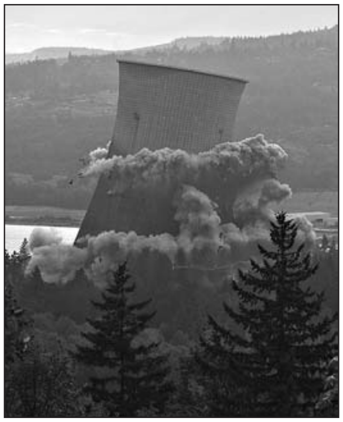
NUCLEAR ROULETTE

THE CASE AGAINST A "NUCLEAR RENAISSANCE"



BY GAR SMITH

Editor ERNEST CALLENBACH
Foreword AILEEN MIOKO-SMITH

This publication is No.5 in the International Forum on Globalization series focussed on False Solutions to the global climate crisis.

JUNE 2011

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FALSE SOLUTIONS PUBLICATION SERIES

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NUCLEAR ROULETTE

THE CASE AGAINST A "NUCLEAR RENAISSANCE"

CHERNOBYL—UKRAINE, APRIL 1986.

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COVER PHOTO:
Trojan Nuclear Power Plant demolition.
Portland General Electric Company

PORTLAND GENERAL ELECTRIC CO.

The 1,130-MW Trojan plant in Oregon was plagued with construction problems. It was forced to shut down in 1992 after a cracked steam tube released radioactive gases into the atmosphere. It was shut down after only 16 years of its expected 36-year life. Once the largest reactor in the U.S., the $450-million plant became the first U.S. commercial reactor to be decommissioned. The 1,000-ton reactor vessel was shipped by barge to the Hanford Nuclear Site in Washington and buried in a 45-foot-deep pit.The 500-foot-tall cooling tower was brought down by dynamite in 2006. All 800 spent fuel rods are still stored in a pool on the reactor site since there is no place to send them. Removing the plant cost nearly as much as building it. Portland General Electric customers are still paying for the costs of decommissioning. The site has now been turned into a 75-acre lakeside park.

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PROLOGUE

FALSE SOLUTIONS

BY JERRY MANDER & ERNEST CALLENBACH

This publication focuses on the appalling attempt to revive and celebrate nuclear power as a grand "green" climate-friendly energy system that can successfully replace fossil fuels and continue to sustain our industrial society at its present level. Author Gar Smith systematically refutes all the nuclear industry arguments, including one of their most critical assumptions—*that the deadly radiation from nuclear wastes can be successfully sequestered for the 250,000 years they will remain dangerous to all life*, an assertion bordering on insane.

Nuclear technology was originally devised as a tool to fabricate weapons of mass destruction. Its goal was to deliver an unprecedented level of death and devastation (with accompanying pollution to air, water, and biological systems) well beyond anything that had ever before been achieved. At Hiroshima and Nagasaki, atomic power proved it could excel at destroying buildings and lives. But after the end of WWII, nuclear's corporate advocates tried to re-brand it as a benign, efficient, sustainable source of energy that would be "too cheap to meter." Today, the atom's corporate boosters have been touting nuclear reactors as the best solution to the world's energy and climate crisis.

In the pages that follow, Gar Smith demolishes these claims. If the nuclear dragon can be slain with the weapons of logic and information, this document should prove fatal. Nuclear's inherent problems include its extravagant and noncompetitive costs, the absurdly long time-spans required to deploy it, and its little-noted but very important *net energy* deficiencies. On this latter point, all *full-life-cycle* studies—measuring total energy expended on mining, processing and shipping uranium, to plant construction, operation, and ultimate decommissioning—conclude that nuclear energy requires about as much energy *input* as the *outputs* it may ultimately provide. There are no bargains here. Sustainable alternatives, including wind, solar, hydro and geothermal, have far better net-energy ratios.

But that's the least of it. The over-riding problem with nuclear energy, which dwarfs all others, is that nuclear production demands that society deal with all the spectacularly dangerous emanations and waste products intrinsic to its production. The risks of this lie far beyond the horizon of our imaginations. Nuclear accidents can make large regions uninhabitable. They can bankrupt nations. Even a nuclear reactor's routine, day-by-day leaks pose generational hazards that should make us shudder. To run the industry safely would mean isolating its waste products for at least tens of thousands of years—not to mention controlling the risks of weapons proliferation. Are we somehow exempt from history? Few civilizations last more than a couple of hundred years. The Romans lasted about 700 years, and did very well for awhile. But they made some mistaken assumptions about their own permanence that are very similar to those we are making now. The situation would be comical if it weren't so deadly. What hubris. What madness!

How exactly will the nuclear industry's vast tonnage of radioactive waste be safely isolated from future generations? What will shield our grandchildren—and theirs? This report goes to great lengths to demonstrate that no successful containment system has yet been invented to package this stuff successfully beyond a very short period. Everywhere, efforts to store these wastes underground have been resisted vigorously by local communities—and with every good reason.

The problem of long-term storage lasting eons begins to suggest that we contemplate some kind of permanent *signage* we might deploy around these danger zones. But what language should we use? Will English still be spoken after a quarter million years, in say, the year 252011 AD? And even then, the radioactive danger will just have notched down a bit. Our legacy of poisoned earth will be, effectively, eternal.

The only thing more bizarre than the demand that we accept these circumstances is that the governments of numerous highly developed well-educated countries, including our own, have agreed to let this technology operate. They expect the public to agree to these grim prospects. They tell us we must let this technology proliferate; we must blind ourselves to its risks; we must continue to contribute our tax dollars to subsidize the unknowable costs of maintaining the industry and cleaning up the devastation it leaves behind. But it's not only governments, desperate for energy, that accept these conditions. Much of the public, as well, remains entranced by the energy industry's reassuring public relations and advertising mantras. We need to shake off this state of denial. The situation is so grave that we should more properly be camped out night and day in front of legislative and regulatory bodies demanding the permanent end to any and every expression of this continued nuclear menace, be it civilian or military.

Snake Eyes

At Japan's Fukushima Daiichi nuclear power complex—a facility knowingly constructed in a seismically active site—the reactors' spent fuel rods (which are more radioactive than the working core itself) were stored *aboveground* in *open pools* of water. If that arrangement sounds somehow primitive, more like a roll of the dice than a serious design solution, please remember that most of Japan's nuclear power plants were designed by General Electric, which also built nearly two dozen similar Mark-1 reactors in the United States. Many of these U.S. reactors have the same aboveground storage systems that were devastated by the earthquake and tsunami that swept Fukushima. So, instead of remaining safely contained for 250,000-plus years, the containment lasted 30 years, and radioactive isotopes now spill wildly into the air and the ocean. As this report went to press, three of Fukushima's five reactors were experiencing meltdowns and a huge region of north-central Japan had been left uninhabitable (although it has not yet been so declared). Some argue that thousands of square miles should be declared uninhabitable. Meanwhile, radioactivity continues to waft unabated into the jet stream. The future risks from these radioactive emissions remain incalculable.

How do such things happen? It's not as if the Japanese government and corporations were not warned. As Japanese anti-nuclear activist Aileen Mioko-Smith writes so movingly in the Foreword that follows, a very active citizens movement comprising tens of thousands of people in Japan has been demanding the shutdown of this industry for nearly three decades, and if not that, at least many more protections. That movement predicted exactly what happened at Fukushima, but it was criminally ignored by both government and the media. Only after the fact have government and industry officials agreed to shut down, *temporarily*, a couple of trouble-plagued GE Mark-1 reactors near Tokyo. Unfortunately, when it comes to nuclear power, "shut down" doesn't actually shut things down since reactor cores remain live and dangerous even when not operating. But Japan *has* done more than the United States to address the terrifying dangers of nuclear power.

How could President Obama, so soon after the Fukushima meltdowns, propose that the U.S. should now *increase* its already immense subsidies for nuclear power? How could we accept this gamble? How did things get so bad? One commentator simply called it "Wishful thinking." We just "kinda really hope" we can work it out. But in fact, the government's primary commitment is *not* to sustain life on earth. Rather, its primary commitment is to sustain an energy-desperate economic system that is based on the insane notion that economic growth can continue *forever*, though we live on a finite planet. The depletion of our resources base—energy, fresh water, forests, arable soils, key minerals—is already well advanced. Faced by escalating examples of climate change—tornados, floods, droughts and melting glaciers —the preposterousness of our fundamental assumptions could not be more obvious.

It was all just a really bad gamble. We have been rolling the dice since the industrial revolution—or maybe since the Enlightenment, when we decided our technologic superiority would get us anything we want and would solve all problems. *A world with no limits*. We could take over for Nature, and stand in for God. But then the dice rolled snake eyes.

Atoms For Peace?

The writing of this report was well underway months before the quake and tsunami added the name "Fukushima" to the growing list of nuclear disasters. Gar Smith has added an Introduction on the implications of Fukushima for the United States. He goes on to cover crucial perspectives on nuclear energy that we don't hear much about. In addition to costs, inefficiencies, delays and dangers, Gar also reviews the little-publicized injuries caused to generations of Indigenous peoples (especially in the U.S. and Australia) who have mined uranium and raised families alongside the so-called "low level" radioactive wastes that poison their soil and their homes. And then there are the multifold impacts on water, air and land from the numerous accidents that preceded Fukushima—including Chernobyl, Three Mile Island and hundreds of other "near-misses" that have received tragically little notice. Our report includes a chart [*See Box IV*] that lists dozens of these little-known events.

This report also discusses what may be the least talked about problem: the industry's contribution to *weapons proliferation*. The military-industrial complex is also a political-corporate alliance. A courtship that began in the earliest days of the Atomic Age quickly blossomed into a marriage of military and civilian atomic enterprises. Westinghouse and General Electric have been called the "Coke and Pepsi" of nuclear power. Westinghouse, the world's leading manufacturer of nuclear reactors, is also a major Pentagon weapons contractor. Similarly, GE derives its wealth from the sales of both civilian reactors and military weapons.

When WWII ended, the U.S. faced two post-war dilemmas: How to maintain the Pentagon's huge infrastructure of nuclear scientists, uranium enrichment facilities and research labs and how to profit from America's massively expanded wartime uranium production. There was considerable fear that, without a war to sustain jobs, the country would soon slide back into a Great Depression—so finding ways to pursue "peaceful uses for nuclear energy" seemed like a good idea. The transition to a "civilian nuclear program" was accelerated by President Eisenhower's "Atoms for Peace" campaign, which was little more than what we now call a "corporate stimulus" program. The program promoted "peaceful uses of the atom" by introducing nuclear reactors to other countries. The first two that received nuclear reactors were Iran and Pakistan.

Then there was also Washington's "Project Plowshare" which actually proposed a series of nuclear explosions to replace the Panama Canal with a "sea-level canal" across Central America. And "Project Chariot," which would have used an A-bomb to create a harbor near Cape Thompson, Alaska. Other plans for "nuclear landscaping" involved using "peaceful" A-bombs to blast tunnels and create reservoirs for dams. These make-work projects kept the Pentagon's nuclear scientists and atomic labs occupied during peacetime while the "civilian" energy program gave GE, Westinghouse and other corporations something to do while waiting for the next war, which came soon enough.

Better Options?

Gar Smith doesn't rest with a negative critique. In Chapter 10, "Better Options Exist," he offers an optimistic perspective on ways to "power down" an overheated industrial economy to a sustainable level —by rapidly deploying an array of alternative energy ideas that are gaining attention. Alternate sources of energy are now outracing not only nuclear pipedreams but also the outdated technologies of coal and oil.

No sane utility executive would any longer contemplate building a single nuclear plant without huge government subsidies. Still, with about 450 aging nuclear power plants in the world right now, more than one hundred in the U.S., and plans for at least 60 new plants in the works—and with the unsolved problems of nuclear waste storage and radiation—how much hope is really appropriate?

The Japanese government, in the sad wake of Fukushima, is now, at least discussing turning away from its former gung-ho nuclear ambitions and turning toward renewables. The Chinese also are re-examining their nuclear plans and pushing harder to accelerate their wind and solar projects. It seems we are at a tipping point where the powerful and wealthy are being forced to realize that nuclear is not viable as any kind of solution, anywhere. We simply cannot afford more Three Mile Islands, Chernobyls and Fukushimas.

But does this mean that the corporate world is at last finally ready to back off from its commitment to endless growth, an absurd drive that no combination of renewables can possibly sustain? We will see if governments can finally get real about the central challenge of this century: learning to live in new ways that we have the power to maintain. Thousands of groups worldwide are already working hard on "economic transitions" that involve realistic assessments of our global dilemma, the possibilities for increased efficiencies, alternative technologies, and opportunities to replace the emphasis on globalization with a reinforcement of *local* sustainable systems in all crucial areas, from food production to energy to transport and banking. But first we need to let go of our fantasies of limitless production and consumption.

It will be an auspicious beginning to our new century if we can revitalize a global movement to stop all nuclear production and close down every nuclear facility—military and civilian. Remarkably, as we go to press, Germany has announced it will do exactly that, closing down all nuclear production over the next decade, substituting renewables. It doesn't solve the problem of radioactive wastes, but it's a good start. Will others follow? Then we can move on toward a greater goal: evolving a sustainable, energy-sane, peaceful society.

FOREWORD

FUKUSHIMA: NOTES OF A JAPANESE ANTI-NUCLEAR ACTIVIST

BY AILEEN MIOKO-SMITH

Aileen Mioko Smith directs Green Action, Kyoto, Japan's leading anti-nuclear organization. She was visiting San Francisco when Fukushima exploded. We asked her to send us a brief review of the 30-year history of the movement to block nuclear power development in that earthquake-prone country, only to be thwarted by government and by corporate media. These are the notes she wrote in the airplane on her way home.

We are asked, "Is there an anti-nuclear movement in your country? It appears weak or nonexistent." Let me say, there have been tens of thousands of us working on this since the 1970s, warning about the seismic issues, warning about fuel rods and dozens of other things, trying to stop nuclear power in every form. We tried our best. We couldn't have tried harder. When I heard the news about the earthquake and tsunami, the entire panorama of the last three decades' struggles passed before my eyes. We were always met by government stonewalling, utility company lying, and media smugness and blindness. The result was predictable. We predicted it. We hoped it would never happen but it did. We believed the first disaster would be at the Hamaoka nuclear power plant near Tokyo, but it was Fukushima instead. It should never have happened.

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Back in 1988, citizens groups began a nationwide effort to phase out nuclear power. Within a short while, we had gathered 3.6 *million* signatures seeking a law to completely dismantle nuclear power in Japan because of the immensity of the dangers it posed. It was a very impressive performance. We submitted the signatures to the Diet, Japan's parliament. But, as if they were cardboard boxes of meaningless shredded paper for recycling, these signatures didn't make it very far. The Diet's Trade and Industry Committee refused even to discuss them or meet with us.

Gathering petition signatures in a conservative country like Japan is not an easy thing to do. This is especially true in areas where nuclear power plants are located. The local economy usually depends on the nuclear plant, and there has been little effort toward alternatives. Wives are often heavily reprimanded by their husbands for signing such petitions. I recall one activist saying a very upset woman appeared at his house late at night begging to see the petition sheet she had signed earlier in the day. She erased her name so vehemently that she left a hole in the sheet by the time she was through.

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The Japanese government commitment to nuclear energy is immense and unyielding. In Japan, 88% of all public funds for electric supply go to nuclear. Not only do citizens pay as taxpayers, but as consumers as well. When the enormous public subsidies, plus surcharges on electric bills are included, nuclear costs more than all the major electricity supply sources. Yet the electric utilities, with the support of the government, have constantly told the public, with big national advertising campaigns, that nuclear is "cheap." They don't advertise that the so-called figures they present are not based on actual costs but on very false projections (plugging in, among other things, capacity factors, which are "goals" that have never been sustained.) Nor do they cover the costs of catastrophic events like Fukushima, which may be *hundreds of billions* of dollars. Citizens' groups don't begin to have enough money to run ads to counter all the misinformation.

A couple of months before the March 11th Fukushima earthquake, many of us submitted a complaint to the Japan Advertising Review Organization (JARO) about Japanese electric utilities' false advertising concerning various nuclear power issues, including their fake advertisements about the cost. But JARO wrote us back saying: "We aren't experts on nuclear power and therefore could not make any judgment." They dropped our complaint. False advertising continued to bombard the Japanese public. Weeks later, the earthquake hit. Even if JARO had ruled on the ads, their policy is: "You must not ever make public the ruling you receive."

