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The Energy Box

S. Julio Friedmann
Lawrence Livermore National Laboratory
Livermore, CA

Thomas Homer-Dixon
University of Toronto
Canada

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The Energy Box

Colossal scale, geopolitical insecurity, supply constraints, rising cost, and climate change. These problems build an energy box around us—but there's one way out

S. Julio Friedmann, Lawrence Livermore National Laboratory
Thomas Homer-Dixon, University of Toronto

Only Nixon could go to China.

And maybe only petroleum industry CEOs can spur action on global climate change. Here's Lord Browne, head of BP, in a recent issue of *Foreign Affairs* magazine: "Global temperatures have risen by about 0.6 degrees Celsius since the nineteenth century. Other measures of climate bolster the theory that the world is getting warmer. . . . [The] trend is undoubtedly due in large part to substantial increases in carbon dioxide (CO_2) emissions from human activity."

But should we do something about this trend? Browne is unequivocal. In a speech to the Council on Foreign Relations at about the same time his article appeared, he declared: "It would be too great a risk to stand by, do nothing, and to wait so long that when the impact on the climate really does begin to be felt, you have to take action which is so disruptive as to cause serious damage to the world's economy. There is a very strong case for precautionary action."

And when it comes to climate change, Browne isn't a lone, renegade CEO. Other leaders of the oil industry are saying similar things. Lord Ron Oxburgh, Chairman of the British arm of the Royal Dutch/Shell Group and a highly respected geologist, recently told the *Guardian* that "no one can be comfortable at the prospect of continuing to pump out the amounts of carbon dioxide that we are pumping out at present . . .with consequences that we really can't predict but are probably not good."

For a while, it wasn't obvious that the effects of increased carbon dioxide wouldn't be good: early analysis of the implications for societies and economies talked about a complex mix of winner and losers. Inhabitants of places like Chicago and Winnipeg thought a bit of global warming looked pretty appealing.

Alas, most recent scenarios of future climate don't look very good at all. Many include terrible droughts, crop failures, and forest die-off in the United States, the Mediterranean, India, China, and all of Africa and South America. They include significant sea level rise, with attendant drowning of island nations and displacement of hundreds of millions of people from seacoasts, the home of more than a third of the world's people. Ground water supplies will diminish and reservoirs will disappear. The number and severity of wildfires and of storms like hurricanes, typhoons, and tornadoes will likely rise dramatically. Quite shockingly, much of this change is predicted to happen within the next fifty years, long before today's children are ready for retirement.

Alas, the primary culprit in this story is us. The CO_2 emissions that are stoking global climate change come from energy consumption. We use massive, almost inconceivable amounts of energy to do everything from making mountain bikes and airplanes to running sewer systems and hospital equipment. It's no wonder that the rebuilding of post-war Iraq has focused on providing electricity and securing oil pipelines. Energy is the essence of civilization, and as our societies and economies grow, so does our energy consumption.

Indeed, global energy consumption continues to rise exponentially, at over 2 percent per year, and is expected to double by 2035 and triple by 2055. In the United States and most other rich developed countries, 85 percent of this energy comes from fossil fuels (mainly coal, oil, and natural gas) and almost all the rest from nuclear and hydroelectric power. In poor developing countries, wood, charcoal, straw, and cow dung still meet a large portion of heating and cooking needs, but the shift to fossil fuels is happening fast.

The good news is that fossil fuels are still relatively abundant and cheap. Coal reserves are huge, especially in the U.S. Oil reserves are also large, at least when we look at the globe as a whole and consider non-conventional reserves like tar sands and oil shales. The bad news is that burning fossil fuel emits carbon dioxide (CO_2), the major contributor to global warming. Today, we're emitting far more carbon dioxide than it is naturally absorbed by oceans, forests, and soils: global energy consumption is so great and rising so fast that humans are demonstrably changing the climate.

