PIR

THE MAGAZINE FOR SCIENCE & SECURITY

Summer 2011 Volume 64 No 2

War and Peace: Cyber Edition

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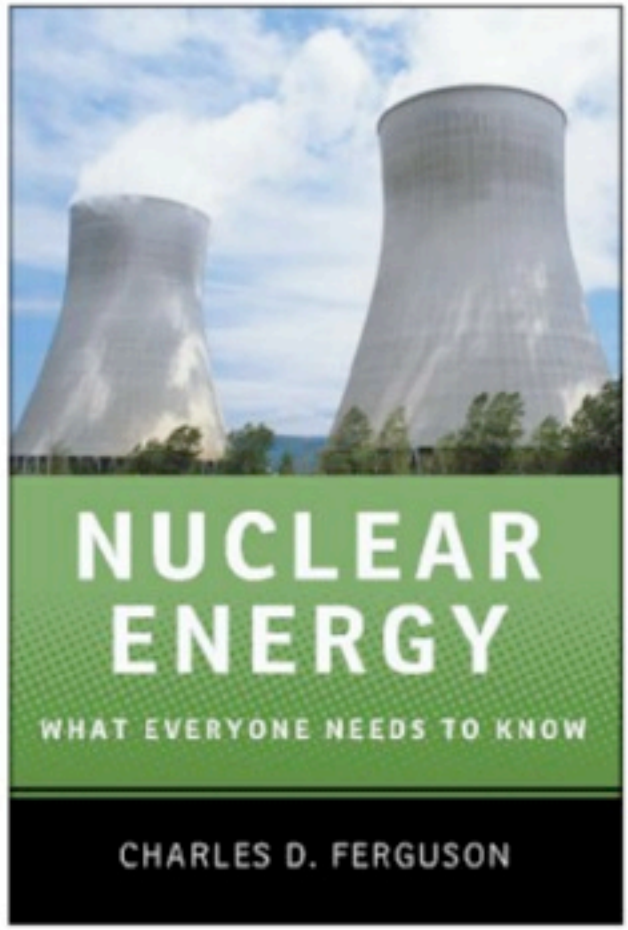
Nuclear Energy

What Everyone Needs to Know

By Charles D. Ferguson

Originally perceived as a cheap and plentiful source of power, the commercial use of nuclear energy has been controversial for decades. Worries about the dangers that nuclear plants and their radioactive waste posed to nearby communities grew over time, and plant construction in the United States virtually died after the early 1980s. The 1986 disaster at Chernobyl only reinforced nuclear power's negative image. Recent years have seen a marked change, however. The alarming acceleration of global warming due to the burning of fossil fuels and concern about dependence on foreign fuel has led policymakers, climate scientists, and energy experts to look once again at nuclear power as a source of energy.

In this accessible overview, Charles Ferguson provides an authoritative account of the key facts about nuclear energy. What is the origin of nuclear energy? What countries use commercial nuclear power, and how much electricity do they obtain from it? How can future nuclear power plants be made safer? What can countries do to protect their nuclear facilities from military attacks? How hazardous is radioactive waste? Is nuclear energy a renewable energy source? Ferguson addresses these questions and more in a book that is essential for anyone looking to learn more about this important issue.



May 2011
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Key Features

- Easy to navigate, accessible Q&A format is ideal for an introduction to the subject of nuclear energy.
- In a clear, engaging style, the book provides a comprehensive survey of this controversial topic.
- Readily accessible and suitable to readers with various levels of background knowledge on the topic.
- Includes updated information on the nuclear crisis in Japan.

Charles D. Ferguson is President of the Federation of American Scientists and an Adjunct Professor in Georgetown University's Security Studies Program. Trained as a physicist and nuclear engineer, he has worked on nuclear policy issues at the U.S. Department of State and the Council on Foreign Relations.

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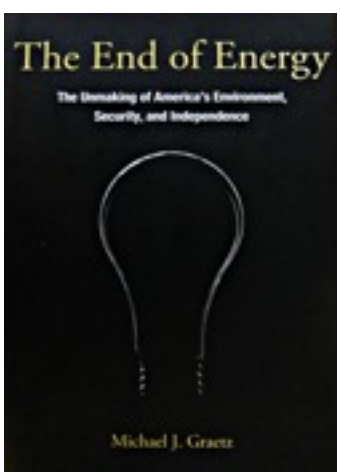

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20th ANNIVERSARY OF START

The 20-year anniversary of the signing of the Strategic Arms Reduction Treaty (START) between the United States and the Soviet Union was on July 31st. The treaty, also known as START I, marked the beginning of a treaty-based reduction of U.S. and Soviet (later Russian) strategic nuclear forces after the end of the Cold War.

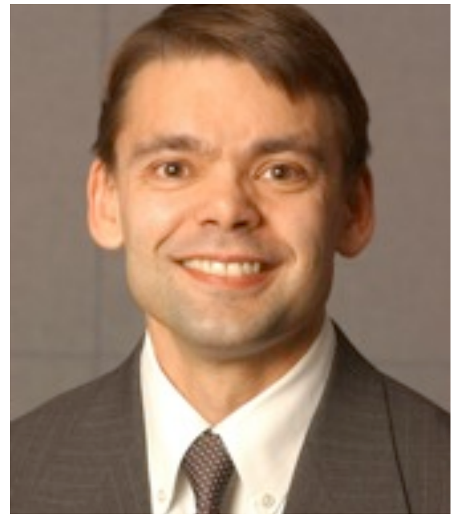
START I required each country to limit its number of ballistic missiles and long-range bombers to no more than 1,600 with no more than 6,000 accountable warheads. The treaty came with a unique on-site inspection regime where inspectors from the two countries would inspect each other's declared force levels. Thousands of other warheads were not affected and the treaty did not require destruction of a single nuclear warhead. START I entered into effect on December 5, 2001, and expired on December 4, 2009.

START II followed in 1993, limiting the force levels to 3,500 accountable warheads by 2007 with no multiple warheads on land-based missiles. START II was never ratified by the U.S. Senate but was surpassed by the Moscow Treaty in 2002, limiting the number of operationally deployed strategic warheads to 2,200 by 2012. The Moscow Treaty was replaced by the New START treaty signed in 2010, which limits the number of accountable strategic warheads to 1,550 on 700 deployed ballistic missiles and long-range bombers by 2018. New START does not limit thousands of non-deployed and non-strategic nuclear warheads and does not require destruction of a single warhead.

The Obama administration has stated that the next treaty must also place limits on non-deployed and non-strategic nuclear warheads.

http://www.fas.org/blog/ssp/?s=START

PRESIDENT'S MESSAGE



ADDRESSING BARRIERS TO GREENER ENERGY USE

I consider myself an optimist. But I must admit to frustrations on the personal and national levels in efforts toward a lower carbon and more efficient energy economy. I think back to February 2009 near the start of the Obama administration. The administration convinced Congress to pass massive stimulus spending including tens of billions of dollars to promote greener energy technologies.

One measure was to lift the cap on the federal tax credit for installation of solar photovoltaic (PV) and solar thermal systems. Thousands of Americans, myself included, seized on this opportunity. By early March, I had a company under contract to install a 3-kilowatt PV system on the roof of my house. So far so good, but then the work bogged down. In some respects this slowdown was a positive sign. It meant that these companies had a lot of work. The workers were fully employed. This seemed good for the economy. But Congress had a time limit to this offer. It would expire in a couple of years. The idea was to stimulate a larger market demand for solar and wind power. Through greater economy of scales, the price of these technologies would drop.

While prices have recently fallen to just under $6 per watt for residential PV, they are still far from the goal of the Department of Energy's Sun Shot initiative of achieving $1 per watt. This initiative is aiming to reach that goal by the end of this decade. Doing so will require innovations in the efficiency of the solar energy systems and the installation and financing costs. The latter challenge should not be underestimated because if these technologies are going to take off, consumers will need effective and easily deployable ways to ease the economic hurdle.

Although tax credits from the federal government and grants from local governments can stimulate further installation of solar PV and other renewable systems, many economists have argued convincingly that these stimuli are not the best economic policy for mature industries. But solar PV, for example, is too much of a niche industry. And it is not receiving much of a boost because the major federal tax credits expired at the end of last year, and local governments' grants have come to a halt or been significantly scaled back because of the financial crisis across the country.

Even with tax credits and grants, most consumers will need other means of financial support to cover the remaining costs. While net metering of PV systems will reduce consumer's electricity bills, this will still not be enough to convince many people to consider these systems. Fortunately, some electric utility companies have programs that allow homeowners to rent out their roofs and other programs such as renewable energy credits can further reduce the costs to consumers.

Even if all these financing methods were available across the United States, renewable and efficient energy for the home use will not reach its full potential until Americans receive much better education about these technologies. I have to admit that I've been somewhat confused about the choices among LED lighting. This type of lighting offers the advantages of very low energy use (typically one fourth of a comparable incandescent bulb), no use of mercury (a toxic element used in compact fluorescent light bulbs), and very long lived (typically 25 years in contrast to less than two years for incandescent bulbs or about 12 years for CFLs). But if one does not know to check the lumens rating or the Kelvin temperature listing, one might be disappointed in the quality of the light from an LED as compared to incandescent lighting. I know of at least one colleague who works for an environmental non-governmental organization and was disappointed in his LED purchases. And the major barrier is the much higher cost (20 times or greater). Of course, factoring in the longer life and electricity savings, one will more than earn back the additional cost. But convincing consumers of that fact presents a huge educational challenge for companies, the government, and science organizations such as FAS.

As Editor-in-Chief , I want to apologize for the delay in publishing the Summer 2011 issue of the *PIR*. It is my hope that you value our new format and expanded coverage. This issue is our largest to date and the new features took more time to edit and design than anticipated. Readers will find in this issue of the *PIR* several thoughtful articles addressing the challenges confronting energy use and the environment.

On behalf of FAS and the editorial staff, I welcome your thoughts about the new *PIR* design, as well as how all of us can reduce and remove the barriers to a lower carbon and much more energy efficient future.

Charles D. Ferguson
President, Federation of American Scientists

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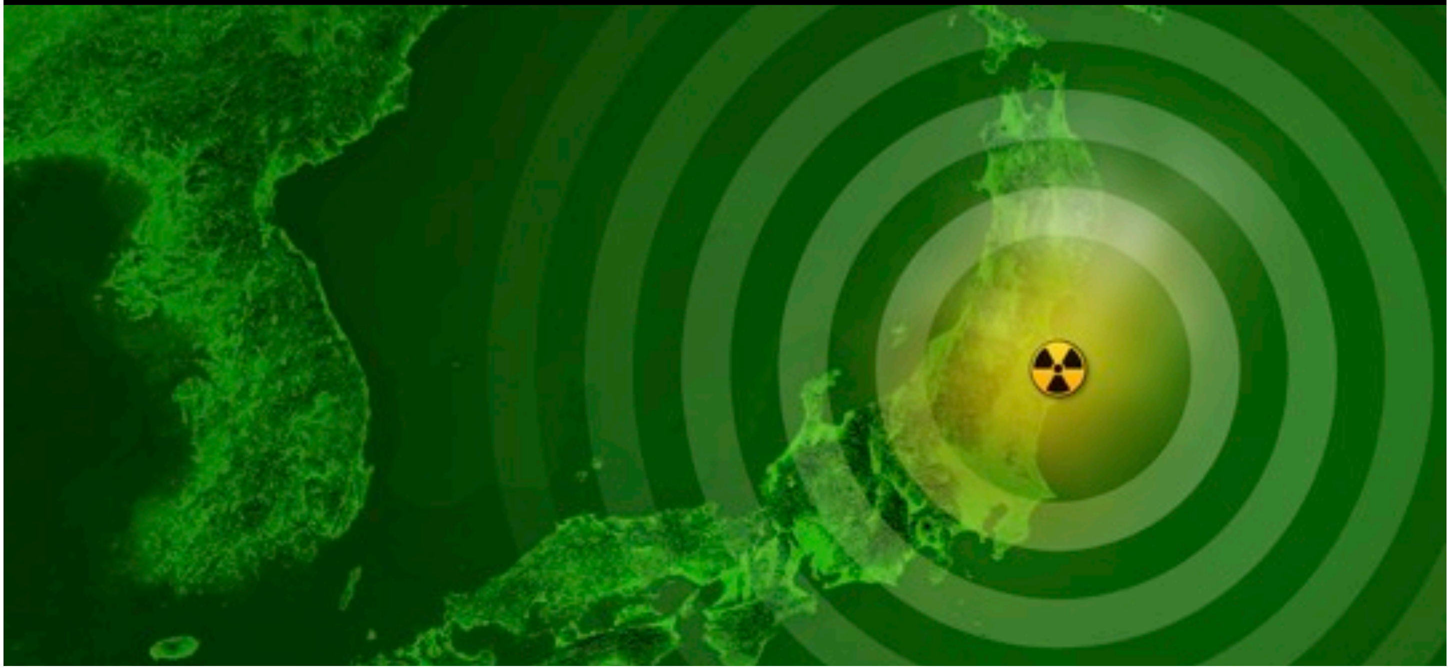


Protection of Nuclear Installations from Disasters

BY BASANT KUMAR MOHANTY, Ph.D, and NOSHIR SOONAWALA, Ph.D

The 9.0-magnitude Tohoku earthquake on March 11, 2011 off the eastern coast of Japan, and the subsequent tsunami, caused more than 14,600 deaths, about 5,300 injuries, and more than 11,000 people went missing in the affected area. The disaster was compounded by severe damage to Units 1, 2, and 3 of the Fukushima Daiichi Nuclear Power Plant and the resulting radiation leaks. The World Bank estimates that the damage due to the 2011 Tohoku earthquake and tsunami could be between US$122 billion and $235 billion. The Japanese government's official figure puts the damage at $309 billion, making it the most expensive natural disaster on record. Japan is facing one of its toughest times in the 65 years since the end of World War II.

So, it is time to think about ways to reduce the impact of future natural disasters on nuclear installations. All national nuclear regulatory agencies, as well as the International Atomic Energy Agency (IAEA), have produced voluminous safety standard guidelines and regulations for the siting of nuclear power plants, and no doubt, the Fukushima Daiichi plant was built in accordance with such guidelines. All the same, the disaster happened. It is evident that this plant withstood the earthquake quite well: immediately after the earthquake, structures seemed to be intact and there was no breach of the reactor cores. The principal causes of the catastrophe were the events triggered by the tsunami such as the loss of offsite power and the flooding of the standby generators. The accident-analysis scenarios for seismicity used for the design of the plant were obviously adequate, but not those for the tsunami. Tsunamis have at least cursorily been recognized as a natural hazard even in the earliest safety guidelines. Notably, a Nuclear Regulatory Commission document published in 1976 (NSIC-118) makes a passing reference to "…waters associated with hurricanes and/or tsunamis…" but obviously safety analyses for tsunamis have not been as thorough as for earthquakes.

The IAEA and national regulatory agencies should revise their safety analyses for tsunamis and ensure that existing nuclear power plants, as well as those in the planning stage, are able to withstand tsunamis of the magnitude that have occurred in the last decade. Revised safety guidelines should consider siting new power plants well away from the shoreline at suitable elevations. Seawater that is required for cooling, can be pumped to reactors sited at a distance from the shore. Very strong barrier walls should be built between the coastline and the existing nuclear installations. The walls should be built of materials able to withstand the force of future tsunamis and should be designed to reduce the strength and impact of any tsunami. The walls should be backed up by deep trenches to reduce the destructive strength of the sea waves following a tsunami. Finally, a few layers of concrete structures, one to two feet in size, should be built between the sea and nuclear installations and around the installations to reduce the destructive strength of tsunami waves. Plants where this is not possible should be shut down.

The nuclear industry is making a major push for expansion into regions of Asia prone to tsunamis. For example, a mammoth power station of up to 9,000 megawatt capacity is planned for Jaitapur on the Maharashtra coast in India. This plant will likely be built by a French company. The rapid expansion of nuclear power into developing economies of the world raises two questions regarding credible safety analyses for natural events: first is there sufficient historic seismic and meteorological data available for these sites; and secondly, do the European and North American manufacturers have sufficient knowledge of the natural conditions prevalent in Asia, and have these site-specific conditions been included in their safety-related design procedures.

Even the best safety features built into a nuclear power plant would fail miserably if the operators ignore the safety procedures -- a safety culture has to be well established at every level in an organization, from the executive down to the humblest worker. The immediate cause of the other major disaster in the history of nuclear power, the Chernobyl accident of 1986, was the shutting down of major safety systems of the reactor by operators who thought that was a way to meet a tight deadline for resumption of power to the grid following a planned outage. Many countries with nuclear power ambitions have a culture in society at large that encourages flouting of rules, and they suffer from entrenched corruption. Such a culture, if it ever seeps into the nuclear industry, would be an invitation for disaster. Nuclear is unforgiving -- all safety rules have to be followed all the time. No exceptions.

The rapid expansion of nuclear power into developing economies of the world raises questions regarding credible safety for natural events.

Many see the replacement of nuclear power with benign sources of energy such as wind, solar, tidal and so on as the ultimate guarantee against disasters like Fukushima and Chernobyl. However, that may not be realistic because in almost every industrialized country, nuclear has established itself as a reliable base-load electricity supplier, and developing economies are hungry for additional power. Major disasters at nuclear power plants can be avoided with better and updated accident scenario analyses for tsunamis and other natural events, and revised mandatory regulations. Costs of these revisions and the retrofitting of existing nuclear power plants though considerable, would still be orders of magnitude less than the cost of an avoidable future accident, a cost that developing economies in particular can ill afford. ■

Basant Kumar Mohanty is a professor at the King Fahd Medical Research Centre in Saudi Arabia.

Noshir Soonawala retired in 2004 after a 40-year career that included working in high-level nuclear waste management, environmental protection and mineral exploration.

Q&A: Burton Richter

Many of the issues of concern to the FAS founders exist today. Burton Richter received the Nobel Prize in Physics (1976) and the E. O. Lawrence Medal of the Department of Energy (1976). This long time supporter of FAS was interviewed and supplied his answers to FAS questions via email.

Learn more about Burton Richter by visiting: http://www-group.slac.stanford.edu/do/people/richter.html

The California Council on Science and Technology (CCST) released "California's Energy Future - Powering California with Nuclear Energy," a report that recommends building 30 new nuclear power plants to provide 2/3 of Califonia's electricity by 2050. Following the devastating earthquake and tsunami that led to the Fukushima Daiichi accident, only 11 of Japan's 54 reactors were online as of September 19, 2011; Germany plans to close all nuclear power reactors by 2022; Switzerland plans to shut down 5 reactors by 2034; and Italy recently rejected to return to nuclear power. Have your recommendations changed? If so, how?

The nuclear energy report is part of a larger effort commissioned by the California Energy Commission. The study takes a comprehensive look at how to achieve the state's goal of reducing greenhouse gas emissions in 2050 to a level of 20 percent of the emissions in 1990. It uses the state's own assumptions on population and economic growth, estimates what energy efficiency methods can do, and then finds that the goal cannot be met with technology now in the pipeline. Further, even adding new technology including large-scale carbon capture and storage, it cannot be met with renewables alone, which has surprised many. The full report (California's Energy Future - The View to 2050) recommends a balanced portfolio with nuclear supplying 31 percent of electricity, not 67 percent. The larger number was one of many exercises that had different technologies leading. All the reports are available at www.ccst.us.

As to Fukushima, the first lesson to be learned by all is that regulators have to be truly independent of promoters. The United States learned that lesson for nuclear energy years ago and our Nuclear Regulatory Commission became independent in 1974. The Japanese recently decided to make their regulators independent, and India announced it would do so two weeks after Fukushima. The United States should address this issue in other, non-nuclear areas. The BP oil disaster in the Gulf of Mexico is an example of what can happen when our regulators, promoters and those regulated have too cozy a relationship.

Lessons from Fukushima are still being learned as more information becomes available. The NRC has completed its first round study and from that has come some initial recommendations that will soon be put into effect. It is clear now, for example, that reactors have to be able to function in conditions when no external power is available (called station blackout) for longer than has been assumed up to now. It was eleven days before electricity from outside was restored at Fukushima. The United States will certainly require more than three days worth of fuel for emergency generators. Also, consequences of simultaneous disasters will have to be reexamined.

From what we know now, the reactors at Fukushima came through the earthquake fine but the tsunami flooded the emergency generators and knocked them off, precipitating the loss of cooling that those generators were designed to prevent.

