Countdown to Climate Disaster

The carbon era and strategies to move beyond it

Carter F. Bales*

> "Down there where coal is dug it is a sort of world apart which one can quite easily go through life without ever hearing about. . . . Yet it is the absolutely necessary counterpart of our world above. Practically everything we do, from eating an ice to crossing the Atlantic, and from baking a loaf to writing a novel, involves the use of coal, directly or indirectly."

These words from George Orwell's *The Road to Wigan Pier*, written in 1937, are still true today. Our dependency on coal, oil and natural gas has accelerated over that period and now threatens humankind with the possibility of ecological disaster within thirty to forty years unless a massive adjustment is made in how efficiently, and how prudently, we use our remaining reserves of fossil fuel; accordingly, we must undertake a massive effort to develop alternative energy sources and enhance the efficiency of our energy-dependent infrastructure and devices.

It wasn't until after NASA's outspoken James Hansen and others forced the issue onto the public consciousness that solution proposals to global warming began to emerge. Concerning the prospect of failure to rein in greenhouse-gas emissions, Hansen, in a talk delivered February 26, 2007 at the National Press Club, said, ". . . we will have dramatic climate changes that produce what I would call a different planet—one without sea ice in the Arctic; with worldwide, repeated coastal tragedies associated with storms and a continuously rising sea level; and with regional disruptions due to freshwater shortages and shifting climatic zones." The vast majority of climatologists and scientists from other disciplines now agree.

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But how can we afford to change the very basics of our energy infrastructure in the face of the current economic meltdown, one whose outcome can only be guessed at? Few individuals and industries seem immune to the effects of poorly regulated financial markets beset by greed and ignorance. Even Toyota, that bastion of profitability, will show a loss for its fiscal year ending March 2009. Tax revenues from the local to the federal level are shrinking. Lending institutions are virtually out of the consumer loan business and simultaneously retreating from extending credit to even the most trustworthy of businesses.

Until economic problems took center stage, "global warming" and "climate change" seemed to be the topics of the moment, drawing interest from the media, academics, environmental groups, state and local government officials and the new Obama Administration -- and increasingly, though haltingly, from business executives. The G-8 meeting held in July 2008 bore this out, as did last summer's attempt to legislate a solution in the U.S. Congress. Both were weak assaults on the problem: the G-8 merely promised future meetings, specifically in Copenhagen in 2009, and set a general goal of reducing carbon emissions 50% by 2050; Congress promised another attempt at cap and trade in 2009 with a new Administration in place.

Climate change poses threats that go well beyond its obvious manifestations and is likely to affect world security. *The Age of Consequences*, a report released in 2007 by the Center for Strategic and International Studies, noted that if current projections are correct and the planet warms by 1.3 degrees Celsius by 2040, there will be "heightened internal and cross-border tensions caused by large-scale migrations; conflict sparked by resource scarcity, particularly in the weak and failing states of Africa; increased disease proliferation, which will have economic consequences; and some geopolitical reordering as nations adjust to shifts in resources and prevalence of disease." In direct support of these ominous prospects, the Proudman Oceanographic Laboratory in Britain forecasts a rise in sea levels three times higher than that predicted by the Intergovernmental Panel on Climate Change (IPCC) in 2007. The study showed that the pace at which sea levels are rising is accelerating, with world average increases of up to 1.5 meters by 2100. This would result in tens of millions of the world's poorest migrating to bordering countries

equally poor and often only marginally stable politically. Under the worst scenario, the Antarctic ice shelf would melt, raising sea levels as much as 20 feet.

According to observations at Mauna Loa observatory in Hawaii, current levels of atmospheric CO_2 stand at 388 ppm (parts per million), up almost 40% since the industrial revolution and the highest level in 650,000 years. World CO_2e emissions (CO_2e, a measure of all greenhouse gases—CO_2, methane, nitrous oxides, etc.—on an equivalent basis) stood at approximately 45 Gigatons (billions of tons) in 2007, of which the United States contributed 7.2 Gigatons. Under a business-as-usual (BAU) scenario, world CO_2e emissions are forecast to rise significantly, and we could see an increase in global temperatures of up to 4 degrees Celsius by 2030 (CO_2 at 450 ppm) and runaway global warming by 2050 (CO_2 at 550+ ppm).

To put the root cause of climate change in graspable terms, the average per-person CO_2e emissions rate for 2007 is 20 tons in the United States; in Europe, 10 tons; and in India, 2.2 tons. The global rate must be reduced to India's current level if we are to avert disruptive climate change. But even if the world rate were reduced to India's rate, the increase in world population alone—from, say, 6.5 to 9.5 billion by 2050—would contribute approximately 7 Gt of CO_2e to the atmosphere.

