and eliminated 15 pumps that will never again waste electricity and maintenance.

My team has lately redesigned more than $30 billion worth of facilities for radical energy efficiency. In motor systems, for example, 35 kinds of improvements can save about half the electricity (not counting any previous, and typically even cheaper, savings in the systems that the motor is driving, like pumps and pipes). But the cost is repaid within a year because you need to buy only 7 kinds of savings; the other 28 are free byproducts. We see similarly rapid returns when saving half the energy used to make chilled water and clean air in chip fabs. Whether we're retrofitting an oil refinery or platform, a naval vessel, a huge liquefied natural gas (LNG) plant, or a giant platinum mine, or designing a new Fischer-Tropsch plant, data center, chip fab, supermarket, two chemical plants, even a luxury yacht, we typically find that retrofits can save ~30-60% of the energy with a 2-3-year payback, while in new installations, we save more, generally 40-90%, and the capital cost almost always goes *down*. We have "tunneled through the cost barrier" in 29 diverse sectors of the economy-every one we've tried. Of course, none of this would be possible if the designs had been optimal to start with. I'm getting tired of retrofitting things that weren't designed right the first time. To get to the root of the problem, we must reform engineering practice and pedagogy fundamentally. I hope next summer to help leading practitioners write a casebook on *Factor Ten Engineering*, presenting in detail such vivid examples that they will irreversibly rearrange engineers' mental furniture. Our aim is the nonviolent overthrow of bad engineering. We warmly invite practitioners who think this way to share their most compelling case-studies via www.10xE.org.

Now let's turn to oil, whose burning releases 42% of the world's CO_2, and which has many other problems. (For example, two-thirds of Saudi oil flows through one processing plant that's already been attacked, and through two terminals of which the larger has already been attacked twice.) In 2004, my team published *Winning the Oil Endgame* (www.oilendgame.com)-an independent study, cosponsored by the Office of the U.S. Secretary of Defense and written for business and military leaders, for getting the United States completely off oil by the

2040s, with a much stronger economy, all led by business for profit.

Slide 18 - Rather than always rising, U.S. oil use (the solid red line) and oil imports (the dashed red line) could be turned down along the green lines by redoubling the efficiency of using oil-already doubled since 1975-at an average cost of $12 per saved barrel (2000). We could then turn down even more steeply along the blue lines by replacing the other half of the oil with saved natural gas and advanced biofuels such as cellulosic ethanol, all at an average cost of $18 per barrel. Thus the average cost of eliminating U.S. oil use is only $15 per barrel, or about one-fifth the current world price-assuming that the hidden environmental, security, and other costs of oil are worth zero, a conservatively low estimate.

Even faster oil savings are possible, because the U.S. actually achieved them when it last paid attention to oil. During the eight years 1977-85, America's GDP grew 27%, oil use fell 17%, oil imports fell 50%, and oil imports from the Persian Gulf fell 87%. (They'd have been gone in the next year if this had continued.) The world, including Japan, saved so much oil that OPEC's exports fell 48%, breaking the cartel's pricing power for a decade. We customers-especially in America, the Saudi Arabia of "negabarrels"-had more market power than the suppliers, because we could save oil faster than they could conveniently sell less oil. That was practice; this is real. Today we could re-run that old play much better, using our far more powerful technologies.

Suppose that by 2025 the United States invests $180 billion in the journey beyond oil-half to retool its car, truck, and plane industries, half to build an advanced biofuels industry. Suppose that the world oil price were then just $26 a barrel (2000) which might be true if we saved that much oil! But even against this low oil price, the $180 billion investment would earn a handsome net return of $70 billion per year. As a free byproduct, CO_2 emissions would fall 26%. America would also get a million new jobs (three-fourths rural) and could save a million jobs now at risk, mainly in automaking, where the choice is whether to continue importing efficient cars to replace oil or to *make* efficient cars and import neither the cars nor the oil.

Our study's competitive-strategy analysis for the car, truck, plane, fuel, and military sectors found a business logic so compelling that public policy need only support, not distort, the business logic. Rather than needing government to force us to commit unnatural acts in the marketplace, the profit motive could implement this off-oil transition without new energy taxes, subsidies, mandates, or national laws-though a compatible policy framework would speed the transition, and we did suggest new policies more effective and attractive than traditional ones.

Technologically, the key is transport, which uses 70% of U.S. oil. But making trucks, cars, and planes lighter-weight, lower-drag, and with advanced propulsion could triple their efficiency, with uncompromised comfort and performance and better safety, and repay the buyers' extra cost in 1, 2, and 4-5 years respectively at low U.S. fuel prices. Often performance would improve too, as in the Opel Eco-Speedster carbon-fiber diesel hybrid car that gets 250 km/h (155 mph) and 40 km/L (94 mpg), although not at the same instant! Surprisingly, the ultralighting that doubles the efficiency of these carbon-fiber concept cars doesn't raise their production cost, because the costlier material is offset by simpler automaking and a 2-3-times smaller powertrain.

Slide 19 - This opportunity emerges from the physics of a typical car. Each day it burns ~100 times its weight in ancient plants (very inefficiently converted to gasoline). But where does that energy go? Seven-eighths of it never reaches the wheels, but is lost first in the engine, idling, driveline, and accessories. Of the one-eighth that does reach the wheels, half heats the tires and road or heats the air that the car pushes aside. Only the last 6% of the fuel energy accelerates the car and then heats the brakes when you stop. But since only one-twentieth of the mass being accelerated is you-the rest is the car-only 5% of 6%, or 0.3%, of the fuel energy ends up moving the driver! After 120 years of devoted engineering effort, this is not very gratifying.

But there's good news. Three-fourths of the energy needed to move the car is caused by its weight, and every unit of energy we save at the wheels saves seven more units we needn't waste getting it to the wheels, so there's huge leverage in making the car radically lighter-weight.

Slide 20 - Traditionally this meant light metals like aluminum, which cost more but work well. I drive a 27-km/L (3.56 L/100 km, 64 mpg) Japanese aluminum hybrid car. New ultralight steels are starting to compete too. The strongest, lightest solution is composites reinforced by carbon fiber. This Mercedes *SLC McLaren* supercar, handmade for a half-million dollars, is made of such "advanced composites." It was hit by a VW Golf, which was totaled, but the *McLaren* only lost a side-panel, which they'll snap back on and fix the scratch later. At the front corners, under the hood, is a pair of 3.5-kg carbon-fiber crush cones that can absorb the entire crash energy of this car's hitting a wall at 105 km/h, because such materials in the right shapes can absorb 6-12 times as much crash energy per kg as steel, and do so more smoothly. Such light-but-strong materials let us make cars big (which is protective and comfortable) without also making them heavy (which is hostile and inefficient), so we can save oil, lives, and money all at the same time.