My recommendations for California, indeed for the world, have not changed. Nuclear electricity is clean and safer than that from most other sources. Infrequent big problems are more feared than frequent smaller ones. Every study I have seen finds coal, gas, and oil responsible for more health problems than nuclear when averaged over a long period. What I think will happen to the nuclear renaissance is a pause in the expansion of nuclear while the lessons from Fukushima are absorbed. The big expansion was always going to be in Asia and that will continue to be the case. The need for more electricity is acute if they are to meet their development goals and other sources are too dirty or too expensive or too hard to come by. As far as Germany is concerned, this has happened before when nuclear was to be phased out only to have the phase-out phased out to meet environmental goals. It is ironic that Germany as they shut down reactors (if they really do so) will get more nuclear-generated electricity from France and coal-generated electricity from Poland.

The polarization of U.S. politics grows worse. In July 2009, you authored a letter, signed by 33 fellow Nobel laureates, to the Obama administration in support of the Clean Energy Technology Fund, which would provide $150 billion over 10 years for research and development into energy technologies. With a skittish economic recovery and contentious debate to reduce the U.S. deficit, do you still support this scale of federal investment in energy research? How would you advise the United States in terms of its investment in energy technology?

It is not at all clear that the country is as polarized as is Washington. The polls tell us that Democrats, Republicans, and Independents all seem to scorn Congress for the absurdities of the maneuvering over the debt limit. The 2012 election will tell us all if we are heading to revenue enhancement as part of deficit reduction. I do still support investment in advanced technology and energy R&D, and our legislators would too if they would only open their eyes. If they did they would see the rest of the world gaining on us in R&D. Part of this is natural. China and India, like Japan and Korea before them, have entered a stage of rapid economic development. First their manufacturing expanded and now their science and technology base, both short term and long term, is expanding as well. But if we slow down as they speed up our long-term leadership will be lost. A long-term view is needed, and in Washington long term seems to be defined as the time to the next presidential election. Fortunately that is not too far away.

As you did for the May 2011 report "California's Energy Future - The View to 2050," could you look a generation ahead to what energy policy should become art the national level? How would you define U.S. energy objectives to create a coherent long-term energy policy? How would you prioritize the steps to transform the U.S. energy system?

Because I was Director of a DOE lab for many years as well as a President of the American Physical Society, I have had lots of opportunity to see how the government really works. If something big is to be done, and changing the energy system of the country is very big, an army of lobbyists on all sides of the issues mobilizes. If something is not only big but controversial it is easy to find all sorts of excuses for doing nothing and it takes something major to get action. From this experience I have derived Richter's Four Laws of Government Inertia:

1st Law: The future is hard to predict because it hasn't happened yet.
This one is an excuse for inaction because we do not know enough yet.

2nd Law: No matter how good a solution is, some will demand we wait for a better one.
This is what some environmental organizations use to block sensible proposals like incentivizing the switch from coal to natural gas for electricity generation. If we did that we would decrease greenhouse gas emissions by 25 percent. It is opposed because it does not eliminate all emissions from electricity generation.

3rd Law: Short-term pain is a deterrent to action no matter how much good that action will do in the long-term.
This is the one that blocks things like cap and trade or carbon emission fees. You can always find a lobbyist to explain why hurting their clients hurts the nation (and maybe campaign contributions).

4th Law: The largest subsidies go to the least effective technologies.
This one keeps things like subsidies for corn ethanol going.

My 2010 book *Beyond Smoke and Mirrors: Climate and Energy in the 21st Century* looked at energy policy mainly from the perspective of climate change. I have come to the conclusion that I should have chosen a wider base, and if I do a second edition I will broaden the discussion to what I have begun to call Energy in Three Dimensions. These are our economy, our national security and our environment (and environment can include more than just climate change). Looked at this way, some things become obviously good from more than one perspective. CAFÉ standards for cars and light trucks are going to go to 54 miles per gallon, roughly double today's. If I could make it happen today, I would reduce oil imports by six million barrels of oil a day, saving the economy half a billion dollars per day, reducing our balance of payments deficit, reducing risk of disruptions from the Middle East, and cutting greenhouse gas emissions as well. If I electrify light vehicles, I improve their energy efficiency and reduce gasoline use further. If I switch from coal to natural gas for electricity generation I reduce mercury emission, bronchitis, smog, and greenhouse gas emissions. Looked at from multiple dimensions, one can broaden an alliance for action and perhaps get things done.

As to government policy, I am not a fan of prescriptive programs like renewable portfolio standards, low carbon fuel standards and the like. Government policy should have two important parts. One is to tell industry what has to be done, not how to do it. CAFE standards are an example. The EPA defines a goal and manufacturers can do it with better engines, hybrids, electric drive, or whatever works. California's low carbon fuel standard is an example of the wrong approach. It says that by 2020 the fuel you use must emit less greenhouse gas by 10 percent compared to today. The new CAFE standard does far more for far less cost.

The other government role is to fund the longer term basic and applied work needed to take possible new technologies to the point of understanding their real usefulness and their potential to be scaled up enough to make a national impact. That can be done at both small scale and large scale. For example, the battery technology in the Chevy Volt plug-in hybrid came out of a research program at MIT funded by the DOE. It did not cost much on the scale of government-funded R&D to reach the point where General Motors picked it up and brought it along to the scale necessary for car production. Fusion energy is a very much more expensive program and here many countries are joined in a multi-billion dollar effort to see if it can be made to work.

I think of myself as a pragmatist, not a perfectionist. I want to move us in the necessary direction and am quite happy to do it incrementally. For example, I would like to see revenue neutral carbon tax like that put into effect by a conservative government in Canada's province of British Columbia. Why revenue neutral? Because I think it can gather support from all sides of the debate. Cap and trade may have a better theoretical basis, but to gather support in the House, so much had to be given away as to make it unworkable. Why better CAFE standards – because they can be justified from more than one dimension. I am happy to be impure and effective rather than pure and ineffective. It is a long time to the end of the century, and no one knows what technologies the scientists and engineers just now being born will bring to reality. Bring things along as they develop and do not fall victim to Richter's second law.

The Energy Star ratings system introduced a "Most Efficient" standard. How will this new label influence energy efficiency? What more should the EPA and DOE be doing to increase efficiency in appliances?

When I led the group that produced the APS energy efficiency report in 2008 (http://www.aps.org/energyefficiencyreport/) we found that DOE was not setting standards for all the products they were allowed to. I have not kept up with what has been happening, but I hope it includes rating more products.

Another of our findings was that there was no real understanding of why consumers did not buy the things that saved them the most money, and we recommended some social science research was in order. I think that has begun and perhaps the "Most Efficient" rating comes from that.

The new "Most Efficient" rating is very useful if it is properly advertised. In looking at the clothes washers and TVs (42 inch), I found that the number two in both cases cost only 60 percent of number one.

There is great debate over energy policy and climate change. Interest groups and industry often control the message and presentation of information. How can FAS improve the understanding of energy technology and policies by a wider, general public?

You should be asking people younger than I. The virtual world has changed the way people communicate and get information. People like Prof. Jeremy Bailenson who directs Stanford's Human Interactions Lab have impressed me with how different today's world of communications is from what I grew up with.

What issues should FAS tackle in the next 65 years?

FAS was born about 65 years ago (different name, same initials) to deal with nuclear weapons and the threat of Armageddon. While the nuclear weapon problem is still with us, large-scale nuclear war is much less likely now. Today's problems include climate, developing countries, population growth, natural resources, etc. FAS might do well to broaden its horizons including perspectives from more disciplines. Sixty-five years is a long time given the rapid evolution in science, technology, and, above all, society. FAS should evolve alongside the things it reports on.

What is your advice to students entering the fields of biology, mathematics and physics today?

Science has evolved a long way from what it was when I entered MIT as a freshman in the September of 1948. I arrived not sure if I wanted to go into chemistry or physics. At MIT then the first year was the same for the science majors and I quickly settled on physics. I had arrived with a notion that I wanted to understand how the universe worked, and physics seemed to be a much more likely road to that goal. In the summer between my sophomore and junior years I persuaded one of the faculty, Prof. Francis Bitter to let me work in his lab. Over the next two years I moved from being a pair of hands to some real research. My bachelor's thesis was the first measurement of the quadratic Zeeman Effect in hydrogen. The first advice I would give to students is to get into research as soon as possible.

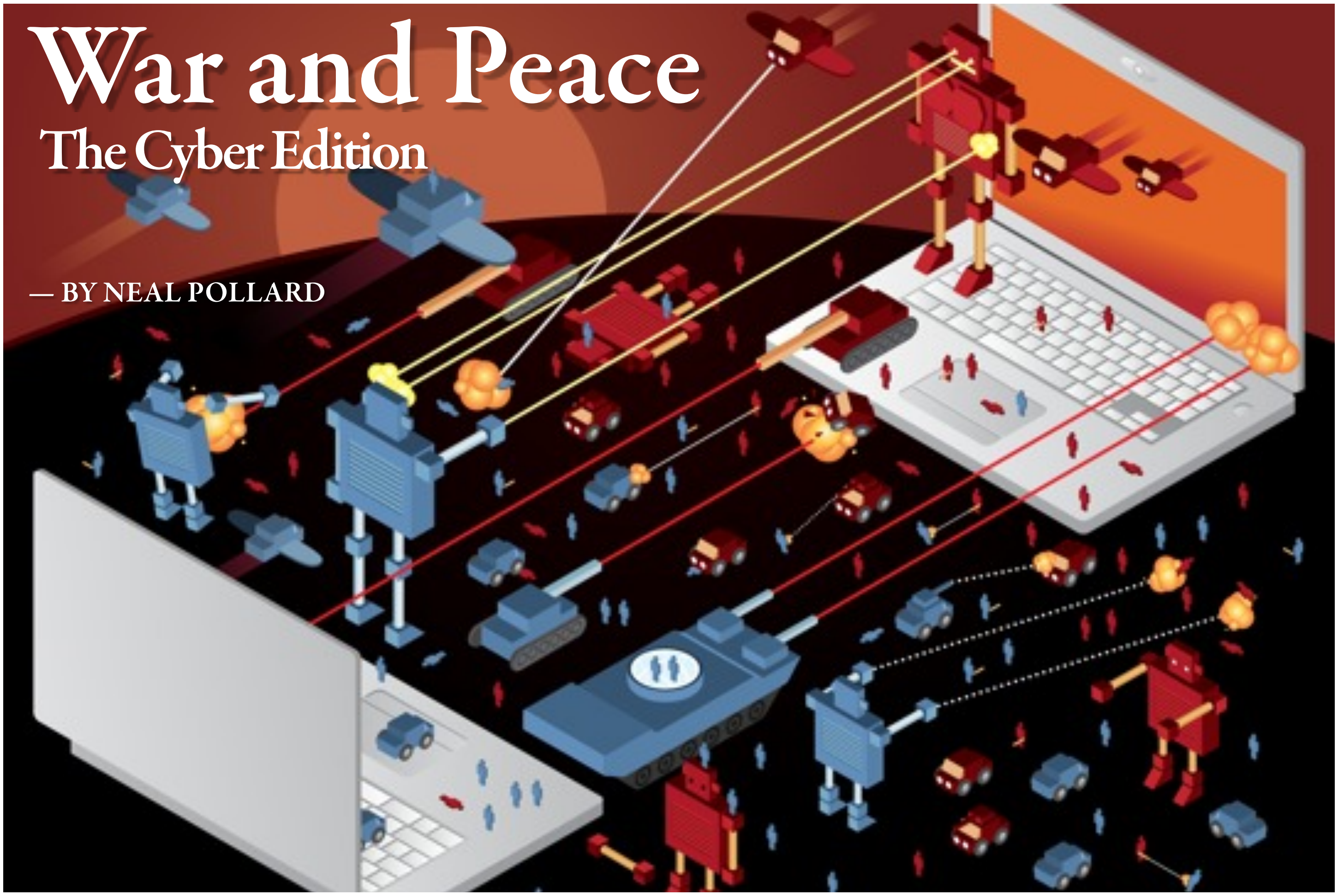
I began graduate school with Bitter's group, but as time went on I found that I was not as interested in the area he was exploring than in what is now called Elementary Particle Physics (which has evolved a long way too). I was one of the fortunate few with a fellowship rather than a research-assistantship (first from DuPont and then from the NSF). That meant that the support was mine and to move I did not require anyone's permission because the support money was mine. Bitter helped me to move on for which I am forever grateful. The second bit of advice I would give is to grab a fellowship over an assistantship any time. If you come with your own money you are a hot property. Given the huge increase in cost of an undergraduate education, I am not sure that life is as simple as in my day.

As to advice on what to do, one question has been bothering me for years, and if I were starting over, I think I would go after its solution. How is it that for certain problems, facial recognition for example, the human brain can do the job as fast as a computer even though the computer has a cycle time more than a million times faster than the brain where the time cycle is determined by chemistry not transistors? This is much more a physics and mathematics question than a biology one. We know how neurons communicate and what they communicate with, but we have not a clue on how things are organized. I think this is more a physics and mathematics question than a biology one, but expertise in all three would be useful. I hope I am still around to read how the system that does this job really works. ■

War and Peace

The Cyber Edition

— BY NEAL POLLARD



On May 26, 2011, President Obama released his administration's International Strategy for Cyberspace, which stated that, as a last resort, the United States reserves the right to respond to cyber attacks with conventional military force. Additionally, the Defense Department's new strategy for cyber security reportedly will consider that computer sabotage coming from another country can constitute an act of war. A military official was even quoted saying, "If you shut down our power grid, maybe we will put a missile down one of your smokestacks." Since these reports, pundits have opined on how unprecedented this is, how things have changed, what should or could possibly constitute an act of war, and even that a state of war currently exists between the United States and other nations.

But there is little new here from a security perspective. The notion the president will use the military, if need be, to protect the nation from hostility is as old as the nation itself, and the advent of cyber conflict does not change that basic fact. Even Obama's declaratory policy, while novel at the pPresidential level, has some precedent: in 1998 testimony to the Senate Government Affairs Committee, Lt. Gen. Ken Minihan, then-Director of the National Security Agency, suggested that a large-scale cyber-attack by a foreign government against U.S. computers could be considered a weapon of mass destruction, saying "we perhaps ought to consider adding information infrastructure threats to our definition of weapons of mass destruction." [2] What is new, however, is a requirement now, for a new policy and operational framework that raises the military's unique capabilities in cyberspace to the level of a national resource, bridging the gap between military cyber capabilities, and those of civilian agencies and the private sector, clarifying when and how that gap should close.

Legally speaking, the United States has an inherent right to self-defense, and the president is obligated to use all instruments of national power, including the military, to defend the nation from all attacks, including cyber attacks. Politically speaking, the United States is in a state of war when – and only when – the president or the Congress says it is. Practically speaking, there is a finite set of circumstances in which a cyber attack would be widespread and threatening enough that only the military has the unique capabilities necessary to prevent or respond.

In these circumstances, such an attack would also likely take place in a geopolitical context, where something else is going on in the "real" world, probably related to the cyber event. The attacks against Georgian networks in summer 2008 are an example, when cyber events occurred roughly the same time Russia invaded Georgia.

The issue at hand is not what kind of cyber attacks should be considered an act of war demanding a conventional military response. It is neither necessary nor desirable for the president to stipulate what he would consider a cyber act of war. Drawing boundaries eliminates options – rarely a good thing for a president – and even in cyberspace there is value in Thomas Schelling's notion that ambiguity strengthens deterrence by the "threat that leaves something to chance."

If the United States is at war, then the military is clearly the lead federal agency, even in a cyber war.

Rather the issue at hand is gaining a deeper understanding of, and creating an interagency planning framework around, what kind of cyber events – intentional or accidental – would necessarily involve the military in a lead or supporting role, how the military should make the best use of its full set of capabilities as a national resource, and how it can support the lead of civilian agencies and the private sector in securing cyberspace, establishing trust, and responding to failures. Here, there are two sets of circumstances to consider: when the military would be the lead agency for response, and when it would be in support of civilian authorities. Drawing even that distinction is not easy.

If the United States is at war, then the military is clearly the lead federal agency, even in a cyber war, as the president has made clear. The military can expect a lead role in conducting cyber operations from a political perspective – the Commander-in-Chief so orders it – or from the perspective of perpetrators or consequences of cyber events. Clear involvement of a state in a cyber event, societal-level damage such as national power grid failure, or loss of life and physical damage, would likely see the military leading the response, as would specific targeting of military systems that degrade the nation's ability to defend itself, or insertion of malicious software in the cyber-supply chain of weapons programs. But theft of information, even widespread, is at worst espionage, and is neither an act of war nor an incident calling for the unique capabilities of the military. Sabotage is a gray area, but again, it is not a new concept – the president would consider the response based on the attributed perpetrator, intentions, and effects of the attack, as well as the broader costs, benefits, and consequences of possible response options.

Military involvement does not necessarily presuppose armed aggression, kinetic response, or even an intentional failure. There are circumstances today in which civilian agencies lack the capabilities to respond to natural or manmade crises, and must request military action in a supporting role. Here the issue is, what is the policy, operational and legal framework for the Defense Department – especially the National Security Agency – to support civilian authorities such as the Department of Homeland Security (DHS), the Federal Bureau of Investigation (FBI), or even the private sector, in responding to significant cyber events? Are there such circumstances, well short of armed conflict or societal grid failure, in which DHS or FBI will lack the technical capabilities to respond, and will require the support of the military, similar to how DHS requires the support of the military via Northern Command in Colorado, in responding to natural disasters or catastrophic physical events? It is comparably easy to draw a border around a real-world disaster zone, where governors request Federal assistance, statutes such as the Stafford Act make routine Defense support to civilian authorities, and military capabilities support DHS. However, in the event of a cyber failure, how does one draw the disaster zone boundary, who is the "governor" or indeed any government official requesting federal assistance, when will military capabilities be required, and what are the appropriate statutory and operational frameworks by which DOD will support Federal civilian authorities, let alone the private sector? Or, should the United States replicate the cyber capabilities of the DOD within DHS, and what are the resource implications of that? What are the respective expectations and assumptions among FBI and the Departments of Homeland Security and Defense, for when the military will be involved and in what capacity, and how are those expectations and assumptions reflected in departmental strategies, plans, and resources?

The creation of U.S. Cyber Command (USCYBERCOM) in 2010 provided a military combatant command authority and structure, analogous to U.S. Northern Command, but it is less clear how this structure would support military integration with civilian authorities, and under what circumstances. Although DHS co-locates cyber personnel with USCYBERCOM, the commander of USCYBERCOM (a combatant command) is also the Director of the National Security Agency (an intelligence agency). The director of an intelligence agency directing cyber activities on U.S. infrastructures or in support of U.S. companies implicates numerous legal and operational issues. Unless, and until, DHS replicates the military's capabilities, legal, policy, and process issues will remain, and will present even more of a response challenge than an obvious act of war in cyberspace.

Even a potential kinetic response to cyber threats poses challenges beyond speculation of what constitutes an act of war. The White House should be commended on announcing its policy. Cyber is a unique domain that challenges traditional international legal concepts like necessity, proportionality, and attribution in responding to attacks. Cyber attacks that are used to preclude or prevent a war might not look different from a preemptive attack. Concerns about disclosing our intelligence capabilities to deconstruct and attribute a cyber attack might undermine our ability to make a compelling legal case for a kinetic response. These issues do not, however, require defining what constitutes an act of war. Even attribution, while a technical challenge, will be mitigated by the current geopolitical context and political judgment. The president need not be held to judicial standards of proof in attribution, and indeed the United States has been to war over less.

What is important is that planners consider how to position the Defense Department – especially USCYBERCOM and the NSA – as national resources, to provide their unique capabilities and technical skills for attack detection and characterization, response, and foreign intelligence insights to protect civilian government and private-sector critical infrastructure networks. This requires first characterizing the circumstances in which military capabilities would truly be required, the range of possible responses to such events if they appear intentional, and how different agencies' capabilities work in tandem to respond across the spectrum of the cyber failure –prevention, detection, attribution, response, and recovery. In this respect, definitions and plans are less important than the planning process that produces them, as this will be the process that enables the United States to stay proactive in the event of a crisis. U.S. behavior in response to a cyber attack will set an important precedent, both in international law and in cyber operations for armed conflict among allies and adversaries. It would be best if this response is carefully considered in advance and guided by deliberate planning, rather than, ad hoc, reactive, and driven by crisis.

Toward this end the nation would benefit from a new policy and operational framework, led by the White House, that provides guidance, structure, and authorities for when military capabilities are uniquely necessary to respond to cyber attacks and events, under what circumstances, and how they should be used, especially in support of civilian authorities and the private sector. This framework would provide a means to implement the president's strategy for cyberspace, as well as a mechanism for integrating and coordinating the respective cyber strategies of the Departments of Defense, Homeland Security, and Commerce. In support of strategy integration, this process would also help set expectations and assumptions, and facilitate decisions and resource planning, on when the military should be in the leading or supporting roles of response. This framework would also highlight for the Congress legislative authorities still required to meet national strategic requirements for cyber security. This framework would enable operational concepts and planning to streamline military response and support to civilian authorities and the private sector, in the event of severe crises or attacks in cyberspace. Finally, this framework will establish a foundation for predictability and expectations, for both the Departments of Defense and Homeland Security as well as the private sector, for when and how the military will play an active role in responding to national-level events in cyberspace, while balancing the multiple public policy imperatives of security, economic viability, civil liberties, and public/private partnership. By providing these benefits to the nation's security, economy, and social vitality, this framework would help the U.S. government meet the president's stated national values for cyber space.