The following "what-if" table shows the effects of an annual 1.5% increase in CO_2e emissions, i.e., BAU, as opposed to a 1.5% decrease (population figures are based on a straight-line forecast out to 2050). The extrapolation is dramatic and indicates a 47% decrease in global CO_2e emissions over the period under the negative annual rate of 1.5%, despite a world population increase of 3 billion. The current G-8 target of a 50% cut yields slightly lower totals, but to realize either end game will require a dramatic shift to renewable energy sources along with much-enhanced energy efficiency. To bank on carbon capture from utilities and heavy industry as the primary means of attaining such a steep cut is unrealistic.

Global CO_2e Emissions, 2008 to 2050: Two Scenarios

		BAU Case		***Abatement Case***	
Year	World Population (billions)	World CO_2e emissions at 1.5% annual **increase** per year (Gt)	Annual per-person CO_2e emissions per person (tons)	World CO_2e emissions at 1.5% annual **decrease** per year (Gt)	Annual CO_2e emissions per person (tons)
2008	6.5	45	6.9	45	6.9
2020	7.2	54	7.4	38	5.2
2030	7.9	62	7.9	32	4.1
2040	8.7	72	8.4	28	3.2
2050	9.5	84	8.9	24	2.5

Simply put, we are combusting fossil fuel—coal, oil, and natural gas—at an unsustainable rate; consequently, we are raising levels of greenhouse gases at a rate that puts humankind at risk, unless strong remedial measures are undertaken in the very near future—specifically, during President Obama's first term in office.

Developing countries today hold more than half of the solution to greenhouse-gas emissions growth and must be a party to any global attack on climate change by both preserving and extending forest land coverage and developing low carbon energy infrastructures. Doing this will require financial help from wealthier countries in recognition of the contribution that forests provide for the common good. Moreover, active investment by the private sector must be forthcoming once a price on carbon has been established. Without that help, developing countries may feel they have no choice but to "sell" their forests into harvest and agricultural after-use in order to free up funds to support national economic development.

Forests represent much more than their economic or aesthetic worth; they are a natural "carbon sink," sequestering atmospheric carbon in their woody tissue. Today nearly 20% of greenhouse-gas emissions come from deforestation (mostly tropical forests), plus another 10% or more from poor agricultural practices on deforested land (releasing methane and other emissions). World tropical forests are disappearing, and even in the United States, the slowing growth of our mature forests, together with land-use conversion, is forcing a change in our carbon sink from being an expanding absorber of CO_2 to one that is declining.

Unacknowledged until recently, the Arctic tundra is another vast carbon sink containing some 220 Gt of carbon stored in the top meter of organic matter, which is equivalent to about one quarter of the atmospheric load of 800 Gigatons. Indications are

that the tundra is under attack from general warming plus encroaching darker boreal forests that absorb heat and thus exacerbate the effects of atmospheric heating. Although boreal growth itself absorbs carbon, the release of carbon from microbial action on the warmed tundra might greatly exceed the absorption rate.

Despite the empirical evidence and dire forecasts by climate scientists (most notably the IPCC), the inertia of the body politic, industry and the general public has hampered the conversion of solution proposals into policy initiatives. There are exceptions to this general apathy, especially those in business who see opportunities in carbon that range from advancing new technologies that reduce CO_2 emissions through energy-efficiency enhancements, renewable energy, and carbon capture and storage for major emitters, and from trading carbon credits on recent additions to world financial exchanges such as the Chicago Climate Exchange and the recently-formed Green Exchange.

Action to adopt energy-saving initiatives should have been taken 30 years ago in the aftermath of the gas-station queues that struck a blow to the national ego at the time; instead, that time has been spent in the uninhibited expansion of the role of fossil fuels in the world's economies. It will take the next 30 to 40 years just to get greenhouse-gas emissions under control and thus stabilize global temperatures at 2 degrees Celsius above current levels, the consensus target to avoid catastrophic outcomes. To accomplish this, global emissions of greenhouse gases must be reduced by 80% by mid-century, or not much later. A look at the anticipated demand for energy shows how difficult this will be.