Our energy demands and environmental constraints create a tight box around us. The structure and nature of our economies and the sheer scale of our energy needs mean that we're going to be burning vast quantities of fossil fuels for the foreseeable future. When supplies of oil and natural gas become harder to find, or if they become unavailable for political reasons, that means vast quantities of coal—in terms of carbon dioxide, the dirtiest stuff around.

Improved energy efficiency will help, as will reduced consumption, but they wont' be enough. The walls of the energy box are too high and too strong. But one important technology has emerged that may help quite a bit. Called carbon sequestration, it could allow us to continue burning of fossil fuels while we store CO_2 in a benign form and in a safe place. This approach could allow us to escape the dreadful risks of climate change and, in fact, it may be the only way out of the energy box. Shell's Lord Oxburgh sees it very simply: "Sequestration is difficult," he says. "But if we don't have sequestration I see very little hope for the world."

THE FLOOR: SCALE

If climate change is one wall of the energy box—say, the front wall, because it means there are high costs to going forward with business as usual—the scale of our energy problem is the box's floor, its fundamental and underlying constraint. Behind the electrical plug and gas pump is arguably the largest single human enterprise on Earth.

The task of supplying the world with energy is about twice as big as all global agriculture, which itself requires lots of energy. Producing, processing, and transporting energy costs over $3.5 trillion annually—more than the U.S. Federal budget or the GDP of all but a handful of nations. This cost grows significantly every year, as the world's population and economy grow.

To get a sense of the scale constraint, let's say for the sake of argument that we want to use nuclear power to cover just the growth in U.S. energy consumption in the next fifty years. Love it or hate it, nuclear power is worth considering seriously, because it provides a lot of baseload electric power without emitting carbon dioxide. In the U.S, 104 active plants run with an average capacity of about 1000 megawatts (roughly enough electricity for a city of about half a million people). In 2002, these plants together generated 8.1 quadrillion British Thermal Units of energy (a standard measure of large amounts of energy, conventionally called Quads), or about 21 percent of U.S. electricity and 8.3 percent of overall U.S. energy consumption.

Now, U.S. energy consumption in the next fifty years is predicted to grow by an additional 95 Quads. To cover this growth with nuclear plants would require about 1500 new plants, or about one every ten days—an enormously difficult task. Even then, we wouldn't have reduced our carbon dioxide emissions at all; we'd have just kept them from growing above today's already very high levels.

The scale of our energy requirement means that humankind can't get out of the box simply by conserving. That's not to say we shouldn't conserve, but conservation alone won't be enough. Our energy requirement is too large, and growing too fast.

For example, although the U.S. has significantly improved its energy efficiency over the past two decades, it still hasn't reduced its carbon emissions. That's because total economic output has grown faster than improvements in energy efficiency: while efficiency has improved, on average, almost 2 percent annually over the last 20 years, GDP has grown faster, at over 3 percent annually. So, despite a total energy efficiency gains since 1980 of over 35 percent, annual U.S. energy use still soared from 78 to nearly 100 Quads between 1980 and 2000, and carbon emissions followed in lockstep from 1288 to 1562 million metric tons.

With less than a twentieth of the world's population, the U.S. produces about a quarter of humankind's emissions of carbon dioxide. So the whole world has an interest in seeing America reduce its emissions. Unfortunately, efficiency improvement can't continue at 2 percent annually forever, because manufacturers and entrepreneurs exploit the easiest ways of saving energy first. And even if the U.S. could raise efficiency at such a rate indefinitely, it won't reduce its carbon emissions unless economic growth is less than this amount. But no economic policymaker, and certainly no politician, is going to settle for a growth rate of less than 2 percent, because it's not even enough to absorb new labor entering the workforce.

A strict conservation approach is even less feasible for the developing world. Quite the contrary, the world's poor countries aim to dramatically increase energy consumption and economic growth together. In 2003, China grew at 9.1 percent, and the country's phenomenal appetite for steel, aluminum, copper, and cement caused its fossil fuel consumption to surge (China is now the world's second largest importer of petroleum). Chinese leaders have made it clear that they want a billion cars for their billion potential drivers. No amount of energy conservation will allow China to achieve its goal of a Western standard of living without a huge increase in energy consumption and carbon dioxide emissions. Indeed, some current projections show China overtaking U.S. carbon dioxide emissions by 2020.