Of course, advanced composites' challenge is cost. They're used in military and aerospace applications at about a thousand times higher cost and lower volume than automakers need. But I became encouraged about bridging that gap when I met a young Lockheed-Martin Skunk Works engineer who had led the development of a 95%-carbon fighter plane that was one-third lighter, yet two-thirds cheaper, because it was optimally designed for manufacturing from carbon, not metal. It was so unusual that he couldn't find a military customer, so in due course I was able to hire him to do the same for cars, which we did in 2000 with two European Tier One auto engineering firms (www.rmi.org/images/PDFs/Transportation/T04-01_HypercarH2AutoTrans.pdf).

Meanwhile, a new manufacturing method for making cost-competitive advanced-composite automotive structures is being rapidly commercialized by a small firm I chaired; for example, this test piece for an ultralight helmet, tougher than titanium and able to withstand a sledgehammer, can be made in less than a minute. Cars made of similar materials would weigh half as much as today's steel cars, save half the fuel, be safer, yet cost the same to make. Making American cars this way would be like finding an inexhaustible Saudi Arabia under Detroit.

Here's the car we designed in 2000 that could be made with such a process. It's an uncompromised midsize SUV that can carry five adults in comfort and up to 2 m^3 of cargo, haul a half-ton up a 44% grade, accelerate 0-100 km/h in 7.2 seconds, yet increase efficiency by 3.6-fold to 28 km/L (3.51 L/100 km, 67 mpg) using a *Prius*-like gasoline hybrid powertrain. Such a car would have an extra retail price of $2511 (2000 $), repaying its extra cost from one year's fuel savings in Japan or two years' in America. Or if run on a hydrogen fuel cell, it would achieve 6.2-fold higher efficiency, 48.5 km/L (2.06 L/100 km, 114 mpg), and could compete one or two decades sooner than heavy steel cars. That's because needing two-thirds less energy, the car's hydrogen tanks would become small enough to fit and its fuel cell would become small enough to afford early. Most interestingly, such vehicles would have ~99% lower tooling cost than today's steel cars, would need no body shop or paint shop (the two hardest and costliest stages in automaking), and would need at least two-fifths less capital than the industry's leanest plant today.

Such gamechanging technologies make me wonder if U.S. automakers might use radical energy efficiency as a competitive strategy, much as Japanese automakers did in boldly introducing and then selling more than a million hybrid-electric cars and building up a formidable lead in that technology-in which GM was once 18 months ahead of Toyota but then stumbled. Such an American leapfrog, in airplanes, is now getting attention in Detroit. In 1997, Boeing was in a crisis much like Detroit's today. The Toyota Manufacturing System and other wrenching changes at Boeing Commercial Airplanes brought costs under control, but there was little viable innovation in the pipeline after the *777*. In 2003, Airbus outsold Boeing, and some serious analysts were starting to doubt Boeing's longevity. But in 2004, Boeing's riposte was the *787 Dreamliner*-one-fifth more efficient at the same price, 50% carbon-fiber composites by mass (up from 9% in the *777*), with many customer and operator advantages and with assembly time cut from 11 days to 3. It's now sold out into 2014. Its order takeoff has been the fastest of any airplane in history. Now Boeing is bringing those innovations to every commercial airplane it makes, before Airbus can even steer itself out of the ditch. This stunning success naturally makes U.S. automakers wonder: if you're in the ring with the world champion *sumo* wrestler, do you just keep training to become a little faster and stronger-or do you quietly shift the game to *aikidoh*?

My team is two-thirds of the way through an effort to make America's journey off oil irreversible, via "institutional acupuncture": we figure out where the business logic is congested and not flowing properly, and we stick needles into it to stimulate the flow. I think we're already past the tipping point-with much more work to do, but it gets easier from now on-in three of the six sectors we must influence. In aviation, Boeing's efficiency leapfrog has won, and will doubtless finance rapid development of even more efficient airplanes to make its lead unassailable. In heavy trucks, based on our analysis, Wal-Mart (the world's largest company) is requiring double defficiency trucks from its suppliers; that "demand pull" drags the trucks into the market where everyone can buy them, saving 6% of U.S. oil use (ultimately 8% with the next step-tripled-efficiency trucks). The U.S. Department of Defense is rapidly becoming the most important part of the Federal government in leading the country off oil, so ultimately they needn't fight over oil. Military leaders really like the idea of nega-missions in the Persian Gulf-Mission Unnecessary. There is also gratifying progress in the fuel and finance sectors: in 2006 alone, the "clean energy" space received $71 billion of new private investment.

Obviously the slowest and hardest sector to transform is automaking, but here too, progress is quickly accelerating. In 2004, our study proposed that Detroit follow Boeing's competitive strategy based on breakthroughs in ultralight materials, advanced propulsion, and integrative design. Two years later, Ford Motor Company hired the head of Boeing Commercial Airplanes, who had led that revolution, as its new CEO; he is now in Detroit with transformational intent. The United Autoworkers' Union and the car dealers are keen for such innovation to save their industry. The tsunami of "creative destruction" (as economist Joseph Schumpeter called it) sweeping over the global auto industry-plus emerging competition from India, China, and others-is now the greatest since the 1920s. It will change automakers' managers or their minds, whichever comes first: both Ford and Chrysler now have turnaround-expert CEOs from outside the auto industry. Indeed, my team currently has two transformational auto projects underway, one at an automaker level and one at a Tier One supplier level, and this spring, both surpassed expectations.

Japanese automakers' extraordinary achievements since the 1990s in commercializing hybrid-electric cars are just the first step. An excellent hybrid like Prius, properly driven, roughly doubles efficiency, much more if ultimately equipped with a diesel engine (if it can be clean enough) or its ~60% efficient successor, the "digital engine" first tested by Sturman Industries, a small Colorado firm, in January 2007. Making today's hybrid cars ultralight, with better aerodynamics and tires, can redouble their efficiency at no extra cost with highly integrative design. Fueling such "Hypercars " with 85% sustainably grown cellulosic ethanol or butanol and only 15% gasoline quadruples again their kilometers per liter of oil, reducing cars' oil use to $1/16^{th}$ the current level.

