FOREIGN AFFAIRS

NOVEMBER/DECEMBER 2004

Out of the Energy Box

S. Julio Friedmann and Thomas Homer-Dixon

Volume 83 • Number 6

Out of the Energy Box

S. Julio Friedmann and Thomas Homer-Dixon

THE HEAT IS ON

ONLY RICHARD NIXON could go to China. And maybe only oil industry CEOs can lead action on global climate change. Lord Browne, the head of BP, has stated in no uncertain terms that climate change is real, and he has made it BP's responsibility to cut down on the greenhouse-gas emissions that are upsetting the earth's climate.

The prognosis for the future of climate change is indeed alarming. Scientists say plausible scenarios include terrible droughts, crop failures, and dying forests around the Mediterranean and in the United States, South America, India, China, and Africa. Sea levels are expected to rise significantly, drowning islands and possibly displacing hundreds of millions of people from coastlines, where more than a third of the world's population lives. Ground water supplies are set to shrink, reservoirs to dry up. Wildfires and violent storms will strike more often and much harder. And much of this change is expected within the next 50 years.

Most scientists believe that recent global warming is largely the result of human energy consumption, which releases carbon dioxide, a powerful greenhouse gas, into the atmosphere. Massive, almost inconceivable amounts of energy are used to do everything these days, from building airplanes to running sewer systems and hospital equipment. Energy is the essence of modern

S. JULIO FRIEDMANN heads the Carbon Storage Initiative at Lawrence Livermore National Laboratory. THOMAS HOMER-DIXON is Director of the Pierre Elliott Trudeau Centre for Peace and Conflict Studies at the University of Toronto.

civilization, and as societies and economies grow, so does their energy consumption.

In the United States and most other developed countries, 85 percent of this energy comes from fossil fuels (mainly coal, oil, and natural gas). In 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. Global energy consumption is growing at roughly two percent per year and is projected to double by 2035 and triple by 2055.

The good news is that fossil fuels are still relatively abundant and cheap. Coal reserves are huge, especially in the United States. Oil and gas reserves are also significant, at least when one considers the world at large and includes unconventional reserves such as tar sands, oil shales, and coal-bed methane. The bad news is that burning fossil fuel emits carbon dioxide. And global energy consumption is so great and rising so fast that humans are demonstrably changing the climate.

Reducing the consumption of energy and increasing its efficient use would help control emissions. But such measures will not likely be sufficient to solve the problem. Nor will replacing fossil fuels with alternative sources of energy, which remain prohibitively expensive or too impractical to be used on a large scale. Modern economies are thus bound to remain dependent on carbon dioxide–releasing fuels for the foreseeable future.

Although energy needs and environmental constraints have created this tight energy box, an important technology has emerged that offers a way out of it, at least temporarily. Called "carbon sequestration," it is a way to store carbon dioxide in a benign form and in a safe place, allowing the continued use of fossil fuels without the dreadful effects of climate change. With the right economic incentives and regulatory framework, moreover, sequestration can be made attractive to investors and so developed more widely. And it should be, because the technology may be the only realistic way to satisfy the world's gargantuan energy needs while responsibly mitigating their side effects. As Lord Oxburgh, the chairman of the British arm of the Royal Dutch/Shell group, said recently, "sequestration is difficult. But if we don't have [it], I see very little hope for the world."

INSUFFICIENT EFFICIENCY

THE WORLD'S ENERGY NEEDS—and their potential effects on the environment—can hardly be exaggerated. Producing, processing, and transporting energy costs more than $3.5 trillion every year—more than the U.S. federal budget or the GDP of most nations. The expense increases significantly every year, as the world's population and economy grow.

Consider the energy needs of the United States, home to less than one-twentieth of the world's population but which produces about a quarter of its carbon dioxide emissions. U.S. energy consumption now reaches 97.6 quadrillion British thermal units (quads), and it is expected to grow by at least another 95 quads over the next 50 years. Assuming these new needs were to be covered by nuclear power, which provides a lot of electricity without emitting carbon dioxide, one would have to build 1,500 nuclear plants to supplement today's 104 facilities—a new plant about every 10 days—to meet projected demand. Even if such a plan were possible, it would do nothing to reduce carbon dioxide emissions; it would only help keep them at today's already very high levels.