There are other long-term steps the U.S. government can take, looking toward the future. In the context of cyber conflict, the United States is truly at a stage analogous to the 1950s and the advent of nuclear weapons – not comparable to the destructive capability of nuclear weapons, but rather to basic questions of strategy, planning, organization, and doctrine. How should the U.S. military organize, recruit, train, and equip around cyber capabilities? What does the resultant force structure look like? What is the difference – in technology, operations, law and policy – in offensive and defensive capabilities, or in intelligence and military operations, and what are the consequent implications for force organization and command? While it might be difficult, and even undesirable, to parse civilian vs. military "targets," are there concepts comparable to "counterforce" vs. "countervalue" calculations, that have merit in cyber conflict planning? Is it possible, or desirable, to orient arms control policies or mechanisms around certain classes or uses of cyber technology, e.g., selling or bundling of zero-day exploits? What do escalation ladders and "confidence-building measures" look like? How intrusive can "active defense" options be, what are the operational or legal constraints (international and domestic) of specific options (and under what circumstances), and how do traditional notions of sovereignty hold up against active defense?

The creation of USCYBERCOM and Service components such as the 24th U.S. Air Force represent a step to adapt the current military command structure around cyber operations. However, USCYBERCOM's subordination under U.S. Strategic Command (USSTRATCOM) – also the command responsible for the nation's strategic nuclear forces – poses basic issues for how the commander of USCYBERCOM reconciles his dual reporting to both the commander of Strategic Command and the director of the office of National Intelligence, let along the questions of strategy outlined above. Yet the placement of USCYBERCOM under USSTRATCOM holds many long-term implications about the unique nature of cyber conflict, in that USSTRATCOM is the lead command, and wields the weaponry for, only two types of conflict: nuclear and cyber. These implications ought to be explored in a deliberate enterprise, not ad hoc and in the heat of a crisis, and preferably outside the bounds of the "Washington Beltway," where the urgent and tactical frequently drowns out the important and strategic.

How should the U.S. military organize, recruit, train, and equip around cyber capabilities?

In the early 1950s, the RAND Corporation rose to answer very similar questions, also focused on the business of USSTRATCOM – to wit: how should the United States conduct warfare in the nuclear age? RAND's work offered answers at multiple levels, from how nuclear weapons fit within the order of battle, to high questions of nuclear strategy, including deterrence, containment, the doctrine of Mutually Assured Destruction, and Herman Kahn's *On Thermonuclear War*. It was intellectually and geographically located outside the din of the Washington Beltway, and it made an indelible impact on how the United States considered the role of nuclear technology in its military capabilities and doctrine, organization, policy, diplomacy, and national security strategy.

There might be value today in the U.S. government creating a new research and development think-tank, devoted to the long-term study of the role of cyber technology and operations within military and geopolitical strategy. Like with RAND, located in Santa Monica, California, any such endeavor should be located outside of Washington, D.C. – perhaps Palo Alto, California; Newport, Rhode Island; or Austin, Texas. Its mandate and research effort should be unbothered by current buzz of technological fads and what they mean for security, convenience, or communication, but rather focused on long-term trends, how they can be shaped, and what they mean for strategy. Technological innovation can be a driver of strategy development, given intellectual distance from the "tyranny of the inbox." This is more so, and more important, when crafting long-term strategy around capabilities, whose underlying technology can change dramatically within a single governmental budget cycle. Within four years a social networking platform—Facebook—went from connecting college students across the Ivy League to connecting reformers and protesters that changed the political landscape across the Arab world, possibly beyond. The United States defense community has the mission to avoid technological surprise. That imperative should continue in cyberspace. ■

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Steve HAMBLEN

According to Steve Hamblen, the very best thing about his work as owner of Fairview Builders is "meeting and making friends with new clients, and driving every day in such beautiful surroundings." As a Ph.D. in Environmental Engineering, he has long understood the vital connections between residential construction and the environment.

Hamblen loves the Upstate's friendliness and conservative values, and he feels privileged to be the only builder whose main office is located in the heart of the Cliffs Communities. His interest in and commitment to this area is highly vested, in that his sons Andrew (Georgetown, '07) and Christopher (Clemson, '12) plan to continue the business long past his own eventual retirement.

"When I started this business, I never envisioned I would be building the highest quality, multi-million dollar homes that we are building today. It makes my day when a customer says they chose me to be their builder because they have confidence in my abilities and integrity."

And it's not just local homebuilding that keeps this builder involved in the engineering community. He also is a member of the Federation of American Scientists located in Washington, DC, and serves as advisor to the organization's Earth Systems Program. This program "develops and promotes sustainable, scientifically sound, and inclusive solutions, policies, and technological developments to key energy and environmental challenges."

Hamblen has long been known as a "shaker and a mover." He knows how to get things done, and works "like a tornado," according to his office manager Jan Grover. His wife Cindy adds, "He is like an on/off switch - there's no in between for Steve!"

On the rare day off, Hamblen will most likely be found reading or watching sports, travel and scientific programs on TV, preferably with a wood fire crackling beside him. And for more than a day off, he enjoys family cruises with his wife, sons and friends.

He truly epitomizes the company slogan for Fairview Builders: "Your Friend in the Foothills."

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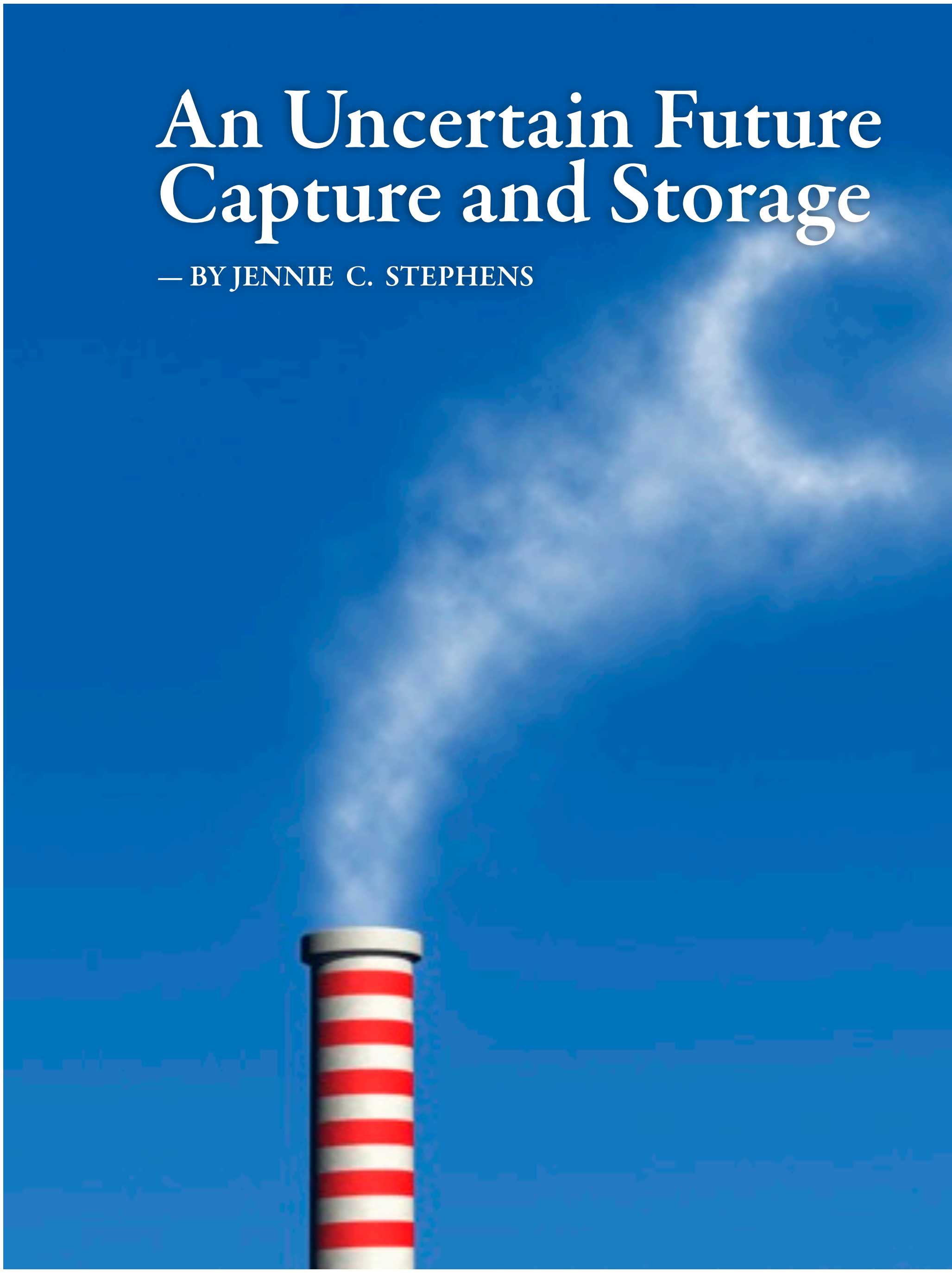
An Uncertain Future Capture and Storage

— BY JENNIE C. STEPHENS



INTRODUCTION

As the coal-reliant countries of the world have been increasingly forced to consider reducing carbon dioxide (CO_2) emissions to mitigate climate change, carbon capture and storage (CCS) has emerged as a technology with critically important political influence. Visions of "clean" coal-fired power plants that will not emit CO_2 into the atmosphere have provided powerful motivation for large public and private investments in CCS technology [1]. And the scale of CO_2 emission reductions deemed necessary for climate stabilization is so large that some consider CCS a necessary future technology without which society will be unable to mitigate climate change. Despite growing interest and investment in CCS, the technology's future remains uncertain and the pace of technological development has been slower than many had envisioned five or ten years ago. [2]

STATUS OF CCS TECHNOLOGY

CCS incorporates various technologies associated with capturing and transporting CO_2 and storing the compressed gas somewhere other than the atmosphere. Most current conceptualizations of a complete CCS system focus on the potential of storing the CO_2 in underground geologic reservoirs, although ocean storage and terrestrial storage have also been considered. The different components of a fully integrated CCS system are at various levels of technical readiness, but most parts of a full CCS system have been used and applied, often at a smaller scale, in other industrial applications. Despite growing interest and investment, a fully integrated coal-fired power plant with CCS has not yet been demonstrated. [3] There are, however, numerous small scale projects that focus on demonstrating a limited part of a full CCS system. [4] A public database maintained by the U.S. Department of Energy's National Energy Technology Laboratory currently documents a total of 254 CCS projects, including proposed, active and cancelled projects.[5] These projects are geographically distributed in 27 countries including 65 projects focused on capture, 61 projects focused on storage, and 128 that involve both capture and storage. Of these projects, most are in the planning phase and only 20 are actually currently capturing and/or injecting CO_2. Among the current priorities for advancing CCS are enhancing the capture process to reduce the energy intensity and cost of capture, demonstrating underground CO_2 capture in a diverse set of geologic formations, and demonstrating and deploying integrated and scaled-up CCS power-plant systems that allow for "learning-by-doing."

A CHANGE IN COAL POLITICS IN THE UNITED STATES

The potential of CCS technology has changed the politics of coal in many places, but its influence in the United States is particularly pronounced. The United States has so far focused its national response to climate change on technology rather than policy and is

for Carbon (CCS)

among the countries in the world that has invested most heavily in CCS. [6]

The scope and scale of U.S. interest in CCS is critical, because due to its size, status, and disproportionate contribution to accumulated CO_2 emissions, the United States has unique potential for political and technological influence over energy technology development and the trajectory of global atmospheric CO_2 concentrations.

The magnitude of the U.S. reliance on coal (about 45 percent of the nation's electricity comes from coal) has been a dominant factor influencing both national energy policy and the lack of national climate policy. Politicians from regions of the country where the coal industry is most influential have been among the most powerful opponents of national climate change legislation. For coal states and politicians representing those states, however, CCS has provided a potential vision of a carbon constrained future in which the coal industry could still thrive. From a political perspective, therefore, the potential of CCS technology has been valuable in contributing to the engagement of critical actors in national climate policy discussions; CCS has enabled some constituents who had been previously reluctant to even acknowledge the challenges of climate change to engage in the climate-energy political discourse.

Despite the powerful political influence of coal, public opposition to building new coal-fired power plants has grown rapidly in the past few years. In 2005, over 100 new coal-fired power plants in the United States were in various stages of planning, but cancellations have been frequent and since then only a handful of new plants have actually been built. While economic factors and rising capital costs clearly contributed to these proposed plant cancellations, some plants have been cancelled in direct response to concerns about CO_2 emissions and the economic and environmental liability of locking-in to a high carbon emitting power plant.

In this context CCS can be viewed as playing a new moderating role in opposition to coal. A few years ago anti-coal advocates who called for a moratorium on coal-fired power plants may have been considered radical and impractical. Now some of the same advocates can use CCS as a qualifier to their calls for a moratorium on coal fired power plants. That is, a position that says "no new coal plants unless they have CCS" represents a more practical stance. This anti-coal position seems more reasonable. Given the long anticipated time horizon before CCS may be implemented (due to the need still to demonstrate the technology at scale and also the complicated changes to the regulatory and economic system that would be necessary to create incentives for actual CCS implementation), a call for no new coal plants without CCS is, in the short-term, equivalent to a call for no new coal plants.

CHANGING INVESTMENT LANDSCAPE

Given the large-scale infrastructure investments required to develop CCS and the minimal regulatory requirements to incentivize its advancement, both public and private investment has been and will continue to be critical to the technology's advancement.

Artist rendering of carbon capture and storage facility.

Since 2005, US$25 billion in direct government funding for CCS has been announced worldwide, with 80 percent of these announcements focused on support for large-scale CCS demonstration projects.[6] While not all of these announcements have resulted in distribution of public funds, the magnitude of government investment has been large, with the United States, Canada, Australia, and Norway among those with the largest public commitments to CCS. Although the global financial crisis has contributed to the cancellation or delay of several projects,[7] it also resulted in some increases of funding in the United States because the 2009 American Recovery and Reinvestment Act committed more than US$3.1 billion to CCS.

Given the high cost and large risks (both financial and environmental) associated with CCS investments, the vast majority of CCS projects around the world have relied on a combination of public and private funding. Quantifying levels of private investment is difficult, but it is clear that levels of private funding are related and to some extent connected to levels of public support. In addition, private sector investment in CCS has been influenced by firms' perceptions of an emerging CCS market which is influenced by perceptions of the emerging legal and regulatory framework for CCS. In the private sector, the oil and gas industry has dominated private CCS investment due in large part to the strategic opportunity associated with their technical capacity in sub-surface geological engineering.

AN INTERNATIONAL CCS COMMUNITY

As both public and private investment in CCS has grown, a diverse international network of professionals focused on the advancement of CCS technology has emerged. This international CCS community has been developing and expanding in multiple ways as the level of interest in CCS has been increasing. This community is dynamic and includes scientific and technical experts, as well as representatives from business, government, academia and non-governmental organizations. Within this international community, a shared perception of the value of advancing CCS technology is generally assumed.[8] The community seems to have a consistent and rather homogenous policy message related to the need for government support to advance the technology, and this message appears to have been influential in lobbying for increased support in many countries and at the international level. Like any community of professionals focused on the advancement of a specific technology, the growth of the CCS community has been, at least in part, self-perpetuating, i.e., the community has effectively advocated for increased investment in CCS technology, which has contributed to its expansion. While technological advocacy is a necessary part of the innovation process, [9, 10] some concern has been raised that the degree of advocacy among CCS experts could have a net negative impact on CCS advancement if public concerns about the technology are not understood or taken seriously by the community. [11]

PUBLIC CONTROVERSY

Although many who work within the CCS community accept the usefulness and necessity of CCS technology, public controversy has potential to thwart its advancement. Public concern and opposition to CCS can be divided into two categories related to different perceived risks at global and local levels:

(1) general opposition to the technology as an end-of-pipe, expensive climate mitigation option that is resource-intensive, promotes the use of fossil fuels, competes with renewable energy sources, and is technologically complex and environmentally risky and;
(2) project-specific opposition among communities that are confronted with planned projects and perceive local risks associated with those projects. [12, 13]

The environmental community has been divided in their level of support for this technology.[14] Skepticism about the technology's potential to facilitate a transition away from fossil fuels is strong, [15] but there are also environmental organizations that are highly supportive or accepting of CCS (e.g., the World Wildlife Fund, Bellona, and the Natural Resources Defense Council).

Project-specific opposition can be seen in various recent proposed CCS projects, such as Vattenfall's cancelled and postponed storage projects in Denmark and Germany [16] and the cancelled Barendrecht project in the Netherlands.[17, 18] The first public reporting of CO_2 leakage at a CCS storage project occurred in January 2011 in Saskatchewan Canada, where a farmer alleged that CO_2 from the Weyburn project was degrading his land and killing animals on his property.[19] While representatives of industry and the government moved quickly to reassure the public that the leaking CO_2 was likely from a natural source rather than from the CO_2 storage project, the controversy is not yet over as the community is waiting for an independent investigation that is currently underway. The impact of these public controversies on the future of CCS is not yet clear.

AN UNCERTAIN FUTURE

As a climate mitigation technology, CCS has a particularly interesting, unique attribute which is that it offers no co-benefits, i.e. quite literally the only reason to implement CCS is to reduce CO_2 emissions. While most climate mitigation strategies (including renewable energy, reduced resource consumption, changes in agricultural practices, promoting local food systems, etc), offer multiple benefits, CCS is an expensive, technologically complicated approach to CO_2 emission reductions that offers limited versatility and flexibility once infrastructural investments are made. Among other challenges facing CCS are: liability concerns (who will be ultimately responsible for ensuring the long-term underground storage of the CO_2),[20] monitoring and enforcement (how will stored CO_2 be accurately and confidently measured and documented),[21] and leakage risks (what are the potential environmental, health and safety risks of potential CO_2 leakage). With respect to the technology's potential to meaningfully contribute to stabilization of atmospheric CO_2 concentrations, another challenge facing CCS is the large-scale of deployment that would be required.

The only reason to implement CCS is to reduce CO_2 emissions.