But then we can go further, beyond our oil-endgame analysis. For example, Toyota is to road-test in November 2007, and is rumored to be preparing to sell as early as Model Year 2008, a plug-in hybrid-electric car. Such vehicles could again at least redouble the efficiency of using oil, reduce carbon emissions, and require no new power stations. Moreover, a plug-in hybrid intelligently connected to the power grid when parked could exploit the "vehicle-to-grid" opportunity I invented in the early 1990s, selling electricity from its distributed storage capacity back to the electric companies when and where it's most valuable. This could justify utility financing for the costly batteries. Later, fuel-cell Hypercars could act as power plants on wheels, able when parked (~96% of the time) to earn impressive profits-for the first two million Americans to do so, roughly the whole cost of the car-by selling power back to utilities downtown on hot afternoons. This could readily put the coal and nuclear power plants out of business, since a full U.S. Hypercar fleet would have 6-12 times as much generating capacity as all the utilities now own. Thus Hypercar technology could end up profitably eliminating the majority of CO_2 emissions by addressing both their oil and electricity causes. But even without fuel cells, just biofueled plug-in ultralight hybrids could cut cars' oil use per km by 97%. Then hydrogen (and battery-powered pure-electric cars) could compete for the last 3% as well as for the biofuel market. Hydrogen fuel cells, practical and affordable when put in Hypercars, will reduce drivers' cost per km and will cut CO_2 per km by 2-6-fold, then become carbon-free with sequestration or renewable hydrogen.

Cars last about 14 years (except in Japan, where the government makes us scrap them prematurely), and planning and tooling new models takes years, so big automotive change is painfully slow. But U.S. automakers took only six years in the 1920s to switch from wood to steel autobodies, and at the start of World War II, converting all car factories to make war materiel took just six months. The last time the U.S. paid attention to oil, it cut oil intensity by more than 5% per year (like displacing a Persian Gulf's worth of imports every 2.5 years); the biggest saving came from a nearly 5% annual gain in the efficiency of new domestic cars-96% from making them smarter, and only 4% from making them smaller.

In recent years, Boeing has inverted the airplane industry's competitive ranking in just 2-4 years, with a breakthrough product a hundred-fold more complex and even more highly regulated than a car. General Motors's small team took the breakthrough *EV1* battery-electric car from concept to street in three years. Thus even big organizations can move quickly if the efficient new product is simpler than the inefficient old one. Of course, normal S-curve diffusion of new technologies normally takes 12-15 years to take the stock of product from 10% to 90% adoption, but the kinds of innovative competitive strategies and public policies we suggest in *Winning the Oil Endgame* can reach the 10% "takeoff point" three years earlier and then spread much faster.

Slide 21 - The oil industry views its global extractable resource base as a supply curve with rising costs. One trillion barrels have already been burned. The International Energy Agency says the world will need about that much again through 2030-about the amount that OPEC countries in the Middle East officially claim they can provide at a price far above the competitive free-market price of about $5-14 per barrel. After that, oil or its conventional substitutes become rapidly more difficult, remote, costly, and disagreeable.

Slide 22 - But if we add the savings and substitutes documented in *Winning the Oil Endgame*, conservatively scaled from the United States to the world, the whole supply curve slides three trillion barrels to the right, saving probably tens of trillions of dollars.

Slide 23 - Since resources like tar sands, oil shales, and coal-to-liquids are not only costly but also far more carbon-intensive than conventional oil, not using them also keeps more than a trillion tonnes of carbon out of the air.

Let me conclude with a few remarks about electricity-the other two-fifths of the CO_2 problem-and about Japan's unique opportunity to lead all these changes.

Slide 24 - With electricity at least as much as with oil, efficiency is a rapidly moving target. In the early days of exploring America's "negawatt" potential, 1984-89, the efficiency resource became twice as big but three times cheaper in just five years. Since then, it has become still bigger and cheaper, thanks to mass production (often in Asia), innovation, competition, and the pervasive effects of the IT revolution. Consider refrigerators, for example-the biggest user of electricity in most U.S. houses that don't use electricity to heat space or water. The electricity used by a new refrigerator soared until the first oil shock, partly because refrigerators kept getting bigger. They stopped getting bigger around 1980 so they could still fit through the door and into the kitchen. But meanwhile, California and then Federal efficiency standards quadrupled their efficiency, saving energy by 5% a year, while refrigerators also became 64% cheaper. Japan's recent progress (though under a different test procedure) has been even faster. And there's still room for improvement, as illustrated by the custom-made refrigerator I've used since 1985 and the Dutch state of the art in 2000.

Slide 25 - In the late 1980s, my team synthesized a decade of what is probably still the most detailed effort to assess how much electricity can be saved at what cost. Measured cost and performance data showed that fully applying ~1,000 efficiency technologies in new and existing buildings and factories could save ~75% of America's 1986 electricity use, at an average technical cost that in today's money would be about 1 U.S. cent per saved kWh. The North American utilities' think-tank, the Electric Power Research Institute (EPRI), found a somewhat smaller potential saving-only 40-60% by 2000-but still cheaper than the cost of just *operating* a coal or nuclear power plant and delivering its electricity. (Most of the differences between these two studies were due to methodology, not substance.) Our findings were also consistent with other studies in Europe. And as EPRI agrees, the efficiency technologies continue to improve in cost and performance faster than we're using them up, so saved electricity, or "negawatts," keeps on becoming an ever bigger and cheaper resource. The "low-hanging fruit" is mushing up around our ankles and spilling in over the tops of our waders while the innovation tree pelts our head with more fruit!

Slide 26 - A similar but even less visible revolution is happening in electricity supply: low- and no-carbon decentralized generators are eclipsing central thermal power stations. These graphs show the electricity produced and the capacity installed, both worldwide, for what *The Economist* magazine calls "micropower." Real data are on the left side of the vertical line, industry projections on the right. Micropower has two components:

- The tan wedge is combined-heat-and-power ("cogeneration")-making electricity together with useful heat. It's very efficient and about two-thirds gas-fired, so it saves over half the carbon emitted by the separate power plants and boilers or furnaces that it replaces.
- The colored wedges are all the renewable sources of electricity except big hydroelectric dams (units over ten megawatts).

Astonishingly, micropower now provides a sixth of the world's electricity-slightly more than nuclear power-and a third of the world's additions of electricity. Micropower in 2005 provided from one-sixth to more than half of all electricity in 13 industrial countries. These graphs don't show "negawatts," which are probably about as big, so together, micropower and negawatts now provide the majority of the world's new electrical services. Because they're mass-produced, quickly built and installed, and bought by millions of dispersed market actors, they're more like cellphones than like cathedrals, so they can grow very quickly. For example, in 2005 (the last full data available), micropower added four times the output and 11 times the capacity that nuclear power added worldwide (both net of retirements). Moreover, even though it gets smaller subsidies and faces bigger obstacles than its traditional competitors, micropower won investments of more than $100 billion of private risk capital-$56 billion just for the distributed renewables-while nuclear got none (it's bought only in centrally planned power systems).