World energy demand is forecast to double by 2050, despite the effect of possible improved energy efficiency and despite a temporary slowdown in world economic growth brought on by the global recession. Even Shell Oil Company agrees that this demand cannot be met by conventional fossil fuels. The world is being electrified rapidly, with billions more people in China, India and other countries receiving electric power for the first time from old-technology, coal-fired power plants, the leading source of CO_2 emissions. Electricity is the oxygen of the world economy, and electricity demand is forecast to double by 2030, according to the International Energy Agency

(IEA). Accompanying this demand will be steep rises in the cost of all fossil fuels once the world economy begins to recover.

The long-term rise in oil and natural gas prices, together with commodity scarcities and economic bottlenecks, could lead to hyperinflation, which would be the cruelest tax of all, especially for the billions of indigents in the undeveloped world who would be further victimized by even the slightest increase in the cost of basic foodstuffs and other essential goods.

Electricity represents roughly 40% of total U.S. energy consumption, and its use is growing rapidly. The North American Electric Reliability Corporation (NERC) in a recent report forecasts U.S. peak demand for electricity to increase nearly 20% by 2020, but the nation's transmission grid capacity is projected to increase by less than half the demand forecast, which reflects both inherent design flaws in the national grid originally configured for local electricity distribution, and a chronic lack of investment in the transmission system. Recent Obama-sponsored legislation is beginning to address the issue of a "smart grid," but the capacity deficit may sustain, thus inhibiting adoption of renewable energy sources and all-electric vehicles that will come on line over the next 20 years.

Coal is the lowest-cost source of world energy and the leading emitter of greenhouse gases. In the United States alone, more than 130 conventional pulverized coal-fired power plants are proposed to be built in the coming 20 to 30 years, although there are indications that this projection is overstated. In the absence of a shift to non-carbon-based energy initiatives, U.S. rural electric cooperatives could spend $35 billion on conventional coal-fired plants over the next decade, thereby offsetting all U.S. greenhouse-gas emissions reduction efforts over that period. Thankfully, U.S. coal-fired plants have become a much riskier investment because of the virtual certainty of a national carbon cap, lawsuits and delays by environmental groups, soaring construction costs, and competition from renewables, to say nothing of the enormous capital commitment, which would expand exponentially should carbon capture and storage be mandated.

Nuclear power generation emits no greenhouse gases and will compete well on a cost basis once a carbon cap or tax is imposed. Nuclear is part of the answer to energy

shortages, but there is no "nuclear renaissance" in the offing, at least not in America. U.S. forecasts see nuclear growing from its current level of approximately 20% of electric energy produced to almost 30% by 2030. The United States has not built a nuclear plant in more than 30 years; in contrast, Russia, Japan, and several other countries are significantly expanding their nuclear capacity.

The nuclear power industry is starting to build the next generations of reactors to fill orders now materializing. Generation I reactors were developed in the 1950s but few are still running today. Generation II reactors comprise the present U.S. fleet and most others in operation elsewhere. Generation III are advanced reactors and in operation in Japan. Generation IV designs will not be operational before 2020 at the earliest. Third-generation reactors have standardized designs to expedite licensing, reduce capital costs, and reduce construction time. They are simpler and ruggedized, making them easier to operate and less vulnerable to failure. Most incorporate passive safety features that require no active controls or operational intervention to avoid accidents.

Scientists at Los Alamos have developed a nuclear power plant that is smaller than a garden shed and is able to power 20,000 homes. The miniature reactors will be sealed, contain no weapons-grade material, and will be encased in concrete and buried underground. The licensee, Hyperion, a New Mexico-based company, plans to start mass production within five years. John Deal, Hyperion's CEO, said, "Our goal is to generate electricity for 10 cents a kilowatt hour anywhere in the world [at a cost per unit of] approximately $25 million." The company plans to set up three factories to produce 4,000 units between 2013 and 2023.

Renewable sources of energy offer hope once a carbon cap or tax is instituted to make these sources cost-competitive with coal-fired generation. Wind energy is nearing cost competitiveness already, and solar is expected to be competitive within the coming decade. Energy storage issues owing to "intermittency" of most renewable sources and the need to expand the electricity transmission system are continuing and costly challenges. Unfortunately, renewables, including solar, wind and wave power, hydro and geothermal, are unlikely to produce more than 20% of world energy in the foreseeable future and that itself may be a stretch. The United States stands at 9.5% today (including

hydro), although a few countries such as Sweden and Portugal produce up to 40% of their energy from renewables.