A complicated uncertain future for CCS emerges when the strong levels of interest and investment that the technology has received to date are juxtaposed with its multiple challenges. From a technological perspective, it has been argued that the infrastructural requirements and inflexibility of CCS result in difficult "technological lock-in."[22] From a political perspective, it could also be argued that investment requirements and the sunk-costs associated with the amount of money already invested in CCS result in a difficult "political lock-in." For those governments and private companies that have already invested millions or billions of dollars to advance CCS, ending their support for this technology may be difficult even if perceptions of the relative challenges and potential of CCS continues to change over time. ■

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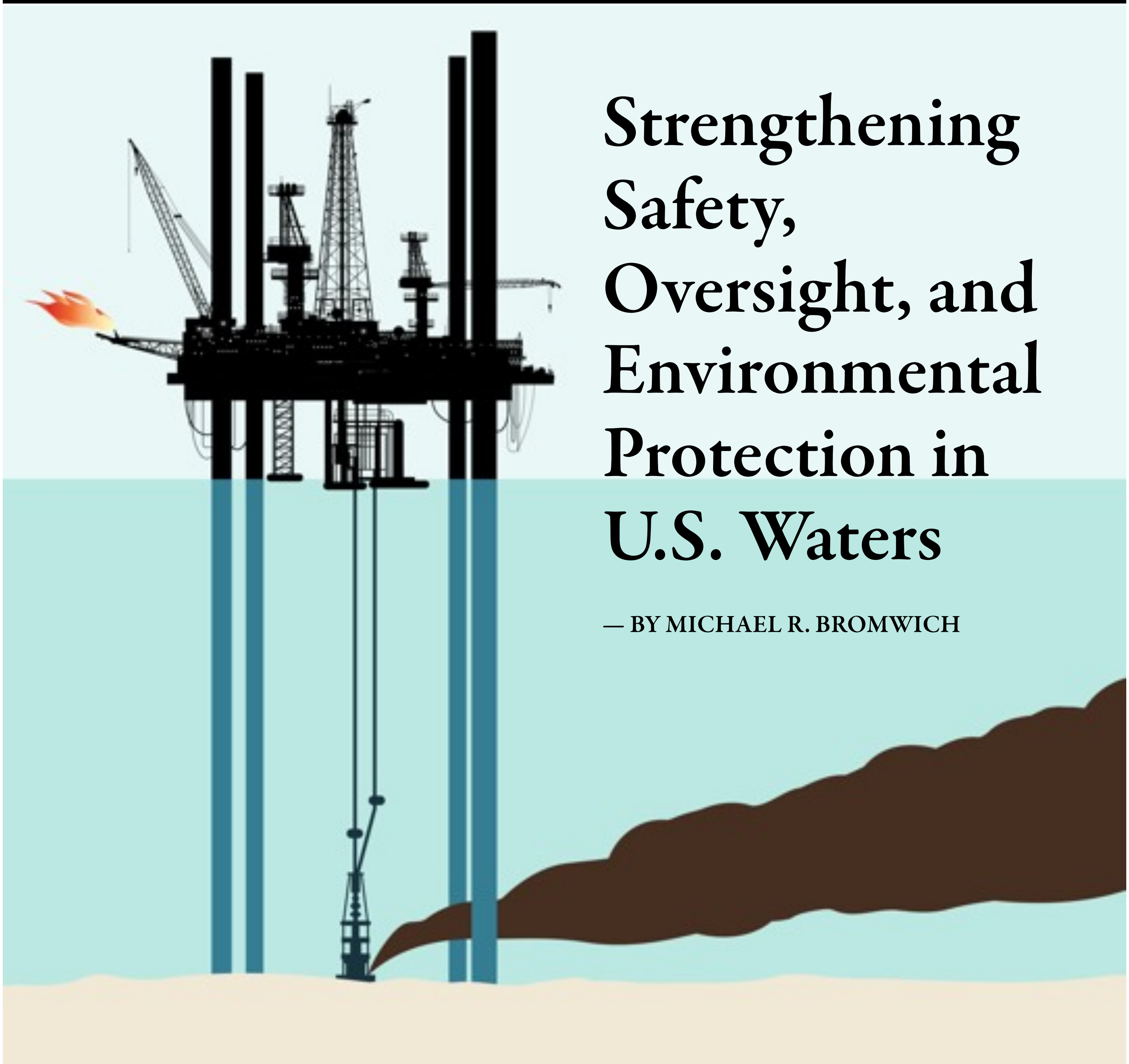


Strengthening Safety, Oversight, and Environmental Protection in U.S. Waters

— BY MICHAEL R. BROMWICH

INTRODUCTION

In June 2010, President Barack Obama and Secretary of the Interior Ken Salazar asked me to serve as director of the U.S. Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), the agency responsible for regulating offshore drilling and production in U.S. waters. BOEMRE was the institutional successor to the Minerals Management Service (MMS), which had been responsible for those functions since the early 1980s.

At the time of my appointment, our mandate was challenging, ambitious and above all urgent – to reform offshore energy development and the agency responsible for overseeing it. Two months earlier, the *Deepwater Horizon* drilling rig had exploded, taking the lives of 11 workers and unleashing nearly 5 million barrels of oil into the Gulf of Mexico. The tragic loss of life and the enormous environment damage resulting from the *Deepwater Horizon* tragedy transformed the unthinkable into the actual; it served as a wake-up call for industry and government alike.

Since that time, we have been working diligently and aggressively to make the changes necessary to restore confidence that offshore oil and gas drilling and production are being conducted safely and with appropriate protections for marine and coastal environments.

STRENGTHENING REGULATIONS

One of the initial challenges was to strengthen the rules and regulations governing offshore drilling in U.S. waters. Those rules and regulations had not been adequately revised and updated to address some of the challenges of offshore drilling, especially in deep water. We promptly recognized the need to identify and examine improvements to drilling and workplace safety and to enhance protection of the marine environment.

BOEMRE swiftly developed and implemented new rules to improve the effectiveness of government oversight of offshore energy drilling and production. The first rule, the Drilling Safety Rule, created tough new standards for well design, casing and cementing, and well control procedures and equipment, including blowout preventers. For the first time, operators are now required to obtain certification by a qualified engineer of their proposed drilling process. In addition, an engineer must certify that blowout preventers meet tough new standards for testing and maintenance and are capable of severing the drill pipe under anticipated well pressures.

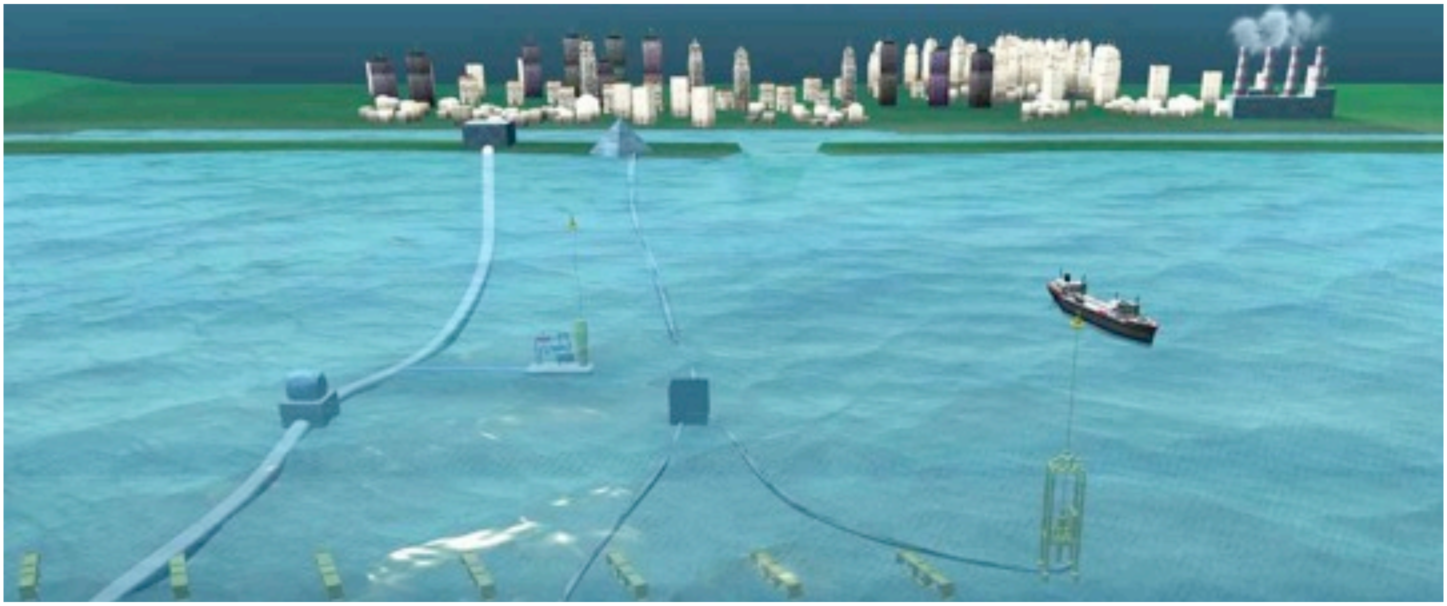
A second rule, known as the Safety and Environmental Management Systems (SEMS) Rule, requires operators to systematically identify risks and establish barriers to minimize those risks. It seeks to reduce the human and organizational errors that lie at the heart of many accidents and oil spills. The SEMS Rule, sometimes referred to as the Workplace Safety Rule, introduced, for the first time in the U.S. regulatory regime, performance-based standards similar to those used by regulators in the North Sea. U.S. operators are now required to develop a comprehensive safety and environmental management program that identifies the potential hazards and risk-reduction strategies for all phases of activity, from well design and construction, to operation and maintenance, and finally to the decommissioning of platforms.

A second proposed SEMS Rule will require third-party audits of operators' mandatory SEMS programs and addresses additional safety concerns that were not covered by the initial SEMS rule. The proposed rule, which will be announced this month, will enhance safety for offshore workers and provide greater protection of the marine environment through additional safety procedures, training programs, notification obligations and strengthened auditing procedures.

In addition to these important new rules, we have issued Notices to Lessees (or NTLs) that provide additional guidance to operators on how to comply with existing regulations. In June 2010, we issued NTL-06, which requires that operator's oil spill response plans include a well-specific blowout and worst-case discharge scenario – and that operators provide the assumptions and calculations behind these scenarios. Our engineers and geologists then independently verify these worst case discharge calculations to ensure that we have an accurate picture of the spill potential of each well.

Following the lifting of the deepwater drilling moratorium in October 2010, we issued NTL-10, a document that establishes various informational requirements, including a mandatory corporate statement from the operator confirming that it will conduct drilling operations in compliance with all applicable agency regulations, including the new Drilling Safety Rule. For the first time, this includes the submission of an operator's subsea blowout containment plan that identifies the equipment and resources that would be available in the event of a subsea blowout in deep water.

We have also identified the need for the thoughtful consideration, development and implementation of additional rules designed to further enhance offshore drilling safety. This process will be broad and inclusive, with the goal of increasing drilling safety and diminishing the risks of a major blowout. It will address improvements to blowout preventers, as well as many other issues.



STRUCTURAL REFORMS REDUCE CONFLICTS AND INCREASE EFFICIENCY

On October 1, 2011, we will complete our top-to-bottom, comprehensive reorganization of MMS. The reorganization and internal reforms that we have implemented were designed to recognize the diverse and sometimes conflicting responsibilities of the former MMS by thoughtfully separating these missions into three new agencies and providing each of the new agencies with clear definitions of their respective missions and – for the first time – needed new resources to adequately fulfill those missions.

These functions will now be carried out by three separate agencies within the Department of the Interior. The Bureau of Ocean Energy Management (BOEM) will manage the development of the nation's offshore resources in an environmentally and economically responsible way; the Bureau of Safety and Environmental Enforcement (BSEE) will enforce safety and environmental regulations offshore; and the Office of Natural Resources Revenue (ONRR), which has been operating separately from the rest of the agency since October 2010, will be responsible for collecting revenues from offshore leases.

Our guiding principles over the past 15 months have included a commitment to expand the scope of our scientific and environmental studies, to enlarge the universe of data that serves as the foundation for our decisions, and to rely on credible and unfiltered scientific data as the basis for those decisions. While important science has always been conducted in the agency, a number of internal and external reviews of our agency have suggested that our scientific community has not always had a strong enough voice. We are changing that.

As concrete reflections of that commitment, we have created top-level management positions for a Chief Environmental Officer in BOEM and a dedicated Environmental Compliance capacity both in Headquarters and in the regional offices in BSEE. The creation of these new positions will help ensure that decisions made by each bureau will appropriately balance the nation's need for energy security and economic development with enhanced safety and environmental protection. We are also hiring a large number of additional environmental scientists to perform work that includes environmental studies, *National Environmental Policy Act* review, and environmental compliance – all of which are critical to the balanced development of offshore resources.

Through this important institutional and organizational transition, our staff will work to ensure continuity for the science organizations that rely on our funding to conduct research that expands our knowledge and serves as the basis for our decisions. BOEM will continue to fund scientific studies in the Gulf of Mexico, the Atlantic, the Pacific, and the Arctic through our Environmental Studies Program. BSEE will carry on the mission of the Technology Assessment & Research Program, which supports research associated with operational safety and pollution prevention, as well as oil spill response and cleanup capabilities.

There is an urgent need for upgrading safety rules and practices within the offshore oil and gas industry.

We will continue to support important research initiatives and to strengthen the knowledge base of coastal and marine environments through partnerships with federal agencies, including the U.S. Fish and Wildlife Service and the U.S. Geological Survey, and with respected academic institutions, including the National Academies of Science. We recently signed a Memorandum of Understanding with the National Oceanic and Atmospheric Administration (NOAA) to enhance our coordination and collaboration and to ensure we approach decisions with the best available information.

THE FUTURE OF OFFSHORE DRILLING IN U.S. WATERS

Offshore drilling in the United States, and indeed around the world, will never be the same as it was a year ago. That much is clear. The changes that we have put in place will endure because they were urgent, necessary and appropriate. And more change will surely come, although not at the rapid pace of the past year. The process of making offshore energy development both safe and sufficient to help meet the nation's and world's energy demands will never be complete. It is – and must be – a continuing, ongoing, dynamic enterprise.

The central challenge that *Deepwater Horizon* highlighted is the need to establish the institutions and systems – and the processes of cultural change and improvement– necessary to ensure that neither government nor industry ever again becomes so complacent that no further change is considered necessary – because that sort of complacency set the stage for *Deepwater Horizon*.

Following *Deepwater Horizon*, a broad consensus quickly emerged – in government and industry – that there was an urgent need for upgrading safety rules and practices within the offshore oil and gas industry. As we move forward, we must do everything possible to keep the complacency from creeping back. We must have the discipline to continue pushing for improvements that will enhance the safety of offshore drilling. Both industry and government regulators must continue to use the memory of *Deepwater Horizon* as an ongoing reminder of the continued urgency of improving safety. ■

Michael R. Bromwich is the Director of the Bureau of Ocean Energy Management, Regulation and Enforcement in the U.S. Department of Interior.

http://www.fas.org/member/index.html

Lessons Learned from the BP Oil Spill

— BY ANDREW WINSTON

From April 2010 to March 2011, all three of the world's biggest sources of energy experienced serious, industry-threatening accidents. Coal mines in West Virginia and China collapsed, BP's Deepwater Horizon oil rig spewed 210 million gallons of oil into the Gulf of Mexico, and the Fukushima nuclear plant melted down. All of these disasters demonstrated how tenuous our energy system could be and they all have deep implications for companies and national security. But perhaps no event was so crystal clear as BP's fiasco.

Looking back with a bit of perspective, we can sift through the wreckage for some learning, both for companies and for countries – lessons about risk management, about relying on volatilely priced, tough-to-get-to fuels, and about the multi-trillion-dollar wealth creation opportunity we can seize.

While I'm sure there are countless lessons from a disaster that big, here are my top 5 covering the gamut from corporate-level strategy to the geopolitical and philosophical:

IT CAN BE VERY EXPENSIVE TO CUT COSTS

In the late 90s, BP declared itself a new kind of oil company. The CEO, Lord John Browne, set BP on a path to go "beyond petroleum." The future seemed bright. In the book I coauthored in 2006, *Green to Gold*, we open with two key stories of green value, one of which is about the money BP saved through carbon reductions. For years, the sustainability community praised BP as best-in-class.

In more recent years though, BP quietly reduced its investment in renewable energy to a negligible percentage of sales and profits. Tony Hayward, the CEO at the time of the spill, focused the company on cutting costs today, not markets of the future. But with the Gulf spill, and the earlier refinery explosion in 2005 that killed 15 employees, it's clearly not a stretch to say that BP has under-spent on safety.

Before the wave of cost cutting, the company seemed to believe that the benefits of a broad, green investment strategy were many, from access to new markets to the company's ability to attract and retain talent. Ironically, BP execs told me in the past that their reputation as a green leader was making recruiting the best engineers far easier. But that brand image is now shattered. Warren Buffett once famously said, "It takes 20 years to build a reputation and five minutes to ruin it." Having a reputation as a green, sustainability leader is valuable, but it's a tenuous thing, and it can be lost very fast.

But if reputational value is too soft for you, let's get concrete about the value of the enterprise. BPs market cap was cut in half after the spill (and dragged down its competitors' stocks as well). And while the value bounced somewhat, BP is still valued at a far lower price to sales ratio than the other big four.

And who knows what will happen to BP's operating costs. The assumption that we will continue to dig up more carbon-emitting fossil fuels without penalizing companies for the externalized costs of that fuel (public health, military costs to defend oil, destroyed ecosystems, and so on) should have been called into question in a serious way by the Gulf oilpocalypse.

At the very least, it's a reasonable outcome that regulators may demand that companies invest not only in the technologies to dig oil up, but also in cutting edge ways to greatly reduce the risk of it going all over the place. But smart companies get ahead of those kinds of rules.

It's worth spending money to build more resilient, lower risk systems.

How much should BP have spent on extra precautions and new clean-up technologies for worst-case scenarios? Imagine if every well had a second, relief well nearly dug *before* opening the main one. Expensive, yes, but so is the destruction of your reputation and business, not to mention an entire ecosystem.

Given the level of profits the oil companies reap – the big five U.S. firms netted nearly a *trillion* dollars during the decade ending in 2010 – why shouldn't they spend more to reduce risk? Why not build much greater redundancy into the system? The backup well to relieve pressure took months to build while oil continued gushing. Calling for more systematic backups is an obvious conclusion – and one that the Department of Interior's report on the disaster came to just one month later.

The answer to how much BP, or any company, should spend to avoid these problems is somewhere between zero and how much the company is worth. Unfortunately for BP, that latter number is far smaller than it used to be.

Of course for most companies, sustainability-related, enterprise-threatening risks are not quite as tangible as miles and miles of your product killing an entire ocean. But even harder-to-measure threats can destroy a business model. Think of the "stroke of the pen" risk from regulations that outlaw a component of a product due to toxicity (one recent candidate: plastics chemical BPA) or greatly raise energy efficiency standards on light bulbs or cars. Or consider the risk of losing revenues for companies that do not meet sustainability-themed supply-chain demands from business customers.

We've all had major blinders on about the risks to our society from our reliance on traditional fuels.

Preparing for a world where things only go right is extremely dangerous.

To hearken back to the (first) recent recession for a moment, one of my favorite tidbits about the financial meltdown was something I read about the ratings agencies (you know, the groups that gave horribly risky investments triple-A ratings, but now feel qualified to downgrade the entire U.S.). In the spreadsheet models they used to estimate the value of mortgage-backed securities, analysts could only plug in a positive number in the "growth" cell. That is, they could not predict the value of those derivatives if housing prices actually went *down*. You have to wear very large blinders to build a model like that.

But the oil companies have done the same thing. They've invested heavily in exploration technologies, finding ways to do things – like dig a mile under water – that were only space-age fantasies until recently. But where are the technologies to avoid spills, contain them, and clean them up?

But arguably, we've all had major blinders on about the risks to our society from our reliance on traditional fuels. So here's where we pivot from BP to a larger perspective. The risks and rewards apply to our entire society as well. A focus on only cutting spending and hoping for best-case outcomes ignores the realities of our planetary resources, our climate instability, and our infrastructure and energy needs.

We've allowed ourselves to be reliant on volatilely-priced resources that are harder and harder to get to, and cost us more and more. Arguably, the "market cap" for the U.S. has taken a hit much greater than BP's; the financial crisis stemmed mainly from a lack of risk management and control over our credit and finance system. What might it do to the value of the U.S. enterprise if we don't better manage the even deeper risks inherent in our carbon-based economy?

Our reliance on old, fossil-fuel based technologies is extremely expensive, a massive security threat, and it's devastating our country.

The spill was, in many ways, an expected result of the path we have chosen. Given the declining stocks of easy-access oil, our addiction is forcing us to dig up extremely remote oil – something very, very hard to do that comes with enormous complexity and myriad risks of catastrophic failure.

An oil addiction is not just expensive to ecosystems and public health, but hits our pocketbooks directly. But it's worse than that; we spend at least a billion a day buying oil from regions of the world that don't like us very much. The military, not surprisingly, has noticed this threat. Leaders at think tanks like CNA and very well-respected security experts such as former CIA head Jim Woolsey have been making the case for years that we need to get off of fossil fuels (in particular oil, which we don't have enough of ourselves, so we prop up dictators and fund terror through our purchases). As Woolsey puts it, "Except for our own Civil War, this [the war on terror] is the only war that we have fought where we are paying for both sides."

To lower its reliance on fossil fuels, the Navy has set aggressive reduction goals and has been innovating rapidly, powering forward bases with solar panels and assault ships with batteries (see sidebar), for example. There are many reasons the Navy is doing this, but perhaps most important is that it saves lives. According to a powerful study from the Army Environmental Policy Institute, for every 24 fuel convoys, we lose one soldier is injured or killed. This tragic loss of life is unacceptable to our military leaders.

BP was right the first time – we really do need to go beyond petroleum

Let's ignore all the environmental benefits of building a clean energy economy for the moment. Let's just think in terms of cold, hard numbers and economic expansion. The bank HSBC has estimate that the climate change solutions and clean tech market will be $2.2 trillion by 2020.