If humankind *really* wants to reduce global carbon dioxide output, we must either shrink our population (unlikely to happen in most of the world: population in United States and almost all developing countries is projected to grow for decades) or accept low or negative economic growth (a politically and economically inconceivable option). Otherwise, our already gargantuan and growing energy demand and carbon dioxide output will just keep rising, probably doubling in the next thirty to fifty years.

THE RIGHT SIDE: SECURITY

Even if we're not concerned about carbon dioxide emissions, we still have to feed our voracious appetite for energy. But many countries with energy-intensive economies, like

most of those in Europe and Asia, have minimal oil reserves. This is particularly true of the growing giants China and India. And although the U.S. still has substantial oil in the ground, it's not nearly enough to meet the country's demand. So the U.S. imports nearly 60 percent of its oil from countries like Venezuela and Nigeria. This figure will steadily increase in coming years; even a massive oil-exploration campaign stateside, stricter auto fuel standards, and aggressive drilling in Alaska's Arctic Northern Wildlife Refuge will not reverse our import growth

The majority of the world's oil, about 65 percent of conventional global reserves, lies in the Persian Gulf. The largest share is in Saudi Arabia, Iraq, and Iran—countries of questionable stability and friendliness, to say the least. Roughly 10 percent of U.S. oil, 30 percent of Europe's oil, and 75 percent of Japanese oil comes from this region. Dependence on Gulf oil is also of grave concern to China: the country's petroleum imports have increased 30 percent in the last year, surpassing Japan's. If China's billion future cars all run on gasoline, the country will be exceedingly vulnerable to Persian Gulf politics.

Analysts might dispute oils importance as a factor behind the 1991 and 2003 wars against Iraq, but no one can dispute the assertion that Iraq has been a major focus of U.S. foreign policy partly because it has a lot of oil. The same is true for the Middle East as a whole. If not for oil dependence, the US government would have likely responded to Saudi Arabia's sponsorship of anti-American Wahhabism in less compromising terms. The desperate need for oil leads many Western nations to tolerate and collaborate

with authoritarian, corrupt, and often-unstable regimes in regions rife with ancient conflicts.

Clearly, national and geopolitical security is another firm wall of the energy box. The U.S. and the world need more sources of high-quality energy with enough geographic dispersion that the risk of political conflict over these sources—and of price shocks associated with such conflicts—is greatly reduced.

One possible source is, again, nuclear power. Although expensive—almost double the cost of fossil-fuel energy—nuclear power nevertheless has a number of advantages beyond its zero emissions of carbon dioxide. Nuclear plants can be located close to populations that need energy. They can be designed to be "inherently safe," so the risk of meltdown is infinitesimally small. They can also be designed to produce their own fuel from low-grade uranium, using "breeder" technology. Because they're unconstrained by fuel supply, we can build as many of these plants as we want.

But we almost certainly don't want them, again for security reasons. Nuclear power plants, especially breeder reactors, produce a lot of highly radioactive waste. Scientists might be able to figure out how to safely store this material for the tens of thousands years necessary for it to become innocuous, and politicians might be able to deal with the NIMBY problem, which has held up U.S. storage plans for decades and recently scuttled plans to build twelve plants in Japan. But high-level nuclear waste could still be diverted or stolen and converted into bombs. It's extremely toxic, so terrorists can use it for

radiological or “dirty” bombs; and it contains plutonium, which can be extracted to make atomic weapons. After 9/11 the world is acutely aware of such dangers. We now realize that there are countless people around the world who would like to get hold of these materials and use them against their enemies, whoever they may be. A planet awash in nuclear waste would be a truly terrifying place.

THE BACK: SUPPLY

If oil is increasingly concentrated in geopolitically insecure regions, and greatly increased reliance on nuclear power is no longer sensible, what do we have left? Can humankind back out of the energy box, simply by increasing the supply of other energy sources?