These staggering requirements mean that simply conserving energy and using it more efficiently cannot solve the problem. Although the United States has grown much more efficient over the past two decades, it still has not reduced its carbon emissions. Despite total efficiency gains of over 35 percent since 1980, annual use in the United States soared from 78 quads to nearly 100 quads between 1980 and 2000, and annual carbon emissions from 1,288 to 1,562 million metric tons. Why the disparity? Because although efficiency has improved on average by almost two percent annually over the last 20 years, GDP has grown at over three percent annually.

Moreover, even at that rate, efficiency cannot improve indefinitely, because manufacturers and entrepreneurs exploit the easiest ways of saving energy first, and so it may be harder and more expensive to achieve more gains. Even if that were not so, carbon emission rates would not drop unless economic growth dropped even more. And no economic policymaker—certainly no politician—would settle for a growth rate of less than two percent, when that level is too low even to absorb new labor entering the work force.

Strict conservation policies are even less feasible for the developing world, which sees poverty as its chief problem and is trying to grow as fast as possible. China grew at 9.1 percent in 2003, and the country's phenomenal appetite for steel, aluminum, copper, and cement caused its fossil fuel consumption to surge—turning it into the world's second-largest petroleum importer after the United States. Chinese leaders have made it clear that they want a billion cars for their billion potential drivers. But they cannot achieve a Western standard of living without also drastically increasing energy consumption and carbon dioxide emissions. In fact, current projections show that by 2020 China will overtake the United States as the world's leading carbon dioxide emitter.

POOR SUBSTITUTES

With rising energy needs and volatile oil prices, some advanced economies have started to look for alternatives to conventional coal and petroleum. But substitution is only a partial solution. Making most electricity from pulverized coal, natural gas, nuclear power, or solar energy is either problematic or too costly.

Coal is a versatile, high-energy fuel that is plentiful, cheap, and easily transported. It is also very dirty. 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 sulfur dioxide (which causes acid rain), and extracting coal is harmful to both the environment and workers, who often suffer accidents in mines or contract black-lung disease.

Natural gas (or methane), which burns cleanly, with small emissions of carbon dioxide and even smaller emissions of other pollutants, has become a preferred energy source for many countries. It too is abundant around the planet: on land in Bolivia, the Middle East, Central Asia, and Siberia and offshore in the Arctic, the Gulf of Mexico, and along the western coast of Africa.

Unfortunately, most gas supplies lie far away from users, so transportation costs are high. The United States, once impervious to these concerns thanks to abundant resources at home and in Canada, has recently had to face problems caused by dwindling domestic supplies and increased demand. Although about 16,000 new gas wells were drilled in the lower 48 states in 2002, production declined by six percent and shortages caused the price of gas to spike to three times its base cost. In the past decade, moreover, the base cost of natural gas has almost doubled in the United States, causing many gas-powered plants to sit idle.

Energy experts have considered one solution: importing gas from far-flung suppliers by transporting it, in liquefied form, in ships fitted with high-pressure storage tanks. But right now the United States has only four terminals equipped to receive liquefied gas, which together accept only a quarter of a quad every year. Another 40 terminals are planned or proposed, but they would likely provide less than three quads in total. To meet demand, hundreds more would have to be built. But with their berthed tankers and fields of storage units, they would make appealing targets for terrorists, as would incoming ships, each one of which would carry ten kilotons of explosive potential.

Given their growth rates, modern economies are bound to rely on fossil fuels—and suffer from harmful emissions.

Nuclear power does not emit carbon dioxide either, and it has other advantages to boot. Nuclear plants can be built in large numbers close to the populations they serve, without risk of interrupted fuel supply. They can be designed to be "inherently safe," with an infinitesimally small risk of meltdown, and thanks to "breeder" technology, to produce their own fuel.