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How democratic is Japan's deliberation of nuclear policy?

Flashback to 2000. Public hearings were held by the Committee on Japan's Long Term Plan for the Research, Development and Utilization of Nuclear Energy. We citizens and our organizations had labored hard for a year and a half to make that round of deliberation on nuclear power in Japan more inclusive and democratic, to gather massive numbers of public comments, and to clearly demonstrate the level of opposition. Seats were limited but citizens had "observer" status during the hearings. So we were in the audience when the Chairman of the Committee turned to his fellow Committee members and said, "We've received public comments from the people of this country. But the comments have come in too late. This is our next-to-last session. We've already deliberated the new policy for well over a year."

The man who spoke those lines, the Chair of these grand deliberations, was Sho Nasu, top advisor for the Tokyo Electric Power Company (TEPCO). He had been appointed by the Atomic Energy Commission (AEC) to head the committee. Nasu had been president of Tokyo Electric from June 1984 to June 1993. From June 1993 to May 1999 he was chairman of the board. Anyhow, the Committee had knowingly set the schedule for receiving public comment at the *end* of the deliberation process, so now Chairman Nasu was saying they were "too late." Nasu did publicly admit that, "over 90% of the people are against Monju." (Monju is Japan's prototype fast breeder reactor, the government's showcase nuclear development program.)

A brief discussion followed. The committee concluded that, "The Japanese public still doesn't seem to understand nuclear power correctly. We must step-up our efforts to educate the public." The committee decided that better programs were needed to "educate" children about nuclear power. School teachers would be obligated to use pro-nuclear materials to "teach" the children of this nation. So much for the democratic process.

The national newspaper *Asahi Shimbun* finally ran a small article reporting the results of the hearings. The headline read: *"Virtually No Comments from the Public Taken-In by the Committee."* That article was the total sum of our efforts. I remember the article well; it was so small that I cheated and blew it up larger so it would have some impact.

In 2002, citizens created a great, robust national network to push a new law that would promote renewable energy in Japan. Citizens succeeded in getting the support from more than 250 members of the national Diet for the bill. However, after a lot of negative lobbying by the nuclear utilities, the effort ultimately failed. Instead, the Diet took the opportunity to do nearly the exact opposite by passing the Basic Act on Energy Policy (June 2002) which greatly *strengthened* national support of nuclear power.

The "Framework for Nuclear Policy," the latest national deliberations for a long-term plan for Japan's nuclear program, began in December 2010. Three months later came the Fukushima Daiichi disaster. The Framework hearings have since been put on hold. That process was set up supposedly to be more open and fair, but the AEC's selection of committee members was, as usual, stacked with members with direct or indirect electric utility connections, or people who were pro-nuclear. The outcome is inevitable, though they certainly have a lot more to think about now.

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I think I need to say some things about the Japanese media. As Americans may not know, the Japanese media divides the subjects it covers via "press clubs"—associations of reporters who are assigned to a single package of issues. Stories are generated more by appealing to press clubs than to, say, newspaper editors. This is a major problem for groups wanting their stories to break out of previously determined silos.

The Japanese press club system has proven very effective at keeping nuclear news *out* of mainstream media. I often say, "If you want to make sure that you don't get any media coverage, go to the METI (Ministry of Economy, Trade and Industry) press club." The problem is, if you try to take the issue elsewhere, you are violating tradition and are effectively insulting the system. You are quickly told: "The METI press club addresses that issue. Take it there." We had done that; then we did it again, but nothing happens.

Citizens have been bringing these issues to the media since the 1970s, but they remain virtually invisible when it comes to national coverage. Utility company ads are nearly the sole expression of Japanese views on nuclear issues. Everything else is pretty much underground. There have only been a few brief moments when our opposition was reported in a major way in Japanese media. One such moment was in January 2003, when our movement won an appellate court decision to shut down the prototype fast breeder reactor at Monju. That was a glorious victory, but it was inexplicably reversed by the Supreme Court. We are still trying to find evidence of what happened.

Another media break came in March 2006 when, after an eighteen-year effort, citizens won a lawsuit that ruled a nuclear power plant operated by Hokuriku Electric should suspend operations because it was not safe. The reactor's earthquake design was found to be deficient. That was a rare front-page lead story in the national media. But that was a big exception to the usual rule.

In August 2010, Green Action was among 794 citizens groups from around the country that submitted a petition addressing major nuclear safety concerns to Japan's nuclear safety regulator, the Nuclear and

Industrial Safety Agency (NISA). Included in our concerns was a focus on the pressing issue of the safety of spent nuclear fuel pools. During the meeting, we also addressed the danger of earthquakes yet again.

Citizens had been pointing out that the Fukushima Daiichi nuclear power plant complex, built by Tokyo Electric, was operating on 1978 earthquake-resistant guidelines for nuclear power plants. In 2006, new guidelines had come into place, but the electric utilities were not yet required to meet them. At Fukushima Daiichi, only Unit 5 served as a model for implementing these newer guidelines.

But even the new guidelines are grossly deficient. We pointed out at the NISA meeting that spent fuel pools and other important parts of the plant are exempt from the new earthquake guidelines. *Utilities are not required to consider the issue of the aging of the nuclear power plants. Analyses are done assuming the plants are brand new*. On top of that, Tokyo Electric's analysis of the earthquake magnitude potential at the Daiichi site was unscientific and grossly underestimated—the study's main technique considered fault lines as short and separate threats when they are clearly parts of a much longer system. (If you only add up the quake potential of short fault lines, you get lower overall figures for potential earthquakes).

The petitions of the 794 citizens groups and other petitions submitted by citizens around the country covered all of the above arguments. In fact, there is a decades-long paper trail of citizens addressing these points. But the government rubber-stamped Tokyo Electric's submission and ignored all our points. So did the media. No national media reported anything on these issues until nine months later, when Fukushima exploded. Suddenly, spent fuel rods are news. This is so typical. Japanese media rarely report on issues unfavorable to utilities unless an accident occurs.

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There had been plenty of other warnings. Back in 2007, the Chuetsu-oki earthquake shook Niigata prefecture, causing Tokyo Electric's Kashiwazaki-Kariwa Nuclear Power Plant complex—the largest capacity nuclear power plant complex in the world—to temporarily shut down.

Immediately after the earthquake, we held a press conference at the Foreign Correspondents' Club of Japan. The media interest among the *foreign* correspondents was tremendous. One of our speakers was Kazuyuki Takemoto, a Niigata resident who has been involved in lawsuits and citizen actions since 1974. Another speaker was seismologist Katsuhiko Ishibashi of Kobe University. A member of the government-appointed committee to reassess seismic guidelines, Ishibashi had *resigned* in protest at the last session of the committee's proceedings. The two speakers were avidly sought after by the foreign media and they were widely quoted in foreign newspapers and magazines.

We had to quickly leave this event and move to a scheduled METI press club briefing being held by Tokyo Electric. When we arrived, members of the METI press club were already rushing around joined by about one hundred members of the Japanese media (all men except for two women reporters). Tokyo Electric Power Company staff offered some minute details, which the media took down diligently. The METI minister then held a press conference, followed by more TEPCO briefings on further minute details.

We were told we had to wait for our turn to testify. We waited two-and-a-half hours. During that whole time, just one member of the media came over to talk with our two star speakers—for perhaps 2 or 3 minutes. Otherwise, we were ignored. Since I had arranged for us to attended the METI press briefing and had insisted that we should leave the event with the foreign correspondents, I felt terrible. Takemoto—who had come over from Niigata for the day and whose own house had partly collapsed from the earthquake—had only eaten rice balls for days. Finally, Takemoto said he had to go home to Niigata. It would take hours. There wasn't a single quote from either of them in the newspapers the next morning.

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The Japanese electric utilities are great at getting what they want after a crisis. One thing they got out of the Kashiwazaki-Kariwa earthquake crisis was to be able to advertise: "Look how Japan's CO_2 releases increased after nuclear plants had to be shut down." In other words, nuclear power stops global warming. They got what they wanted, because a major government program immediately followed to support nuclear energy as a means of reducing global warming gases. That argument is standing the truth on its head, however. The reality is that these CO_2 spikes occur when a country that depends heavily on nuclear power for its electricity, may have to shut down its nuclear plants *en masse* and be forced to use *coal* as a back-up. But the utilities have the advertising money, so it is their message that gets out to the general public.

A similar thing happened following a 2002 scandal when Tokyo Electric was found to have deliberately falsified voluntary inspection data. The outcome? The Japanese utility monopolies (headed by TEPCO) got what they'd been asking for: a *relaxation* of inspection standards. The government decided that the reason the utilities had resorted to falsifying data was because the existing standards were *too strict*.

Postscript:

Now I am back in Japan. The situation in Fukushima remains unstable and very dangerous. The status quo persists. The media are still ignoring citizen efforts, the TV programs are stacked with pro-nuclear spokespeople, and there are very few signs of real change. I worry about what will happen when the eyes of the world turn away from the Fukushima crisis, as soon as some other crisis erupts.

Meanwhile, in late May the government announced a "temporary" shutdown of the Hamaoka site near Tokyo. This was supposed to make things safe. But all the utility is planning to do is construct a higher wall to protect against tsunamis, and then to start the plant running again. This is despite evidence that there's an 87% chance the region could suffer a magnitude 8 earthquake at any time. Kobe University seismologist Katsuhiko Ishibashi has warned that a nuclear accident at Hamaoka on the scale of Fukushima would force 30 million people to evacuate, "signaling the collapse of Japan as we now know it."

We will have to step up our efforts. What more can we do? Should we take to the streets?

NUCLEAR ROULETTE: THE CASE AGAINST A NUCLEAR RENAISSANCE

SCIENCE PHOTO LIBRARY

Measuring radiation in Natori, Miyagi Prefecture,
after the 2011 earthquake and tsunami in northern Japan.

INTRODUCTION: LESSONS OF FUKUSHIMA

BY GAR SMITH

Within weeks of the 32nd anniversary of the Three Mile Island meltdown and the 25th anniversary of the Chernobyl explosion, an earthquake-driven tsunami swamped the 40-year-old Fukushima reactor complex on the coast of Japan, unleashing a calamity that has forced massive evacuations, contaminated local crops, dumped radioactive water into the sea and spread radiation around the world. A month after the first hydrogen explosions damaged buildings at reactor units 1, 2, 3 and 4, Japanese officials raised the severity of the accident to level 7—the highest rating, on par with the Chernobyl disaster.

As this report went to press, the situation in Fukushima was still not under control and nuclear engineers and government officials were predicting that efforts to prevent future catastrophic damage at the broken reactor complex could take years. In addition to radiation leaking from damaged cores, six fuel-rod storage pools filled with 647 tons of radioactive wastes had suffered damage. Special concern attached to the storage pool atop Unit 3, the only reactor running on MOX fuel (a combination of uranium and plutonium). The rooftop storage pool vanished during a powerful hydrogen explosion on March 14.

Meanwhile, desperate attempts to cool exposed fuel rods (some of which have experienced a partial melt-down) was generating thousands of tons of radioactive water that were being dumped into the ocean, exposing the marine food chain to levels of radiation that the Tokyo Electric Power Company (TEPCO) reported to be 7.5 million times the legal limit.

According to the *New York Times*, a "confidential assessment" from the U.S. Nuclear Regulatory Commission concluded the situation at Fukushima was "far from stable" and that the danger of future harm could persist "indefinitely." Ultimately, parts of northeastern Japan (like the devastated landscapes downwind of Chernobyl) may remain a "No Man's Land" for generations. The eventual cleanup and containment of Fukushima's remains could take decades.

Fukushima was supposedly designed to withstand the greatest credible threat. Now, in the aftermath of the quake and tsunami, TEPCO officials are facing problems "beyond the design capacity" of the plant—with no end in sight. Japan's suffering has caused understandable alarm in the U.S., where 23 identical Fukushima-style GE Mark-1 reactors sit at 16 sites in Alabama, Georgia, Illinois, Iowa, Massachusetts, Minnesota, Minneapolis, Missouri, New Jersey, New York, North Carolina, Pennsylvania and Vermont.

The lesson is clear: if Japan, one of the world's most technologically sophisticated countries, cannot assure the safety of nuclear power, it is time to consider the only rational course of action—the commencement of an immediate global decommissioning process.

The fact that an earthquake triggered the disaster should add an additional degree of alarm, given the fact that seismic activity has been increasing worldwide. A study of more than 386,000 earthquakes between 1973 and 2007 shows seismic activity increasing five-fold over a 20-year span. According to Dr. Tom Chalko, the Australian scientist who conducted the survey, "the most serious environmental problem we face…[is] rapidly and systematically increasing seismic, tectonic and volcanic activity." In the U.S., five active reactors are located on the coast near earthquake faults. These at-risk reactors include California's Diablo Canyon and San Onofre, Louisiana's Waterford Steam Electric Station, North Carolina's Brunswick plant and the South Texas Project. These are the first reactor sites that should be targeted for decommissioning.

The "invisible tsunami" of radiation drifting eastward from Japan's smoking reactors quickly reached the U.S., contaminating rainwater, pine forests, crops, water and milk from California to Vermont with detectable amounts of iodine-131, cesium-134 and cesium-137. On April 10, *Forbes* reported that milk samples in Phoenix and Los Angeles were found to contain iodine-131 "at levels roughly equal to the maximum contaminant level permitted by EPA." (The EPA only tests for iodine-131 and ignores the presence of more dangerous radioactive isotopes from cesium, uranium and plutonium.)

Dr. Natalia Miranova is a Russian engineer who once risked her life as a Chernobyl "liquidator," helping to control the radiation billowing from the damaged plant. Her reflections on Fukushima are sobering. "Chernobyl was one reactor releasing radioactive materials for two weeks in a relatively rural setting with low population," Miranova noted during a visit to San Francisco in April. "Fukushima is at least four [active] reactors, plus their spent fuel pools, venting radionuclides… in a populated area. Fukushima is not just 'as bad as' Chernobyl. It is eight times worse already, with no end in sight."

Some 60 new reactors are under construction in 15 countries. Before another ton of concrete is poured, before another bolt is secured, before another nail is driven, three basic reforms should be required:. *1)* End government bailouts that make it possible to build new reactors, *2)* require power plant operators to accept full financial responsibility for covering all potential damages, *3)* require operators to establish adequate funds for decommissioning their plants and safely storing radioactive wastes for a minimum of 10,000 years.

Holding the nuclear lobby financially accountable would pull the plug on this dangerous technology. The money saved could then be put to better use promoting the transition to sustainable economies powered by clean, safe, affordable, renewable energy.

BOX I
GLOSSARY OF KEY TERMS

Power: The rate of doing work, measured in watts (joules per second).

Joule: A unit of electrical energy equal to the work done when a current of one ampere passes through a resistance of one ohm for one second.

Energy: The capacity of a physical system to do work, measured in joules.

Efficiency: The ratio between the useful output of an energy conversion machine and the input, in energy terms.

EROEI: "Energy Returned on Energy Invested," also known as EROI (Energy Return On Investment). The ratio of the amount of usable energy acquired from a particular resource to the amount of energy expended to obtain that resource. Not to be confused with efficiency.

Kilowatt-hour (kWh): The energy used by ten 100-watt bulbs in one hour.

Megawatt (MW): 1 million watts. In 2008, the Energy Information Administration reported the average US home consumed around 11 MWh per year. A single nuclear reactor may generate 500 to 1350 MW.

Gigawatt (GW): 1 billion watts. This unit is for large power plants or power grids. For example, in 2009, the installed capacity of wind power in Germany was 25 GW.

Terawatt (TW): 1 trillion watts. The total power used by humans worldwide (about 12.5 TW) is commonly measured in this unit.

Boiling Water Reactors: BWRs operate like fossil-fuel-powered plants except that a nuclear core is used to heat water to produce steam that drives turbines to generate electricity.

Pressurized Water Reactors: The most widely used Western reactor, PWRs were originally designed for military use. Water is not allowed to boil but is kept under high pressure in a steam generator, which is used to spin turbines that produce electricity.

Advanced Pressurized Water Reactor: An improved design based on the existing BWR and PWR reactors but incorporating passive safety systems.