In this respect coal is still king. It’s a versatile, high-energy fuel, and it’s plentiful and cheap. It’s also easily transported by barge or railcar. Importantly, coal can provide energy security for the world’s most populous countries. It’s particularly abundant in India and China, but also in Indonesia, Canada, Australia, South Africa, and the U.S., with hundreds of years of reserves. But there's a big problem: burning coal creates a lot of carbon dioxide—much more, per unit of energy produced, than burning any other fossil fuel. It also releases mercury, particulates, and produces the sulfur dioxide that causes acid rain, while extracting it from the ground causes mining accidents, stripped hillsides, and black-lung disease.

If not coal, perhaps natural gas (methane) is the way out. For many countries, gas is increasingly the preferred energy source, in part because it burns cleanly with minimal emissions of pollutants and relatively low carbon dioxide output. There's still a huge amount of gas around the planet—on land in the Middle East, Bolivia, Siberia, and Central Asia and offshore in the Arctic, in the Gulf of Mexico, and along West Africa's coast. Unfortunately, though, most of these large gas supplies are "stranded," which means they're far away from the people who could use them.

The U.S. has already begun to encounter supply problems with natural gas. In 2002, although rigs drilled about 16,000 new gas wells in the lower 48 states, production declined 6 percent, and shortages caused the price of gas to spike to three times the base cost. In the past decade, the base cost of natural gas has almost doubled in the U.S., and Alan Greenspan has warned Congress that gas shortfalls could become a significant drag on the U.S. and global economies.

Experts have considered one possible solution: ships fitted with high-pressure storage tanks to transport liquefied natural gas (LNG) from gas-rich to gas-short regions. But again there are obstacles. Dozens of new receiving terminals would be needed in Europe, Asia, and the U.S. (which currently has only four). People are also understandably concerned that these terminals, with their berthed tankers and vast fields of LNG storage tanks, would be appealing targets for terrorists.

How about solar power? Although it's still pretty expensive—about three to eight times more costly than coal or gas power—the price per kilowatt-hour is falling, and optimists believe that solar may be widely competitive with conventional energy within ten to twenty years.

But solar power faces other difficulties. First, many regions in the world that consume the most energy don't have bright, year-round sunlight (think New York, Chicago, London, Berlin, Moscow, and Tokyo in the long fall and winter seasons). Second, and even more fundamental, solar energy has a low "power density." This means that even in regions where sunlight is steady and bright (like the Mojave or Saharan deserts), a square meter of Earth's surface doesn't receive a lot of solar energy on a daily basis. Humankind's industrial zones and high-density, energy intensive urban cores consume many times more power per square meter than they receive from the sun. So, for example, despite the fact that Japan is aggressively pursing solar electricity, Tokyo could not power itself from the sun without covering a large chunk of Honshu with photovoltaic cells.

This brings us to cost, the final wall to the energy box. Solar power not only requires huge amounts of land but also huge amounts of money. Supplying current U.S. electrical consumption would require nearly 10 billion square meters of photovoltaic solar panels. At about $500 per square meter, the total cost for the panels alone would be $5 trillion, twice the U.S. 2004 budget or nearly half of U.S. GDP. Connecting this power to the grid and installing a means to store it would double or triple the price tag.

Could hydrogen solve our energy problem? Burning hydrogen creates no carbon dioxide emission, no acid rain, no ozone, and no soot—just water and heat. But there's a crucial problem: hydrogen is not a primary energy source. One can't drill for it like oil or mine it like coal. Instead, one *makes* it, by, for instance, running an electric current through water, in a process called "electrolysis."