No alternative technology holds as much long-term promise as solar power. Sunlight could theoretically supply 5,000 times as much energy as the world presently consumes. The need is for cost-effective solar technology, which is now making significant strides in thin-film and nanotechnology. The goal is to produce solar panels costing less than $1 per watt of output. Significant progress is also being seen in the development of solar concentrators that greatly increase the efficiency of thin-film solar collectors and energy storage devices (super batteries). Another virtually inexhaustible energy source with long-term promise is geothermal. Geothermal plants have low operating costs, are highly reliable, and can provide baseload power not subject to intermittency. In the United States, 103 new geothermal power plants are currently under development.

Thirty-million acres (about 7% of U.S. farmland) converted to switchgrass could produce sufficient biofuel in the form of cellulosic ethanol to satisfy half of current U.S. gasoline consumption. Production of cellulosic ethanol at scale, however, is at least 5 to 10 years off owing to technology and cost challenges. Issues of supply management, distribution of the refined product and pump conversion at the gas station, plus modifying the stock of new cars to accept higher ethanol concentrations, remain to be resolved and will require federal action in the form of regulation and subsidies. Similarly, the production of biodiesel from switchgrass or other sources of cellulose requires intensive R&D.

We have identified the cause of climate change—increased atmospheric carbon dioxide and other greenhouse gases—but the problem is us and our human tendency to devalue the future and to resist change. As that future comes rushing toward us, it is important to examine five overarching forces that are driving fundamental changes in the world and contributing to climate change and other challenges confronting humanity: (1) rapid population growth, (2) rising disposable incomes, (3) growing commodity shortages, (4) technology as a demand stimulator, and (5) the failure of governments to solve problems. These forces

are not new, and some, like "rising incomes" and "technology as a stimulator of demand," are generally thought to benefit mankind, at least from a strictly capitalist standpoint. However, they all have their downside and, taken together, are pushing us toward a catastrophe from which recovery may be irretrievable.

By 2050, world population will likely exceed 9 billion (up from 6.5 billion today) and perhaps reach more than 10 billion, with growth primarily in developing countries, a category with only a tentative meaning, given the recent entry of India, China, and Brazil into the upper tier of economic powerhouses. (Over the same period, the population of the United States is expected to swell to 420 million, from 305 million.) The pressure on resources of every description will increase exponentially—that is, the negative effects on the environment (on our quality of life) of such growth will be compounded by the addition of each person, particularly if that person becomes a member of the world of "conspicuous consumption" that dominates lifestyles in the West. To claim that technology will find the means to support a world population of 9 billion or more denies the fact that it has failed to do so equitably up to this point.

The rise of middle-class purchasing power in emerging economies is a critical demographic trend. Absent a protracted economic downturn, rising household incomes will see a doubling of the world consumer base by 2025, while world GDP will quadruple by 2050. A recent Goldman Sachs study suggests that by 2030, the world middle class—those with annual incomes of between $6,000 and $30,000—will see their numbers increase by 2 billion. Discretionary spending and resource consumption will increase accordingly, as communications and media technologies expose these new consumers to spending opportunities that we in the West take for granted. A new consuming class is being born in rapidly growing economies like China, India, Brazil, Russia, and the Middle East.

Rising incomes, however, will not lift all the world's populations out of poverty—far from it. Indigent populations in Pakistan, Bangladesh, and most of Africa will continue to swell. According to the United Nations, 95% of all population growth is now absorbed by the developing world and 5% by the developed world. By 2050, the population of the more-developed countries as a whole will be declining slowly by about

1 million persons a year and that of the developing world will be adding 35 million annually, 22 million of whom will be absorbed by the least-developed countries.

Wendell Berry wrote in the May 2008 issue of *Harper's* that "There is now a growing perception, and not just among a few experts, that we are entering a time of inescapable limits. We are not likely to be granted another world to plunder in compensation for our pillaging of this one." This pillaging will lead to growing shortages and greater inflationary pressures, and its effects are seen now in the scramble for basic foodstuffs and water. Little attention is being paid to developing longer-term, "sustainable" technologies (the UN defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs").

On a world scale, for example, the energy required to run the Internet today is on the order of 40 gigawatts and rising and leaves a carbon footprint of approximately 200 megatons of CO_2 per year. Twenty years ago, when the Internet was first opened for commercial use, its demand for energy and the resultant carbon emissions were negligible. Yet the cost of this one input factor on global warming is not calculated in the overall cost structure of the Internet. Nor are such negative externalities generally calculated in the cost profiles of any technological advance, manufacturing process, or electricity generating plant. In effect, the environment has absorbed the cost of carbon emissions to the long-term detriment of planetary health. The move toward carbon cap-and-trade agreements, or a carbon tax, will begin to address humankind's tendency to look upon the environment as a dumping ground for such negative externalities.