ONE

IMPOSSIBILITY OF SPEEDY DEPLOYMENT

NUCLEAR REGULATORY COMMISSION

The Watts Bar-1 reactor, 60 miles southwest of Knoxville, Tennesee, took 24 years to build.

In 2009, the International Energy Agency (IEA) conducted its first detailed assessment of the world's 800-plus oil fields and found that most had already "peaked" and 75% of the planet's global reserves were falling at the rate of 6.7% a year (twice as fast as estimated just two years earlier). The world may start running out of oil by 2012—a decade earlier than previous estimates. "We will have to leave oil before oil leaves us," IEA's Chief Economist Dr. Fatih Birol warned. "The earlier we start, the better."[1] Nuclear proponents have argued that "clean atoms" can replace dirty and depleted fossil fuels to provide a hedge against Global Warming. But facts do not support this call for a Nuclear Renaissance.

More than 200 new reactors have been proposed around the world but not enough reactors can be built fast enough to replace the world's vanishing fossil fuel resources.[2] Even if nuclear output could be tripled by 2050 (which seems unlikely in light of the industry's record to date), this would only lower greenhouse emissions by 25 to 40 billion annual tons—12.5 to 20 percent of the reductions needed to stabilize the climate.[3] The International Energy Agency estimates that renewables and efficiency measures could produce ten times these savings by 2050.

The IEA estimates that cutting CO_2 emissions in half by mid-century would require building 1,400 new 1,000-MW reactors—32 new reactors every year. But since it usually takes about 10 years from groundbreaking to atom-smashing, these reactors could not be constructed fast enough to prevent an irreversible "tipping" of world climate. This hardly seems feasible since the industry has only managed to bring 30 new reactors on-line over the past ten years. Of the 35 reactors the IEA listed as "under construction" in mid-2008, a third of these had been "under construction" for 20 years or longer. Some may never be completed. By contrast, a 1.5 MW wind turbine can be installed in a single day and can be operational in two weeks.[4] Still, the pace of nuclear construction has picked up lately. In 2010, the number of reactor projects underway had ballooned to 66—with most located in China (27) and Russia (11).

And it's not just a matter of designing and building new reactors. The construction of 1,400 new nuclear reactors also would require building 15 new uranium enrichment plants, 50 new reprocessing plants and 14 new waste storage sites—a deal-breaker since the sole proposed U.S. storage site at Yucca Mountain is apparently dead. The cost of this additional nuclear infrastructure has been estimated at $3 trillion.[5] Moreover, since the operating lifetime of these new reactors would still be a mere 40 years, even if new construction was practical, quick and affordable, it would only "solve" the global-warming problem for another 40 years, at which point the plants would need to be decommissioned.

The last completed U.S. nuclear reactor, Watts Bar-1, took 24 years to build.[6] It currently takes the Nuclear Regulatory Commission (NRC) about 42 months to review and approve a reactor application.[7] Given this track record, it's apparent that nuclear plants will be unable to meet the goal of reducing greenhouse gas emissions by 20% by 2020.

In 2006, global nuclear power grew by only 1,400 megawatts (MW), the equivalent of the addition of one large nuclear power plant. Even in France (which is frequently cited as a nuclear power success story), the atom's record is *un embarras*. Between 1970-2000, the costs of construction per kilowatt/installed tripled.[8] In March 2007, the NRC approved its first request for a site permit in 30 years. The approval process took 3.5 years. At the start of 2011, the NRC had received applications to build 26 new nuclear reactors (more than half would be modified versions of the Westinghouse AP1000 design) but it is unlikely that more than three of these reactors would actually be built—even with the $54 billion in government loans the Obama Administration has proposed for the construction of new reactors.

Case in point: one of the top candidates for a federal loan guarantee—a proposed nuclear power plant in San Antonio, Texas, that already had agreements in place to sell power to customers—stalled after sky-rocketing cost projections convinced one investor to abandon the venture. Financial concerns also prompted the Tennessee Valley Authority to cut plans for four new reactors down to one. The utility Ameren UE pulled the plug on a proposed reactor in Calloway, Missouri, after it failed in a bid to start billing utility customers for the plant *before* construction had even started. And in Florida, pending reactor projects were thrown into question after the state Public Service Commission rejected a request to raise customers' rates to subsidize construction.

Ironically, the twin-reactor Vogtle project in Georgia—the first recipient of an $8.3 billion Department of Energy (DOE) construction loan—has had trouble obtaining an NRC permit due to safety short-comings with its shield design.[9] (Despite the billion-dollar loan guarantee, not a single private investor has stepped forward to help match the remaining costs for the $10 billion Vogtle plant.)

Meanwhile, the argument that "clean" nuclear power can help fight Global Warming has been given the cold shoulder by climate activists. It turns out that nuclear reactors are only marginally useful in countering climate change—and an examination of the complete life-cycle costs reveals that nuclear energy actually helps stoke Global Warming. While it is true that a fully functioning reactor releases little CO_2, an honest greenhouse-gas assessment cannot overlook the significant volumes of CO_2 generated by the overall operations of the nuclear industry.

Vast amounts of CO_2 are generated by all the fossil-fuel-powered drills, trucks, locomotives and cargo ships involved in mining the ore and delivering it to refineries, enrichment facilities, power plants and, ultimately, to a radioactive waste storage site. Fossil fuels also are consumed (and CO_2 released) in the fabrication of the thick concrete housings and assembly of the huge metal parts that go into making a nuclear power plant. It takes many years for a fully operational nuclear plant to generate sufficient energy to offset the energy consumed in the plant's construction.[10]

When the entire fuel cycle is considered, a nuclear reactor burning high-grade uranium produces a third as much CO_2 as a gas-fired power plant. But the world's supply of high-grade ore is running out. When reactors are forced to start enriching low-grade ore (containing only one-tenth the amount of uranium), the nuclear fuel cycle will start pumping out *more* CO_2 than would be produced by burning fossil fuels directly.[11]

On the other hand, clean, low-cost renewable power sources (led by wind-turbines and solar technologies) are racing far ahead of nuclear power. This new reality is gaining some powerful advocates. On May 5, 2009, Federal Energy Regulatory Commission Chair Jon Wellinghoff assured reporters that all future U.S. electricity demand can be achieved with a mix of renewable technologies and efficiency measures. "We have the potential in the country," Wellinghoff emphasized, "We just have to go out and get it." [12]

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Meanwhile, in the ongoing (and still precarious) aftermath of the Fukushima disaster, the future of nuclear power appears to be approaching an historic "tipping point." On May 30, Germany's coalition government—alarmed by Fukushima's multiple meltdowns and relentless fallout—announced plans to close all of the country's nuclear plants by 2022. The decision followed massive anti-nuclear protests that saw 160,000 people marching against nuclear power in more than 20 German cities. According to the BBC, "The decision makes Germany the biggest industrial power to announce plans to give up nuclear energy." In announcing the decision, German Chancellor Angela Merkel stated: "We believe that we can show those countries who decide to abandon nuclear power—or not to start using it—how it is possible to achieve economic prosperity while shifting the energy supply toward renewable energies."

In 2010, Germany installed a record 7,400 MW of solar-electric panels. Renewables now provide more than 100 TWh of Germany's electricity—nearly 17% of total consumption. On Monday, February 7, 2011, combined real-time wind and solar generation achieved an all-time peak, producing 32% of Germany's total electricity. Over the past decade, Germany has tripled its reliance on renewable energy while creating 370,000 "green" jobs. In Scotland, Energy Minister Fergus Ewing said Germany's decision "adds further weight" to plans to close all five of Scotland's nuclear sites. Scotland plans to be generating all of the country's energy from renewables within ten years.

BOX II
"RENAISSANCE" REACTORS: PLAGUED WITH PROBLEMS

The two new reactor designs touted to lead the "Nuclear Renaissance"—the Westinghouse/Toshiba AP1000 and AREVA's advanced EPR—keep running into road-blocks. While completion of AREVA's showcase plant in Finland remains overdue and over-budget, the AP1000 is still stuck in the approval process with the NRC repeatedly expressing dissatisfaction with the plant's design.

In April 2010, alarmed nuclear watchdogs called on the NRC to suspend the operating license for Westinghouse's new AP1000 Pressurized Water Reactor (PWR) design after documenting several dangerous defects that NRC regulators apparently failed to detect. Alarms were sounded after existing PWRs were found to contain corrosion-caused "holes and cracks" in their containment vessels. At least 77 cases of corrosion, cracks, crevices or actual holes have been found in reactor containment vessels. In eight reactors, corrosion had eaten all the way through the steel containment walls. Because visual inspections cannot detect all potential corrosion problems, some went undetected until the containment vessel was actually breached. In 2009, a finger-sized hole was discovered in the containment vessel at the Beaver Valley reactor. A nuclear accident at this plant could have exposed residents of Pittsburgh to dangerous levels of radiation.

The AP1000 design—a hybrid design with no operational history—threatens to be even more vulnerable to containment corrosion. One analysis concluded the design "appears to invite corrosion."[52] Corrosion failures are critical for the AP1000 because these reactors have no secondary containment protections—the AP1000 is designed to vent unfiltered emissions directly into the sky. In place of a secondary containment building, the AP1000 features a large water tank designed to pour water on the reactor shell in the event of an accident or a meltdown. Because of these risks, watchdog groups have called on the NRC to halt licensing efforts for 14 AP1000s planned for seven U.S. locations.

In November 2009, the NRC informed Toshiba that the AP1000's steel-and-concrete containment shield did not meet "fundamental engineering standards"[53] after concluding that it might not be able to withstand damage from high winds or handle the weight of the plant's emergency water tank.

TWO

CATASTROPHIC DANGERS

Chernobyl victim, Minsk, Belarus.
Photographed in 1991—five years after the
Chernobyl Nuclear Power Plant disaster.

On March 29, 2009, the 30th anniversary of the Three Mile Island (TMI) meltdown, former Nuclear Regulatory Commissioner (NRC) Peter A. Bradford told a Senate committee: "Among the lessons of TMI is that nuclear power is least safe when complacency and pressure to expedite are highest." Bradford attributed the TMI catastrophe to "a technology that had rushed far ahead of its operating experience." The result was "a landscape dotted with nine-figure cost overruns, a nine-figure accident, eight-figure cancellations and eight-figure mishaps in such areas as steam generator tubes, pressure vessels, seismic design and quality assurance." The industry's current desperate rush to extend the operating lives of aging reactors and to impose a taxpayer-financed "Nuclear Renaissance" gives new urgency to Bradford's warning.

Bradford offered another stern lesson from TMI: Granting an operator a license is no guarantee that the operator won't inadvertently "turn a billion-dollar asset into a two-billion dollar clean-up in ninety minutes." Bradford noted that the "near-rupture" of a reactor vessel at Ohio's Davis-Besse reactor in 2002 was partly due to NRC's "undue solicitude for the profits of the licensee." The NRC had agreed to delay inspections of a vital safety component to accommodate the plant's owner. This allowed corrosive liquids to eat through six inches of the reactor vessel's carbon-steel top, leaving only a half-inch of metal behind to prevent a massive explosion.[13]

The Chernobyl reactor, which detonated in a rural region of Ukraine, has caused more than $500 billion in clean-up costs to date. Initial government reports claimed that only 31 "liquidators" (members of the clean-up crew) died. By 2005, however, between 112,000 and 125,000 of these "liquidators" had succumbed to radiation exposure. Over the past 23 years, according to the most recent estimates, the Chernobyl blast may have caused the cancer deaths of nearly 1 million people worldwide.[14] While Chernobyl was built in a remote location, most U.S. reactors are located near major population centers, including Baltimore, Baton Rouge, Boston, Chicago, Los Angeles, Manhattan, Miami, Minneapolis and Philadelphia. U.S. government reports estimate the meltdown of a single nuclear reactor could irradiate an area as large as Pennsylvania.[15]

When the accident at Three Mile Island happened, nuclear reactors were providing 12% of U.S. electricity. Thirty years later, with reactors providing 20% of the country's electricity, nuclear power is often taken to be a safe, reliable technology. Most Americans are unaware of an ominous spate of recent near-disasters that have occurred at reactor sites in other countries. (This ignorance could persist because two powerful companies with interests in nuclear technology controlled two of the three major TV news networks: General Electric owns NBC and, until 2000, Westinghouse owned CBS.)[16] The public also remains largely unaware of the many operational "incident reports" at U.S. reactors that are filed with the NRC every year.

In 2006, the emergency power failed at Sweden's Forsmark plant, affecting four of the country's ten nuclear power stations. Plant officials later admitted: "It was pure luck there wasn't a meltdown."[17] In another close call, the Yankee Rowe reactor in Massachusetts was disabled by lightning in 1991. The owners refused to conduct safety tests until ordered to do so by Congress.[18]

Ironically, nuclear plants are sensitive to Global Warming. Summer heat waves have forced reactors in the U.S. and Europe to shut down to avoid overheating.[19] French reactors have been forced to shut down during summer when the heated water discharged by their coolant systems raised river temperatures far beyond legal limits. Reduced river flow (due to climate-change) has forced reactor shutdowns in Europe and the U.S. during hot summer months when electricity demand peaks. In the summer of 2003, French firefighters had to be dispatched to hose down overheating reactors at the Fessenheim nuclear plant.[20]

In July 2010, the three nuclear reactors at Browns Ferry in Alabama were forced to cut power production 50% when the temperature of the river water upstream from the plant's discharge pipes hit 89 degrees. (When the river's upstream temperature soars past 90 degrees, state regulations require that the reactors be shut down.[21]) Because some reactors draw their cooling water from the oceans, plants built on the coasts are at risk from oil spills. Every coastal reactor from Texas to south Florida faced a possible shut-down after oil from BP's Deepwater Horizon spilled into the Gulf of Mexico. As the DOE's Office of Electricity Delivery and Energy Reliability warned: "If water supply for these facilities becomes contaminated with oil, cooling water systems could be damaged."[22]

Whenever shutdowns occur, costly replacement energy has to be purchased on the spot market.[23] Reactors are also at risk from floods, hurricanes and tsunamis, which can disrupt off-site power, endangering plant operation and safety. An earthquake, as we learned from the Fukushima disaster, can cause displacement of storage-pool cooling water. A quake can even cause a shifting of spent-fuel storage racks, bringing fuel rods into contact and risking a nuclear fission chain reaction explosion.

When outside power is interrupted and back-up power fails, reactor operators can lose the ability to monitor and control the reactor core, which can quickly lead to a catastrophic meltdown. In Belgium, two out of three back-up power systems failed during a test at the Tihange 2 reactor in 2005. A massive power blackout in 2003 forced the shutdown of 20 reactors in the U.S. and Canada. On March 5, 2009, a fire occurred in an underground pump room at Tokyo Electric's Kashiwazaki-Kariwa nuclear power plant, injuring a worker. On the same day, a device carrying nuclear replacement fuel failed at Belgium's Doel reactor. The heavy fuel unit dropped to the floor, prompting an evacuation.[24]

AREVA's European Pressurized Water Reactor (EPR) has been hailed as a new design that would be safer and more reliable, as well as cheaper and quicker to build. But the prototype of this "Renaissance Reactor"—the 1,600 MW Olkiluoto 3 plant under construction in Finland—remains 80% over-budget and at least four years behind schedule (which translates into a $2.8 billion loss). Its concrete base, reactor vessel, pressurizer and primary cooling pipes all have failed to meet critical quality and safety standards. By mid-2007, 1,500 safety and quality defects had been recorded.[25] AREVA's 1,600 MW Olkiluoto reactor is now set to open at the end of 2012, three years behind schedule. Costs for Electricité de France's (EDF) delayed Flamanville EPR are up 25%—$6.4 billion over budget. (Meanwhile, EDF continues to push plans to build four EPR reactors in Britain at an estimated cost of $9.3 billion per unit.)

Many of the proposed new U.S. reactors would be built by the French nuclear firms EDF and AREVA. To avoid the Atomic Energy Act's explicit ban on direct foreign ownership or control of U.S. plants, these French firms have purchased major shares in key U.S. energy companies. In addition, between 2005 and 2008, AREVA spent $5.2 million on lobbying Congress.[26] The first U.S.-sited French reactor —a double-sized EPR (an experimental design that has never operated anywhere in the world)—would be erected at Calvert Cliffs, Maryland (one of the DOE's three top loan-guarantee applicants). AREVA has proposed building new reactors in New York, Pennsylvania and Missouri, as well as in various other countries. (AREVA's plans were not helped by a November 4, 2010, University of Greenwich study that concluded AREVA's EPR reactor should be abandoned because of its excessive costs.)