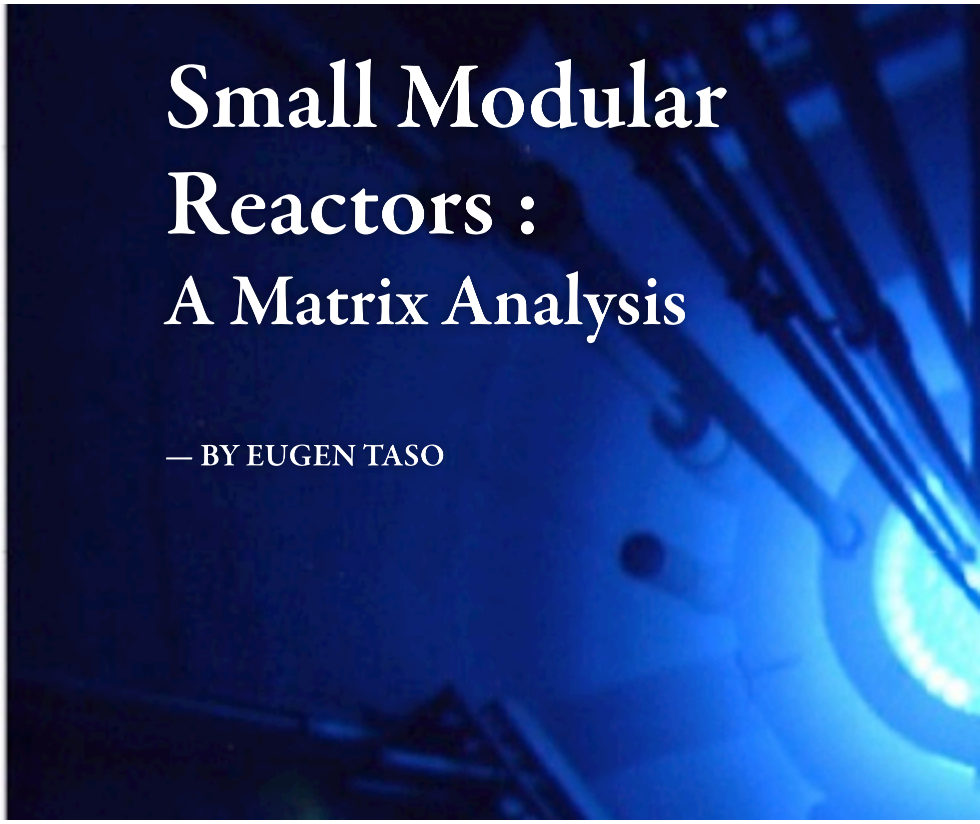
The U.S. is searching for a new path forward. Where will the jobs of the future come from? While the computer revolution, Internet, and wireless revolutions of the last few decades drove innovation and growth, what will do that now? Social media and new Internet companies are exciting but don't create many jobs (global connection octopus Facebook has a couple thousand employees, Twitter far fewer).

The "debate" about green jobs has always been way off the mark. Skeptics like to argue that we can't replace all the old-fuel jobs. But that misses the point. I have no ideahow many people we'll need to insulate and retrofit every building, put up solar on millions of homes, build electric cars, or develop new water-saving technologies. While I believe a very large number, it doesn't matter.

One side of this equation – fossil fuels – will be shrinking, through economics as renewables get cheaper and through labor efficiency (it's not like oil companies are dying to hire more wildcatters). The other side of this green equation will definitely be growing. Which side would you want to invest in?

The risks of continuing on our current path – as well as the profit available to those who pursue the clean economy – are too great to ignore. China, Germany, South Korea, and Spain are all spending a great deal to go green. They all get the strategic opportunity. When will we? ■

Andrew Winston advises some of the world's leading companies on how to profit from environmental thinking. He is a globally recognized expert and speaker on the business benefits of going green. Winston is the author of Green Recovery *and co-author of the international best-seller* Green to Gold.



Small Modular Reactors : A Matrix Analysis

— BY EUGEN TASO

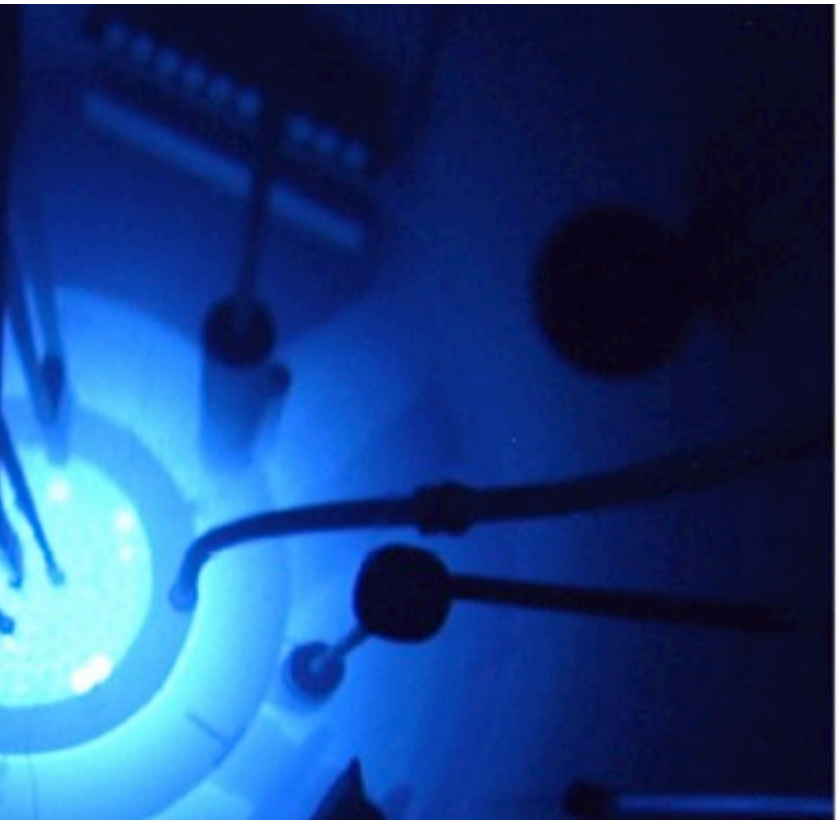
Civilian nuclear power has had a tumultuous history. Although it provides benefits, such as reduced carbon emissions, low operating costs, provision of reliable baseload electrical power, and a path to reducing energy dependence, it has experienced an uphill battle since the 1960s. There are multiple reasons for the opposition to nuclear power, and most of them are valid, albeit not always proven or supported by evidence. Many are concerned about issues like capital cost, safety, regulation, waste, subsidies, public perception, proliferation, and above all, economics. Furthermore, in the wake of the Fukushima nuclear accident following the devastating earthquake in Japan in March, 2011, policymakers, opponents and the public at large are intensifying their scrutiny of the already ailing industry. Despite its advantages of being a near zero-carbon energy source, operating on very high density fuel at typically over 90 percent capacity and having low operating costs, nuclear power is today not materializing its "renaissance," as was predicted at the beginning of the 21st century. However, a new technological approach is currently being promoted in the nuclear industry – small modular reactors (SMRs) – perceived as an innovation allowing the industry to rebound and expand beyond its current capacity, and to areas that were not possible before, a development that some argue could bring a "renaissance" of the industry.

In the master's thesis project which prompted setting up the attached SMR matrix and this article, large-reactor civilian nuclear power is analyzed in an effort to explore its costs and benefits.[2] The thesis presents the history of the technology and industry, the current situation worldwide, and the future outlook. It analyzes the benefits and complete costs of nuclear power in order to present the reader with a full picture of the issue and the dilemma policymakers have to face. Concerns like safety (significantly enhanced after the Fukushima accident), cost (including constructions, subsidies, and insurance, among others), waste disposal, public perception, proliferation are introduced and discussed. Benefits are also explored, such as low operating and fuel cost, baseload capacity, high capacity factor, zero emissions in operation, and others, in order to paint a full picture of this energy source. It is of course not a clear–cut situation. A cost-benefit analysis, performed with the help of an economic and financial model reveals that a utility considering fossil fuels, renewables or nuclear has a hard time deciding what to pick, given the uncertainties in the market.

deciding what to pick, given the uncertainties in the market. Concretely, despite its appeal, in the absence of subsidies and other influences in the market (like a carbon tax or higher fuel prices), nuclear is not an attractive option in its current form.

However, SMRs have the potential to be different. The paper introduces the concept, definition and promising models being discussed by industry and regulators currently. Their benefits, such as modularity, reduced initial capital cost, versatility for remote areas and applications, and simplified designs, and their costs, including overruns, safety and proliferation, as well as waste management are also discussed. The analysis is conducted based on an extensive literature review, the opinions of 22 experts in the nuclear industry, and economic modeling.

This leads to policy recommendations for large and small reactors. In the case of the large plants, the government should remain involved with the industry and provide assistance necessary to maintain the civilian nuclear power industry.



Cost information was specifically omitted. While some reactors do have cost estimates, most do not, and since none have yet been built, the information was deemed too speculative and therefore not included. In fact, cost is one of the major concerns that experts indicated when referring to SMRs. There is little indication on how much they will cost to build, deploy and maintain, and until there are a few operational models, this will remain a big unknown.

The conclusion of the project is that SMRs, although likely not game-changers per se, can play a complementary role in re-inventing the industry without significant support from policymakers. SMRs present a great opportunity for the industry to move forward into a new market. This matrix is meant as a tool for whoever is interested in SMRs and wishes to get a quick summary of the promising models that are being discussed, both at an industry and a policy-making level. Overall, nuclear power is a fiercely contended topic, but it is also an opportunity to bridge to the future until new, renewable ways of producing energy become viable. Therefore, if SMRs can be proven to make a positive contribution to the industry, it is likely that their adoption could be considered a priority and the most promising models, which have been developed privately and without major government subsidies, could compete in the market, changing the trend in the nuclear industry. ■

Eugen Taso is an international manager with HSBC. Prior to joining the bank, he received a dual masters degree in urban and environmental planning and in law and diplomacy from Tufts University. He graduated cum laude in economics from Harvard University and worked for two years in procurement and strategy consulting (CGI, CSMG) and public policy in local and state government.

Existing plants should be maintained, while new projects should be carefully analyzed economically before being approved and subsidized by taxpayers. SMRs should receive little government assistance, and only when they are ready to be deployed, as a first-to-market incentive. R&D should remain in government hands, as well as researching a solution for waste and reprocessing.

While SMRs are not likely game-changers, they can play a role in re-inventing the nuclear power industry without significant support from policymakers.

The SMR matrix presents the most promising models that are currently being considered by private companies and that have expressed at least some interest with the NRC or other regulatory agencies. The matrix is a table summarizing primary and secondary research. It was compiled with information from manufacturer's websites, discussions with marketing officers, NRC representatives and industry affiliates. The table contains information on the company, its country of origin, reactor type and capacity, size, fuel type, refueling needs, lifetime and license application information. Notes are presented at the end, based on interviews and conversations with experts.

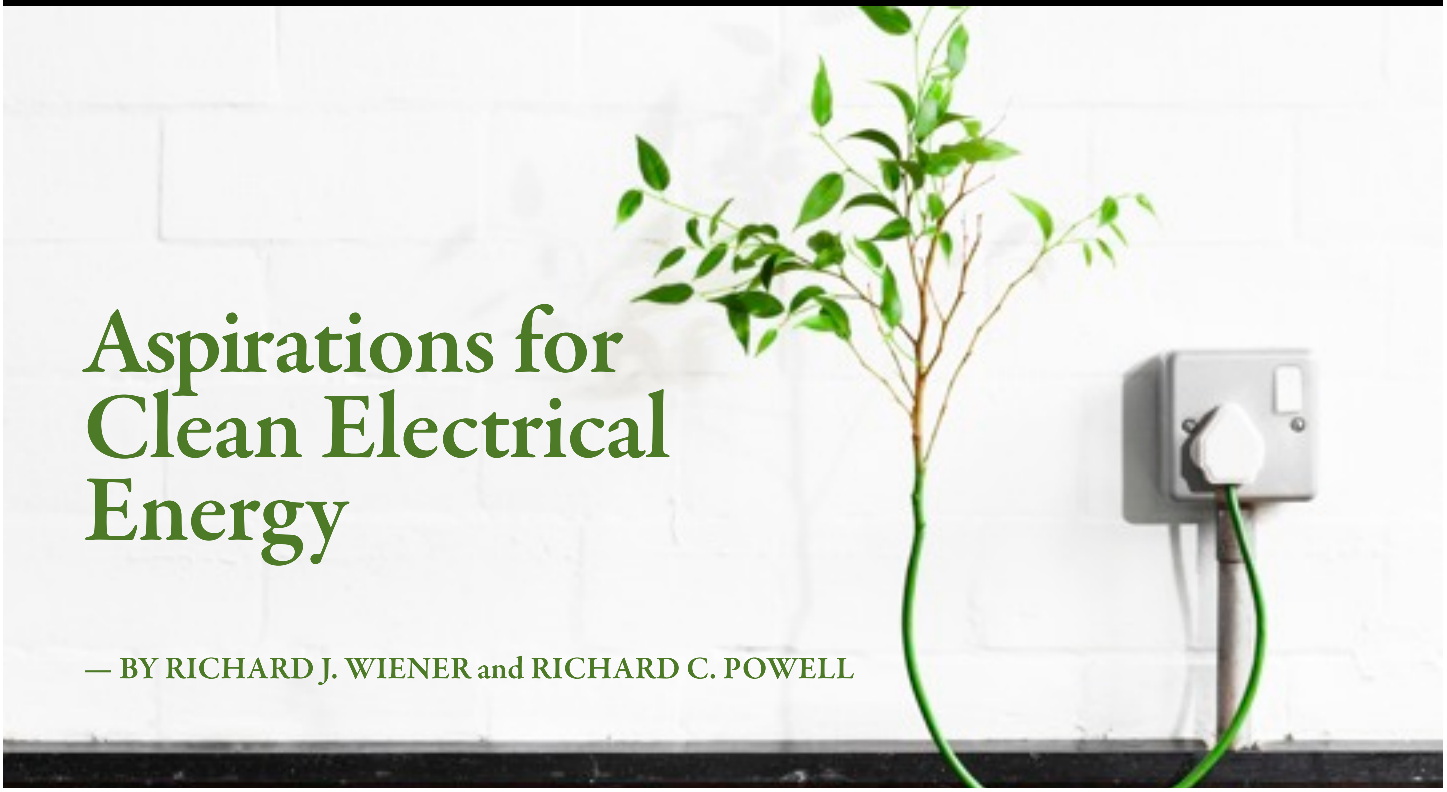
Small Modular Reactor

Manufacturer	Country of Origin	Reactor Name	Reactor Type	Reactor Capacity (MWe)	Reactor Size (m, Diam, Height)	Coolant
NuScale Power, Inc.	USA	NuScale	MASLWR (iPWR)	45	4.3 x 18	Water (gravity)
Babcock & Wilcox Cmpany.	USA	B&W mPower	ALWR (iPWR)	125	4.5 x 23	Water
PBMR, Ltd/ESKOM	South Africa, China, Germany, Netherlands	Pebble Bed Modular Reactor	Fast Reactor (High Temperature, Gas-Cooled)	165	Graphite pebbles 60 mm diam	Pyrolytic graphite moderator, inert or semi-inert gas (helium, nitrogen or carbon dioxide)
Toshiba CRIEPI	Japan	Toshiba 4S	Fast Neutron	10 / 50	30m undergound, building 22×16×11	Sodium
GE Hitachi	USA/Japan	GE Hitachi PRISM	Fast Reactor	311	Underground Containment	Sodium
Hyperion Power Generation, Inc.	USA	Hyperion Power Module Reactor	Fast Reactor	25	1.5 x 2m	Lead-bismuth eutectic (LBE)
Atomenergoprom/OKBM	Russia	KTL-40s	PWR	70	21,500 tonnes Length: 144.4 meters, Beam: 30 meters, Height: 10 meters Draught: 5.6 meters	Water
General Atomics	USA	General Atomics EM2	Sodium-Cooled	285	Unavailable	Helium
Westinghouse	USA	Westinghouse SMR	iPWR	200	Unavailable	Water
Areva	France	ANTARES	Fast Reactor	285	Unavailable	Nitrogen/Helium mixture
INET & Huaneng	China	HTR-PM	High Temperature, Gas-cooled PBMR	100	Unavailable	Graphite
Bhaba Atomic Research Center	India	Unknown	AHWR	300	Unavailable	Boiling water coolant heavy water moderator
Invap/CNEA	Argentina	CAREM	iPWR	27	Unavailable	Water
KAERI	South Korea	SMART	Co-generation plant	100	Unavailable	Unavailable

Notes:
* Information obtained from manufaturer's website and other sources (WINS, etc). Information should be treated as preliminary until models are built

r Matrix (Promising Models)*

	Fuel Type	Refueling (#, Months)	Spent Fuel Storage	Service Life (Years)	NRC Application (Expected)	Notes
	4.95% Enriched Uranium	24	On-Site	40+	1^{st} Quarter, 2012	NuScale has recently run into financing trouble, but its reactor is deemed by experts and the NRC to be a promising design that could be among the first to be certified
	5% Enriched Uranium	60	On-Site	60	4^{th} Quarter, 2012	B&W are in advanced talks (non-binding agreement with TVA to build a reactor, and are in advanced licensing talks with the NRC
r r	UO_2 particles 1mm in diam	36	In pebbles	36	2013	PBMRs have had a long history and their history is uncertain. There have been instances when the fuel caught on fire. South Africa is not puruing it currently, but China is
	20% enriched Uranium or 11.5 – 24% MOX	Never	Not Applicable	30	2nd Quarter 2012	Partnership with city of Galena, AK for a reactor, and good candidate for the 2012 budget funding for SMRs if design is licensed
	Recycled fuel from Advanced Recycling Center (Pu or DU)	12 to 24	ARC on site - reuse spent fuel	40+	2012 or 2013	NRC staff conducted pre-application review in the early 1990s, resulting in NUREG-1368, "Pre-application Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor (January 1994)."
	20% enriched Uranium	Never	N/A	7 to 10	Unknown	Hyperion entered an agreement with Savannah River National Laboratory (SRNL) in fall 2010 to deployment the 25MWe modular reactor at the US Department of Energy's (DOE) Savannah River Site (SRS); details on timeline are unclear
	90% enriched Uranium-235	36	On Barge	12	Not Applicable	Based on the commercial KLT -40 marine propulsion plant, an advanced variant of RPs that power nuclear icebreakers. The first reactor was delivered in May and the second one in August 2009. Akademik Lomonosov was launched on 30 June 2010
	12% Uranium 253	Never	Not Applicable	30	Unknown	Unclear timeline, as design in in incipient phases
	4.95% Enriched Uranium	Unavailable	Unavailable	Unavailable	Unknown	Released on February 17, 2011, many details yet unavailable
	graphite speres, 10 - 19.9% enriched Uranium	Unavailable	Unavailable	Unavailable	Unknown	
	UO_2 particles	Unavailable	Unavailable	Unavailable	Not Applicable	Full-size demonstration module expectved in 2013. License application filed and under review
t,	233U-Pu-Th	Unavailable	On-Site	Unavailable	Not Applicable	Pre-licensing negotiations with the Atomic Energy Regulatory body of India. Construction expected in the next decade
	3.5% enriched PWR fuel	Unavailable	On-Site	Unavailable	Not Applicable	CAREM reactor is a test reactor for larger, 150-300MWe units to be built mainly for domestic market
	Unavailable	Unavailable	Unavailable	Unavailable	Not Applicable	Currently in pre-licensing process



Aspirations for Clean Electrical Energy

— BY RICHARD J. WIENER and RICHARD C. POWELL

Seventy-five percent of the electricity generating capacity in the United States depends on the combustion of fossil fuels. However, there is growing recognition that a large scale transition to clean energy is desirable. This recognition is based on a multitude of concerns, perhaps foremost that dependence on fossil fuels for electricity is causing severe environmental and health hazards including large emissions of toxic air pollutants and greenhouse gases. What will this transition to non-fossil fuel energy look like? How quickly can it come about? Will it be driven primarily by top-down official regulatory agencies, by bottom-up grass roots efforts, free market incentives, or a combination of these effects?

By now the majority of states in the country have officially established renewable energy standards that require their utility companies to generate a specific fraction of their electricity production by clean energy sources by some specific future date. In general these official requirements are in the range of 20 percent clean energy by around 2020. The portfolios for meeting this demand almost always include solar and wind power with other options including hydroelectric, geothermal, nuclear, and biomass generation. The variation from one state plan to another is determined by potential for each type of generation source in each geographical area and local environmental issues affecting the use of these technologies. For example, states such as Nevada and California have a high potential for geothermal electrical generation while Arizona has a very low geothermal potential. As another example, states with sparse water resources such as Arizona are less likely to meet renewable energy standards by adopting non-fossil fuels electrical generation technologies that require significant amounts of cooling water such as nuclear plants, whereas water usage is less of an issue in the Pacific Northwest. As a result of these considerations, it is not possible to have one plan that is appropriate for every state, but rather many different plans tailored to regional needs.