Technological advancements whose sole purpose is to stimulate greater demand and unnecessary product obsolescence (the "throwaway society") only hasten the demise of our finite set of natural resources. Most new technology today is really incremental technology, designed for minimum risk and quick payback, an instrument of incremental efficiency enhancement and short-term profit improvement. Many industries, such as the energy industry, have chronically low investment in research and development and, because of high capital investment cost, little incentive to replace existing performing assets with new technological approaches. On the brighter side, technological innovation can push aside old technologies and give rise to more-efficient products that generate cost

savings across sectors, which lies at the core of Joseph Schumpeter's theory of "creative destruction."

The last force that is driving fundamental changes in the world is the universal failure of governments to maintain responsiveness, to look ahead and anticipate problems, or to collaborate with each other. There is little tradition of government units, from federal to local, cooperating with each other; there is little tradition of rich governments helping poor governments in any significant way (the Marshall Plan was an exception); there is little tradition of legislating sufficient profit into public problems to motivate a strong private sector response. Problems are increasingly misaligned with the government structures that exist to solve them (government structures which were established when most problems were local) – witness our national need to regulate power companies toward energy efficiency and remove the costly crazy quilt of state-level utility regulation when U.S. energy policy really resides in state public utility authorities. Moreover, the rapid growth of market economies around the world has encouraged new entries to lurch toward the free market, often insensitive to prudent resource management or externalities like environmental costs.

As anthropologist Joseph Tainter notes, "[S]ocieties . . . grow more complex in part through the process of addressing problems. As problems grow larger and more complex, easier solutions become exhausted. Responses to problems grow complex and costly. Greater complexity always carries greater costs, in any kind of living system." Complexity also leads to additional layers of bureaucracy, the most insidious barrier to the adoption of reasoned solutions made in response to society's needs.

Clearly, these five forces impact each other and have many cross-reinforcing relationships. The most obvious interlocking effect is between population growth and shortages derived from the accelerating depletion of natural resources. Similarly, rising incomes have led to improved diets increasingly based on animal protein, which has led, in turn, to intensifying freshwater and world grain shortages and higher prices for wheat, rice, and corn, as well as for natural-gas-based ammonia fertilizer. Because few socioeconomic forces act in a vacuum, the ongoing conversion of U.S. farmland, prairie, and forest to corn ethanol production has exacerbated grain shortages and pushed grain

prices even higher. Yet the net gain derived from corn ethanol is doubtful at best from both an environmental and economic perspective.

Because natural resources of all kinds have been looked on as nothing less than a "free lunch" to be exploited with few restrictions, waste rules. Developed economies are particularly wasteful. A report from the World Resources Institute, *The Weight of Nations: Material Outflows from Industrial Economies*, found that "One half to three quarters of annual resource inputs to industrial economies are returned to the environment as wastes within a year." Part of the output can be recycled, but eventually, all resource inputs become wastes. Daly and Farley, in *Ecological Economics: Principles and Applications*, describe this process as "throughput": the flow of raw materials and energy from natural resources, through the economy, and back to the ecosystem's sinks— atmosphere, oceans, dumps—as wastes.

The longevity of any resource, whether fossil fuels or mined ores, depends on how wisely and efficiently it is used. For example, cogeneration—turning waste heat into electricity—reduces power demands on generating plants and thus conserves, say, coal; variable-rate fertilizer application, so-called "precision farming," conserves ammonia and phosphates plus the energy needed to produce or mine them. According to IEA estimates, each dollar spent on more-efficient electrical equipment, appliances, and buildings avoids the investment of more than two dollars in new electricity supply. Many energy-efficiency opportunities exist to save electricity, but adoption rates are slow. For example, eighty coal-fired power plants could be eliminated if compact fluorescent lamps (CFLs) were fully adopted in the United States.

A short-term, self-interested outlook pervades the thinking of individuals, corporations, and governments. As Gustave Speth says in *The Bridge at the End of the World*, ". . . there are fundamental biases in capitalism that favor the present over the future and the private over the public." These biases lead directly to a general overexploitation of natural resources and make folly of the term "sustainable development," a conclusion that lies at the heart of Garrett Hardin's "tragedy of the commons." The problem is made worse by the fact that negative externalities like greenhouse-gas emissions, if they bear no financial burden to the polluter (and,

ultimately, to the end user), encourage overexploitation. Thus, to "get the prices right," that is, to arrive at the true cost of production—whether involving manufactured goods or energy delivery—requires that all costs, in this case environmental costs, be internalized and thus become part of the price paid by the purchaser.