In September 2010, Maryland's Calvert Cliffs-3 project was near collapse as concerns rose over foreign ownership, insufficient proof of need, and costs. On October 9, 2010, Constellation Energy withdrew from the project. Meanwhile, Peter Shumlin, Vermont's new governor, pledged to shut the state's troubled Vermont Yankee plant and growing public campaigns are demanding the closure of reactors in New York and New Jersey.

Regulators in France, Finland and the UK have raised safety concerns about AREVA's EPR reactor. AREVA's critics point to a performance review from the Autorité de Sûreté Nucléaire, France's nuclear safety authority, that found 5 of 19 French reactors were "underperforming" and only 74% of the power plants were being operated safely. In 2008 alone, French reactors spilled radioactive particles into three French rivers and the Mediterranean. And it's not just French reactors that have problems. In November 2009, the NRC determined that the Toshiba-Westinghouse "standardized" AP-1000 reactors might not survive hurricanes, tornadoes or earthquakes.[27]

While there are plans to add another 16.6 GW of unproven nuclear capacity in the U.S., 4.5 GW are expected to be lost as older plants are retired. Under pressure from the reactor operators, the NRC has begun extending the operating life of 52 aging U.S. reactors to 60 years and is considering extending some operating permits for up to 80 years—twice the reactor's intended operating life.[28] The gap in output will be partially filled with 2.7 GW coming from "uprates" of existing plants.[29] These "uprates" have allowed half of U.S. reactors to exceed their original generation maximums by replacing aging turbines and pipes to boost performance. Uprates now account for 25% of the total generating capacity of U.S. reactors.[30] Instead of running these old reactors with heightened caution, the NRC is allowing owners to try and extract extra profit by running their aging nuclear cores "hotter and harder."

Back in 1974, Congress became so alarmed by the boosterism of the Atomic Energy Commission that it replaced the AEC with the Nuclear Regulatory Commission (NRC). Today, the new agency's clear failure to fulfill its role as an independent watchdog has prompted critics to call for the abolition of the NRC.[31] The NRC has become such a handmaiden to the industry that it routinely hands out operating permits before plants are even built or inspected. This "preconstruction licensing" was first proposed when the Shoreham, Seabrook and Zimmer reactors were refused operating permits after critics demonstrated they were unsafe to operate. A U.S. Appeals Court ruled that the NRC's "one stop" policy (designed to speed the introduction of a "new generation" of reactors) violated the Atomic Energy Act.[32]

With nuclear construction halted or stalled, other nuclear nations also are extending the lives of plants that were only designed to run for 30 to 40 years. In most cases, aging reactors are being re-licensed for another 10 years of use but two Finnish reactors have been granted waivers to keep running for 60 years.[33] The practice of extending a reactor's service beyond its intended life (while simultaneously allowing it to operate at more intense levels of generation) has been referred to as a game of "Chernobyl Roulette."

In terms of road-wear, many of these reactors would qualify as "jalopies." You can't keep changing the tires and replacing parts forever. New Jersey's Oyster Creek reactor—a GE Mark-1 Fukushia-style reactor and the oldest US plant to win an operating extension—was not designed to survive a direct hit from a plane. Its containment vessel is essentially identical to the ones that ruptured in Japan. The reactor shell (which is supposed to control a radioactive steam leak in an emergency) is too corroded to guarantee safety. Despite visible rust around the reactor core and a history of steam and radiation leaks, the NRC did not require testing the plant for metal fatigue before re-licensing.[34] Even pro-nuclear advocate William Tucker[35] has publicly criticized the NRC's re-licensing of Oyster Creek.[36]

Nearly 30 years ago, the government estimated an accident at Oyster Creek would cause at least 16,000 early fatalities, 10,000 injuries, 23,000 cancer deaths and $79.8 billion in damages. One estimate for an atomic accident at Indian Point 3 (just 24 miles north of New York City) predicted 50,000 early fatalities, 167,000 injuries, 14,000 cancer deaths and $314 billion in damages.[37] Because the past three decades have seen major increases in population and development near reactor sites, the risks today are even greater.

As Fukushima made clear, reactor cores aren't the only peril when it comes to nuclear accidents. The loss of cooling water in spent-fuel storage pools can lead to catastrophic fires and radiation releases. If safety were paramount, these pools would be closely monitored and would only be used for the first five years, after which fuel rods would be removed to dry-cask storage facilities hardened against terrorist attack and monitored for safety. Currently many of the dry-cask containers in the U.S. are stacked like bowling pins under open skies, clearly visible from nearby roads, rivers and from the air.

No reactor—not even the latest state-of-the-art reactor—will ever be "inherently safe." This is because most nuclear accidents (Chernobyl, Three Mile Island, Fermi, Tokai-Mura) were caused by human error rather than purely technological failure. Until you have foolproof humans, the notion of an inherently safe and foolproof reactor remains absurd. As nuclear physicist Edward Teller once observed: "There's no system foolproof enough to defeat a sufficiently great fool."[38]

BOX III

THREE MILE ISLAND AND INDIAN POINT

When Three Mile Island's Unit 2 reactor started operation on December 28, 1978, it was hailed as a state-of-the-art nuclear facility. Three months later, the $900 million power plant turned into a multi-billion-dollar liability in a matter of hours. After the TMI disaster, no new reactor orders were placed and none of the reactors started after 1974 were ever completed.[39] (The last U.S. reactor order was placed a year *before* the TMI meltdown.)

On the 30th anniversary of the TMI disaster, Peter A. Bradford, a NRC commissioner at the time of the accident, told a Senate Environment and Public Works subcommittee "the melting of the core during the early hours of the accident was far more severe than was known at the time." The truth was that half of the core melted.

The story Bradford told the Senate was quite different from the story that was given to the public at the time. For days, public officials issued one false statement after another, including: there were no radiation releases; there were radiation releases but they were "controlled;" radiation releases were "insignificant;" there was no melting of the reactor fuel; there was never any danger of an explosion; there was no need to evacuate the surrounding communities. Thirty years after the accident, the NRC still does not know how much radiation was released or where it went.[40]

Local, state and federal officials promised to conduct thorough health studies of the exposed residents. Instead, the state hid the health impacts by deleting cancer reports from the public record, abolishing the state's tumor registry and ignoring an apparent tripling of the infant death rate around the damaged reactor. The TMI accident was followed by a die-off of birds and bees. Diseases killed neighboring live-stock. Dogs and cats were born dead or deformed.[41]

Years later, it was revealed that TMI's containment vessel had failed, releasing a cloud of radiation that was about 100 times more significant than estimates offered by the industry and the NRC. Independent surveys by local residents found high incidences of cancer, leukemia and birth defects. Cancer rates within a 10-mile radius of TMI jumped 64% between 1975 and 1985. Some 2,400 residents filed a class-action lawsuit demanding compensation but, 25 years later, the federal courts still refuse to grant them a hearing. TMI's owners have paid at least $15 million in out-of-court settlements to parents of children born with birth defects—on the condition that the families remain silent about the settlements.[42] In the mid-1980s, the people of Harrisburg voted three-to-one to shut down TMI's Unit 1. The Reagan administration ignored the vote and ordered Unit 1 back on line. The reactor is still operating.

Meanwhile, the operators of New York's Indian Point reactor on the Hudson River have asked the NRC to extend the licenses of the plant's Units 2 and 3 for another 20 years. The aging Indian Point reactor has a history of operational problems including a steam boiler rupture, a transformer explosion and blocked cooling-system intake valves.

The NRC has issued a Draft Supplemental Environmental Statement declaring that Indian Point poses no "significant" public health threat, but Indian Point's neighbors have challenged this conclusion. Local residents have presented the NRC with data compiled by the New York State Health Department showing that rates of thyroid cancer in the four counties nearest the reactor site were nearly twice the U.S. average. Childhood cancers were also above average. Over the past four years, 992 residents have been diagnosed with thyroid cancer. Samples of milk from breastfeeding mothers living within 50 miles of the reactor showed significant levels of strontium-90, a radioactive isotope. Strontium-90 levels climb the closer a resident is to the Indian Point plant. Strontium-90 also has been detected in local fish and crabs.

The NRC has deemed most of the health issues raised by the Westchester County residents to be "out of the scope" of the relicensing proceedings.[43] For their part, county officials have announced an ambitious plan to reduce the county's carbon footprint by 20 percent in the next seven years and by 80 percent by mid-century—turning away from the False Solution of nuclear power.

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BOX IV
MAJOR NUCLEAR ACCIDENTS *(PARTIAL LIST)*

United Kingdom (1957)—Reactor fire at Windscale facility contaminates 35 workers, sends radioactive cloud over Northern Europe.

Soviet Union (1957)—More than 100 killed in explosion at a secret nuclear reprocessing site in Chelyabinsk: 270,000 evacuated from 217 cities and villages.

U.S.A (1961)—Three U.S. Army technicians killed in reactor explosion in Idaho.

U.S.A (1966)—Core melts when cooling system fails at Detroit's Enrico Fermi breeder reactor.

Scotland (1967)—Fuel element melts, catches fire at Chapelcross reactor.

Switzerland (1969)—Coolant leak in underground reactor in Lucens causes explosion and severe contamination.

U.S.A (1975)—Alabama's Browns Ferry plant catches fire and burns for 7.5 hours with two GE reactors operating at full power. Meltdown feared as one reactor goes "dangerously out of control."

U.S.A (1979)—Three Mile Island: thousands of Pennsylvanians evacuated in worst U.S. reactor accident.

France (1980)—Radioactive leak after fuel bundles rupture at Saint Laurent reactor.

United Kingdom (1981)—Radiation leak from Sellafield (née Windscale) contaminates dairy pastures. Local leukemia rates soar to triple national average.

U.S.A (1981)—California's San Onofre plant closes for 14 months for repairs to 6,000 leaking steam tubes. During restart, plant catches fire, knocking out one of two back-up generators.

Argentina (1983)—Engineer killed by radiation exposure at research reactor; 17 others injured.

MAJOR NUCLEAR ACCIDENTS *(continued)*

United Kingdom (1983)—Sellafield fallout contaminates coastline and ocean.

United Kingdom (1984)—Sellafield fallout triggers nine-month closure of local beaches. Operators face criminal charges.

Russia (1986)—Chernobyl: world's worst nuclear accident to date. Number of dead remains unknown; estimates run from 300,000 to nearly 1 million.[44, 45, 46]

Germany (1986)—Fuel accident releases fallout up to two kilometers from plant.

Japan (1997)—Explosion at Tokaimura plant leaves 35 workers exposed to high levels of radiation.

Japan (1999)—Uncontrolled nuclear reaction at Shika reactor. Incident covered up by plant operators.

Japan (1999)—Two workers killed at Tokaimura during unplanned chain reaction that exposes 116 workers to radiation.

Germany (2001)—Failure in emergency cooling system of Philippsburg reactor.

Germany (2001)—Heavy hydrogen explosion in Brunsbüttel boiling water reactor.

U.S.A (2002)—Undetected corrosion on pressurized reactor chamber of Davis-Besse reactor comes close to causing a massive radiation accident.

Hungary (2003)—Radioactive leak caused by ruptured fuel elements at Paks reactor.

Japan (2004)—Four killed in reactor accident in steam explosion at Mihama reactor.

Bulgaria (2005)—Control rods jam in Kosloduy-5 reactor, preventing safe shutdown.

Sweden (2006)—A catastrophic core meltdown of the Forsmark reactor is barely averted after an external short circuit causes a failure of the emergency power system.

Germany (2007)—Transformer fire results in failure of emergency power supply.

Japan (2007)—Transformer fire following earthquake triggers radioactive leak at the Kashiwazaki-Kariwa plant. Quake shuts down the 8,000-MW reactor in 90 seconds. Seven reactors damaged by quake.[47]

France (2008)—A major leak at the Tricastin nuclear facility in southeastern France spills 30 cubic meters of uranium-rich water onto the plant's grounds.[48]

Russia (2009)—The Leningrad Nuclear Power Plant is shut down after a crack is discovered in a pump, threatening a "potentially catastrophic technical malfunction."[49]

France (2009)—A "significant" incident causes the evacuation of the reactor unit in the Gravlines nuclear plant in northeastern France—the fifth "level-1" emergency in three years.[50]

Japan (2011)—Six coastal reactors at Fukushima disabled by earthquake and tsunami. Cooling system failure leads to explosions, partial meltdowns and massive release of radiation.

Additional significant accidents have occurred at the following U.S. plants: Shoreham, Seabrook, Nine Mile Point, Midland, Zimmer, Marble Hill, WPPSS, Byron, Braidwood, Grand Gulf, Comanche Peak, South Texas and Diablo Canyon.

For a more detailed List of Civilian Nuclear Accidents, see *An American Chernobyl: 'Near Misses' at US Reactors Since 1986* (Greenpeace, 2006) and Wikipedia.[51]

THREE

INHERENTLY INEFFICIENT AND UNRELIABLE

TVA

Brown's Ferry—In 1975, a worker using a candle to check for air leaks, started a fire that closed the Brown's Ferry nuclear plant for two decades. In 2011, a tornado cut power to the rebuilt reactors, triggering an emergency shutdown.

Of the 253 nuclear power plants originally proposed for the U.S., only 132 were ever built and 21 percent of those were permanently closed because of cost or safety problems. More than a quarter of U.S. reactors have completely failed for a year or more—some more than once. Even when a reactor operates perfectly, it still needs to be shut down about every 17 months for maintenance and refueling.[54] *These shutdowns average 39 days and, once the reactor is restarted, it takes several weeks to achieve full electric production. And reactors don't always shut down only when planned. In August 2003, nine reactors in the Northeast U.S. were forced to shut down when a power blackout cut all outside electrical power.*

Yet, the lure of the nuclear False Solution continues to transfix politicians—even in Japan, a country that has good reason to fear nuclear power. In September 2009, Prime Minister Yukio Hatoyama announced a national goal of cutting greenhouse gases 25% by 2020 while building eight new nuclear power plants over the same 20 years. The government's plan assumed existing reactors would operate at 80% capacity but the hard truth is, these aging plants have only operated at 77% capacity since 1980. (Operating capacity dropped to 64.7% in 2009.)

Waiting in the wings is Japan's fast-breeder program but, after more than 50 years of delays and investments, the project's commercial debut has been pushed back to 2050. In the meantime, the Japanese environmental group Green Action notes with alarm that Japan's energy planners hope to increase capacity by running the country's existing reactors past their original retirement dates and with fewer (and shorter) shutdowns for safety inspections and maintenance. It's a troubling scenario. As Green Action activist Aileen Mioko-Smith notes, these "nuclear reactors, which only ran half-marathons during their youth, are being asked to run full marathons in their old age."

Producing one kWh of electricity from coal emits nearly a kilogram of carbon dioxide. While it is true that, once built, a reactor can produce electricity without generating a coal-plant's CO_2, it is also true that wind power and cogeneration are 1.5 times more cost-effective at displacing a coal plant's CO_2. Efficiency is an even better bet, beating nuclear by a ten-to-one margin, coming in at one to three cents per kWh. Investing a dollar in a new nuclear plant rather than efficiency improvements would have a worse effect on climate than spending the same dollar on a new coal plant.

Some industries (like the electronics and information technology sector) evolve rapidly, with impressive rates of innovation and remarkable profitability. Some industries (like the Detroit auto industry) go through long periods of technological stagnation. The nuclear industry, with its cumbersome scale, its daunting hazards, its inability to control construction costs and its profound unprofitability (sans massive taxpayer subsidies) has evolved only haltingly. In December 2010, the U.S. Energy Information Administration increased the estimated cost for constructing a nuclear plant by 37 percent. By contrast, the agile renewables industries of wind power, solar, and biomass have been leaping ahead, surpassing not only nuclear but also natural-gas turbines and other old technologies.