In many regions there are grass roots efforts to push for the adoption of clean energy far beyond official renewable energy standards. Groups such as the National Wildlife Federation (NWF) have developed plans for several states.[1] The NWF plan for New Mexico calls for 65 percent clean electricity by 2050. An environmental group in Utah obtained funding from several foundations to form a committee of experts that developed five possible scenarios for the state.[2] The most aggressive of these scenarios calls for 100 percent clean electricity by 2050. Energy policy experts at universities have published plans setting the goal for California at 100 percent clean electricity by 2020 and for the entire world[3-5] by 2030. In Massachusetts a group of citizens have initiated a petition to the governor and legislature to require 100 percent clean electricity by 2020. We have developed a plan for Arizona[6] that calls for the state to generate 100 percent of its electricity through clean technologies by 2040. President Obama, perhaps influenced by grass roots advocacy, has set the goal for the United States at 80 percent clean electricity by 2035, and the Department of Defense has announced its electricity use will be 25 percent clean energy by 2025. The various groups advocating these aggressive goals cite the need to become free of volatile price fluctuations of fossil fuels, acquire greater energy independence, create local employment, reduce water usage, reduce emissions of greenhouse gases and toxic pollutants, and establish a revenue source by exporting clean electricity. All of these objectives improve the quality of life and potential for regional economic development. These state plans provide roadmaps with plausible scenarios for phasing out fossil fuels and achieving clean energy generation of electricity. But these plans also illustrate the scale of the challenge of replacing fossil fuels with clean energy in a matter of decades.

The generation portfolios for the clean electricity plans vary significantly for the reasons discussed above. The total quantity of electrical energy projected for each plan depends on the estimated growth in demand, estimated effect of efficiency programs, and the seriousness of the intent to export electrical energy to other regions. States such as Utah, Arizona and California have experienced an increase in electrical power demand over the past decade, but the severe economic downturn, due to the housing bubble bursting, suggests this trend will weaken at least in the near term. Also states like Arizona have recently adopted very aggressive conservation measures in an attempt to stem the continual increase in demand for electricity. And if the cost of electricity rises substantially over the next several decades, elasticity in demand will likely dampen growth. On the other hand, population growth and a transition to plug-in hybrid and electric vehicles will undoubtedly increase demand. Due to such contravening potential effects, there is significant uncertainty about electric power demand several decades from now. The plans for each region have to be flexible enough to accommodate this uncertainty.

The plan for Arizona that we have proposed suggests that the current amount of electrical power generated through hydroelectric and nuclear plants in the state remain constant through 2040, while the current coal and gas fired power plants are phased out. Solar and wind generation along with compressed air energy storage will be phased in to replace the fossil fuel plants and to meet the future growth in demand. The proposed photovoltaic energy is a mix of distributed roof top generation and grid power plants.

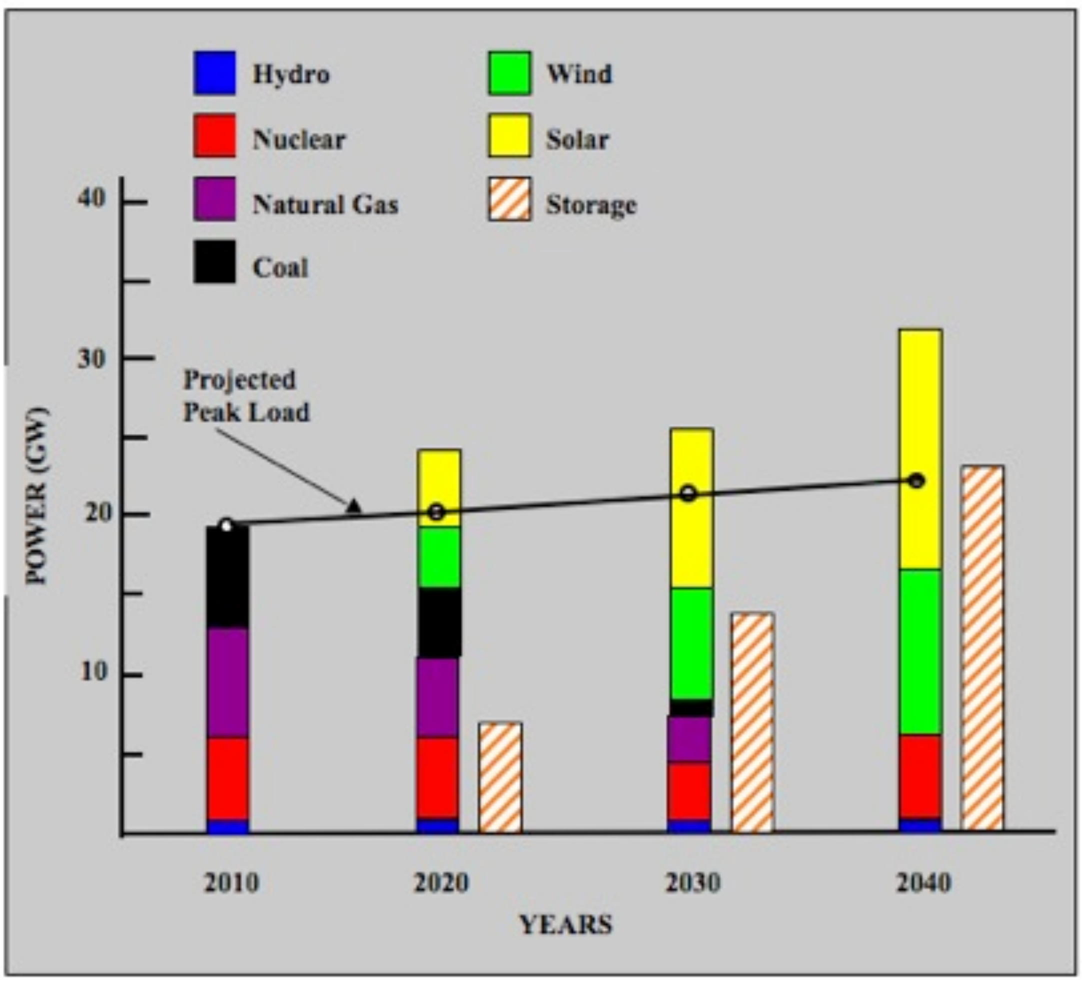


Figure 1. Phased implementation of the Arizona Clean Energy Vision.

demand for electricity in Arizona is assumed to grow at a modest rate of 0.5 percent per year over the next thirty years. This estimate for the rate of growth in demand in Arizona is based on an analysis by University of Arizona economist Stan Reynolds.[7] If this projected growth in demand proves accurate, Arizona will need approximately 10 Gigawatts (GW) of wind power, 15 GW of solar power, and 20 GW of energy storage to be built in the next thirty years to achieve 100 percent clean generation of electricity and have additional capacity for exporting clean energy by 2040.

Although the amounts of needed clean energy generating and storage capacity are substantial in this example, it is certainly conceivable that such a transition could occur. However, there are several key actions required if any of these clean electricity plans are to succeed. The first is addressing the issue of intermittency. All of the plans require a significant amount of solar and wind energy, both of which are intermittent on short term (seconds or minutes) and long term (hours or days) time scales. Currently, the demand response required of utility companies cannot handle this type of intermittency in more than about 20 percent of their generation portfolio. Having a grid penetration of 80 to 100 percent can only be achieved if a significant amount of energy storage capability is present to mitigate the intermittency. For short-term intermittency, supercapacitors appear to be a promising technology, but additional research and development is needed to bring these devices to the level of commercial products. For long-term intermittency, both pumped hydro and compressed air energy storage are proven technologies. The choice for a specific region will depend on issues such as the availability of water and environmental concerns over siting. The current round trip efficiency of compressed air storage technology must be improved through the use of heat exchangers and more efficient compressors. Thus, for both short-term and long-term energy storage there is a critical need for more research and development.

Another important action item for implementing clean electricity plans is upgrading the current electrical grid. The command and control software must be updated to accommodate multiple generation sources with intermittency and two-way flow of electricity. Much of the hardware is old and needs to be replaced and expanded to meet future demand regardless of the type of generating technology. The amount of new grid lines associated with implementing new wind and solar generating stations will depend on the location of the stations. The amount of land available in Arizona, for example, that has been identified as appropriate for solar energy generation is many times more than enough to supply electrical demand far into the future. But deciding which part of this land to use is critical. There are existing solar generation areas near Springerville and Gila Bend, both of which have major grid lines near to them. Expansion of these facilities would require relatively little grid upgrade. However, some advocates of clean energy in Arizona have argued it would be better to have many smaller solar generation stations located on old mine tailings, since such land is already severely damaged and no longer ecologically sensitive. This latter option would require a significant number of miles of new grid lines. Obviously many environmental and social concerns will enter into the decision making process. One major issue in Arizona is that much of the income of some Native American tribes comes from coal mines and power plants. Replacing coal energy by solar and wind energy must be done in such a way that tribal economies are not damaged.

Perhaps the largest issue of all in making the transition from fossil fuel electricity to clean electricity is cost. The installed cost of photovoltaic solar energy is still significantly higher than that of coal and natural gas. To meet the goal of $1/W installed cost of solar electricity (i.e. approximate parity with fossil fuels) set by Secretary of Energy Steven Chu will require targeted research to improve the efficiency of photovoltaic cells and lower the manufacturing costs of both the cells and the balance of system components as well as the installation costs. Even when grid parity for solar energy is achieved, creative financing will be required to provide the incentive for utility companies and private power providers to invest in new clean electrical generation plants. There is a need for a detailed economic analysis of each of the clean electricity plans to determine their financial feasibility as a function of cost curves for clean energy and storage technologies.

Implementing any of these aggressive clean electricity plans will require a shared vision of all the stakeholders as well as strong leadership of the decision makers in a region. As noted above, making these plans happen will require targeted research and development in several key areas and critical decisions about details in the plan such as the siting of new power plants. But articulating aspirations for clean energy in detailed regional plans is a critical first step on the path to a sustainable future. ■

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RESEARCH REPORT

Impacts of Biofuels on Climate Change, Water Use, and Land Use

MARK A. DELUCCHI *

INTRODUCTION

Governments worldwide are promoting the development of biofuels, such as ethanol from corn, biodiesel from soybeans, and ethanol from wood or grass, in order to reduce dependency on oil imported from politically unstable regions of the world, spur agricultural development, and reduce the climate impact of fossil fuel combustion. Biofuels have been promoted as a way to mitigate the climate-change impacts of energy use because the carbon in a biofuel comes from the atmosphere, which means that the combustion of a biofuel returns to the atmosphere the amount of carbon dioxide (CO_2) that was removed by the growth of the biomass feedstock. Because CO_2 from the combustion of fossil fuels, such as oil, is one of the largest sources of anthropogenic climate-active "greenhouse gases" (GHGs), it might seem, at first blush, that the elimination of net CO_2 emissions from fuel combustion per se, as happens with biofuels, would help mitigate the potential for global climate change. It turns out, however, that this elimination of net CO_2 emissions is a small part of a complete accounting of the climate impacts of biofuels. Indeed, as I delineate here, calculating the climate impact of biofuels is so complex, and our understanding is so incomplete, that we can make only general qualitative statements about the overall impact of biofuels on climate. Moreover, the production of biofuels can have significant impacts on water use, water quality, and land use – because per unit of energy produced, biofuels require orders of magnitude more land and water than do petroleum transportation fuels – and these impacts should be weighed in an overall assessment of the costs and benefits of policies that promote biofuels.

At the start of each major section, I first discuss the overall metric by which impacts typically are measured. This overall metric is important because many analysts use it is a basis for evaluating and comparing the impacts of biofuels; hence, the overall metric should be as broad as possible yet still represent what society cares about. I argue that the absence of broad, meaningful metrics for climate-change, water-use, and land-use impacts makes overall evaluations difficult. Nonetheless, in spite of the complexities of the environmental and technological systems that affect climate change, land use, and water use, and the difficulties of constructing useful metrics, we are able to make some qualitative overall assessments. It is likely that biofuels produced from crops using conventional agricultural practices will *not* mitigate the impacts of climate change and will exacerbate stresses on water supplies, water quality, and land use, compared with petroleum fuels. Policies should promote the development of sustainable biofuel programs that have very low inputs of fossil fuels and chemicals, that rely on rainfall or abundant groundwater, and that use land with little or no economic or ecological value in alternative uses.

CLIMATE-CHANGE IMPACTS OF BIOFUELS

Over the past twenty years, researchers have performed hundreds of analyses of "CO_2-equivalent" (CO2e) GHG emissions from the lifecycle of biofuels. These analyses typically have estimated emissions of CO_2, methane (CH_4), and nitrous oxide (N_2O) emitted from the production of biofuel feedstocks (e.g., growing corn), the production of the biofuel (e.g., producing ethanol from corn), and the distribution and end-use of the biofuels (e.g., the use of ethanol in motor vehicles). Analysts multiply emissions of CH_4 and N_2O by their respective "Global Warming Potentials" (GWPs) and add the result to estimated emissions of CO_2 to produce a measure of total lifecycle CO2e GHG emissions. Several reviews discuss LCA of biofuels, results from biofuel LCAs, and issues in biofuel LCA (United Nations Environment Programme [UNEP], 2009; Menichetti and Otto, 2009; Reijnders and Huijbregts, 2009; Delucchi, 2006; Farrell et al., 2006; International Energy Agency, 2004). Here, I discuss problems with the CO2e metric, well-known and emerging issues in conventional LCAs, and other potentially important issues.

Problems with the CO2e metric.
As mentioned above, virtually all biofuel LCAs measure the climate impact of biofuels on the basis of the GWP of CO_2, CH_4, and N_2O emissions. The GWP estimates the radiative forcing of gas *i* (e.g., CH_4) relative to that of CO_2 integrated (typically) over a 100-year period, accounting for the decay of the gas in the atmosphere and the direct and indirect radiative forcing (IPCC, 2007). Hence, biofuel LCAs estimate the total relative radiative forcing over a 100-year period, for three GHGs.

There are several problems with this metric (IPCC, 2007; Fuglestvedt et al., 2003; Bradford, 2001). First, we care about the impacts of climate change, not about radiative forcing per se, and changes in radiative forcing are not simply linearly correlated with changes in climate impacts. Second, the method for calculating the GWPs involves several unrealistic simplifying assumptions, which can be avoided relatively easily. Third, by integrating radiative forcing from the present day to 100 years hence, the GWPs in effect give a weight of one to every year between now and 100 and a weight of zero to every year beyond 100, which does not reflect how society makes tradeoffs over time (a more realistic treatment would use continuous discounting). Fourth, the conventional method omits several gases and aerosols that are emitted in significant quantities from biofuel lifecycles and can have a significant impact on climate, such as ozone precursors, carbon monoxide (CO), nitrogen oxides (NO_X), sulfur oxides (SO_X), and black carbon (BC).

Some preliminary work indicates that a method for estimating CO2e factors that addresses the shortcomings above can produce comparative assessments that are appreciably different from those that use traditional GWPs and consider only CO_2, CH_4, and N_2O (Delucchi, 2003, 2006).

Well-known and emerging issues in conventional biofuel LCA. In most biofuel LCAs, the estimated CO2e climate impact (based on GWPs, as discussed above) is a function of four factors, the first three of which have long been known, and the fourth of which is an important emerging issue (UNEP, 2009; Börjesson, 2009; Menichetti and Otto, 2009; Reijnders and Huijbregts, 2009): 1) the amount and kind of fossil fuel used in cultivation of biomass feedstocks and in the production of the biofuel; 2) the amount of nitrogen fertilizer applied, and the assumptions regarding N_2O emissions from that fertilizer; 3) the benefits of any co-products of the biofuel production process (e.g., animal feed is produced along with ethanol in corn-to-ethanol plants); and 4) the assumptions and analytical methods concerning carbon emissions from land-use change (LUC). As Börjesson (2009) notes, "depending on these four factors, production systems for ethanol may mean anything from major climate benefits to increased emissions of GHG compared with petrol" (p. 593).

Börjesson's (2009) conclusion, however, applies mainly to biofuels derived from agricultural crops such as corn, soybeans, and wheat – so-called "first-generation" biofuels. It certainly does not apply to biofuels derived from waste products (which however are usually available only in small quantities), and it applies with less force to so-called "second-generation" biofuels derived from cellulosic sources such as grasses and trees. Compared with biofuels from agricultural crops, cellulosic biofuels generally require less fertilizer (and hence produce less N_2O), use non-fossil sources of energy (such as part of the plant material) in the production of the biofuel (and hence do not emit fossil-CO_2), and in some circumstances cause lower emissions related to LUC on account of the relatively high carbon stocks maintained in the soils and biomass of grass and wood plantations. In the best case, if cellulosic biofuels are derived from mixed grasses grown on degraded lands with little management and low inputs (Tilman et al., 2006), lifecycle CO2e emissions almost certainly will be lower than from petroleum fuels.[2]

Potentially important issues that have not been investigated in the context of biofuel LCA.

The production of biofuels will cause at least two kinds of changes in the environment that are likely to have major impacts on climate but that have not yet been included in any published biofuel LCAs: changes in biogeophysical parameters due to changes in land use, and perturbations to the nitrogen cycle due to the use of nitrogen fertilizer.

Biogeophysical impacts. Changes in land use and vegetation can change physical parameters, such as albedo (reflectivity) and evapotranspiration rates, that directly affect the absorption and disposition of energy at the surface of the earth and thereby affect local and regional temperatures (Bala et al., 2007; Marland et al., 2003). Changes in temperature and evapotranspiration can affect the hydrologic cycle, which in turn can affect ecosystems and climate in several ways, for example via the direct radiative forcing of water vapor, via evapotranspirative cooling, via cloud formation, or via rainfall, affecting the growth and hence carbon sequestration by plants.

In some cases, the climate impacts of changes in albedo and evapotranspiration due to LUC appear to be of the same order of magnitude but of the opposite sign as the climate impacts that result from the associated changes in carbon stocks in soil and biomass due to LUC. This suggests that the incorporation of these biogeophysical impacts into biofuel LCAs could significantly change the estimated CO2e impact of biofuel policies.

The nitrogen cycle. Anthropogenic inputs of nitrogen to the environment, such as from the use of fertilizer or the combustion of fuels, can disturb aspects of the global nitrogen cycle and ultimately have a wide range of environmental impacts, including eutrophication of lakes and coastal regions, fertilization of terrestrial ecosystems, acidification of soils and water bodies, changes in biodiversity, respiratory disease in humans, ozone damages to crops, and changes to global climate (Galloway et al., 2003; Mosier et al, 2002). Galloway et al. (2003) depict this as a "nitrogen cascade," in which "the same atom of Nr [reactive N, such as in NO_X or NH_Y] can cause multiple effects in the atmosphere, in terrestrial ecosystems, in freshwater and marine systems, and on human health" (p. 341; brackets added).

Moreover, nitrogen emissions to the atmosphere, as NO_X, NH_Y, or N_2O, can contribute to climate change through complex physical and chemical pathways that affect the concentration of ozone, methane, nitrous oxide, carbon dioxide, and aerosols. Yet even though the development of many kinds of biofuels will lead to large emissions of NO_X, N_2O, and NH_Y, virtually all lifecycle analyses of CO2e GHG emissions from biofuels ignore all N emissions and the associated climate effects except for the effect of N fertilizer on N_2O emissions. Even in the broader literature on climate change there has been relatively little analysis of the climate impacts of N emissions, because as Fuglestvedt et al. (2003) note, "GWPs for nitrogen oxides (NO_X) are amongst the most challenging and controversial" (p. 324).

Summary of climate-change impacts.

Nobody has yet done an analysis of the climate-change impacts of biofuels that uses a metric for the impacts of climate change that considers all of known or suspected potentially important climate-altering effects. As a result, we cannot yet make quantitative estimates of the climate impacts with confidence. However, we can make some useful qualitative statements. It is likely, for example, that biofuels produced from crops using current agricultural practices will *not* offer appreciable reductions in CO2e climate impacts, and might even exacerbate climate change, compared with the impact of petroleum fuels. At the other end of the spectrum, we know that biofuels produced from true waste material (i.e., material with no alternative use) do not, by definition, affect agricultural practices or land uses, and hence will not significantly exacerbate climate change, unless the fuel-production process uses significant amounts of fossil fuels or fuel combustion produces nontrivial amounts of non-CO_2 GHGs. Similarly, biofuels produced from cellulosic materials, such as grasses, that are grown in the most ecologically sustainable manner possible, are likely to cause less climate-change damage than do petroleum fuels.

With our current knowledge, however, it is difficult to asses the impact either of biofuels produced from crops using the *best*, most sustainable practices, or of biofuels produced from cellulosic materials using practices similar to those in conventional agriculture. In order to assess these production systems, and in general to provide more comprehensive assessments of the climate impacts of biofuels, we need improved, integrated lifecycle/economic/environmental-systems models, able to address the problems discussed here.