This reveals hydrogen's critical limitation: where do we get the electric current? If the world had enough cheap, clean, emissions-free electricity in the first place, we wouldn't have much need for hydrogen. Currently, industry makes most hydrogen from natural gas, not water. This is the cheapest approach, but if widely deployed it would seriously exacerbate the already serious scarcity of natural gas. The next cheapest is a process called coal gasification and chemical shifting, which involves mixing coal with steam and burning the mixture at very high temperature, producing heat, hydrogen, and carbon dioxide. In other words, today the world gets its hydrogen from fossil fuels and then vents the waste carbon dioxide straight into the atmosphere. If the hydrogen needed for a full-scale hydrogen economy is obtained this way, then it's is no solution at all—it's just one more contributor to the climate-change problem.

Once again, let's keep in mind the scale involved. Replacing the oil the U.S. uses just for surface transportation would require 230,000 tons of hydrogen *every day*, which would fill about 13,000 Hindenburg dirigibles. The U.S. could get this hydrogen by electrolyzing water using electricity from sources that emit no carbon dioxide, like solar

power. But the country would have to nearly double its average electricity generating capacity and cover an area the size of Massachusetts with solar panels. And that's just to produce transportation fuel!

These problems aren't really solved by turning to other energy sources. Wind energy, like solar, has a power-density problem and can supply power only intermittently—when the wind is blowing. Geothermal, fusion, and space-based solar power all face major hurdles due to cost, deployment, supply, or technology. Hydropower? There are very few good locations left for large dams in most of the world. Traditional biofuels (like biodiesel and ethanol), while neutral in terms of carbon dioxide emissions, have cost, land-use, water, and other requirements that limit their effectiveness at the scale required.

So, for the foreseeable future, the U.S. and the world are stuck with fossil fuels and their attendant climate-altering emissions.

GOING OUT THE TOP

The situation may seem grim, but there *is* a way out of the energy box. The world has to start by recognizing that greenhouse gas emissions are a kind of trash. Little more than one hundred years ago, most people just chucked their trash out the window. Cities were rank concentrations of sewage and garbage. Today, the world generates vastly more trash than a century ago, but in most places we don't toss it out the window. Instead, we

put it somewhere else, in a place where we hope that the rot, disease, and smell are contained and managed. In essence, we sequester trash.

Humankind can sequester carbon dioxide too. We can take our carbon dioxide trash and store it somewhere else. Trees and plants do this: they absorb carbon dioxide and turn it into leaves, wood, and roots. Any system that takes up and stores carbon dioxide can do the job.

But the since the carbon needs to stay there a long time—for at least a few hundred years—trees and plants are not up to task, either in terms of permanence or total carbon storage capacity. A truly useful approach must also be cheap, safe, and environmentally sound.

Geologic carbon sequestration is all these things. In essence, we return the carbon dioxide from whence it came—we stuff our exhaust back underground. Carbon dioxide can be injected into old oil fields, into unmineable coalfields, or into deep, briny aquifers (today's preferred storage site for toxic waste). These geological reservoirs are huge, with enough capacity to hold many decades, even a century or more, of emissions. They are likely to be secure for millennia, with a low chance of leakage or any other risk to ecosystems or the public.

Not surprisingly, there are a few catches. Geologic sequestration requires a highly concentrated stream of carbon dioxide. To produce this stream, countries must build new

fossil-fuel electricity plants or retrofit existing plants—both costly endeavors. However, these costs aren't unmanageable: they're already comparable to those of wind and nuclear power, and in many instances lower. If a low-cost device were engineered to capture carbon dioxide from fossil-fuel streams, then carbon sequestration would add only an incremental cost to today's energy sources. Such an approach would also resolve the initial scale problem. If we could capture the carbon dioxide of most of today's emitters, like coal-fired power plants, we could lower emissions dramatically without reducing energy supply.

Geologic storage at this scale requires porous and permeable reservoirs deep underground surmounted by a layer of impermeable rock that prevents leakage. Preliminary estimates indicate that there’s already enough geologic capacity close to today's major sources of carbon dioxide. Proper geologic storage would also require sophisticated analysis and planning, especially to monitor and verify underground storage.