The logic inherent to any finite resource (and name one that is not) says that, eventually, it will be depleted. Humankind has two concurrent imperatives: (1) use that resource as prudently as possible, and (2) anticipate its depletion in advance so that an alternative might be found or developed. The excluded choice is to continue "business as usual" and end up, in the case of disruptive climate change, with an inhospitable planet. But logic, too, tends to cower before special interests and often lies buried at the feet of impenetrable bureaucracies. Plus the boundary between special interests and national interests is often vague at best. For example, coal-fired power-plant operators are a special interest that serve and disserve the national interest simultaneously by providing low-cost electricity while emitting greenhouse gases. Efforts to reduce the latter must do so without inhibiting generating capacity. That is why a carbon cap can only work in this particular case when Congress recognizes its responsibility to subsidize the development of enabling technologies like carbon capture and storage for major emitters.

The UN glossary of the environment lists three *Precautionary Principles*: (1) renewable resources should not be used in excess of their natural regeneration, (2) non-renewable resources should be used prudently and efficiently with care that the same function is available to future generations, and (3) sink functions should not be used beyond their assimilative capacities. All three have been generally ignored by policymakers, business leaders, and by individuals, with the possible exception of the world's poorest. A continuing failure to adopt these principles will presage global disaster.

Virtually every world leader in power today looks on the prolongation of economic growth as his or her primary responsibility. Indeed, growth is considered a critical component of national security. Politicians recognize growth as the key to electoral success, absent a national emergency or war, and know that the electorate votes with its wallet. Interleaved with the drive toward economic growth is the self-

aggrandizing tendency toward the accumulation of power, both economic and political—the stuff of nationalism.

The alarms sounded by the prospect of disruptive climate change represent a great opportunity for American business to occupy the leading edge of a technological and applications revolution and thus serve the nation's economic interests while ensuring the survival of follow-on generations. To do this will require three major acknowledgements by the American mindset: (1) growth for growth's sake is ultimately self-defeating, (2) corporate shareholder interests must also be made to consider the common good, and (3) the only "special interest" that should hold sway over elected officials is the common good. Naïve and idealist, to be sure, but for the United States to lead in the move toward a sustainable future, these acknowledgements must be proclaimed from the bully pulpit of the presidency and by the nation's policymakers and business leaders. To borrow from Francis Bacon, it is time to honor the common good and thus "destabilize" narrow self-interest.

There is heightened public awareness about climate change, but the question must be asked, how wide and how deep is that awareness? A recent Harris Interactive poll showed that 67% of Americans believe that humans are contributing to an increase in global temperatures, while only 30% felt that it will present a threat to them and their families within their lifetime. However, when polled on where they would locate it on a list of national priorities, climate change lies near the bottom. This implied lack of a sense of urgency is partly derived from government inaction illustrated by the failure last year of the Lieberman-Warner Bill in the Senate.

But there are other factors as well, not the least of which is the fragmented nature of the information that the public receives via the media, which has moved from reporting with some semblance of integrity to striving for a "false balance" in which the so-called case against human-induced climate change still receives serious coverage despite the overwhelming weight of evidence assembled by the scientific community. Similarly, much information access today is via the Internet where quality ranges from the authoritative to the absurd to the conspiratorial.

In 2007, the global consultancy McKinsey & Company undertook a project to examine more than 250 greenhouse-gas abatement options in the United States and to

weave these options into a series of "abatement curves" showing the most effective and least-cost sequencing of actions. The results revealed that nearly 40% of feasible abatement can be accomplished at "negative cost" (in effect, creating positive economic benefits) to the economy. This amount, achieved largely through energy-efficiency programs, would be sufficient to offset the remaining costs of bringing down greenhouse-gas emissions, assuming that a carbon cap is instituted, that investments are made in emerging energy technologies, and that other low-cost investments are made to expand the U.S. carbon sink (the stock of trees and agricultural acreage, which absorb CO_2).

The McKinsey study concluded that, despite worries to the contrary, the United States (and, by extension, other nations) can bring greenhouse-gas emissions down sharply at reasonable cost and with little if any negative effect on GDP. Required is a four-part policy framework that focuses on: (1) a cap-and-invest system to reduce carbon emissions; (2) a set of hard-hitting energy–efficiency programs; (3) federal support to bring critical technologies to scale (carbon capture and storage for utilities, solar, advanced wind, and advanced biofuels); and (4) programs to tap the carbon-reducing potential in those sectors of the economy lying outside a cap-and-trade regime—e.g., expanding standing forests and improving agricultural practices.