Yet nuclear power is almost twice as expensive as fossil-fuel energy, and, like liquefied gas, it presents serious security risks. Nuclear-power plants, especially breeder reactors, produce a lot of highly radioactive waste, chiefly plutonium. Scientists might eventually figure out how to safely store waste for the tens of thousands of years it takes to become innocuous, and politicians might be able to convince reluctant constituencies to accept living by it in the meantime. But such nuclear material could still be diverted or stolen and converted into bombs. As it is extremely toxic, terrorists could use it for radiological or "dirty" bombs, and it contains plutonium, which can be extracted to make atomic weapons.

Sources of renewable energy, such as solar power, pose no such danger, but they are inherently ill suited to modern energy needs. Many of the regions that consume the most energy do not have bright, year-round sunlight. (Think of New York City, London, Moscow, and Tokyo in the long fall and winter seasons.) Solar energy has a low power density, so even in regions where sunlight is steady and bright, as in the Mojave or Sahara deserts, a square meter receives little power every day. Industrial zones and high-density urban cores consume many times more power per square meter than they receive. To power Tokyo from solar energy, for example, a large chunk of the island of Honshu would have to be covered with photovoltaic cells.

As a result, generating power from the sun requires huge amounts of land and money. Admittedly, the price of solar energy is falling, and optimists believe that it may be competitive with that of conventional energy within 10 to 20 years. But, for now, it remains expensive: about three to eight times more than coal or gas power. Satisfying current U.S. electrical consumption would require nearly 10 billion square meters of photovoltaic solar panels. At about $500 per square meter, the panels alone would cost $5 trillion, twice the U.S. federal budget for 2004 and nearly half of U.S. GDP. Connecting this power to the main electrical grid and installing a means to store it would double or triple the price tag.

Hydrogen is no panacea either. It is much touted for yielding only heat and water—no carbon dioxide, acid rain, ozone, or soot—when it is consumed. And, when used as a fuel for transportation, it is critical in helping reduce carbon dioxide emissions. But because it is not a primary source of energy, it has large-scale supply problems. Hydrogen cannot be extracted like oil or coal. It can be made through electrolysis, by running an electric current through water. But that process begs the question: where does the electric current come from? If the world had enough cheap, clean, emissions-free electricity to make hydrogen, there would not be much need for making it at all. In most industrial applications, hydrogen is made by combining steam with natural gas and then changing the mixture into hydrogen. But that process emits carbon dioxide. So although consuming hydrogen for energy does not pollute, making hydrogen this way in the first place does. In sum, running a full-scale hydrogen economy with either this process or electrolysis would turn hydrogen into another contributor to global warming.

Although it is also possible to make hydrogen without generating undesirable byproducts, those methods are not economically viable yet. The United States could produce hydrogen using electricity from solar or nuclear power. But to replace the oil it uses for surface transportation would require 230,000 tons of hydrogen every day (enough to fill 13,000 Hindenburg blimps). That, in turn, would require nearly doubling the country's average electricity-generating capacity and covering an area the size of Massachusetts with solar panels—just to produce transportation fuel.

No other single source of energy offers a viable solution. Wind energy, like solar energy, poses a power-density problem, and it supplies power only intermittently: when the wind blows. Geothermal, fusion, and space-based solar power all face major hurdles due to cost, deployment, supply, or technology. There are few good locations left in the world to build large dams and generate power from water. Traditional biofuels (like biodiesel and ethanol), while neutral in terms of carbon dioxide emissions, have requirements relating to cost, land use, and water that limit their effectiveness at the scale required.

TAKING OUT THE TRASH

FOR THE FORESEEABLE FUTURE, then, the United States and the world must continue to rely on fossil fuels—and suffer their attendant climate-altering waste. This is a grim conclusion, of course, but it need not foreordain the end of the world. Although it is unrealistic to stop the emission of dangerous byproducts, their harmful effects can be drastically limited.

First, it is important to recognize that greenhouse-gas emissions are a kind of trash. One hundred years ago, most people just chucked their garbage out the window, turning cities into rank concentrations of waste and sewage. Vastly more trash is generated now than then, but in most places it is removed and taken where rot, stench, and contamination can be contained.

Like trash, carbon dioxide can be sequestered. Trees and plants already do it: they absorb the gas and turn it into leaves, wood, and roots.

But to make a dent in global warming, massive amounts of carbon need to be stored away for a long time—at least a few hundred years—and trees and plants are not up to the task.