These requirements, although formidable, may be simply the price we have to pay to maintain our energy-intensive economies, much as we pay for trash collection and disposal. If so, we should get cracking, because we aren’t doing enough in this direction at the moment—the technological, infrastructural, and organizational requirements of a serious effort to store greenhouse gases underground will be immense. Once in place, though, geologic storage will allow us to burn coal for energy, capture hydrogen for fuel, and bury the waste carbon dioxide to mitigate global warming.

It turns out that just such a marriage of technology is already available: the IGCC, or Integrated Gasified Combined Cycle coal-fired power plant. Never has burning coal been so sexy. The black rock is crushed and mixed with steam to make a hot combustible fluid called "syngas." This process strips out sulfur, mercury, and other pollutants, thereby reducing toxic emissions. When the syngas is consumed, it releases hydrogen. The only other IGCC emission is a pure stream of carbon dioxide, suitable for geologic storage. And of course, an IGCC plant makes large amounts of electric power. This technology can generate both electricity and hydrogen, eliminate coal's toxins, and produce the pure stream of carbon dioxide that we need if we're serious about burying our greenhouse gases. Such zero-emission power plants (with the catchy acronym ZEPs) must be central to any serious energy policy.

Can it be done? The U.S. Department of Energy thinks so. They have released their vision for the *FutureGen* power plant—a ZEP exactly as described above. It's small, at only 275 megawatts, but it's a worthwhile start nonetheless. When deployed, it should make power, hydrogen, money and—amazingly—no emissions of any kind. The European Union is hoping to do the same thing, and there's talk of building these plants in China and India, countries with huge populations, energy demands, and coal supplies. An added bonus is that gasification-based ZEPs can burn a wide range of fuels besides just coal and, by doing so, can actually reduce the atmosphere's concentration of carbon dioxide. Fuel inputs to ZEPs can include waste biomass like corn residues, lawn clippings, and wood chips. ZEPs can also burn a gooey petroleum substance called orimulsion, a mixture of water and tar that can be produced in colossal volumes in

Canada and Venezuela. These two nations together possess more than 2.5 trillion barrels of tar—more than twice the volume of all conventional oil left in the world.

Supply, security, scale, and even cost become tractable in this context. By burning coal, orimulsion, biomass, and even garbage in ZEPs, we can provide enormous amounts of electrical power for our houses, office buildings, and factories and the enormous amounts of hydrogen for mobile applications like cars. We can dramatically cut our greenhouse gas emissions. And, if we're clever, we can do all these things without breaking the bank.

This is one ladder out of the energy box.

POLICY MATTERS

CEO's of coal, power, and petroleum companies have gone on record with their concerns about global climate change and their support for sequestration efforts. At least one coal provider's CEO is on record as saying that if sequestration fails, we should probably stop burning coal!

The kind of technological brew we've described above—ZEPs combined with geologic sequestration—doesn't build and deploy itself. It requires motivated and ingenious scientists, engineers, and investors, and it also requires ingenious market and government institutions that create the right economic incentives and regulatory environment.

One example is a carbon-dioxide commodity exchange. If there's social value in reducing greenhouse gas emissions, then there should be market value too. People who take carbon dioxide from burning fossil fuels and inject it into Earth—and who, by doing so, produce benefits for current and future generations—should be rewarded. Investors should be rewarded for risking their capital to build the physical infrastructure of new electricity plants, pipelines, and storage reservoirs. To generate and allocate these rewards, we'll need sophisticated markets to assess the potential of carbon-storage ventures and to return profits to the people who provide their labor and skills and who risk their capital. The Chicago Climate Exchange is an embryonic carbon dioxide market, which in June traded it's first one million tons of CO_2. A world-wide market is a key component of the Kyoto protocol. Such markets are underpinned by a regulatory regime that places a cap on emissions and allow countries, corporations, and other economic actors to trade emission credits. In the U.S., a similar mechanism has helped reduce acid rain, mercury pollution, and byproducts of coal burning.