Effective solutions to the climate change problem do exist if the world will embrace them. The only fair long-term goal is one of equalizing emissions rights per capita, whether a country is wealthy or poor, at a much lower level over the coming period when world population is doubling and world incomes are tripling. Global trading schemes and other measures can be devised to move the world toward equalization if (and only if) OECD nations come to accept that they will have to help offset the costs of middle-income developing countries and poor countries in the move toward a clean energy infrastructure, while concurrently protecting tropical forest stands from being cut down. Equalizing emissions rights per capita over time is fair and is familiar to many policymakers. We do not need new ideas. We need action on the well-established ideas that can work.

To move climate disruption to the top of a "concerns list" will require a unified public message that spells out the problem clearly and consistently along with a roadmap for its solution. Human nature begs for a single cure for any illness. In the case of a sick

planet, there is no single cure, but rather many separate cures that will impact peoples' daily lives in sometimes discomforting ways. And that is the problem facing legislators as they grapple with climate change: how to be honest (and cause discomfort) and still retain one's seat in Congress.

CEOs whose companies have huge carbon footprints face a similar dilemma when they confront shareholders at annual meetings and raise the possibility of reduced profits as, of necessity (and by statute), companies move toward a low-carbon economy. (In fact, experience has shown that corporations can usually find additional efficiencies to offset these costs and, along with other companies in their sector, can pass on unrecovered costs to their customers in the form of higher prices, thus protecting profits.) Yet without a coalition of leaders, including business leaders, it is unlikely that the U.S. Congress will act or will act decisively to set the right stringent policies. In light of the combined influence on the U.S. Senate exerted by the hydrocarbon industries (with the coal industry as an ever-stronger voice), automobile manufacturers, and the farm lobby, can such a coalition be formed? Is a workable U.S. legislative solution possible?

To ensure corporate participation in efforts to reduce carbon emissions, Washington should set up a "cap-and-invest" strategy, by using the revenue generated from selling pollution allowances, to fund innovation in the fields of energy efficiency and clean power generation. This could result in $150 to $200 billion of new federal revenue annually, plus more if Congress and the states were to cut back ill-conceived hydrocarbon subsidies which also run into the billions of dollars. Indeed, the National Defense Council Foundation estimates that hidden subsidies, including military expenditures to protect the offshore oil supply, cost roughly $300 billion per year. Folding those costs into U.S. annual gasoline consumption of 142 billion gallons would add $2 or more to each gallon of gasoline.

Briefly, the four parts of a "cap-and-invest" strategy are: (1) require the government to establish a declining cap on greenhouse-gas emissions together with an effective carbon-trading system absent the problems that plagued the initial European Union model; (2) impose minimum federal energy-efficiency standards on appliances and buildings and other inducements such as a system of "performance-based federalism" in

which the federal government would reward those states that successfully reduce greenhouse-gas emissions through state-level regulation and other initiatives; (3) use most of the revenues from the cap-and-invest program to support research, development, and deployment of advanced clean-energy technologies during a reasonable transition period; and (4) take advantage of the carbon-sink potential of uncapped economic sectors by significantly expanding forest cover and introducing new, low-carbon practices into the agricultural sector. Once the transition to a clean energy economy is well along, funds from the annual auction of emissions allowances should be redirected back to the nation's citizens (a "cap-and-dividend approach"), effectively moving toward a revenue-neutral taxation model. This four-part strategy would allow the United States to move toward a low-carbon economy at a negligible net economic cost. The 2007 study by McKinsey indicates that the net price tag attached to reducing U.S. emissions by nearly 30% before 2030 would be close to zero, if the full cost-savings potential of energy efficiency and innovation is realized.

Because we are in the grip of what will be a protracted recession, with deflation or depression on many people's minds, great pressure will be exerted on the new Administration to formulate short-term fixes whose immediate objective is jobs creation. But there are strong indications that President Obama, while recognizing the immediate needs of working Americans, also sees that the long-term health of the U.S. economy depends on innovation, which will drive new industries that severe our dependency on fossil fuel. And contrary to the pick-and-shovel advocates' approach, innovation has been shown to be the one "trickle-down" concept that does create both jobs and wealth across all income quintiles.