The simplest explanation for micropower's marketplace victory over central thermal stations is that its lower costs and financial risks make it more attractive to investors.

Slide 27 - Let's test that hypothesis by examining the best empirical U.S. data on what it costs to make and deliver (or to save) a new kWh of electricity at the retail meter. We'll examine both remote resources, which incur a delivery cost to reach the customer, and onsite resources, which are already delivered. Your actual costs may vary, but I've done the analysis in a way that favors central stations. For those I used the canonical 2003 Massachusetts Institute of Technology (MIT) study, whose costs included whatever subsidies central stations then got, but not the reserve margin needed to back up those big plants when they fail.

The MIT study found that a new nuclear kWh would cost 7.0¢ to make (2004), so adding a deliberately low, decade-old average delivery cost for U.S. investor-owned utilities would bring the delivered cost to nearly 10¢. The MIT study said that huge new subsidies might, if everything went well, cut that cost by nearly 3¢, though a 2007 industry consensus group found the base-case cost has since *risen* by up to 3¢. Meanwhile, the MIT study found that a coal plant would cost slightly less than best-case nuclear power might achieve, though coal plants too have lately become costlier. Yet a big ($100/tonne) carbon tax could make the coal plant look nearly as costly as the nuclear base case, and similarly for combined-cycle gas-fired plants.

So policymakers keep juggling taxes and subsidies to try to get the market to choose what they want. But meanwhile the market is shifting away from *all* central power stations. For example, let's assume that windpower costs slightly more than the median for the past eight years' U.S. installations. Let's include its delivery cost too, of course, and add more than the actual cost of "firming" the windpower so it's fully dispatchable whether the wind is blowing or not. Even if we took away its Production Tax Credit, smaller than the subsidies to coal and nuclear, windpower would still beat their cost. But they're becoming costlier while wind turbines' cost trends downward, and indeed the cheapest windfarms already cost less than the industry projection for five years from now.

Generally cheaper still is cogeneration-whether it's the normal industrial kind, or "trigeneration" of electricity, heating, *and* cooling in a building, or cogeneration from recovered industrial waste heat. Cheapest of all is end-use efficiency, which typically costs 1¢/kWh or less for industrial and commercial retrofits, up to a few ¢/kWh if you're not as skillful or also retrofit houses, and if you're very skillful in new installations or even for many retrofits, less than zero.

Comparing all these ways to save or make electricity, we can see why investors are losing their old enthusiasm for central stations: they simply cost too much. But the cheaper alternatives also offer better climate solutions. For example, based on the MIT numbers, you can make and deliver one new nuclear kWh for just ten U.S. cents. That nuclear kWh can displace one kWh of coal-fired electricity, helping to protect the climate. But if you'd spent the same money on distributed renewables, cogeneration, or efficiency instead, you'd displace two to ten times as much coal-fired electricity, and you'd do so faster. If climate is a problem, we must invest judiciously, not indiscriminately, to get the most solution per ¥ and the most solution per year. Buying anything costlier and slower will only reduce and retard the climate solution we need.

Of course, there's always a risk that any energy investment will be failure, like a "dry hole" when drilling for oil. So what can we learn from actual market behavior? An encouraging example comes from California during 1982-1985, when all ways to make or save electricity could compete on a fairly level playing-field. During those four years, California's utilities bought or were firmly offered electrical savings and new decentralized supply (mainly renewables) totaling 143% of their total peak demand! The bidding had to be stopped, because in another year the power glut would have forced the shutdown of all the fossil-fueled and nuclear plants (which in hindsight might not have been such a bad idea). Thus letting everything compete will probably yield too many attractive options, not too few—all the more so with today's far more powerful and cost-effective technologies.

Those alternatives are also extremely large. For example, the U.S. potential for electric efficiency is 2-3 or 4 times nuclear power's output, but costs less than just *running* a coal or nuclear plant, even if building it costs nothing. Cogeneration can profitably provide a fifth of U.S. electricity from industry, still more from buildings. On-and nearshore windpower has a practical potential in the U.S. and in China that's over twice total electricity use; in Britain, six times; worldwide, using newer data at 80 meters hub height, about 35 times just from windy areas. Other renewables are even larger. And contrary to a widespread misconception, windpower and solar power don't need impractical amounts of land nor big investments in electricity storage. Diverse, dispersed, but variable solar power and windpower that are forecast and integrated into the grid will actually need *less* storage or backup than utilities have *already* installed to cope with the intermittence of their big thermal plants.

Slide 28 - Meanwhile, a wide range of renewable sources is getting inexorably cheaper, and many are also likely to show discontinuous, "leapfrog" technological progress like the red examples I've added to these U.S. Government projections. And decentralized resources' economic advantage increases by typically about another tenfold when their 207 "distributed benefits," mainly from financial economics and electrical engineering, are properly counted (www.smallisprofitable.org).

Even seemingly costly renewable energy also becomes often cost-effective today when properly integrated with efficient use. For example, a California prison installed 1.2 hectares of photovoltaics on its roof. But first making the roof white (to reject solar heat) and the jail's lights, fans, and air conditioners more efficient reduced demand, so on the hot afternoons when the solar cells produce the most electricity, the jail has the most surplus to sell back to the grid at the best price. Thus this $9-million project, of which the state reimbursed $5 million through subsidies, would have been very profitable even without them, because over 25 years, it yielded $15 million of benefits. The same logic becomes even stronger with distributed generators cheaper than photovoltaics, and at the scale of a house. My own household, using an average of about 120 watts, is entirely powered by 3m^2 of photovoltaics, which-installed with inverter and batteries-cost slightly less than connecting to the utility wires 30m away, even if the saved electricity were worth zero. Today's state-of-the-art technology could reduce my home's usage to only about 40 watts, powered by 1m^2 of photovoltaics, which would cost less than connecting to wires that were already on the side of my house and filled with free electricity. That is, an extremely efficient house can reduce to zero the breakeven distance beyond which it's cheaper to use solar power than to connect to the grid.

Thus efficient use, micropower, and substitutes for oil are all revolutionizing the way we get the services now provided by electricity and by oil. These profound market shifts are good for both climate and security. They profitably protect the Earth's climate, far faster and more effectively than other methods. Smarter choices can also free up huge energy investments to help finance other development needs. For example, building a compact fluorescent lamp factory in Mumbai or a superwindow coating factory in Bangkok needs roughly a thousand times less capital, repaid ten times faster, than supplying more electricity from central plants to run inefficient lamps and air conditioners to provide the same light and comfort. This ~10,000-fold reduction in the capital needed by the power sector, which now gobbles about one-fourth of global development capital, offers unique macroeconomic leverage for global development.