That is where geologic carbon sequestration comes in. The technology, formally called "carbon capture and storage," returns the carbon dioxide to where it came from—underground—by injecting it into old oil or gas fields, unminable coalfields, or deep, briny aquifers (today's preferred storage site for toxic waste). Geologic storage requires deep, porous reservoirs covered by a layer of impermeable rock to prevent leakage. But preliminary estimates indicate that there is enough storage capacity close to today's major sources of carbon dioxide to hold many decades' worth of emissions safely, with a low chance of leakage or other risk to ecosystems or the public.

A new technology allows carbon dioxide to be captured and stored, lowering dangerous emissions without affecting energy use.

There are a few catches, of course. Only a highly concentrated stream of carbon dioxide can be stored, and it must be captured from retrofitted or brand-new power plants. The costs of upgrading or building such facilities are significant. But they are comparable to those of developing wind and nuclear power, and in many instances lower. Once a low-cost device to capture carbon dioxide from fossil-fuel streams is engineered, carbon sequestration will add only an incremental cost—roughly five to ten percent—to today's energy sources. The carbon dioxide of most of today's emitters, such as coal-fired power plants, could then be captured, lowering emissions dramatically without affecting energy consumption.

The technology is already available. The integrated gasified combined cycle (IGCC) coal-fired power plant crushes coal and mixes it with steam to make a hot combustible fluid called "syngas," stripping out sulfur, mercury, and other toxic pollutants. When syngas is consumed, it releases large amounts of electric power, hydrogen, and a stream of carbon dioxide suitable for capture and geologic storage. If the emissions are sequestered, the IGCC becomes a zero-emission plant (ZEP). Coal-power generation has never looked so sexy.

Even better, ZEPs based on gasification technology can burn a wide range of fuels besides coal. Waste biomass, such as corn residues, lawn clippings, and wood chips, and a gooey mixture of water and tar called "orimulsion" are suitable. Thus all could be used to generate both electricity and hydrogen.

The U.S. Department of Energy (DOE) thinks ZEPS can be economically viable. In February 2003, it announced plans to build and deploy the prototype FutureGen power plant. The FutureGen plant will be small, producing only 275 megawatts, but the project is worthwhile nonetheless, for it will validate the technology. Norway, Australia, Canada, and Germany are already developing ZEPS that burn coal, gas, and biomass; China and India, countries with huge populations, energy demands, and coal supplies, are considering the idea. Industry has also begun to invest heavily in the technology. In August 2004, American Electric Power announced plans to build a commercial IGCC before 2010. The plant will cost a lot upfront, but it has two benefits: very high efficiency and an emissions stream that can be captured and stored at low cost.

Given their considerable benefits, ZEPS must be central to any serious energy policy. By burning coal, orimulsion, biomass, and even garbage, ZEPS can provide enormous amounts of both electrical power and hydrogen while dramatically cutting greenhouse-gas emissions—all, if done right, without breaking the bank. They can even enhance energy security. At present, fears that oil supplies could be disrupted powerfully shape the policies of many industrialized nations toward the Middle East and politically volatile producers such as Venezuela, Nigeria, Russia, and Indonesia. Using coal, which is abundant throughout the world, would reduce both dependence on oil suppliers and the terrorist threats that nuclear plants and liquified-gas terminals could attract.

GETTING REAL

ALTHOUGH TECHNOLOGY makes geologic sequestration possible, only the right incentives and regulations can make it viable. Curbing global warming takes motivated and ingenious scientists, engineers, and investors, as well as appropriate market and government institutions.

Creating a carbon dioxide commodity exchange would be a good start. If reducing greenhouse gas emissions has social value, it should be given a market value. People who take carbon dioxide from burning fossil fuels and sequester it underground, producing benefits for current and future generations, should be rewarded. So should investors who risk capital to build new electricity plants, pipelines, and storage reservoirs. To generate and allocate these rewards, sophisticated markets should be developed to assess the potential of carbon-storage ventures and return profits to people who launched them. The Chicago Climate Exchange, an embryonic carbon dioxide market, traded its first one million tons of carbon dioxide in June 2004, and the Kyoto Protocol, if ratified, would create a worldwide emissions market. Both are underpinned by a regulatory regime that caps emissions and allows countries, corporations, or other economic actors to trade emission credits. In the United States, a similar mechanism has significantly reduced acid rain, mercury pollution, and other byproducts of coal burning.