At present, the fuel rods that power nuclear reactors don't even last as long as a compact fluorescent light bulb—they burn out after two to three years, becoming intensely radioactive waste that needs to be safely stored for tens of thousands of years. But the nuclear industry has promised a new generation of "greener and safer" reactors. Instead of relying on mechanical pumps and manual safety controls, some of these new designs would trust "natural forces" like gravity and convection to safeguard reactors without human intervention. Engineers claim massive reactors like the 1,150 MW Westinghouse-designed AP1000 would produce 10 percent less radioactive wastes.[55] Even if true, this is not an impressive reduction. But the AP1000 and smaller reactors like the 25-MW Hyperion only exist on paper. And there's and additional problem: these new-generation reactors would produce plutonium as a byproduct, making it easier for countries with state-of-the-art power plants to also start making state-of-the-art atomic bombs.[56]

While nuclear power advocates stress the importance of gaining independence from costly foreign oil, the nuclear industry relies on ten mines in six countries to supply 85% of the world's mined uranium. The U.S. imports around 60% of its uranium (mostly from Canada and Kazahkstan).[57] The world annually mines between 36,000-60,000 tons of uranium[58] but this is barely enough to supply existing commercial and military reactors. Uranium, like oil, is finite: as supplies diminish, costs will rise. Since 2005, the price of mined uranium has soared from $12 to $45 a pound.[59] With fewer than 5.5 million tons of recoverable uranium worldwide[60] (and 2009 consumption running around 67,000 tons), uranium reserves are not expected to last much beyond 70 years.[61] Building more reactors would only accelerate the depletion of the world's limited uranium supplies.

Even now, the only way the U.S. is able to power existing reactors is by relying on "secondary sources"—reprocessing spent fuel, recycling plutonium and re-enriching depleted uranium. Surprisingly, nuclear disarmament treaties turn out to be another part of the bailout infrastructure since they were intentionally written to allow the U.S. and Russia to use old nuclear weapons as a fuel source. Many warheads contain highly enriched U-235 and some contain plutonium-239 (which can be used in mixed-oxide reactors). Since 2000, 30 tons of decommissioned warheads have been "diluted" and used to produce around 10,600 tons of uranium oxide per year—accounting for about 13% of the world's reactor fuel.[62]

As uranium stocks are depleted, light-water reactors will need to be replaced by plutonium-fueled systems supported by breeder reactors and reprocessing.[63] But breeder technology and fuel reprocessing produce such massive volumes of toxic byproducts that the U.S. and Germany have abandoned their fast-breeder plans. Even the celebrated French Superphénix breeder reactor was shut in 1998 after numerous technical problems and an investment of $10.5 billion. The Superphénix is now known as "the grand failure."[64]

All three U.S. reprocessing plants have been shut down. Britain's $2.6 billion Thorp reprocessing site at Sellafield was set to close in 2010 but, as of March 2011, Sellafield was reportedly still dumping eight million liters of nuclear waste into the Irish Sea—every day. (Sellafield, which was shut for repairs in 2005 following the disappearance of 20 tons of high-level radioactive wastes, has been called a "white elephant" that never operated properly.) Some 100 tons of plutonium will remain after Sellafield closes. (A February 2011 report by the Norwegian Radiation Protection Association warned that an accident at the Sellafield storage site could expose Norway to seven times more radioactive fallout than rained down after the Chernobyl explosion.) This leaves only one commercial plant capable of reprocessing spent fuel—the facility at La Hague, France.[65]

Nuclear advocates love to belittle wind and solar energy as unreliable—susceptible to the vagaries of sunbeams, clouds and unpredictable breezes—but performance records show that, between 2003-2007, U.S. nuclear plants were shut down 10.6% of the time while the failure rate for solar stations and wind farms was typically around 1-2%. [66] Meanwhile, the nuclear power industry suffers from the opposite problem: once started, a chain reaction is difficult to stop. Forced shutdowns and costly restarts put added stress on the integrity of the physical plant.[67]

Unlike a coal-fired plant, where production can be ramped up or slowed to meet power demands, a nuclear reactor spins out a constant level of electricity day in and day out. Because nuclear plants need to be operated full-time, they often "throw away" the electric energy generated during off-peak hours. Day in and day out, nuclear power plants routinely release clouds of 1,000°F steam directly into the atmosphere. According to one estimate, the waste heat from all the world's electric power plants (including coal, oil and nuclear) amounts to more than 27,000 trillion BTUs per year.[68] The added heat from a "Nuclear Renaissance" would only further fuel global warming.

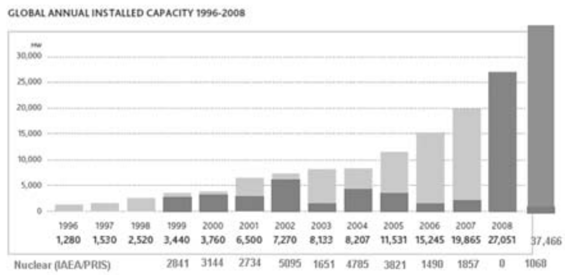
The situation was summed up by energy expert Amory Lovins who calculated that, from an efficiency standpoint, investing in nuclear power would make global warming worse since pouring money into reactors instead of renewables produces "two to ten times less climate-solution per dollar."[69]

The "Nuclear Renaissance" suffered another blow on April 19, 2011, when NRG, a New Jersey-based energy producer and its Japanese partner, Toshiba, abandoned plans to build two massive reactors in South Texas. The *New York Times* reported that the collapse of "the largest nuclear project in the United States" was due to "uncertainties created by the accident in Japan" but there was growing concern the reactors would not be competitive given the fact that Texas enjoys a large inventory of low-cost natural gas and a surplus of electricity. Nearly 8 percent of the state's electricity (620 MW) now comes from wind power. Solar installations (which grew by more than 100% in 2010) now provide Texans with 944 MW of efficient and reliable power.

BOX V
COMPARING ENERGY SYSTEMS: BEST TO WORST

STATE OF RENEWABLE ENERGY

Renewable energy gets up to speed: global wind additions



Compared with the poor performance of nuclear power (dark bars), newly installed wind energy in 2009 provided as much electricity as 12 large reactors. SOURCE: GREENPEACE

How do various energy production options stack up when they are rated not just on energy and pollution produced but also on impacts to water supplies, land use, wildlife, resource availability, thermal pollution, chemical pollution, nuclear proliferation and malnutrition? Stanford researcher Mark Z. Jacobson conducted a detailed "lifetime assessment" survey of current energy choices. The study found that wind, central solar, geothermal, tidal, photovoltaic, wave and hydro can best power the country's transportation, residential, industrial and commercial needs while addressing global warming, air pollution and energy security. Wind is two to six orders of magnitude safer than any other energy source. It causes the least wildlife loss and the lowest human mortality. Replacing oil-burning cars with wind-powered electric vehicles could cut U.S. CO_2 emissions by 32.5-32.7 percent and prevent 15,000 annual deaths linked to exhaust pollution.

Lifecycle Assessments—Best to Worst

(Note: "g CO_2e kWh^{-1}" refers to grams of carbon-dioxide-equivalent per kilowatt-hour.)

Wind

Emissions: 2.8-7.4 g CO_2e kWh^{-1}
Operational lifetime: 30-years
Cents per kWh: 8.55
Time to completion: 2-5 years
Energy payback time: 1.6 months

Concentrated Solar

Emissions: 8.5-11.3 g CO_2e kWh^{-1}
Operational lifetime: 40 years
Cents per kWh: 12.65
Time to completion: 2-5 years
Energy payback time: 5-6.7 months

Solar Panels
Emissions: 19-59 g CO_2e kWh^{-1} — Time to completion: 2-5 years
Operational lifetime: 30 years — Energy payback time: 1-3.5 years
Cents per kWh: 30.00

Wave
Emissions: 21.7 g CO_2e kWh^{-1} — Time to completion: 2-5 years
Operational lifetime: 15 years — Energy payback time: 1 year
Cents per kWh: 12.00

Hydroelectric
Emissions: 17-22 g CO_2e kWh^{-1} — Time to completion: 8-16 years
Operational lifetime: 50-100 years — Energy payback time: 5-8 years
Cents per kWh: 10.53

Geothermal
Emissions 15 g CO_2e kWh^{-1} — Time to completion: 2-3 years
Operational lifetime: 35 years — Cents per kWh: 10.18

Nuclear
Emissions: 9-70 g CO_2e kWh^{-1} — Time to completion: 10-19 years
Operational lifetime: 40 years — Energy payback time: 15 years
Cost per kWh: 15.316

Coal
Emissions: 790-1020 g CO_2e kWh^{-1} — Time to completion: 5-8 years
Operational lifetime: 5-30 — Cents per kWh: 10.55

Coal (with CCS)
Emissions: 255-440 g CO_2e kWh^{-1} — Time to completion: 6-11 years
Operational lifetime: 35 years — Cents per kWh: 17.32
(Note: Adding CCS consumes 14-25% more energy.)

Sources: "Review of Solutions to Global Warming, Air Pollution, and Energy Security," Mark Z. Jacobson, *Energy & Environmental Science*, 2009, 2, 148-173. Costs: California Energy Commission, 2008. Solar panel costs: *National Geographic*, March 2009. Wave power costs: U.S. Federal Regulatory Commission, 2007. Note: costs are approximations and are subject to change depending on such variables as time, technology, resource availability and economic conditions.

FOUR

EXTRAVAGANT COSTS

EG&G

When Three Mile Island's Unit 2 reactor started operation on December 28, 1978, it was hailed as a state-of-the-art nuclear facility. Three months later, the $900 million power plant turned into a multi-billion-dollar liability in a matter of hours.

Between 1950 and 1990, U.S. taxpayers and utilities spent $492 billion on the "direct" costs of nuclear power.[70] Yet, by the 1980s (30 years after the industry received its first taxpayer handout), nuclear reactors were only producing enough power to provide 11% of the country's electricity.[71] Between the early 1970s and mid-1980s, inflation-adjusted capital costs of new plants rose an average of 14 percent each year. Nuclear plants finished in the mid-1980s cost 20 times as much as reactors built in the early 1970s (a six-fold increase when adjusted for inflation).[72] In 2002, the cost of each new reactor was set at $2.3 billion. By 2006, the cost had grown to nearly $4 billion. Nuclear electricity from new plants is at least 2-4 times more expensive than the cost of simply improving end-use efficiency.[73] Even investment guru Warren Buffett backed out of a nuclear power project, saying: "It does not make economic sense."

In 2004, Constellation Energy (CE) believed they could build a new reactor in Maryland for $2-$2.5 billion but, by the summer of 2008, the estimated cost had ballooned to $9.6 billion. (The actual overall costs are likely to reach $13-15 billion.)[74] CE partnered with France's Electricité de France to form UniStar Nuclear Energy. After spending $600 million between mid-2007 and mid-2010, CE saw a taxpayer bailout as essential. On July 28, the CE's CEO warned investors: "We can't keep going at the rate we're going…without the loan guarantee."[75]

In 2005, George W. Bush added $12 billion in direct nuclear subsidies to the government's energy bill. By 2007, however, due to soaring costs, the $18.5 billion in loans Congress authorized to build *six new power plants were only sufficient to cover construction of two reactors.*[76] *In February 2010, President Obama outdid Bush, asking Congress for $36 billion—double the Bush bailout—to subsidize additional nuclear construction loans.*

The nuclear lobby suffered a stunning defeat in December 2010. In the closing days of Congress's lame-duck session, President Obama tried to tuck an $8 billion nuclear bailout into his Omnibus Budget plan. After angry environmentalists and taxpayers flooded the White House and Congress with 15,000 calls and letters, the nuclear "earmark" was clipped from the budget. "Once again," said Michael Mariotte of the Nuclear Information and Resource Service, "taxpayers have been spared the expense of bailing out the wealthy, multinational nuclear power industry."

Although this stands as another defeat for an industry that has spent $640 million lobbying Washington for handouts, Mariotte predicts "the nuclear lobbyists will be back [in the new Congress], hat-in-hand, even while distributing campaign checks to their allies." The bailout battle is set to rage anew as the new majority in the 112th Congress struggles to match its pro-growth philosophy with its spending-cuts rhetoric.

The lynchpin of the Nuclear Renaissance is the American Power Act, introduced by Senators John Kerry and Joe Lieberman on May 12, 2010. In addition to tripling nuclear loan guarantees to $54 billion, the draft version of the APA would grant the nuclear lobby a basketful of perks that would: expand taxpayer-backed "risk insurance" to $6 billion; provide hundreds of millions of dollars in accelerated depreciation write-offs for each reactor; make nuclear construction eligible for Advanced Energy Manufacturing Tax Credits; offer $2 billion in production tax credits; suspend import duties on nuclear components (the largest, costliest components must be manufactured in France and Japan); eliminate the NRC's power to prevent activation of new reactors over questions of fundamental safety; allow inspections and tests to be done during construction (rather than after the reactor is completed); provide an "expedited procedure" for licensing the construction and operation of new reactors and; eliminate the mandatory hearings that currently allow public comment prior to the licensing of new reactors.

There is only one precondition to obtaining a government-backed loan: a power company must obtain an NRC license. But as Physicians for Social Responsibility notes, obtaining a license is merely an expedient formality: "On the last round of reactor construction, over 100 reactors were cancelled after getting a license." [77]

The latest estimates for generating nuclear power run as high as 30 cents per kWh. This is far higher than the costs of more readily available renewable technologies and ten times the cost of energy efficiency measures[78] that can be realized for as little as 1-3 cents per kWh.[79] So-called "negawatts" (the energy saved through efficiency upgrades) can easily accomplish greater reductions in greenhouse gas emissions —and at a much quicker pace.[80]

Because nuclear reactors can cost billions to build, they cannot be constructed without massive government subsidies. If Adam Smith's "free market" had been in force, the atom-smiths of the private sector would never have built a single reactor. The nuclear industry is the offspring of federal excess and taxpayer largesse, a classic example of an economic system that might well be called "subsidism." Coal and nuclear plants receive bountiful subsidies, estimated at $250-300 billion a year worldwide. Eliminating these subsidies would level the playing field, reveal the true costs of these technologies, and speed the necessary transition to more economically attractive renewables.[81]

The estimated cost for building two reactors in Matagorda County, Texas, has soared from $5 billion to more than $18 billion. (The South Texas Project was nearly $4 billion over budget by October 2009 and construction had not even started.)[82] Estimated costs for building two new reactors at Turkey Point in Florida range as high as $24.3 billion.[83]

The nuclear lobby tried to insert $50 billion in loan guarantees into the 2009 federal stimulus package to design new Generation IV reactors. That give-away was stripped from the bill after widespread protests but pro-nuke proponents quickly responded with another attempt (the fourth in two years) to grab billions in nuclear pork from taxpayers' pockets. Lamar Alexander (R-TN) of the Senate Environment Committee hoped to include $50 billion in taxpayer loan guarantees to build 100 new reactors in the next 20 years as part of the Senate Energy Bill's "Clean Energy Development Administration."[84] Another attempt was made to include a nuclear bailout in a bill to aid "small business" and, in May 2010, the White House, in a closed-door maneuver, attempted to tuck $9 billion into the Afghanistan war appropriations bill to bail out the foundering South Texas nuclear project. [85]

Nuclear power has supporters on both sides of the aisle. Under legislation sponsored by two Democrats, Senate Energy Committee Chair Jeff Bingaman (D-NM) and Rep. Jay Inslee (D-WA), a "Clean Energy Bank" would be authorized to grant "unlimited" taxpayer loan guarantees to build new reactors.[86] In January 2010, Sen. Bingaman upped the ante by proposing a Clean Energy Development Administration that would promote "safe" nuclear power and "clean" coal.[87]

In February 2010, President Barack Obama proposed an $8.3 billion loan guarantee to build two AP1000 reactors in Burke, Georgia. These reactors (the first to be built in the U.S. in 30 years) would be run by the Southern Company, a private energy firm with nearly $16 billion in operating revenues.[88] The Southern Company announced its acceptance of the loans on June 18, 2010 but the terms of the guarantees remain secret. Both reactors will be built by Toshiba. Meanwhile, the DOE is pondering more loan guarantees to build reactors in Maryland, South Carolina and Texas.