These innovations can also make energy no longer a source of conflict, corruption, and autocracy, but rather a powerful path to peace, transparency, and democracy. It can make today's brittle energy systems resilient, so major failures now inevitable by design (and easily caused by malice) become impossible by design. And taking seriously the verdict of the global marketplace can stop the main cause of the spread of nuclear bombs to such countries as Iran and North Korea. As I explained in *Foreign Affairs* magazine in summer 1980, civilian nuclear power makes widely available, in innocent-looking civilian disguise, the materials, equipment, knowledge, and skills for do-it-yourself bomb kits. But without today's big nuclear commerce, obtaining those ingredients would be harder, more conspicuous, and more politically costly, because the intention would *unambiguously* be to make bombs, not electricity. This unmasking would not make proliferation impossible, but would make it far more difficult and likely to be noticed in time, because intelligence resources could be concentrated on needles, not haystacks.

Both our countries' leadership right now is vital to global security. If the United States claims that despite all its wealth, technological prowess, and fuel resources, it needs nuclear power, it invites all countries lacking those advantages to draw the same conclusion. Conversely, if Japan, already the world leader in solar power and in some forms of energy efficiency, shows that despite having no fuels, its further efficiency potential and renewables could power its advanced industrial economy, then no other country could claim it cannot do likewise. Indeed, by offering wide access for developing countries to the same inherently nonviolent technologies we'd be adopting for ourselves, the U.S. and Japan could even return to the original purpose of Article IV of the Non-Proliferation Treaty-access to affordable energy for development. Our two nations, intertwined by fate in the only uses so far of these horrible weapons, could now join by choice to expose and penalize their proliferators. This would greatly lessen the risk that they will once again be used, while also helping fair global development and protecting the climate.

In short, using energy in a way that saves money can eliminate the supposed need to choose between dying by climate change, by oil wars, or by nuclear holocaust. All those choices are unnecessary and uneconomic.

So let me summarize how I see Japan's energy achievements and opportunities. Japan's industrial efficiency ranges from #1 in the world to more ordinary; even the best sectors and firms can make considerable further improvements. Japan's energy use in households and transport has more than doubled since 1970, including a doubling for trucks and more than a 6-fold increase for passenger cars. All the cars and trucks on the road have average efficiencies far below the best export models, so at least doubled efficiency is quickly and cheaply available. The biggest opportunities are in the rather inefficient stock of buildings, which need both mass retrofits and stronger efforts toward full adoption of highly integrated superefficient equipment and design. Japan is pioneering some excellent policy instruments, like "Top Runner," but it would be helpful to emphasize price less than ability to respond to price, via comprehensive barrier-busting. The most important reform would be to reward distributors of electricity and gas for cutting your bill, not for selling you more energy. And in a country obviously poor in fuels but astonishingly rich in renewable energy potential, the biggest barrier to fully exercising Japan's extraordinary opportunity for energy leadership is simply *not realizing* that the opportunities for efficiency and renewables are as large as they really are: more than large enough to power the whole country, more securely and more cheaply than present arrangements.

So what are we waiting for? *We* are the people we have been waiting for. And Japan is the leader the world is waiting for.

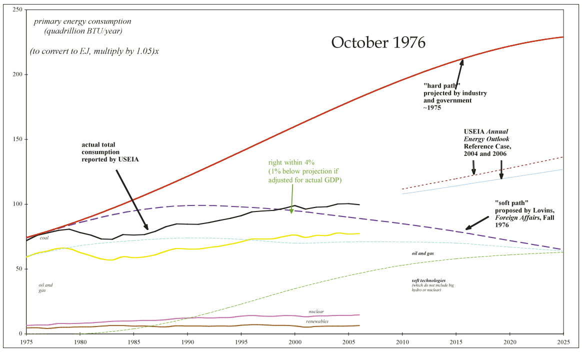
If anything I have said seems too good to be true, please remember Marshall McLuhan's remark that "Only puny secrets need protection. Great discoveries are protected by public incredulity."

It's your move.

Thank you for your kind attention.

Slide 1

U.S. energy/GDP already cut 48%, to very nearly the 1976 "soft path".



but that just scratches the surface. esp. for el. & oil savings

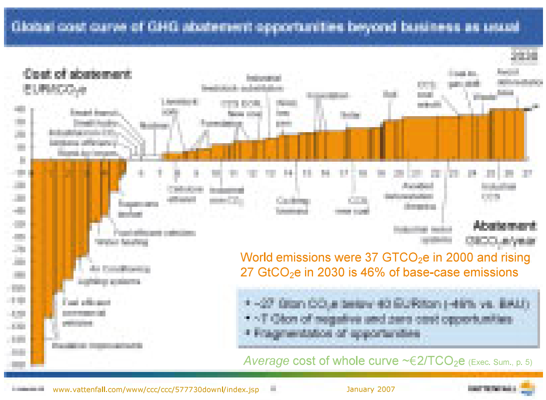
Slide 2

U.S./Japan energy: different prices; other similarities are more important than differences.

Attribute		
energy efficiency	Poor but +3–4%/y	better *but uneven*
oil consciousness	rising fast	high
oil resources	big, old, dwindling	none
renewable energy resources	huge, diverse, *badly underused* but rising	big, diverse, *largely unknown*
policy coherence	nationally poor, states often good	nationally strong, but mixed & opaque
tech. innovation	individualistic	corporate
main strength	entrepreneurial	cohesive
main weakness	dysfunctional, grid-locked national policy—but many workarounds	*belief* (not fact) that Japan is poor in energy and can't get much more efficient

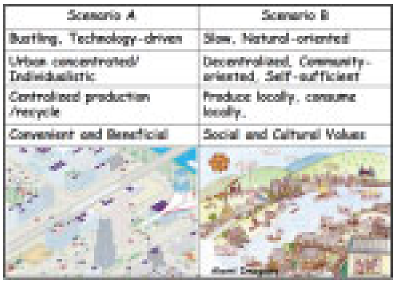
Slide 3

2007 McKinsey Global Institute (MGI) Potential for Abating Global Greenhouse Gases (Technically Very Conservative)



Slide 4

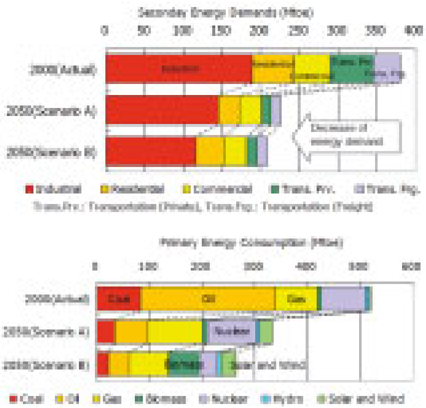
Two "Different but Likely" Japanese Societies in 2050



"Japan has the technological potential to reduce its CO_2 emissions by 70% compared to the 1990 level, while satisfying the expected demand for energy services in 2050."