Many other policies can spur the development of ZEPs combined with geologic storage. Norway, for example, has levied a $50 per ton tax on carbon. Not surprisingly, the Norwegians are the world leaders in geologic carbon sequestration. The national petroleum company, Statoil, runs the worlds largest single carbon sequestration effort at the Sleipner field in the North Sea.

Either a carbon-dioxide exchange or a carbon tax would encourage companies to build ZEPs in any location where a conventional coal plant is under consideration; these policies would also encourage innovation to reduce costs and improve efficiency of ZEPs, geologic storage, and renewable energy technologies more generally. Most importantly, a policy framework would end the uncertainty businesses currently face in long term investment planning, and help level the playing field for other carbon free energy sources, such as wind, solar, or biomass without direct subsidy.

Rich industrial countries like the United States must play a key role in the development and deployment of these technologies, because poor countries have little incentive or means to develop expensive, low-emission sources of energy when they face other urgent economic needs for their large populations. Industrial countries will have to invest heavily in research and development in all energy sectors, including conservation and renewable energy technologies that can be deployed globally at low cost. But one of their top priorities should be testing the viability of large-scale geological carbon sequestration.

Unfortunately, spending on energy research has dropped precipitously in all industrial countries except Japan. In real terms, combined industrial and governmental R&D in the energy sector has declined over 70 percent over the last thirty years. In some countries such as Germany, it has fallen even more, including a shocking recent decline in spending on nuclear and wind research. The IEA estimates investments in excess of $200 billion are needed each year just to meet demand, let alone investigate alternatives. This

trend must be reversed in all industrial countries. Specifically, nations should subsidize a diverse range of field experiments for geologic storage to show that the technology can be made both feasible and safe. Dedicated field experimental facilities, not just more demonstration projects, are needed to produce the knowledge we need for sequestration to succeed.

Towards this goal, the U.S. State Department, the Department of Energy, and relevant ministries from sixteen nations have formed the Carbon Sequestration Leadership Forum. This high-level international group discusses technical and policy issues relating to geologic storage and other forms of carbon sequestration. In June 2003, China, India, Indonesia, Mexico, Brazil, Canada, Japan, Australia, and many European nations signed a declaration stating their commitment to carbon sequestration as an important approach to lower global carbon dioxide emissions. In addition, the DOE has designated Teapot Dome (yes, *that* Teapot Dome) as one experimental facility for carbon storage.

Humankind can't stabilize greenhouse gas concentrations in the atmosphere at current levels. The best we can do, and even this goal may be hopelessly optimistic, is stop the increase at about twice pre-industrial concentrations (for carbon dioxide, that’s about 560 parts per million, compared to a pre-industrial concentration of 280 ppm). We have to hope that this doubling doesn’t, by itself, create climate and environmental catastrophe. But even to limit the increase to a doubling will require very clever technology and policy on a global scale.

It's a challenge that the U.S. and the West should be embracing wholeheartedly and tackling with the same dedication, investment, and smarts that we committed to, say, containing the Soviet Union. We should increase key energy technology funding one-hundred fold with an emphasis on building large-scale field demonstrations and sharply lowering the cost of carbon dioxide capture. This work should proceed as public/private partnerships, with strong government, university, and industrial leadership across many countries. It needs to take place within an international emissions trading framework that sustains economic growth. Incentives, such as tax credits, should be provided to early actors, and multinational companies reducing emissions abroad should be given credit for these reductions in their home countries.

Also, the G8 nations should have separate energy and emissions summits to parallel their annual economic meetings, with emphasis on technologies and policies that could be adopted by large developing countries. Industrial nations must also spearhead a crash, five-year survey of global geology so that humankind has an inventory of the planet's subsurface carbon dioxide storage capacity. Such an inventory will underpin cost predictions and support a carbon dioxide trading regime. Australia has just completed such an effort, which required three years, dozens of scientists, and large-scale industrial collaboration and support.

This isn’t the time for denial or avoidance: every year we wait the problem gets bigger, the work harder, and the costs larger. And every year we wait, it’s less and less likely that we’ll ever climb out of the energy box.