Taxpayer-backed nuclear loan guarantees are promoted as a means to create U.S. jobs but the truth is that all of the 18 currently pending U.S. reactors would be designed and built by Toshiba and AREVA and the high-paid engineering and construction jobs would go to workers in Japan and France. The bailouts planned for Maryland's Calvert Cliffs Unit 3 and South Texas Units 3 and 4 would mainly benefit Japanese and French nuclear companies. As the Nuclear Information and Resource Service notes: "If American taxpayers were upset about bailing out U.S. banks and car companies, they should be furious about being put at risk in order to fatten the bottom line of overseas nuclear companies." (In another taxpayer-giveaway to these foreign corporations, the DOE announced in May 2010 that a $2 billion loan guarantee would be provided to France's AREVA to build a uranium enrichment facility in Idaho.)[89]

The total cost to taxpayers of these Nuclear Renaissance loan guarantees could hit $1.6 trillion.[90] During the 2008 presidential race, Sen. John McCain called for building 45 new nukes by 2030. Factoring in the industry's potential for 250% cost overruns, that could cost more than $1 trillion, with taxpayers taking a hit for billions of dollars worth of tax breaks, subsidies, loan guarantees, insurance breaks and bailouts if the builders default.

The actual cost of constructing a nuclear reactor can be many times the initial estimate. While the nuclear industry cites construction costs of about $2,000 per installed kilowatt (kW), out in the real world, Florida Power & Light has tagged the cost for building its two new Turkey Point units at $8,000 per installed kW. [91] The Energy Information Agency found that the average construction cost for 75 U.S. reactors—originally estimated at $45 billion—had ballooned by more than 300% to $145 billion.[92] Very few U.S. commercial reactors have proven profitable[93] and even with federal support, any utility embarking on the nuclear path risks facing a lowered credit rating since cost overruns remain the norm.[94] In January 2011, in an attempt to reduce the financial burden of nuclear power, North Carolina's Duke Energy and Progress Energy announced a planned merger to help finance three nuclear plants. (On a parallel track, the utilities are continuing to seek new laws to shift financial risk onto customers and taxpayers.) Moody's Investor Service called the merger plan "a 'bet-the-farm' type of project."

No nuclear plant has ever been completed on budget.[95] (One of the most embarrassing cost overruns occurred when the seismic supports for California's Diablo Canyon reactor were installed backwards and upside down. Even worse, New York's Shoreham plant went ten times over budget and never even opened.)[96] U.S. utilities stopped ordering reactors when it became clear that nuclear power's business risks and costs were excessive. The industry's "Generation IV" reactors rely on designs that have never been built or tested. Even with federal loans, these new reactors still would rank among the costliest private projects ever undertaken.[97]

There wouldn't be any talk of a "Nuclear Renaissance" had it not been for the Bush/Cheney Administration, which arranged a massive new handout in 2005. There had been no new nuclear orders in the U.S. for three decades, but Bush's 2005 Energy Policy Act (EPACT) aimed to change that by providing $10 billion over 23 years to jump-start a nuclear revival. The IRS also offered $1 billion in yearly tax credits to any company that (1) filed a licensing request by the end of 2008, (2) began construction by 2014 and (3) received an NRC certification to put its plant in service by 2021.[98] EPACT also offered nuclear operators a credit of 1.8 cents per kWh for first eight years of operation, loan guarantees of up to 80% of the cost of building new reactors, and $1.8 billion for research and construction of "advanced" reactors.

The Price-Anderson Bailout

One of Washington's biggest-ever handouts to private industry was the 1957 Price-Anderson Act, which provides "limited liability protection" to power plant operators. This subsidy is worth several billion dollars annually.[99] Without Price-Anderson, the utilities would have been forced to purchase expensive liability insurance that would have raised the cost of nuclear electricity to prohibitive levels.[100] Federal estimates have placed the potential cost of a "non-worst-case" accident at $500 billion. [101] Bush's EPACT extended Price-Anderson liability exemptions through 2025, added up to $2 billion to reimburse owners for licensing delays caused by legal challenges over plant safety, allocated $1.1 billion for fusion energy research, and provided another $1.3 billion toward future decommissioning costs.[102] Following the September 11 attacks, U.S. nuclear insurers raised premiums on U.S. reactors by 30%. In 2001, the Price-Anderson subsidy was estimated to be around $32 million per reactor. Although U.S. taxpayers would bear the major costs in the aftermath of a nuclear accident, they have no say in the reactor permitting process.

As author and anti-nuclear activist Harvey Wasserman recently noted: "If there is a warning light [for nuclear insurance bailouts], it is the Deepwater Horizon disaster, which much of the oil industry said was 'impossible.' Then it happened. The $75 million liability limit protecting BP should be ample warning that any technology with a legal liability limit (like nuclear power) cannot be tolerated." [103]

When Price-Anderson was first introduced, electricity was provided by regulated monopoly utilities subject to state and federal oversight. The proposed new reactors, however, would be built by independent power producers ("Exempt Wholesale Generators") that have no obligation to serve the public or submit to oversight by state utility commissions.[104]

Under President George W. Bush, the FY2009 U.S. budget included $1.419 billion for programs to support the nuclear industry, including $301.5 million for an Advanced Fuel Cycle Initiative reprocessing plant and another $487 million for building a Mixed Oxide Fuel Fabrication Facility—as well as more money for Generation IV reactors and the Nuclear Hydrogen Initiative, which would use the heat from Gen-IV reactors to produce hydrogen for fuel. In 2011, despite his "world without nuclear weapons" rhetoric, President Barack Obama's FY2011 nuclear weapons budget request is larger, in real terms, than Bush's. Obama has proposed increasing the weapons budget 9.8%—to $7.01 billion—to support a nuclear stockpile that is supposed to be shrinking. The Department of Energy's FY2011 budget request for nuclear power stands at $912 million—more than the DOE's request for solar, wind, geothermal, biomass and hydrogen technology combined. FY2011 calls for $56 billion in loan guarantees to build nuclear plants but only $3-$5 billion to support clean energy projects.

Meanwhile, the ongoing global economic meltdown promises to turn nuclear reactors into (quite literally) "toxic assets"—for utilities, investors and taxpayers. In June 2008, Moody's Investor Services Global Credit Research warned that new "nuclear plant construction poses risks" to the credit rating of power utilities, which could see a 30% deterioration in "cash-flow-related credit metrics." Even without the substantial costs of delivering electric power to customers, the expense of fueling, operating and maintaining a new reactor continues to hover around 25-30 cents per kWh.[105]

This crushing disadvantage is worsened by comparison with burgeoning renewable energy sources such as solar and wind, which are inherently decentralized and thus have lower distribution costs. Even if a new nuclear plant could produce power at 15 cents per kWh, this would still be 50% higher than the national average utilities currently charge their residential customers. To pay for such costs, customer rates would have to rise drastically—as they already have for some nuclear-powered utilities. (One reason Georgia may have been selected for a federal subsidy to build the first new nuclear plants is that Georgia law puts customers on the hook to pay reactor construction costs—even if no power is ever actually generated.)

High costs are not a U.S. monopoly. In India, the average cost for building the country's last ten reactors soared three times over budget.[106] Some reactor construction costs are due to the fact that the huge containment vessels must be imported from Japan, the only country with a steel industry robust enough to tackle the chore.[107] In order to finance construction of these pricy power plants, many countries have become indebted to multinational firms like British Nuclear Fuels, CoGEMA, General Electric, Mitsubishi, Siemens and Westinghouse. The Philippines wound up paying the U.S. Export-Import Bank $155,000 a day in interest for the Bataan nuclear facility, a $2.3 billion atomic power plant that took eight years to build, racked up a list of more than 4,000 defects[108] and never went operational.[109]

In 2009, as many as 22 of the 45 reactors currently under construction were behind schedule.[110] In Finland, AREVA's supposedly vanguard Okiluoto project is four years behind schedule and at least $3 billion over its projected $4.2 billion budget.[111] AREVA's design for "the most powerful reactor ever built," was touted as assuring faster and cheaper construction. Such "new generation" nukes were supposed to help revive nuclear power but this prospect seems even less likely now that cracks have turned up in critical components in AREVA's "advanced" reactor facility in Flamanville, France (which is also 25% over budget and behind schedule).[112] In early 2009, AREVA asked for $4 billion in short-term bailout money. AREVA also needs another $3 billion to buy back shares in a German reactor project after Siemens withdrew from the joint venture.[113] Meanwhile, Atomic Energy of Canada, once seen as the nuclear industry's flagship organization, burned through $1.64 billion Canadian tax dollars in 2008 and, in 2009, the conservative government announced plans to sell its nuclear white elephant.

Decline and Decommissioning

If nuclear reactors are costly to build and run, that's nothing compared to the financial impact when they fail. Dealing with the lasting damage of the Chernobyl disaster will have cost Ukraine an estimated $170 billion by 2015.[114] Of course, even when nuclear plants are operating properly, they generate radioactive wastes that need to be securely stored for thousands of years. Because of this, nuclear power's economic deficiencies will plague the world's economies long after individual plants are finally shut down.

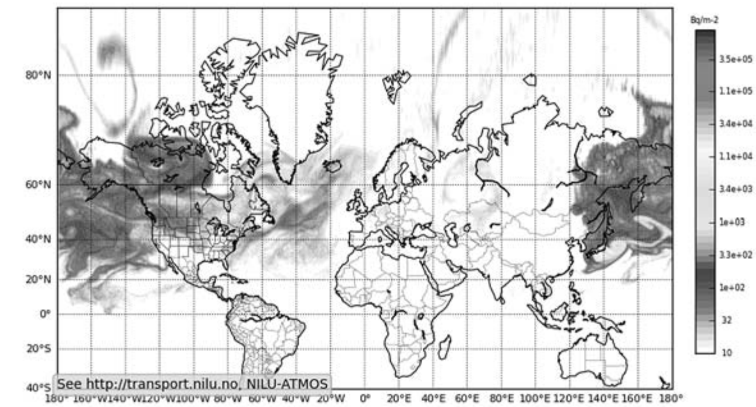
There are three ways (all expensive) to decommission a nuclear plant: "Immediate decommissioning" takes six to eight years; "mothballing" spreads the decommissioning over a 60-year period; "entombment" (the quickest) buries the reactor site under concrete. Eleven U.S. reactors have been decommissioned and two more are in the process of being closed. Most have been mothballed; none have been "immediately decommissioned." The cost of decommissioning ranges between $655 million and $1 billion per reactor, so the total obligation for the U.S.'s 104 reactors alone could top $100 billion.[115] Trust funds were created to pay for eventual decommissioning in the U.S. but the Wall Street meltdown devastated many of these accounts, making proper decommissioning highly unlikely.[116,117]

Neither nuclear nor coal offer any hope for the planet's 2 billion people who remain without access to electricity. In 1988, the United Nations estimated it would cost as much as $46,000 per kilowatt to build transmission lines to all the Earth's 2 million remote villages (that's $83,674 in 2010 dollars).[118] In such situations, renewable technologies offer a cheap, quick and readily available solution.[119] The cost of a 1,000 MW nuclear plant is now on par with retail costs of 1,000 MW worth of solar panels.[120]

In summary, nuclear power's huge costs for construction, decommissioning and waste storage make it a doomed technology. Far from offering a technological breakthrough, the supposed "Nuclear Renaissance" is merely a renaissance in government subsidies—or more precisely, a renewed expansion of the same subsidies that have maintained the industry on life support since its inception. We have much better ways to spend that money.

FIVE

ENVIRONMENTAL IMPACTS: AIR, LAND & WATER



NORWEGIAN METEOROLOGICAL INSTITUTE

An April 20, 2011 map of cesium-133 fallout from Japan's damaged Fukushima reactors showed radiation spreading across China, Korea, the Pacific Ocean, Canada and the U.S..

Nuclear energy is not the "clean" energy its backers proclaim. For more than 50 years, nuclear energy has been quietly polluting our air, land, water and bodies—while also contributing to Global Warming through the CO_2 emissions from its construction, mining, and manufacturing operations. Every aspect of the nuclear fuel cycle—mining, milling, shipping, processing, power generation, waste disposal and storage—releases greenhouse gases, radioactive particles and toxic materials that poison the air, water and land. Nuclear power plants routinely expel low-level radionuclides into the air in the course of daily operations. While exposure to high levels of radiation can kill within a matter of days or weeks, exposure to low levels on a prolonged basis can damage bones and tissue and result in genetic damage, crippling long-term injuries, disease and death.

Air Pollution

Whenever a nuclear accident spews an unusual amount of radiation into the local air, industry spokespeople invariably reassure the public that the release "poses no harm." But radioactive fallout, no matter how small, is not neutral and the industry knows this. There is no "safe level" of nuclear exposure: all exposure to ionizing radiation is potentially harmful.[121]

An average 1,000 MW reactor contains approximately 16 billion curies of radioactive material—the equivalent of 10,000 Hiroshima bombs.[122] Tritium, krypton, xenon-135, iodine-131 and iodine-129 (with a radioactive half-life of 16 million years) are routinely vented into the air, contaminating downwind rivers, land and residents. Tritium, a radioactive form of hydrogen, is dangerous if inhaled or ingested. It can combine with oxygen to form tritiated water molecules that can be absorbed through pores in the skin, leading to cell damage and an increased chance of cancer. The government considers these reactor releases "permissible" so no attempt is made to monitor or regulate them, even though radiation exposure is known to damage human cells and cause cancer, leukemia, birth defects and genetic mutations.

Around the world, nuclear workers, their families and people living near nuclear facilities suffer elevated risks of birth defects, immune system damage and cancer.[123] Radiation exposure is a proven cause of prostate and lung cancer.[124] And genetic damage imposed by radiation exposure is passed on from one generation to the next.

We will never know how many people have died as a result of fallout from atmospheric nuclear bomb tests, the Chernobyl or Fukushima disasters, or the accidents at the British reprocessing facility at Windscale that released radiation worldwide. One Indian researcher has offered the astounding estimate that excess infant deaths attributable to fallout from a series of Windscale accidents in 1971-1989 may have topped 8.7 million.[125]

In the 1980s, the cancer rate for young people in Michigan's Monroe County was below the state average. After the Fermi II nuclear plant began operating in 1988, the cancer rate for people under the age of 25 living near the plant rose to more than triple the state average. Although radioactive iodine has been found in the milk of cows grazing downwind from Fermi II, Michigan's DTE Energy has applied to build a new reactor. While neither the plant operators nor the NRC are required to monitor cancer rates around nuclear reactors,[126] Michigan residents living within ten miles of a nuclear power plant are supposed to draw some comfort from that fact that they are now eligible to receive government-issued potassium iodide anti-radiation pills to be taken "in the event of an accident." [127]

The Chernobyl explosion and fire released a cloud of radiation that the US Lawrence Livermore National Laboratory estimates to have exceeded 4.5 billion curies. Other estimates range as high as 9 billion curies. The cloud eventually spread around the world. While the International Atomic Energy Agency claims only 56 people perished as a direct result of Chernobyl's fallout, a 2010 report by the Belarus National Academy of Sciences attributed an estimated 93,000 deaths and 270,000 cancers to fallout from Chernobyl. Estimates from the Ukrainian National Commission for Radiation Protection set the death toll at 500,000. Chernobyl survivors—and their children—continue to suffer from high rates of leukemia and thyroid cancer.[128] European studies found a significant correlation between cesium exposure and prenatal mortality in "downwind" countries seven months after the Chernobyl disaster.[129]

Some 24 years after the disaster, the journal *Ecological Indicators* reports that the largest study of wildlife in the Chernobyl "exclusion zone" had found the damage of low-level radiation was not limited to vegetation and insects. Damage to birds, reptiles, amphibians and mammals was described as "overwhelming," with barn swallows showing tumors on feet, necks and around the eyes.[130] In 2009, Germany's Environment Ministry was forced to pay $550,000 to compensate hunters for wild boars that were deemed too radioactive to consume. The boars had dined on mushrooms contaminated with cesium-137 from Chernobyl. In Germany, the "safe" level for consumption is 600 becquerel-per-kilogram but these boars averaged 7,000 becquerel-per-kilogram.[131]

Around the world, cancer and leukemia rates in children living within 3.5 miles of nuclear reactors are 53% higher.[132] Children are especially vulnerable to harm from radiation and women are twice as susceptible as men. Residents of Harrisburg, the site of the Three Mile Island accident, now suffer from an increased incidence of cancers.[133]

Across the U.S., children living near nuclear power plants are dying from leukemia.[134] While leukemia deaths near newer plants were 9.4% above the U.S. average, they were even higher near older plants (13.9%). Since Entergy's Vermont Yankee nuclear plant opened in 1972, the rate of cancer deaths in Windham County has risen 5.7 percent above the national average.[135]

In France, up to 150,000 victims of French nuclear testing may finally receive compensation from their government, which had long argued that paying compensation would "pose a threat" to the government's "credible nuclear deterrent."[136] Meanwhile, Britain continues to refuse aid to its soldiers exposed during nuclear tests in the South Pacific.