Slide 5

NIES 2050 Japan Energy Scenarios



Slide 6

The climate problem is caused by one percentage point.

The "Kaya identity" (Kaya Youichi-sensei) shows that:

Emitted CO_2/y = N × GDP/N × $\dot{E}_{primary}$/GDP × C/$E_{primary}$

1990–2100 %/y: +0.69 +1.6 −1.0 −0.26 = +1.0

That +1%/y causes C growth from ~6 to ~20 Gt/y

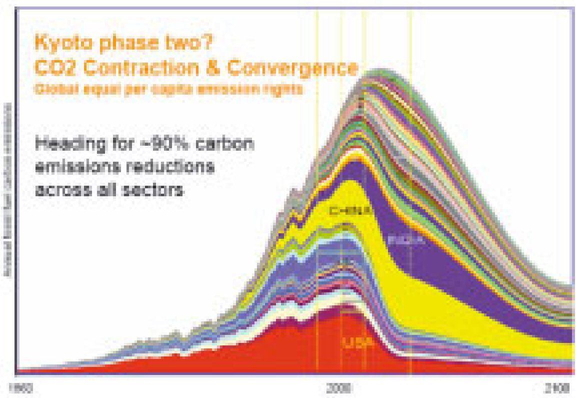
Supply-siders debate the −0.26%/y (no-C energy) term

But let's examine the 4× bigger energy-intensity term…
because *−1%/y → −2%/y flattens CO_2 emissions* (or saves ~30 TW of no-C supply required for 550 ppm), and reducing energy intensity slightly faster, say 3%/y, would stabilize Earth's climate…still at a profit

So how plausible is a 2–3%/y, or even faster, reduction in energy used per unit of GDP?

Slide 7

So could the vision of contraction & convergence be feasible and profitable?



Slide 8

An All-too-common Belief

"Japan's energy efficiency level is unlikely to improve much, since it is already the best in the world."

—*Yomiuri Shimbun*, 7 January 2006

But doesn't *kaizen* apply also to energy?

Isn't Japan still the world's best at *kaizen?*

Japan can lead this global *hiyaku* (飛躍)!

Japanese frogs jump too!

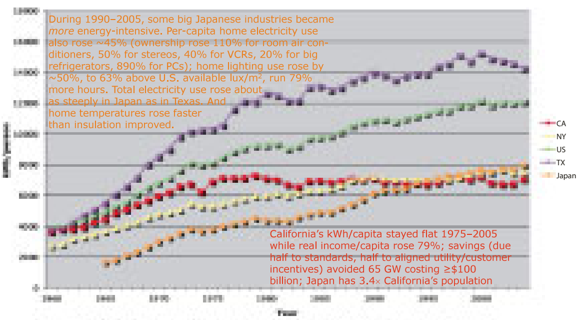
The old pond
frog jumps in
plop

—*Bashô*

Let's see how, focusing on oil (42% of global CO_2 emissions) and electricity (40%)

Slide 9

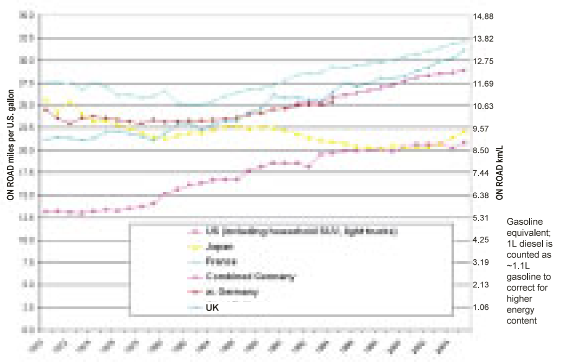
Per Capita Electricity Consumption



Source: EMBARQ, the World Resources Institute (WRI) Center for Sustainable Transport (Dr. Lee Schipper, Director of Research), from official data sources

Slide 10

U.S. cars & light trucks were long the least efficient, but Japan's have become similar.



Slide 11

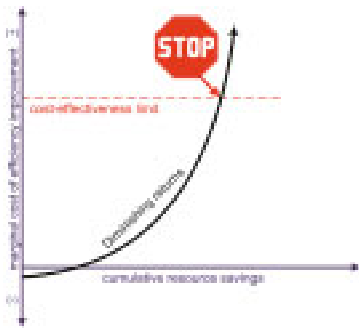
– 44 to + 46˚C with No Heating/Cooling Equipment, Less Construction Cost

- Lovins house / RMI HQ, Snowmass, Colorado, '84
  - Saves 99% of space & water heating energy, 90% of home el. (372 m² use ~120 W_{av} costing ~\$5/month @ \$0.07/kWh)
  - 10-month payback in 1983
- PG&E ACT², Davis CA, '94
  - Mature-market cost –\$1,800
  - Present-valued maint. –\$1,600
  - 82% design saving from 1992 California norm, ~90% from US
- Prof. Soontorn Boonyatikarn house, Bangkok, Thailand, '96
  - 84% less a/c capacity, ~90% less a/c energy, better comfort
  - No extra construction cost

Key: integrative design—multiple benefits from single expenditures

Slide 12

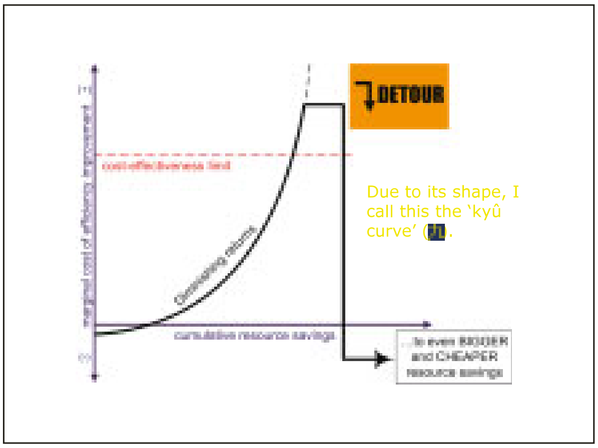
Old Design Mentality: always diminishing returns…