Other policies can spur the development of ZEPs and geologic storage. Norway has levied a carbon tax of $50 per ton. Not surprisingly, the Norwegians are now leaders in geologic carbon storage, with the national petroleum company, Statoil, running the world's single largest carbon sequestration effort at the Sleipner field in the North Sea.

Promoting such mechanisms would encourage companies to build IGCCs and ZEPs instead of conventional pulverized-coal plants and would spur innovation to reduce the costs and boost the efficiency of ZEPs, geologic storage, and renewable energy technologies more generally. Most important, a new policy framework would dispel the uncertainty businesses currently face in long-term investment planning and help level the playing field for the development of other carbon-free energy sources, such as nuclear power, wind, solar power, or biomass.

Rich industrial countries such as the United States, Canada, and members of the European Union must play a key role in the development and deployment of these technologies. Poor countries have little incentive to investigate expensive, low-emission energy sources when they face urgent economic needs. So rich countries should invest heavily in research and development (R&D) in all energy sectors, to promote conservation, develop cheap and versatile forms of renewable energy, and, above all, test the viability of large-scale geologic 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 by more than 70 percent over the last 30 years. In Germany, spending has fallen even more, including for nuclear and wind research. The International Energy Agency (IEA) estimates that investments in excess of $200 billion are needed each year just to meet increased energy demand, let alone to investigate alternatives.

This alarming trend must be reversed in all industrialized 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 experimental facilities, not just more demonstration projects, are needed to establish the viability of sequestration.

To that end, the U.S. State Department, the DOE, and the relevant ministries from 16 nations formed the Carbon Sequestration Leadership Forum to discuss technical and policy issues relating to geologic storage and other forms of carbon sequestration. In June 2003, Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, and many European nations signed a declaration stating their commitment to using carbon sequestration to lower global carbon dioxide emissions. In addition, the DOE has designated Teapot Dome (yes, that Teapot Dome) as an experimental facility for carbon storage and has launched a new storage experiment, the Frio Brine Pilot, in southern Texas.

Concentrations of greenhouse gases in the atmosphere cannot be stabilized at current levels. The most that can be done—if even that—is to stop the increase at about twice pre-industrial levels. This means capping carbon dioxide concentration at about 560 parts per million (PPM). (It is at 380 PPM today.) By itself, that concentration could be high enough to bring a climatic and environmental catastrophe, but limiting it to even that level will require very clever technology and wise, concerted policy.

Nonetheless, the United States and other Western states should embrace this challenge as wholeheartedly and with the same dedication, investment, and smarts they once committed to containing the Soviet Union. Funding for key energy technologies should be increased a hundredfold to develop large-scale field demonstrations and sharply lower the cost of capturing carbon dioxide. Such projects should proceed as public-private partnerships, with strong government, university, and industrial leadership across many countries and an international emissions-trading framework designed to sustain economic growth. Incentives such as tax cuts should be provided to early actors, and multinational companies that reduce emissions abroad should be given credit in their home countries.

The G-8 group of highly industrialized nations should also hold energy and emissions summits in parallel with its annual economic meetings to consider technologies and policies that could be adopted by large developing countries. Industrial nations must also spearhead a crash, five-year survey of global geology to map the planet's subsurface capacity for storing carbon dioxide and so 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. The United States, Canada, and other states have begun to set their geologic surveys to the task, but they should do much more. Meanwhile, they should increase efforts supporting energy efficiency, renewable energy, and nuclear fission, because only a wide portfolio of measures can ultimately be effective.

Storing greenhouse gases underground will require immense technological, infrastructural, and organizational changes. Such measures may seem formidable, but they should be treated as an incidental cost of maintaining energy-intensive economies, much like trash collection and disposal. Now is not the time for denial or avoidance; managing the damage caused by carbon dioxide emissions has become urgent. With every year that passes, the problem and the cost of fixing it become much greater—as does the chance that the damage already done is irreversible.