From 1945 through 1962, aboveground atomic weapons tests in Nevada exposed government workers and downwind residents to direct radiation and downwind fallout. Others were exposed during work as miners, mill workers and transporters. On October 15, 1990, the Radiation Exposure Compensation Act (RECA) was enacted to compensate families that had experienced radiation-related illness and death.[137] By March 2009, the government had processed most of the 22,206 claims filed, at a cost to taxpayers of nearly $1.4 million. More than 175,000 nuclear weapons employees (or their survivors) have applied for medical care under the Energy Employees Occupational Illness Compensation Program. So far, the Department of Labor has paid out more than $4.7 billion but has only processed 50,000 of the claims.[138]

Since the dawn of atomic weapons and nuclear energy, cancer has become global and epidemic. Today more than half of the U.S. population lives within 75 miles of a nuclear reactor.[139] British and German studies have found increases of childhood leukemia in children living near nuclear power plants. U.S. Centers for Disease Control data shows two-thirds of all U.S. breast cancer deaths occur within 100 miles of the country's nuclear plants [140] but, as yet, there is no proven causal link. That could change now that the U.S. National Academy of Sciences is about to update the National Cancer Institute's 1990 survey of diseases and deaths that have occurred near nuclear plants.[141]

Water Pollution

The nuclear fuel-cycle contaminates our water as well as our air. The 104 U.S. reactors operating in 40 of the 50 states routinely discharge used coolant water into the nation's major streams, the Great Lakes, the Gulf of Mexico, and the Atlantic and Pacific Oceans.[142] While much of a reactor's coolant water is released as steam (heating the atmosphere), the remainder—heated and contaminated with radioactive isotopes—is vented back into waters where it wreaks damage on river and ocean life.[143, 144] Thermal pollution of the Hudson River from Indian Point kills more than 2 billion fish a year. The Salem Nuclear Generating Station, which swallows 3 billion gallons a day from the Delaware Bay, has caused a 31 percent reduction in bay anchovy. California's two coastal plants at San Onofre and Diablo Canyon suck in nearly a million gallons of seawater every minute to use as a free coolant.[145] San Onofre's two reactors pour 2,400 million gallons of water (heated to 19°F over ambient temperatures) into the Pacific every day. [146]

When it comes to producing electricity, nuclear is an extravagantly water-wasting technology. [147] A nuclear power station requires between 20 to 83 percent more water than any other kind of power plant. Even Westinghouse's "Generation III" AP1000 needs to consume as much as 750,000 gallons per minute to operate safely.[148]

Impacts on Land

Life on land suffers gross impacts too. By 1978, the U.S. "uranium rush" had left 140 million tons of crushed-rock tailings at 16 operating mills and 22 abandoned sites—with additional wastes piling up at an average of 6 to10 tons a year. The 1.7-million-ton tailings pile at Shiprock, New Mexico, covers 72 acres. All tailings piles release radon gas and long-lived radioactive isotopes into the air, rivers, arroyos and aquifers. Radon gas (believed responsible for a five-fold increase in lung cancer among uranium miners) continues to poison the winds blowing over abandoned piles of mining wastes that lie scattered around the world. [149]

In 1979, 94 million gallons of contaminated liquid tailings burst from a containment dam in New Mexico, sweeping 1,100 tons of radioactive wastes into the Rio Puerco River, which flows into the Little Colorado River and on to Lake Mead, a major source of drinking water for Las Vegas and Los Angeles.[150] In 1984, a flash flood flushed four tons of tailings into a tributary of the Colorado River, which provides irrigation for farms and drinking water for cities in Nevada and southern California. Less dramatic but also deadly is the imperceptibly slow, toxic seepage from tailing ponds that has steadily poisoned critical subsurface aquifers across the Colorado Plateau.[151]

The devastation to portions of America's landscape has been so vast and long-lasting that the government has no hope of ever repairing the damage. Instead, it has created a term to describe these irreparably damaged, nuclear no-man's-lands—"National Sacrifice Areas."

Despite the environmental and health damages wrought by uranium mining, there have never been any binding standards requiring operators to minimize harm to the local land or people.[152] The World Nuclear Association (a trade body representing 90% of the industry) is considering a "Charter of Ethics" but it would be voluntary and self-policed. At best, some local activist communities have been able to demand a higher price for the ore extracted from their damaged lands. In 2008, in a rare victory, the people of Niger forced the French firm AREVA to increase the price of a kilogram of uranium.

Sites storing spent nuclear fuel, high-level radioactive waste, and/or surplus plutonium destined for deologic disposition.
(dots do not reflect presise locations)

BOX VI
NUCLEAR DESALINATION?

By 2025, 3.5 billion people will face severe fresh-water shortages. Nuclear proponents groping for justifications to expand nuclear power have argued that the waste heat from power plants can provide a "cheap and clean" solution to the inherently costly process of removing salt from seawater. Desalination plants (there are 13,080 worldwide, mostly oil- and gas-fired and mostly in wealthy desert nations) already produce more than 12 billion gallons of drinkable water a day.[153] The first nuclear desalinator was installed in Japan in the late 1970s and scores of reactor-heated desalination plants are operating around the world today.

But nuclear desalination is another False Solution. The problem with atomic water-purifiers is that using heat to treat seawater is an obsolete 20th-century technology. Thermal desalination has given way to new reverse osmosis systems that are less energy intensive and 33 times cheaper to operate.[154] Nuclear desalination advocates claim that wind, solar, and wave power aren't up to the task while new low-temperature evaporation technology may be able to produce high-purity water at temperatures as low as 122° Fahrenheit.[155] Promoting reactors as a solution to the world's water shortage is especially ludicrous since nuclear power plants consume more water than any other energy source.[156]

Even proponents admit there is a potential risk that running seawater through a radioactive environment might contaminate the drinking water produced.[157] Undeterred, scientists in Russia and India have proposed anchoring small atom-powered water-plants offshore near densely populated coastal cities. But this would provide no relief for the billions of people living inland in water-starved regions of North Africa and Asia.

Desalination is merely a way of giving a marginal new purpose to existing reactors whose balance sheets would be improved if they were retrofitted with desalination chambers. As with power generation, so with desalination: efficiency in water use (better irrigation technology, crop selection, eliminating transit losses, etc.) beats new production.

A real solution to the growing global water shortage needs to address the increasing amount of water diverted to wasteful agricultural and industrial practices and concentrate on preventing the water from being contaminated in the first place—by, among other things, capping the size of local populations to match locally available water supplies.

SIX

THE DILEMMA OF RADIOACTIVE WASTES

DEPARTMENT OF ENERGY

After spending $10 billion on a vast underground vault to store nuclear waste, Washington abandoned the Yucca Mountain Repository. With a working life of only 125 years, Yucca Mountain would not have solved the industry's long-term waste disposal problem.

The nuclear industry has removed around 270,000 tons of spent fuel rods from nuclear reactors and these highly radioactive encasements continue to pile up at the rate of 12,000 tons per year.[158] *Fuel rods containing enriched uranium need to be replaced every 5.5 years, if not sooner.*[159] *Like the euphemism "depleted uranium," "spent fuel" is an intentionally deceptive term. The radioactivity levels in used rods leaving a reactor can be nearly a million times higher than when they were first installed. Spent-fuel rods are stored in 45-foot-deep concrete cooling ponds lined with lead and/or steel. Diesel-powered pumps must continuously circulate the water in these 100,000-gallon tanks. As the Fukushima disaster showed all too clearly, if the oil-fueled pumps fail and backup systems are dysfunctional, the water will boil away leaving the fuel assemblies to overheat, melt or ignite.*[160]

The average nuclear power plant creates 30 tons of high-level waste per year—and another 70 tons of low-level wastes (workers' clothing, tools and cleaning materials).[161] No proven long-term waste storage sites have yet opened. The U.S. government's showcase deep-storage site at Yucca Mountain, Nevada, was originally projected to cost $58 billion and open for business in 1998. After 30 years and an investment of $10 billion, the Obama White House has abandoned the Yucca Mountain Repository. US Department of Energy officials estimated it would have cost more than $90 billion to open and operate the dump. (Note: The White House decision is being contested in a lawsuit.)[162]

In 2010, President Obama cut funding for Yucca Mountain, due to the project's irresolvable design and environmental problems. Had Yucca Mountain opened when planned, the total operational costs (including its planned decommissioning in 2133) would have topped $96 billion.[163] With a planned working life of 125 years, Yucca Mountain wouldn't solve the long-term waste disposal problem. By law,[164] the Repository cannot store more than 70,000 metric tons but the U.S. already has accumulated 62,000 metric tons of commercial reactor waste and at least 7,000 metric tons of weapons waste.[165] In order to continue operating *current* reactors (let alone trying to build new reactors), the U.S. would first have to locate a new site and start building another Yucca Mountain-sized repository.

Without long-term storage facilities, spent fuel rods must be stored in pools or in dry-cask facilities that are only safe and affordable for less than a century.[166] The Vermont Yankee reactor, for instance, has accumulated 1,911 radioactive waste bundles in its spent-fuel pool and has another 340 bundles stashed on-site in a dry-cask storage facility. Vermont Yankee uses the same GE Mark 1 design as the reactors that failed at Fukushima—and they are the same age. In 2010, the Vermont Senate voted 26 to 4 to retire the aging nuclear plant when its license expired in 2012. Governor Peter Shumlin strongly backed retiring the plant and a 2010 survey found 68 percent of Vermonters supported the closure. Nonetheless, on March 21—ten days after the start of the Fukushima disaster—the Nuclear Regulatory Commission extended the plant's operating license by another 20 years. This marked the NRC's 63rd reactor license renewal (twelve other applications are currently under review). With no place to send high-level and low-level rad-wastes, another 20 years of operation will mean another 20 years of wastes that will need to be stored on-site—essentially forever.[167]

After 53 years of commercial nuclear power (and a half-century of government bailouts), the U.S. still has no sound plan for long-term storage of high-level radioactive wastes—a fact that leads to another costly, but little known, nuclear subsidy. Between 1983 and 1987, DOE signed contracts with U.S. power companies promising to start accepting the stored wastes from more than 100 commercial reactors beginning January 31, 1998.

When the deadline passed and DOE still had no functioning storage facility, the power companies were allowed to sue for "breach of contract." Reactor operators filed 71 lawsuits demanding compensation for the continued costs of storing their wastes on-site. By July 2009, DOE had paid out $565 million in damages to five nuclear operators. (Instead of the payments coming from the $23 billion power companies were required to contribute to the Nuclear Waste Fund, the costs are being borne directly by U.S. taxpayers.) By 2020, taxpayer liability for DOE's failure to solve industry's waste problems could top $50 billion.[168]

Despite this boondoggle, in its last three months, the Bush administration quietly signed deals with more than a dozen electric utilities that obliged the government to assume responsibility for long-term storage for nuclear wastes from 21 proposed *new* reactors. When the agreement was signed, it was already clear that the Yucca Mountain facility—even if it were to open—would not have the capacity to store an additional 21,000 metric tons of toxic wastes from 21 new reactors.

The Bush White House once again gave industry the right to sue if the government was unable to deliver on its promise to provide long-term storage. The beneficiaries were: Duke Energy, Southern Nuclear, UniStar Nuclear, Florida Power and Light, Pennsylvania Power and Light, South Carolina Electric & Gas, Progress Energy, Ameren UE, Luminant, and the South Texas Project.

Despite President Obama's promise to provide "an unprecedented level of openness in government," a shroud of secrecy covers the DOE's $51 billion loan guarantee process. Although taxpayers will bear the costs of a loan default, the public has no role in determining who gets these loans. DOE has not explained how it plans to process and approve the loans and the applicants and their proposed projects remain secret. After DOE routinely ignored numerous Freedom of Information Act requests, a coalition of environmental groups wrote Energy Secretary Steven Chu to protest DOE's "continuing refusal to disclose even the most basic information about the program." [169]

With the future of a storage facility in Germany in doubt, that leaves only two other storage sites in the works—a planned facility in Sweden and the Onkalo site in Olkiluoto, Finland. Because it is located on an island, the proposed Olkiluoto storage site may be swamped by rising seas as the planet warms. Lacking a credible disposal plan, the nuclear industry has promoted "reprocessing" as a response to the growing piles of used fuel rods.[170] A U.S. reprocessing plant would cost $15 billion (and would, most likely, be built in the vicinity of a low-income community). Traditional processing plants use nitric acid to extract plutonium —a nuclear byproduct that is more dangerous than uranium.[171]

Because only 1 percent of the "recycled" material (the plutonium) is actually usable, this creates large volumes of even more toxic leftovers.[172] Reactors powered by reprocessed plutonium are harder to control and could prove to be twice as deadly as uranium-fueled reactors in the event of an accident.[173] Instead of solving the waste problem, reprocessing actually increases the volume of radioactive garbage that needs to be stored—safely and forever.[174] Supposedly "stored" radioactive wastes have contaminated the land and sea around Britain's Sellafield reprocessing plant and France's Le Havre reprocessing facilities.[175] France has no workable plan to safely store or treat its growing nuclear wastes.[176]

Since waste disposal poses a crippling problem for any nuclear "renaissance," various alternatives to the abandoned Yucca Mountain repository are being considered. One involves new drilling techniques that could bore hundreds of barrel-sized holes five kilometers deep into stable bedrock that exists in many parts of the U.S.. In theory, this would avoid the leakage issues posed by Yucca Mountain's geology and circumvent the need to provide leak-proof canisters. Whether such schemes could be carried out successfully and economically remains speculative.

Meanwhile, the Pentagon has found its own False Solution for handling atomic weapons waste. Depleted uranium, a dense radioactive byproduct of nuclear operations, has been used to fortify the Pentagon's tanks and artillery. The Pentagon has recycled more than a billion tons of depleted uranium (DU) into armor-plated vehicles and penetrating projectiles that have been used in Kosovo, Bosnia, Iraq and Afghanistan. The ionizing radiation of DU is inherently toxic. When it burns or explodes, it becomes airborne and can be inhaled, causing lung and kidney disease, genetic damage, miscarriages, birth defects, mutations and death. The U.S. military's use of DU has caused long-lasting contamination of land, air and water and has poisoned civilians in Iraq, Serbia and Montenegro, and Kosovo.[177] With a radioactive half-life of 4.5 billion years, the DU released by the U.S. military in the Middle East, Eastern Europe and Asia will eventually drift and contaminate every region on Earth.

Radioactive contamination from the nuclear arms-building program is another persistent problem. U.S. taxpayers continue to spend about $2 billion annually in an ongoing attempt to clean up the wastes left behind at the government's Hanford Nuclear Reservation in Richland, Washington. The long-term cleanup of nuclear superfund sites in South Carolina, Idaho, New York, and Washington State drains billions of dollars from the U.S. Treasury every year, a nagging reminder that nuclear does *not* mean "green."

Finally, there is the military's legacy of aboveground and underground nuclear weapons tests that have shaken and seared native lands around the globe, leaving large swaths of Australia's outback, the South

Pacific's atolls, China's western provinces, Russia's eastern regions and America's southwest cratered and poisoned by more than 2,000 atomic blasts.[178]

Approximately 5,000 natural and artificial radionuclides have been identified, each with a different half-life (i.e., the time required for the initial amount of radioactivity to decrease by one-half). The half-life of a radionuclide can range from 1.07 seconds (for sodium-26) to 4.47 billion years (for uranium-238). Plutonium-239 has a half-life of 22,000 years.[179] The Yucca Mountain nuclear waste disposal site was to have secured 77,000 tons of hazardous radioactive materials from 110 U.S. commercial power plants.