WATER USE AND WATER QUALITY

The production of biofuels can require orders of magnitude more water than does the production of petroleum fuels (Mishra and Yeh, 2011; Gerbens-Leenes et al., 2009; King and Webber, 2008). This high demand for water can stress water supplies and degrade water quality via salinization and pollution from agriculture and industry (Zimmerman et al., 2008; Shah et al., 2000). Unfortunately, there is no commonly used single metric that captures all relevant aspects of the impacts on water availability and water quality. Instead, most studies provide a relatively simple measure of water consumption or water use, or a measure of one specific impact on water quality, eutrophication. I discuss both of these measures (water use and eutrophication) here. In a separate section, I provide simple, original estimates of the water use of biofuel systems relative to some pertinent measures of water availability.

Impacts on water consumption and water use.
Milà i Canals et al. (2009) distinguish two kinds of water inputs to production systems, "blue" water (in groundwater) and "green" water (from rainfall), and two kinds of water outputs from production systems, non-evaporative uses (corresponding to water withdrawals or water use in other classifications) and evaporative uses (corresponding to water consumption in other classifications). Generally, water withdrawal is water removed from the ground or diverted from a surface-water source, and water consumption is equal to total withdrawals less the amount that is not available for re-use.

Measures of water usage, expressed in terms of volume of water per unit of biofuel energy output, are more meaningful when they are expressed relative to some measures of water availability. But even when expressed relative to water availability, measures of direct water use do not fully represent the impacts society cares about, because the measures still do not capture the costs of water supply, the costs of water treatment, adaptive responses, the possibility of water trade, the impacts of water pollution, and so on. However, it is possible at least to incorporate into a water-use metric a simplified treatment of one of the most important of these impacts, water pollution.

Measuring impacts of water pollution. The production and use of biofuels can cause water pollution from fertilizer and pesticide runoff from crop fields and effluents from biofuel production facilities (Simpson et al., 2009). It is convenient to express the impacts of this pollution in terms of water use, because this then can be added to actual water usage to provide a broader index. The common way to do this is to estimate the amount of clean water that would be required to dilute polluted water to acceptable levels. Generally, pesticides require greater dilution than does phosphorus, which in turn requires greater dilution than does nitrogen. In round numbers, the amount of water required to dilute phosphorous pollution is of the same order of magnitude as the total direct water consumption (rainfall plus irrigation), for all crops, and is many times higher than the amount of water used for irrigation where irrigation is a small fraction of the total.

Eutrophication. A number of studies measure a specific impact of biofuel production on water quality, eutrophication. Increased concentrations of certain nutrients, particularly nitrogen and phosphorous, can promote excessive plant growth and decay in aquatic ecosystems, leading to increases in phytoplankton, decreases in dissolved oxygen, increased turbidity, loss of biodiversity, reductions in commercially important fish, increases in toxic plankton species, and other undesirable ecological effects (Simpson et al., 2009).

To the extent that the production of biofuel feedstocks uses large amounts of nitrogen and phosphorous fertilizer, the runoff from production fields into water bodies can cause significant eutrophication. To represent this, researchers typically estimate a phosphate-equivalent (sometimes nitrate-equivalent) "eutrophication potential" (analogous to the CO_2-equivalent global warming potential discussed above), calculated by multiplying nitrogen and phosphorous emissions by a "fate factor," which represents the fraction of the emitted pollutant that reaches the aquatic environment (this is 1.0 in the case of direct emission to water), and by an "effect factor," which represents the potential production of phytoplankton per gram of the pollutant relative to the potential production from a gram of phosphate (Brentrup et al., 2004).

Several studies have applied eutrophication potentials to lifecycle analyses of biofuels (e.g., UNEP, 2009; Baral and Bashki, 2008). Although these studies use a relatively simple metric for eutrophication impact, as discussed above, they all indicate the production and use of biofuels can cause greater eutrophication than does the production and use of petroleum fuels.

LAND USE

Per unit of energy produced, biofuels require orders of magnitude more land than do petroleum fuels (MacDonald et al., 2009; California Air Resources Board, 2009).
The land requirement per unit of delivered biofuel can be calculated simply as the product of the yield (crop output per unit area), the production intensity (energy per unit crop), and a factor that accounts for the land-use impacts of any co-products of the production process. McDonald et al. (2009) use this method to estimate the land-use intensity of different energy production techniques, and find that biofuels require roughly 10 to 20 times more land per unit of area than do fossil fuels in the year 2030.

However, the land requirement for biofuel production is just a rough indicator of other land-use impacts that society cares about, such as soil erosion, dust and smoke from agricultural activities, loss of habitat, biodiversity, and ecosystem services, and the effects of competition for land on the prices of commodities and services produced by land.

Loss of habitat, biodiversity, and ecosystem services. The use of monocultural feedstocks (such as corn) to make biofuels can reduce biological diversity and the associated bio-control services in agricultural landscapes (UNEP, 2009; Reijnders and Huijbregts, 2009). A simple land-use intensity metric is not a good indicator of these impacts, in part because it does not reflect the impact of the land use on habitat integrity, wildlife corridors, and interactions at the "edges" of the affected area. To address this, researchers have proposed a number of more direct indicators, including the "Natural Degradation Potential" (Brentrup et al., 2002) and the "Ecosystem Damage Potential" (Koellner and Scholz, 2007). By any of these measures, biofuels made from crops can severely degrade natural habitats.

Soil erosion. Biofuel-crop harvesting practices can affect soil erosion and the nutrient and organic content of the soil, which in turn can affect the use of fertilizer (Reijnders and Huijbregts, 2009). For example, if crop residues are removed from the field and used as a source of energy in the production of a biofuel, then soil erosion might increase and fewer nutrients and less organic matter might be returned to the soil (Pimentel and Lal, 2007). Additional fertilizer may be required to balance any loss, and the use of additional fertilizer will result in additional environmental impacts.

Effects of competition for land on prices of commodities and services produced by land. As Rajagopal and Zilberman (2008) note, "allocating land for biofuels means taking land away from other uses like food or environmental preservation" (p. 70). Economic theory and economic models tell us that a demand-driven increase in the price of a biofuel feedstock, such as corn (for corn-ethanol), will benefit the producers of the feedstock but cost those who consume the feedstock directly or use it as a factor of production (Elobeid et al., 2006). In many if not most cases, the people who benefit tend to be wealthy, and the people who lose tend to be poor (Vanwey, 2009).

It is clear, then, that a main effect of the competition for land between biofuel crops and food crops will be higher food prices, which will hit the poor particularly hard. Indeed, if the

competition between biofuel crop production and food crop production is extensive and severe enough, it is possible that the consequent increases in agricultural prices will cause some people to go hungry and even starve (Runge and Senauer, 2007).

EXAMPLE CALCULATIONS OF THE LAND AND WATER REQUIREMENTS

In order to put the discussion of water and land impacts into a realistic context, elsewhere (Delucchi, 2010) I have estimated the impacts of developing the biofuels program that is part of a comprehensive set of global energy projections by the International Energy Agency (IEA, 2008). The IEA scenarios include detailed assumptions about technology and energy uses for power, transportation, and end use. The IEA's "Blue MAP" scenarios, in which biofuels provide 27 percent of total ground transportation energy in the world, requires:

- 6% of current global permanent pasture land;
- 16% of current global arable land;
- 6% of global renewable freshwater;
- 117% of current global water use by agriculture; and
- 82% of current total global water use.

For every 10 percent of the IEA-projected *global* ground transportation energy demand satisfied by cellulosic biofuels, the land and water requirements are:

- 2% of current global permanent pasture land;
- 6% of current global arable land;
- 2% of global renewable freshwater;
- 44% of current global water use by agriculture; and
- 31% of current total global water use.

Note that these calculations assume the use of "second-generation" cellulosic biofuels. The water use of "first generation" biofuels, ethanol from irrigated corn or biodiesel from irrigated soy, is somewhat higher than the water use of cellulosic biofuels (Delucchi, 2010).

Note also that all of these percentages are with respect to the current situation, and hence do not reflect increases in demand for land and water in other sectors, particularly agriculture. Several studies project that total global water withdrawals could increase by more than 20 percent by 2025, leading to severe water stresses in several regions of the world (e.g., Seckler et al., 1999). In the longer term, the number of people living in regions experiencing high stresses on water supplies (defined as less than 1,000 m^3/capita/year) could increase by several billion, with most of the increases occurring China, India, West Asia, and North Africa (Arnell, 2004). However, even if future freshwater withdrawals for all uses other than biofuel feedstock production were to double by 2050, the addition of the water demand estimated for the IEA "BLUE Map 2050" scenario analyzed above still would result in a total water withdrawal of just under 20% of the total global renewable freshwater resource – below the level considered to seriously "stress" water supplies.

Thus, even though the land and water requirements of biofuels are very large with respect to the requirements of current transportation energy systems, on the one hand, and large with respect to the requirements of current agricultural systems, on the other, at the *global* level there will be no evident water and pasture-land resource constraints on the development of bioenergy for several decades, unless the requirements of other sectors have been vastly underestimated.

Still, water and arable land are not distributed uniformly across the globe with respect to population or energy demand, and as a result at the regional level there can be severe constraints on land and water availability. In parts of China, South Asia, West Asia, and Africa current demands already are stressing water supplies, and these stresses are expected to increase dramatically in the coming decades (Alcamo et al., 2003; Seckler et al, 1999). The development of biofuel feedstocks in these areas could place intolerable stresses on water supplies (Müller et al., 2008; Fraiture et al., 2008). Even in the United States, a major expansion of biofuel production could seriously exacerbate water-quantity and water-quality problems (National Research Council, 2008). To avoid these regional water-availability constraints on biofuel production, biofuels would have to be traded globally, the way petroleum fuels are today. If in fact biofuel feedstocks can be grown in water-rich regions at reasonable cost and with minimal environmental impact, and if future demands for land and water by other sectors do not dramatically exceed present expectations, then arguably biofuel production need not be constrained by the global availability of land and freshwater.

Producing biomass energy feedstocks with lower impacts on climate change, water use, water quality, and land use. The environmental impacts of producing bioenergy feedstocks can be reduced by mixing plant species, reducing energy and chemical inputs, managing material flows to achieve nearly a closed system, and targeting biofuel crop production to degraded or abandoned lands (Tilman et al., 2006; Reijnders, 2006; Muller, 2009). For example, Tilman et al. (2006) propose that low-input, high-diversity (LIHD) mixtures of native grassland perenials in the U. S. can provide more biodiverse habitat and even higher yields than can monocultural perennials, at least on relatively infertile soils. They suggest that LIHD systems can be grown successfully on abandoned, degraded agricultural lands, and actually improve the quality of soil and water on such lands. (However, this improvement is relative to leaving the land degraded, not relative to restoring the land to its most environmentally beneficial use.)

However, it is not clear that such bioenergy systems can be sustainable and commercially viable at large scales. For example, Johansson and Azar (2008) suggest that it is unlikely that commercial bio-energy farmers will *choose* to grow bioenergy crops on degraded land, as it is likely to be relatively unprofitable. Similarly, Sala et al. (2009) note that while some small-scale biofuel production systems can maintain high biodiversity, "it is unlikely that solutions that produce biofuels while maintaining bio-diversity can be implemented at the scale necessary to meet current biofuel demand" (p. 131).

CONCLUSIONS

Research over the past two decades has helped us understand many aspects of the impacts of biofuel development on climate change, water use, and land use. However, because of the complexity of the ecological, economic, and technological systems that affect climate change, land use, and water use, and the difficulty of constructing useful metrics of impacts, there are as yet no definitive quantitative assessments that capture all of the aspects of climate change, water use, and land use that we care about.

Nevertheless, we are able to make some qualitative overall assessments. It is likely that biofuels produced from crops (e.g., ethanol from corn) using conventional agricultural practices will not mitigate the impacts of climate change, and will exacerbate stresses on water supplies, water quality, and land use, compared with petroleum fuels. To avoid these problems, biofuel feedstocks will have to be grown on land that has no alternative commercial use and no potential alternative ecological benefits, in areas with ample rainfall or groundwater, and with little or no inputs of fertilizers, chemicals, and fossil fuels. Although this can be done experimentally at small scales, it is not clear that it can be done economically and sustainably at large scales. We can conclude, then, that the development of sustainable biofuels depends not only on technological progress in growing feedstocks and producing fuels, but also on developing the policies, regulations, and incentives that direct commercial biofuel development in socially and environmentally beneficial ways. ■

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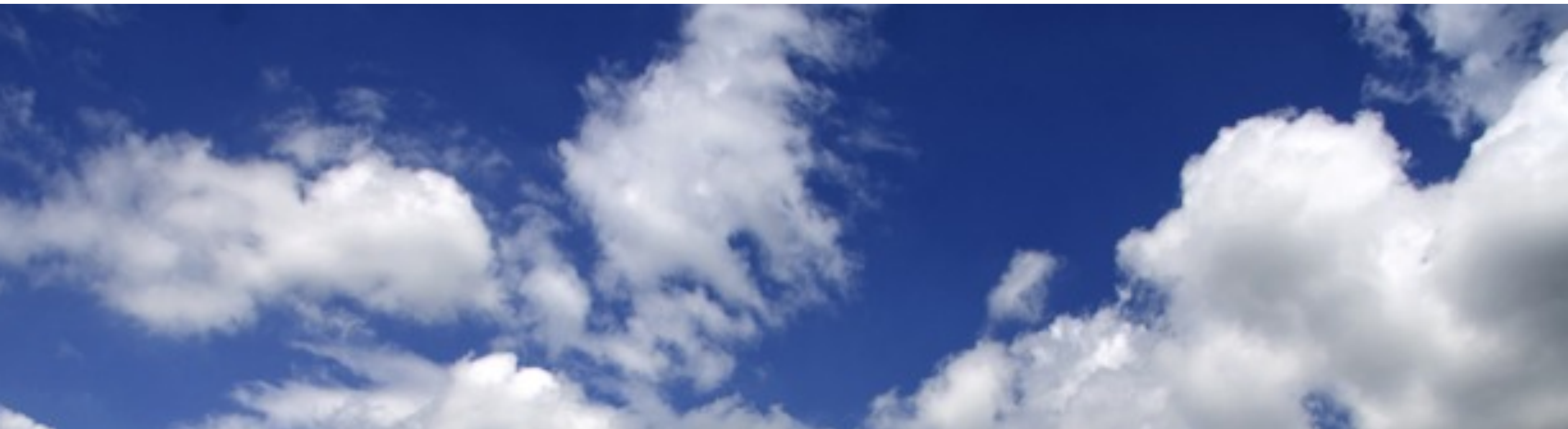

DULY NOTED

Nuclear Energy Program

U.S. Leadership Essential for International Nuclear Energy Programs

EVERETT REDMOND II *

Global growth in the civilian nuclear energy sector represents an annual trade market estimated at $500 billion to $740 billion over the next 10 years. As new nations consider nuclear energy technology to produce low-carbon electricity, the United States should take a leadership role that will enhance the safety and nuclear nonproliferation regimes globally, while creating tens of thousands of new American jobs.

The United States is the world leader in safe and efficient operation of nuclear power plants, with an average capacity factor of 90 percent or higher in each of the past 10 years. When ranked by 36-month unit capability factor, the United States has the top three best performing nuclear reactors in the world, seven of the top 10, and 16 of the top 20. Nuclear energy facilities produce electricity in 31 states and have attained a four-fold improvement in safety during the past 20 years. This underpinning in safety and reliability is one reason why America generates more electricity from nuclear energy than the next two largest nuclear programs combined.

Bilateral agreements on nuclear energy cooperation are vital to advancing global nonproliferation and safety goals as well as America's interests in global nuclear energy trade. A 123 agreement, named after section 123 of the Atomic Energy Act, establishes an accord for cooperation as a prerequisite for nuclear energy trade between the United States and other nations. The agreement contains valuable nonproliferation controls and commitments.

One of the most significant elements of U.S. agreements is approval granted by our government as to how other countries process uranium fuel after it is used in a commercial reactor. Under U.S. agreements, these nations cannot reprocess the fuel—chemically separating the uranium and plutonium—without U.S. notification and consent to do so. This is a significant safeguard against the potential misuse of low-enriched uranium from the commercial sector.

Several public policy considerations must be weighed in evaluating the impact of 123 agreements, including those related to national security, economic development, energy production, and environmental protection.

In the competitive global marketplace for commercial nuclear technology, inconsistent bilateral agreements will have unintended consequences for U.S. suppliers. Imposing overly restrictive commercial restrictions or conditions in U.S. 123 agreements that are not matched by other nations' bilateral agreements may significantly bias the country against selecting U.S.-based suppliers, even if the agreements don't have malicious intentions.

The imposition of requirements that seem unnecessary and unfair can affect commercial decision-making by the affected country. Such conditions put U.S. commercial contracts and jobs at risk. Moreover, if the country does not use U.S.-based technology, fuels or services, the value of conditions in the 123 agreement (i.e., consent rights) would be lost.

Some U.S. leaders are proposing a prohibition on uranium enrichment and reprocessing as part of all bilateral nuclear energy agreements for cooperation. Ensuring enrichment technology and reprocessing technology are used only for peaceful purposes is a paramount goal for government and industry. But U.S. 123 agreements are neither the best, nor

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Fukushima and Iran: The Case for Tightening the Nuclear Rules

HENRY D. SOKOLSKI *

Fukushima and Iran's use of civilian nuclear energy to get the bomb ought to serve as fair warnings to tighten conditions on future nuclear exports. Surely, if we fail to do so when Europe, Japan, and America have slowed new nuclear construction in reaction to Japan's nuclear meltdowns, we risk encouraging the world's hungry nuclear suppliers making up the difference with more dangerous exports to unstable regions, like the Middle East. This would not only risk nuclear competitions in the world's most war torn regions overseas, but jeopardize public support in the world's advanced economies for nuclear power's further development.

Unfortunately, under existing nuclear rules, expanding nuclear power globally also risks spreading nuclear fuel making activities. This, in turn, risks creating more Irans – i.e., more states that can get to the very brink of acquiring nuclear bombs by enriching uranium or separating plutonium from spent reactor fuel. The further expansion of these nuclear fuel making activities in India, Pakistan, and China, also risks increasing these emerging nuclear weapons states' capacity to make significantly more nuclear bombs any time they wish.

The current nuclear control wisdom is that all states have a "right" to engage in such activities so long as they claim that they are for "peaceful" purposes. Unfortunately, there is no reliable method of using nuclear inspections to assure that such fuel making won't be quickly diverted to make bombs. That's why the United States and other states through the United Nations have called on Iran to suspend its nuclear fuel making activities.

It's also why Presidents Bush and Obama, worked so hard to establish a new, tougher set of nuclear nonproliferation conditions with the United Arab Emirates (UAE) in the nuclear cooperative agreement the United States reached with the UAE in 2009. Under this deal, the UAE could not receive any controlled nuclear goods until it forswore making nuclear fuel and ratified the Additional Protocol -- a set of tough, international nuclear inspection rules. President Obama sold this agreement arguing that it established a new non-proliferation "Gold Standard" for civilian nuclear cooperation agreements.

Now, that standard is up for grabs as the U.S. State Department is negotiating nuclear cooperative deals with Jordan, Saudi Arabia, and Vietnam. Congress would like these agreements to meet the Gold Standard. If they fail to do so, the House Committee on Foreign Affairs (HCFA) has proposed legislation that would require such agreements be approved by a majority vote in both houses.

This means that after these nuclear agreements are negotiated, it cannot be assumed, as is currently the case, that they would be approved automatically. Proponents of this legislation note that Saudi Arabia has warned that it must get nuclear weapons if Iran does so and that Jordan and Vietnam refuse to forswear making nuclear fuel and are far from being stable democracies. They insist that if these agreements fail to meet the Gold Standard, it makes sense to scrutinize them closely and put them to a vote.

The HCFA has also called for Congressional approval of new overseas efforts to separate or reprocess nuclear weapons useable plutonium from spent fuel generated from U.S.-origin fuel or U.S.-exported reactors. This would mean that reprocessing such fuel in India or China –

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U.S. Leadership Essential for International Nuclear Energy Programs

EVERETT REDMOND II *

Multilateral agreements are more appropriate mechanisms for policy regarding the global challenge of nuclear proliferation. Promising mechanisms include the decision by the International Atomic Energy Agency to establish a uranium fuel bank, potential nuclear fuel lease/takeback contracts, and other multilateral, institutional nonproliferation arrangements. In addition, the Nuclear Suppliers Group (an international body of 46 nuclear technology supplier nations that sets standards for commercial nuclear trade) recently adopted new clear and strict criteria for the transfer of nuclear energy technology. These institutional controls do not require the receiving country to cede sovereign rights, which the U.S. government and other countries with civilian nuclear energy programs would never give up.

Fast-growing electricity needs in developing countries and concern about air quality and climate change are stimulating significant global demand for nuclear energy. Sixty-six plants are being built worldwide and another 154 are in the licensing and advanced planning stage.