The key to inspiring a call to action is found in the list of priorities set by Obama even before he took office. Top priorities will be to create a $150 billion fund for investing in alternative energy over the next 10 years and to generate 25% of the nation's electricity from renewable sources by 2025, simultaneously creating 5 million new jobs necessary to support this shift. Such a commitment will do much to correct the malaise that has dampened interest in alternative energy investments resulting from the loss of debt funding in late 2008. The immediate beneficiaries of this program will likely be

biofuels, advanced battery technology for hybrid vehicles, improvements to the national electric grid, and energy-efficiency programs.

The Biofuels Security Act of 2007, which Obama co-sponsored, mandates that U.S. motor vehicles use 60 billion gallons of ethanol and biodiesel by 2030. The bill also calls for large oil companies to install enough E85 pumps over the next 10 years so that half of all major brand gasoline stations are so equipped. Should these goals be realized, the current ceiling of 10% ethanol in gasoline blends will have to be raised, since today's roughly 10 billion gallons of domestic production comes close to supplying the gasoline market in the United States.

Another Obama goal of putting 1 million 150-mile-per-gallon, plug-in hybrid cars on the road by 2015 will require the massive production of highly efficient lithium-ion batteries. In a parallel push toward higher vehicle efficiency, Obama plans to raise fuel economy standards 4% annually. This proposal will save nearly 500 billion gallons of gasoline and abate 6 Gigatons of greenhouse gases over the next 20 years.

The United States must modernize its electric grid and make it "smart" to enable the integration of intermittent energy sources like solar photovoltaic and wind power. Al Gore's Alliance for Climate Protection has come up with a strategy to upgrade grid infrastructure over the next 10 years at a cost of $400 billion. Along with making it "smart," overall efficiency would be improved, with 100% of U.S. electricity generation transitioning to non-carbon sources. Presumably, Obama's proposed Grid Modernization Commission will draw on the Gore group's findings.

Mirroring the 2007 McKinsey study, Obama sees energy efficiency as key to reducing electricity demand 15% by 2020 and reducing CO_2 emissions by over 5 billion tons through 2030. For these goals to be realized, new buildings must be carbon neutral, new building efficiency must improve by 50%, and existing building efficiency by 25%. Reacting to Obama's proposals to retrofit public buildings, Robert Pollin, of the University of Massachusetts, Amherst, notes that "The job impacts are very high. Each $1 million in spending would bring about 1,800 [new] jobs."

The world faces a half century of challenges that will determine civil society's triumph or perhaps its downfall. These challenges flow from climate change and resource depletion and involve both national polities and their populations. The

challenges also involve serious discussions about the efficacy of unconstrained economic growth. A parallel discussion hinted at earlier should also begin: an assessment of global natural resources and their relation to optimal world population. Answering these challenges, and entering into these discussions, will require the mobilization of the world's best minds across all disciplines, from business to the academy.

As John Holdren, Obama's new Science Advisor, has written, two challenges in particular stand out above all others in their combination of difficulty and danger: (1) how to reduce the macroeconomic vulnerability arising from oil dependence overall, and the balance-of-payments and foreign policy liabilities associated with the part that is imported, in the face of rising demand from the transport sector; and (2) how to provide the affordable energy needed to sustain prosperity where it now exists, and to create and sustain it where it now doesn't, without entraining intolerable disruption of global climate by the emissions from fossil-fuel use.

To mitigate these challenges, a sweeping mindset change must occur in government chambers, in corporate boardrooms and ultimately in homes around the world, one that is less anthropocentric and more nature-centric, one that embodies a universal respect for both life and its support systems, all of which flow, either directly or indirectly, from a finite inventory of natural resources. A dramatic mindset change must occur at the U.S. federal level, where the concept of "federal subsidy" must metamorphose from one that is essentially a reward system catering to special interests to one that advances the common good. Face it, Washington: corn-based ethanol is a net loser, and oil subsidies of any kind only encourage consumption, whereas low-carbon alternatives are a net winner for us and for succeeding generations.

It is time for the leaders of our nation to grow up, to acknowledge their real responsibilities to its citizens and the world at large, and to take courageous action to address the lethal threat of climate change—in essence: to lead. Enacting climate legislation in 2009 would immediately resolve regulatory uncertainty by establishing long-term emissions limits. This is an essential precondition to get capital flowing into a low-carbon energy infrastructure, including both greener energy supplies and increased energy efficiency in the industrial and buildings sectors. As Tom Friedman wrote in the December 23, 2008 issue of *The New York Times,* "John Kennedy led us on a journey to

discover the moon. Obama needs to lead us on a journey to rediscover, rebuild and reinvent our own backyard.”