Slide 13

New Design Mentality:

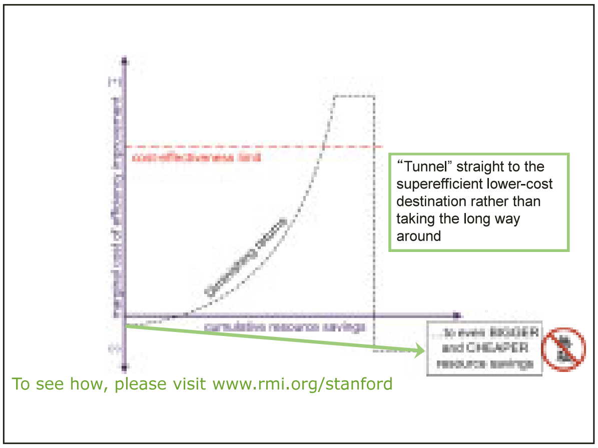
Expanding Returns, "tunneling through the cost barrier" 1



Slide 14

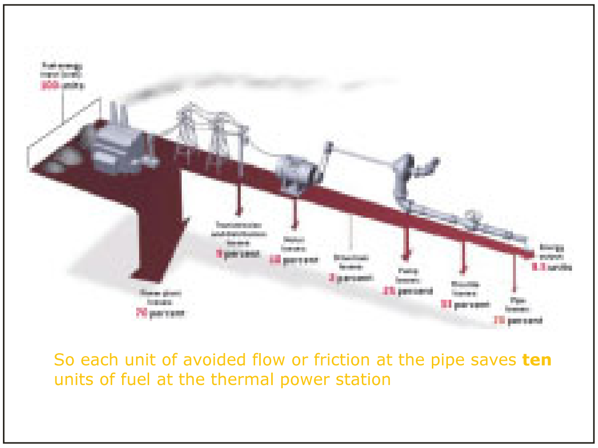
New Design Mentality:

Expanding Returns, "tunneling through the cost barrier" 2

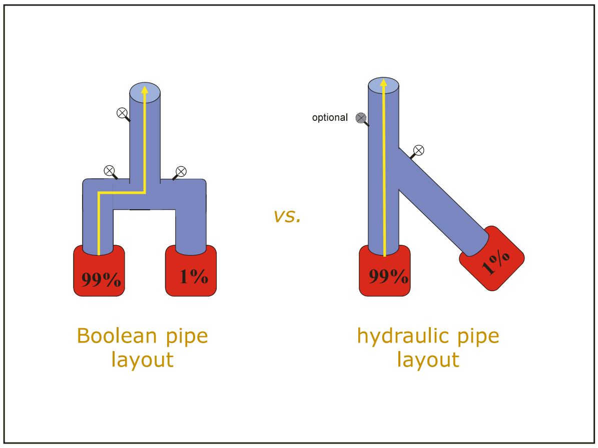


Slide 15

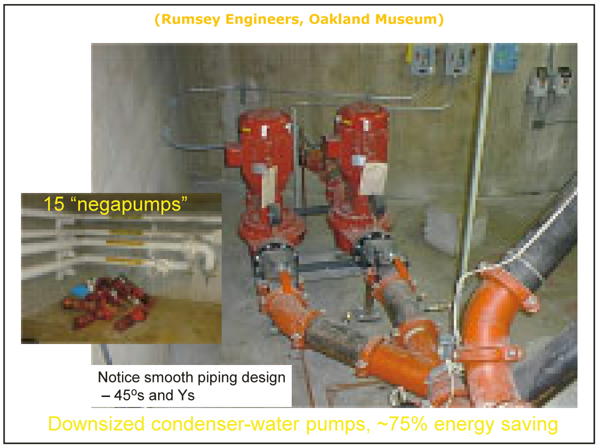
Compounding losses…or savings…so start saving at the downstream end to multiply the fuel and equipment savings upstream



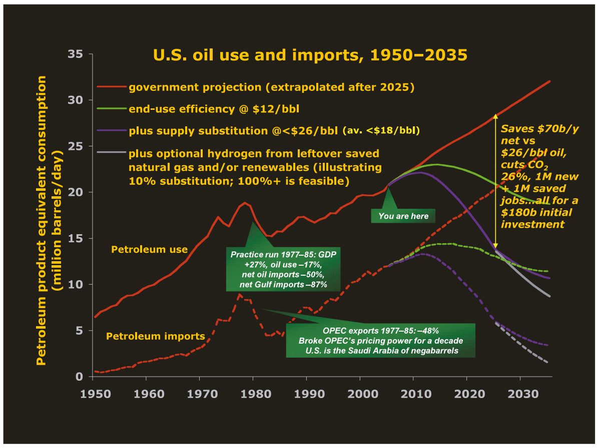
Slide 16
It's often remarkably simple.



Slide 17
High-efficiency Pumping / Piping Retrofit

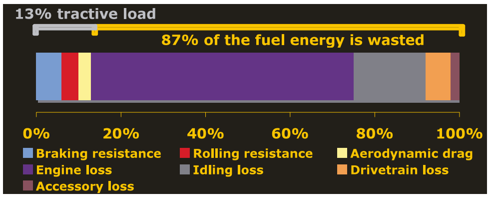


Slide 18
A Profitable U.S. Transition beyond Oil



Slide 19

Each day, a typical car uses ~ 100 its weight in ancient plants. Where does that fuel energy go?



- 6% accelerates the car, 0.3% moves the driver
- Three-fourths of the fuel use is weight-related
- Each unit of energy saved at the wheels saves ~7–8 units of gasoline in the tank (or ~3–4 with a hybrid)
- **So first make the car radically lighter-weight!**

Slide 20

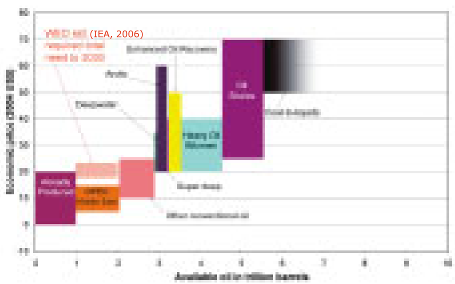
Three Technology Paths: Aluminum, Light Steels, Carbon Composites (the Strongest & Lightest)

- Immaterial damage when T-boned by *Golf*
- 7 kg of carbon crush cones (0.4% of car's weight) can absorb all crash energy @ 105 km/h

- **Carbon-composite crush structures can absorb 6–12× as much energy per kg as steel…and more smoothly**
- **This can make cars lighter *but* bigger *and* safer… *and* simpler and potentially cheaper to manufacture**