U.S. suppliers are vying for business around the world – including China, Poland and India. Continued U.S. leadership in global nuclear safety and nonproliferation matters go hand-in-hand with a strong presence in the global marketplace. Both are critical to our national and global security. We must continue to participate in worldwide trade and nonproliferation policy discussions, or cede leadership in these areas to other governments and industrial competitors. Unless we choose engagement, America will lose tens of thousands of jobs and other benefits such trade has for our economy while forfeiting the nonproliferation benefits that 123 agreements are intended to achieve. ■

Fukushima and Iran: The Case for Tightening the Nuclear Rules

HENRY D. SOKOLSKI *

two states that might later seize the material to ramp up the size of the nuclear weapons arsenals significantly -- would have to be put to a vote in both the House and Senate.

Industry and the State Department oppose these proposals, arguing that the current automatic approval of nuclear cooperation agreements works fine. Under the current rules, Congress can only block or amend a nuclear cooperative agreement if it passes a law to do so with an improbable two-thirds majority.

Also, if the United States insists on new nonproliferation conditions before other nuclear suppliers do, the State Department insists it will disadvantage U.S. nuclear exporters and eliminate the "control" U.S. exports would otherwise exercise. This argument, though, seems strained. After Fukushima, it's unlikely that the United States will be making many nuclear reactor sales – let alone enough to control the trade unilaterally. The U.S.-designed reactors that melted down at Fukushima, in fact, were sold on the condition that U.S. nuclear reactor vendors be exempted of any responsibility for damages in the case of an accident. Now, few, if any, new foreign nuclear customers would be foolish enough to agree to such an exemption.

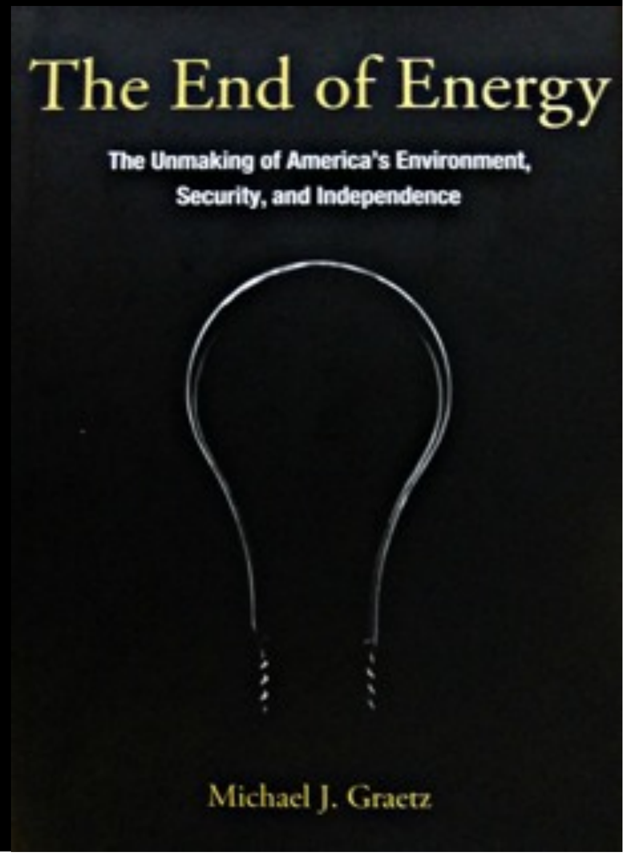
Nonetheless, the United States does have leverage over French and Russian nuclear exporters. Both want to expand their business in the United States. Japan, Korea, and Germany, meanwhile, are inclined to follow the United States on nonproliferation efforts.

Supporters of tightening the nuclear rules point to this leverage and insist the United States should use it to lead. They also point to history.

After India tested a bomb in 1974 using material it diverted from a "peaceful" U.S.-Canadian-exported cooperative power program, the nuclear industry and State Department warned Congress against imposing more nonproliferation conditions on nuclear exports lest it undermine U.S. nonproliferation leverage. Congress ignored these arguments, passed the Nuclear Nonproliferation Act of 1978, and the Nuclear Suppliers Group subsequently adopted all of this law's U.S. export conditions and imposed them internationally.

This history constitutes tough medicine against inaction today. Indeed, it more than suggests why presuming that we can do no better than we have already done to condition nuclear exports is a mistake. ■

BOOK REVIEW



In *The End of Energy,* Michael J. Graetz takes readers on a journey from the fossilized remains of prehistoric zooplankton and algae to the massive oil deposits of the Ghawar Field in Saudi Arabia. Professor Graetz, employing lively prose, explains the trek of the oil throughout America with intellectual stops along the way to discuss various laws and acts that affect the flow and prices of this valuable commodity to all American consumers.

By CHARLES D. FERGUSON

America has been very fortunate when it comes to possessing many resources especially relatively abundant supplies of fossil fuels. These fuels have helped tremendously in driving the United States to become the world's largest national economy. While Americans comprise about five percent of the global population, they consume about 25 percent of the world's energy. Much of this massive consumption is due to the inefficient use of energy as compared to other leading industrialized nations. Americans have a long way to go to catch up to Europe and Japan's efficiency awareness and practices.

But the United States is a sprawling land with more than 300 million people, many of them in suburbs and rural areas spending increasingly large amounts of time in their cars, minivans, and SUVs, which are often getting less than 25 miles per gallon. Although China recently surpassed the United States as the world's largest emitter of carbon dioxide, a significant greenhouse gas, Americans on a per capita basis emit four to five times the amount of CO_2 as the Chinese. But because Americans have had such a cornucopia of cheap fossil fuels, they went for decades without feeling substantial concern or economic pain. That all changed in the early 1970s starting with President Richard Nixon's price controls, which were soon followed by the 1973 Arab Oil Embargo.

While readers when they first pick up *The End of Energy* might expect Michael Graetz to begin with the Arab Oil Embargo, he instead takes them on a journey starting with "the fossilized remains of prehistoric zooplankton and algae," which were transformed through heating over millennia to form the massive oil deposits residing in "the Ghawar Field in Saudi Arabia." He then leads the reader across the Arabian peninsula to a pipeline along the Persian Gulf to the terminal at Ras Tanura, "which processes 10 percent of the global output of crude." From there, the oil makes its way via tanker to multiple spots along the globe. For the American reader, Professor Graetz, employing lively prose, explains the meandrous trek of the oil throughout America with intellectual stops along the way to discuss various laws and acts that affect the flow and prices of this valuable commodity to all American consumers.

The start in Saudi Arabia might have signaled to readers that the author will next turn to the Arab Oil Embargo, but here again Professor Graetz spends profitable pages plumbing the largely adverse consequences of Nixon's controls on energy prices. The struggle to decontrol the price of oil and natural gas lasted well into the 1980s. The author assesses that "Nixon was far from the only U.S. politician to elevate short-term political expediency over sound economic and energy policies." In an enlightening exposition, Graetz explains how every president since Nixon has called for a national energy policy, but every one dishearteningly failed in their endeavors. In particular, every president warned about increasing addiction to oil and wanted the United States to reduce its dependence on imported oil. But this dependence has grown such that today about two-thirds of U.S. petroleum is imported. (However, the leading supplier is Canada, not Saudi Arabia, as some may think. The oil from Canada has huge environmental consequences because it derives largely from tar sands.) But because oil is a fungible commodity, increased demand in one country will have substantial ripple effects and at times even tsunami-like effects on global markets. Hundreds of billions of dollars have left America's shores to pay for foreign oil.

Graetz dispels the notion that the United States can or should become energy independent despite the repeated rhetoric from many politicians on both the Right and Left for doing so. While this message may play well with voters who can monitor the ups and downs (most recently, mostly ups) of gasoline prices, the United States still pays far less for gasoline than most consumers around the globe. One reason is due to politicians' allergic reaction to levying more taxes. The federal tax on gasoline has barely budged in decades. Like all the chapters in the book, the chapters on regulation, carbon taxes, and cap-and-trade are masterful in their clarity and sobering in their analyses that fees on greenhouse gas emissions confront numerous economic and political hurdles.

It is too easy and simply wrong to cast blame on one political party or one president for America's failed attempts at forming an effective energy policy. Even politicians that want to shift the United States to a low carbon economy are conflicted. If they perceive the tradeoff as raising costs on consumers, that is, voters, they are extremely reluctant to take that action. Politicians are not voted out for lowering fuel costs. They can also feel pressure from special constituencies. For example, congressmen from coal states want to keep coal mining jobs and those politicians from corn producing states have tended to be strong supports of corn-based ethanol despite its little efficacy in reducing dependence on foreign oil.

These are political risks. And as Professor Graetz underscores "the barriers to sensible policy are largely political—and they are potent." He has no easy answers for how America can stop muddling through on dealing with energy and the environment because this is an exemplar for a wicked problem, one that is difficult to solve because of the interlinked dynamics of entrenched energy technologies, social and political pressures, and economic interdependencies. For an excellent guide to how America has gotten into this predicament and how Americans and their leaders can begin to find a way out, I recommend reading this insightful book. ■

The End of Energy - The Unmaking of America's Environment, Security, and Independence (MIT Press, 2011).

Charles D. Ferguson, Ph.D., is the president of the Federation of American Scientists. He is a physicist, nuclear engineer, and author of NUCLEAR ENERGY: What Everyone Needs to Know*, available from Oxford University Press.*

Michael J. Graetz is the author of THE END OF ENERGY: The Unmaking of America's Environment, Security, and Independence*, available from MIT Press. He is the Justus S. Hotchkiss Professor Emeritus of Law and Professorial Lecturer in Law at Yale Law School. His specialties include taxation, tax policy, health law and policy, and income security law and policy.*

FAS MATTERS

FAS NEWS FROM DC HEADQUARTERS

MISSILE DEFENSE SYSTEM

On June 8, 2011, Dr. Yousaf Butt, FAS scientific consultant, and Dr. Theodore Postol, a professor in the Program in Science, Technology, and Society at the Massachusetts Institute of Technology, briefed congressional staffers on the Phased Adaptive Approach (PAA) missile defense system proposed by NATO and the United States. These experts analyzed whether the Russian Federation had a legitimate concern over the proposed NATO-U.S. missile defense shield. In September 2011, FAS published the analysis as part of a new series of publications called the FAS Special Report. To read the missile defense report, please visit: www.FAS.org/pubs/index.html.

TERRORISM ANALYSIS REPORT No 1: THE PAKISTANI NEO-TALIBAN

FAS published the first volume of a new report series called the Terrorism Analysis Report. Charles Blair, director of the FAS Terrorism Analysis Project, wrote about the Pakistani neo-Taliban and potential threats to Pakistan's nuclear infrastructure. The report was released at a Capitol Hill event on June 29, 2011. Hans Kristensen, director of the Nuclear Information Project, joined Mr. Blair and discussed developments in Pakistan's production of fissile materials and nuclear weapons. To read the Terrorism Analysis Report No. 1 please visit: www.FAS.org/pubs/tar.html. To read the Nuclear Notebook, which reviews Pakistan's nuclear weapons arsenal, please visit: www.FAS.org/blog/ssp/2011/07/pakistannotebook.php.

TAKING BIOSECURITY NETWORKS TO THE NEXT LEVEL

On September 1, 2011, FAS's Virtual Biosecurity Center hosted a daylong conference at the Mayflower Hotel in Washington, DC. Twelve experts participated in the program. To watch the various tracks and talks, please visit: http://www.fci.tv/webcast/vbc/09-01-11/.

FAS SPECIAL REPORT No 2: ENHANCED SAFEGUARDS FOR IRAN'S NUCLEAR PROGRAM

On October 6, 2011, Ali Vaez, FAS Fellow for Science and Technology and Director of the FAS Iran Project, and FAS President Charles D. Ferguson co-authored an FAS Special Report on Iran's controversial nuclear program, "Towards Enhanced Safeguards for Iran's Nuclear Program." Persuading Iran to accept more intrusive inspections is not an easy task. This new report analyzed options for establishing an enhanced safeguards system for the Iranian nuclear program and outlined incentives that could create a win-win diplomatic outcome. The report offers a set of recommendations for all the key players to reach a negotiated resolution of the nuclear issue. To read the FAS Special Report No 2, please visit: www.FAS.org/pubs/_docs/specialreport2_iran_nuclear_program.pdf.

IN MEMORIAM:
JONATHAN B. TUCKER 1954-2011

On July 31, 2011, Jonathan B. Tucker, an arms control expert who specialized in chemical and biological weapons , died in Washington, DC. He was 56.

For the past four months, Jonathan managed the FAS Biosecurity Education Project. His colleagues remember him as a gentleman, an extraordinary scholar, and a humble soul.

Like his father Leonard Tucker, Jonathan served his country with distinction. In February 1995, he was a biological weapons inspector in Iraq with the United Nations Special Commission. As a staff member of the Presidential Advisory Committee on Gulf War Syndrome, he spoke out courageously at a time when public candor was officially discouraged.

Jonathan was born into a family of engineers. Leonard Tucker and his brother Al headed Tucker Concrete Form Company in Malden, Massachusetts. Jonathan visited the company offices as a child, and often traveled with his father. In 1967, at the age of 13, he accompanied his father to India, which sparked Jonathan's life-long interest in international affairs.

Jonathan studied at Phillips Academy in Andover, Massachusetts. Then he followed in his father's footsteps by attending Yale University and graduated *cum laude* with a BS in biology.

Jonathan was an editor at *High Technology* and *Scientific American* where he covered military technologies, biotechnology, and biomedical research. He combined the highest standards of science with the best traditions of journalism.

After several years in science journalism and, seeking new challenges, Jonathan decided to go back to school for a Ph.D. in political science (with a concentration in defense and arms control studies) from the Massachusetts Institute of Technology. He also was a visiting fellow at the Hoover Institution at Stanford University, the U.S. Institute of Peace, and the American Academy in Berlin, and a Fulbright Senior Scholar at the German Institute for International and Security Affairs.

After finishing his studies, Jonathan worked for the U.S. government as a AAAS Fellow at the United States Department of State, an arms control specialist and international-security analyst at the congressional Office of Technology Assessment, and a specialist in chemical and biological arms control at the Arms Control and Disarmament Agency (ACDA). From 1993 to 1995, while at ACDA, Jonathan served on the U.S. delegation to the Preparatory Commission for the Chemical Weapons Convention in The Hague.

In March 1996, Jonathan joined the James Martin Center for Nonproliferation Studies (CNS) of the Monterey Institute of International Studies in Monterey, CA. He worked there for nearly 15 years, first as the founding director of the Chemical and Biological Weapons Nonproliferation Program and then, in 2000, as a Senior Fellow in the CNS Washington office where he specialized in biological and chemical weapons issues.

From May to December 2008, he was a professional staff member for the bipartisan Commission on the Prevention of WMD Proliferation and Terrorism.

A prolific writer, Jonathan authored and edited four books that showed tremendously powerful scholarship and beautifully crafted prose, most recently *War of Nerves: Chemical Warfare from World War I to Al Qaeda* (Pantheon, 2006). Other titles included *Scourge: The Once and Future Threat of Smallpox* (Grove/Atlantic, 2001); and, as editor, *Toxic Terror: Assessing the Terrorist Use of Chemical and Biological Weapons* (MIT Press, 2000).

The Washington Post named Jonathan's book *Scourge* one of the best books of the year. And in a *New York Times* review of *War of Nerves,* a history of chemical warfare and efforts to abolish it, Jonathan was described as a gifted writer who "makes military science readable and wants a world secure from such repellent weapons."

At the time of his death, Jonathan was waiting on a security clearance to serve in the Department of Homeland Security. Family, friends, and colleagues will dearly miss him. He is survived by his mother Deborah and sister Anne. ■

FALL ISSUE OF PIR

- Role of Science and Technology in Keeping U.S. Safe
- Future of Biosafety and Biosecurity Policy
- Handling, Managing, and Storing Biological Agents
- How to Safely Destroy Chemical Weapons
- How Terrorists Develop Chemical and Biological Weapons
- Intersection of Nuclear Safety and Security

The PIR welcomes letters to the editor. Letters should not exceed 300 words and may be edited for length and clarity. The deadline for the fall issue is November 14, 2011. To submit a letter, please email pir@fas.org or fax 202-675-1010.

The Honorable Steven Chu, Secretary of the Department of Energy

On Wednesday, February 8, 2012, the Federation of American Scientists will host the FAS Awards Ceremony at the Carnegie Institute of Washington. FAS will present the 2011 Hans Bethe Award to the Honorable Steven Chu, Secretary of the U.S. Department of Energy.

FAS is honoring Dr. Chu for his work in search of new and alternative renewable energies, which goes to the heart of FAS's commitment to improving energy security worldwide. After all, energy security *is* national security.

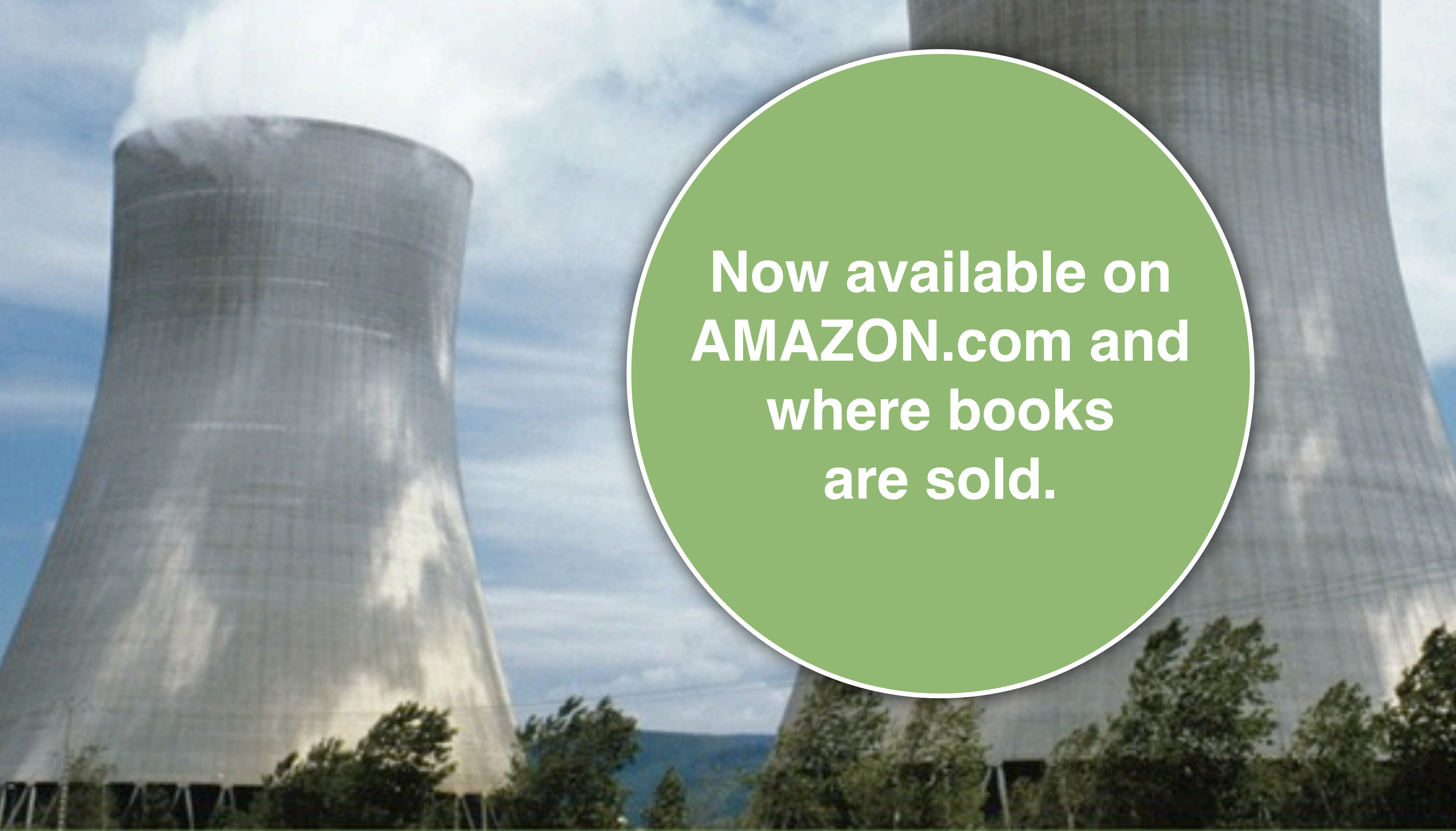
Learn about sponsor opportunities.
Contact Monica Amarelo at TEL 202-454-4680 or mamarelo@fas.org. Please visit www.FAS.org/about/2011awards.html for more information about the 2011 FAS Awards Ceremony.

FAS Awards Ceremony

The Carnegie Institute of Washington in D.C.

Wednesday, February 8, 2012

6:30 - 9:00 pm



NUCLEAR ENERGY

WHAT EVERYONE NEEDS TO KNOW

CHARLES D. FERGUSON