Slide 21

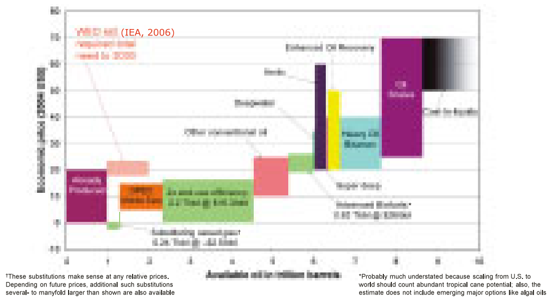
The Oil Industry's Conventional Wisdom: Approximate Long-run Supply Curve for World Crude Oil and Substitute Fossil-fuel Supplies



Source: BP data as graphed by USDoD JASON, "Reducing DoD Fossil-Fuel Dependence" (JSR-06-135, Nov. 2006, p. 6, www.fas.org/irp/agency/dod/jason/fossil.pdf), plus (red crosshatched box) IEA's 2006 *World Energy Outlook* estimate of world demand and supply to 2030, plus (black/gray) RMI's coal-to-liquids (Fischer-Tropsch) estimate derived from 2006–07 industry data and subject to reasonable water constraints. This and following graphics were redrawn by Imran Sheikh (RMI)

Slide 22

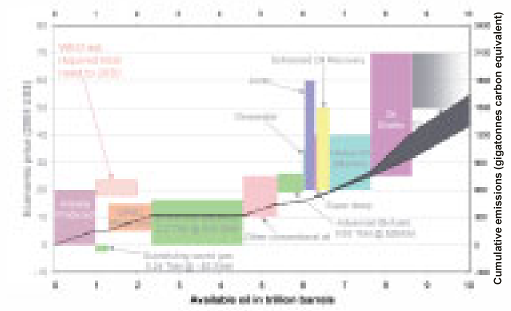
How that supply curve stretches ~ 3 Tbbl if the U.S. potential shown in Winning the Oil Endgame scales, very approximately, to the world



To scale from U.S. alternatives-to-oil potential in Mbbl/d achievable by the 2040s (at average cost $16/bbl in 2004 $: www.oilendgame.com) to world potential over 50 y, multiply the U.S. Mbbl/d × 146,000: 365 d/y × 50 y × 4 (for U.S.→world market size) × 2 (for growth in services provided). Obviously actual resource dynamics are more complex and these multipliers are very rough, so **this result is only illustrative and indicative.**

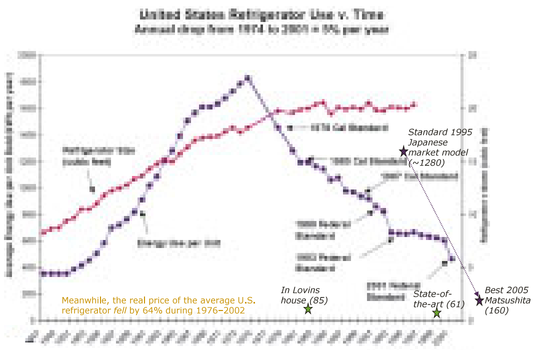
Slide 23

Stretching oil supply curve ~ 3 Tbbl averts >1 trillion tonnes of carbon emissions



Slide 24

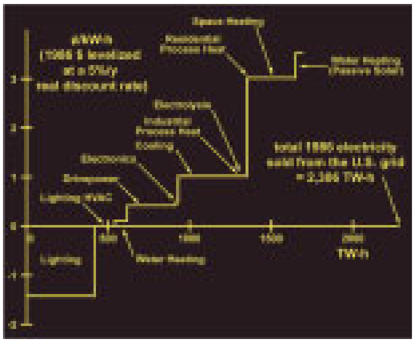
Efficiency is a rapidly moving target.



Japan's standards aim to cut el. use 30% from ~1997 levels for refrigerators, 16% for TVs, 83% for PCs, 14% for air conditioners,...; all can go much lower

Slide 25

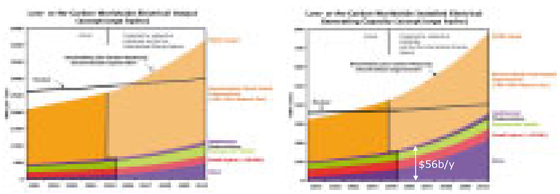
1989 Supply Curve for Saveable US Electricity (vs. 1986 Frozen Efficiency)



Measured technical cost and performance data for ~1,000 technologies (RMI 1986–92, 6 vol, 2,509 pp, 5,135 notes)

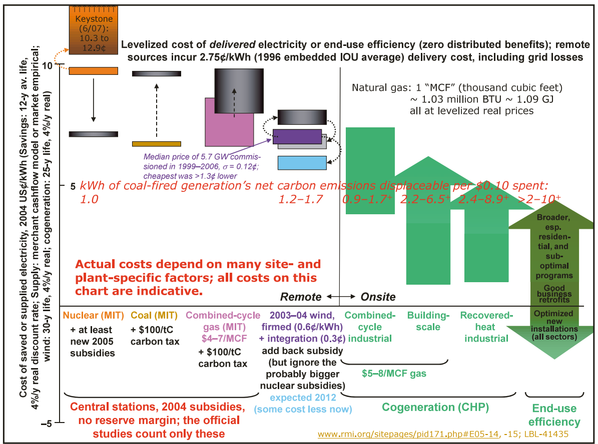
Slide 26

Electric shock: low-/no-carbon decentralized sources are eclipsing central stations.



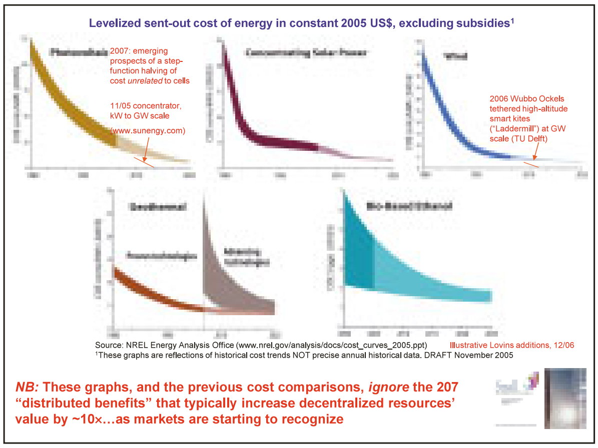
Slide 27

Central Power Stations' Fatal Competitors



Slide 28

Renewable Energy Cost Trends



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