The Yucca Mountain facility was only designed to operate until 2133—at a cost topping $99 billion (in 2011 dollars). Looking to the long term, EPA's "radiation protection standard" for people in the vicinity of Yucca Mountain was set at 15 millirem-per-year for the first 10,000 years (and 100 millirem-per-year thereafter). EPA estimated the100-millirem exposure (equal to about 1,700 chest X-rays) would produce an extra cancer in roughly every hundredth person exposed—a cancer risk 100-10,000 times greater than EPA currently permits. This is an unconscionable legacy to inflict upon future generations.[180]

For nuclear entombment to be even moderately successful, a storage facility must remain intact for at least 10,000 years. No man-made structure has ever survived for 10,000 years (Egypt's pyramids were built around 4,500 years ago). With Yucca Mountain's fate uncertain, the world's only permanent nuclear waste repository still under construction is located 186 miles northwest of Helskini.

Work on Onkalo (the Finnish word for "Hidden") began in 1972 and will not be completed until sometime in the 22nd Century. When (and if) it is completed a century from now, Onkalo would only have room for Finland's nuclear wastes—about one percent of the world's growing stockpile of radioactive garbage, now estimated at between 250,000 to 300,000 tons. The waste would be stored in two-inch-thick copper containers interred 1,600 feet deep in bedrock that has remained stable for 1.8 billion years. The facility was engineered to withstand the weight of a two-mile-thick layer of ice that is expected to accumulate during the next Ice Age.

Onkalo is intended to remain secure for 100,000 years. That's about as long as humans have walked the Earth—3,000 generations. This radioactive graveyard may become the single lasting legacy of our times. In 10,000 years (let alone 100,000), Beethoven's sonatas, Picasso's paintings, Rumi's poems and most modern languages may likely be long forgotten. The only artifact of our civilization that is guaranteed to outlast the centuries is a graveyard of toxic trash buried in Finland's crystalline gneiss bedrock—and around 300,000 tons of radioactive wastes left untended in crumbling surface storage sites around the world.

SEVEN

DAMAGE TO INDIGENOUS PEOPLES

Hundreds of Native American uranium miners died from "red lung" disease. The government was aware of the dangers but withheld the information from the workers.

Bringing power to the cities of the industrialized world has often brought destruction to the lands of Indigenous cultures around the planet. There are uranium mines in more than 25 countries and 100 or more new mines are planned. More than half of the world's uranium comes from mines in Canada, Australia and Kazakhstan. Seven companies mine most of the world's uranium [181] and 70% of this uranium is mined on lands held sacred by Indigenous peoples. Native lands have provided both the raw uranium ore and, more often than not, the final resting place of hazardous radioactive wastes. Producing a ton of uranium fuel can leave behind 20,000 tons of waste rock and more than 4,000 tons of toxic tailings salted with elements that remain deadly for hundreds of thousands of years. Tailings, which can contain 85% of the ore's original radioactivity, release alpha particles from thorium-230, lead-210, polonium-210 and radium-226. The radon gas released by tailing piles can travel 1,000 miles in a day.[182]

The uranium that powered the Cold War era was largely extracted from the yellow dirt of the Colorado Plateau by Navajo, Acoma and Laguna miners of the Four Corners region. Working in unventilated shafts as deep as 2,700 feet underground and exposed to radiation levels 750 times the lax safety standards of the 1950s, these native miners, mill workers, truckers and their families suffered from the consequences of "red lung" disease—lung cancer, pulmonary fibrosis, kidney damage and birth defects. Dine (Navajo) miners who toiled to pull ore from sacred lands in America's Southwest now suffer from lung cancer rates 40 times greater than those found in the general population.[183] It is a sad matter of record that more than 600 Native American uranium miners met early deaths after they were sent to excavate deadly ore by a government that knew the dangers and withheld the information. These workers paid "the ultimate sacrifice," yet there is no national monument to their memory—nor to the legions of other citizens whose lives were cut short or ruined by nuclear contamination.

The EPA has established radiation emission limits for waste sites in the U.S. and monitors those sites but, in most less-developed countries, tailings are simply dumped and abandoned.[184] While the cost of properly securing these waste sites could be as high as the cost of the uranium itself, the expense of handling the uranium waste produced during the enrichment process may be even greater.[185]

Dumping on Native Lands

Having exploited Native lands and poisoned Native lives, the nuclear waste-makers now want to turn Native lands into nuclear waste dumps. Some 17 of 20 potential sites identified for federal interim storage of high-level waste were located on Native American tribal holdings. Among those initially targeted for "repositories" were lands of the Mescalero Apaches in New Mexico and the Skull Valley Band of Goshutes in Utah. Both were proposed as "National Sacrifice Areas" suitable for the government's defunct Monitored Retrievable Storage of radioactive waste. Canada has chosen to store its high-level waste on Cree and Dene lands in Saskatchewan. The controversial U.S. repository at Yucca Mountain occupies land held sacred by the Western Shoshone. Native activists argue that these dumpsites violate promises contained in the 1863 Treaty of Ruby Valley.[186]

Canada dominates Africa's uranium trade, with operations in 35 countries. Canada's Xemplar Energy Corporation holds an exclusive license to explore for uranium in Namibia's ecologically fragile Namib Naukluft Park, home to rare plant and animal life. Mining operations could devastate 80 percent of desert homeland of Namibia's Nama and Topnaar peoples.[187] Namibia is Africa's top uranium producer, followed by Niger. The open-cast mining process has irrevocably destroyed vast stretches of Namibian deserts. While the Topnaar have been told they are no longer permitted to hunt for food or harvest melons in Namib Naukluft Park, Canadian geologists are free to scavenge the park for uranium ore.

Uranium tailings dumped in the deserts of Namibia and Niger poison the food and water used by nomadic tribes. The desert-dwelling Tuareg people of Mali and Niger are also imperiled by uranium mining, which has led to depletion of scarce water supplies and contaminated traditional grazing lands. When the Tuaregs' complaints became too militant, the government responded by labeling them "terrorists."[188]

Australia's Commonwealth Radioactive Waste Management Act allows the government to dump nuclear waste on Aboriginal land without consultation or consent. Australia's new government not only failed to act on a campaign promise to repeal this act, it now plans to expand a Northern Territory nuclear dump located on traditional Aboriginal lands and plans to enlarge uranium mines in South Australia and the Northern Territories. At the same time, the West Australian and Queensland governments continue to call for a ban on uranium mining.

The daily extraction of up to 11 million gallons of water to supply Australia's Roxby Downs mine[189] has destroyed the ancient Mound Springs on native Arabunna land. Pollution from the Ranger mine has poisoned the wetlands in Kakadu. Australia's Environment Minister Peter Garrett has approved expansion of the Beverly mine, despite the fact that the facility has polluted groundwater on traditional Adnyamathanha land.[190] The Olympic Dam mine at Roxby Downs is largely exempt from Australian law, Aboriginal land rights legislation, environmental protection and freedom-of-information requirements. The owner, BHP Billiton, pays nothing for the 33 million liters of water extracted from the Great Artesian Basin every day.[191] Significantly, when the United Nations voted 144 to 4 in favor of the UN Declaration on the Rights of Indigenous Peoples, the four negative votes were cast by Australia, Canada, New Zealand and the United States—none of whom apparently wanted to face the prospect of newly empowered Indigenous nations.

Uranium mining has left a legacy of uncompensated contamination and health problems across Africa,[192] Australia and North America. Residents of Tibet have been subjected to the risks of exposure from Chinese-run uranium mines and waste dumps. Uranium mining and milling has polluted major fisheries in northern Saskatchewan. The uranium mines near Canada's Elliot Lake in Ontario once provided material for U.S. nuclear weapons. Sixty years later, the area remains radioactive and will not sustain agriculture, further damaging the lives of the local Northern Ojibwe peoples.[193]

Meanwhile, in the deserts of the southwest U.S., talk of a supposed "Nuclear Renaissance" has triggered a modern land rush to open new uranium mines. Foreign mining firms have filed 1,100 claims within five miles of the Grand Canyon National Park. If these mining permits are allowed, the park's air and the waters of the Colorado River would be at risk from radioactive pollutants and toxic releases of mercury, arsenic, cyanide and selenium. A Grand Canyon uranium mine that was closed in 1969 is still producing radiation levels 450 times normal, creating a radioactive "no-go zone" inside the park.[194]

The region's long-suffering native peoples, along with their sacred lands, deserve better. It is time for Australia, Canada, New Zealand and the United States to join the rest of the world community in ratifying—and respecting—the UN Declaration on Indigenous Rights.

EIGHT

NUCLEAR WEAPONS PROLIFERATION

The "Godfathers" of nuclear energy—Army Major General Leslie Groves and the Manhattan Project's J. Robert Oppenheimer. The "civilian" nuclear energy program helped provide plutonium for America's nuclear arsenal. In 2000 alone, civilian reactors produced enough plutonium to make more than 34,000 nuclear bombs.

Despite generations of glowing publicity about "safe, clean electricity" and the "peaceful atom," the nuclear industry remains fatally intertwined with nuclear weapons proliferation. In the 1950s, the Pentagon called for the creation of a "civilian" nuclear energy program to fill a plutonium shortage that was slowing the production of nuclear weapons.[195] *Dwight Eisenhower's Atoms for Peace program directly promoted nuclear weapons programs in India, Israel and Pakistan.*[196] *The linked nature of nuclear energy and nuclear weapons was underscored with the revelation that Abdul Qadeer Khan, "the father of Pakistan's atomic bomb," obtained his blueprints for a uranium enrichment centrifuge from URENCO, a Dutch nuclear-power company. (Khan later sold these designs to other countries, including Libya.) The enduring unity of the Military-Nuclear-Industrial Complex was further underscored when AREVA, France's cash-strapped nuclear firm, announced plans to build reactor equipment in Virginia with a new partner—U.S. arms manufacturer Northrop Grumman.*[197]

Every country with a nuclear power reactor has access to the materials needed to produce nuclear weapons. Every country now possessing nuclear weapons (U.S., Russia, UK, France, China, India, Pakistan, Israel, North Korea) got its start building "peaceful" nuclear reactors. The link was re-emphasized in November 2010 when 17 top arms control experts from the Carter, Reagan, Clinton and Bush 1 and Bush 2 administrations called on President Obama to refuse taxpayer loan guarantees to Electricité de France and Maryland's Calvert Cliffs-3 nuclear plant until France agreed to change its lax nuclear non-proliferation policies.

Of the 42 countries now possessing fissionable material, 22 have "civilian" facilities that can separate highly enriched uranium or produce plutonium. International treaties safeguard only about 1% of the world's highly enriched uranium and only 35% of the world's plutonium. While Russia and the U.S. account for 95% of the 30,000 nuclear warheads in existence, enough refined and unrefined fissionable material exists to build another 100,000 such weapons.[198]

An average nuclear reactor produces 20-30 tons of highly radioactive spent fuel each year. Each ton of spent reactor fuel typically contains around 10 kilograms of plutonium—enough to build a primitive nuclear bomb. Any country with minimal industrial skills can build a small "quick and dirty" reprocessing plant capable of extracting a bomb's-worth of plutonium a day.[199] Spent nuclear fuel can also be turned into "dirty bombs," in which conventional explosives are used to blast radioactive material over a wide area.

The International Atomic Energy Agency (IAEA) was created to promote nuclear energy and control the proliferation of nuclear weapons. In practice, these proved to be contradictory goals since the spread of nuclear power inevitably opens the door to weapons programs.[200] One of the reasons there has been so little progress towards the disarmament goals articulated by the United Nations' Nuclear Non-proliferation Treaty is that the five permanent members of the UN Security Council—U.S., France, Great Britain, Russia and China—happen to be the world's five "declared" atomic powers.

The IAEA's shortcomings are evidenced by the fact that India, Israel, North Korea, and Pakistan have all subsequently joined the club of nuclear-armed nations. Every country with a nuclear energy program—30 have commercial power reactors and 56 operate around 250 research reactors[201]—has the potential to build nuclear weapons. Countries with present or past nuclear ambitions include: Algeria, Australia, Azerbaijan, Bangladesh, Belarus, Brazil, Chile, Egypt, Estonia, Georgia, Ghana, the Gulf States, Indonesia, Iran, Ireland, Italy, Jordan, Kazakhstan, Latvia, Libya, Malaysia, Morocco, Namibia, New Zealand, Nigeria, Norway, The Philippines, Portugal, Syria, Thailand, Tunisia, Turkey, Vietnam, Venezuela and Yemen.

More than 40 bilateral treaties allow the U.S. to sell nuclear fuel around the world—so long as all the nuclear waste is returned to the U.S. (ostensibly a weapons-proliferation-prevention strategy). The 2008 India Civilian Nuclear Agreement—a long-term cooperation arrangement between India, the U.S., and other global nuclear technology providers—envisions constructing dozens of atom-powered plants in India, a country that has refused to sign the Nuclear Non-Proliferation Treaty (NPT) and, in 1998, exploded five "nuclear devices" at its Pokhran test site. While this scheme will generate a lot of global cash-flow for the nuclear marketers and their government boosters, it could deal a death blow to non-proliferation hopes by allowing India to become the first country to buy nuclear materials without being a party to the NPT. In April 2010, Washington signed off on a deal that permits India to reprocess its own nuclear fuel. The arrangement, however, has raised fears in neighboring Pakistan, which is now expected to embark on a "significant nuclear military buildup."[202]

Not surprisingly, given the international problems of weak treaties, agreements, inspections and sanctions, the potential for nuclear terrorism continues to grow. From a terrorist perspective, a nuclear power plant is a ready-made weapon, already pre-positioned to do the most damage.[203] The mastermind of the 9/11 attacks reportedly claimed Al Qaeda had planned to strike U.S. reactor sites. Some 53,000 metric tons of highly radioactive spent fuel sit in storage pools upwind from major U.S. cities and 90% have no protection against a terrorist attack.[204] Blowing up a spent-fuel storage site could unleash a devastating plume of fallout over civilian populations.[205]

In wartime, power plants become targets and nuclear power plants are no exception. Israel attacked a nuclear reactor under construction in Iraq in 1981, destroyed a suspected nuclear site in Syria in 2008, and has threatened to bomb nuclear power facilities in Iran. The U.S. has also implicitly threatened to bomb Iranian nuclear sites. When a bomb (conventional or nuclear) hits a reactor, the blast can unleash the long-lived isotopes stored in the reactor core.[206] When an atomic bomb explodes, its fallout is short-lived but if that bomb were to breach a reactor, the resulting blast would render hundreds of square miles uninhabitable.[207] A one-megaton burst over the government's radioactive waste storage site on the Savannah River in Georgia could extinguish all life within 85,000 square miles—an area the size of Utah.[208] By comparison, if a single 1 MW power plant were hit with a single missile carrying a 1-megaton warhead (50 times as powerful as the bomb that destroyed the Japanese city of Hiroshima), the blast would rain ash and molten rock over 4,500 square miles. One Russian SS-18 missile carries the explosive equivalent of 1,250 Hiroshima bombs.[209]

The Nuclear Powers versus Disarmament

The five original nuclear powers encouraged the spread of nuclear-fueled power plants but, to protect the nuclear status quo, Article 4 of the 1967 Nuclear Non-Proliferation Treaty declared that, while all signatories would be allowed to pursue the peaceful use of nuclear energy, only the Big Five could possess nuclear bombs.

Under Article 6, the NPT's signatories pledged to work towards complete nuclear disarmament. Forty-two years later, the nuclear powers have still not disarmed (and the U.S. has actually embarked on new nuclear weapons programs). The only countries to have abandoned their nuclear weapons ambitions are Argentina, Brazil, Libya, South Africa and Taiwan.[210] As a signatory to the NPT, Iran is legally entitled to build and operate nuclear power plants. Israel, however, has refused to sign the treaty and has refused to permit international inspections of its nuclear site at Dimona.

Enrichment and reprocessing make nuclear weapons possible by generating plutonium. To control weapons proliferation, Presidents Ford and Carter suspended support for reprocessing plants. Ronald Reagan reversed the ban on commercial reprocessing; Bill Clinton reinstated the ban when he took office. On February 6, 2006, George W. Bush announced the creation of a Global Nuclear Energy Partnership (GNEP) to address the problem of nuclear waste by reviving the U.S. reprocessing program (while preventing other countries from building their own enrichment and reprocessing plants). [211]

Far from being proliferation-resistant, the GNEP actually threatened to boost stockpiles of enriched uranium and plutonium because it allowed some of the 25 GNEP members (including the U.S. and France) to retain the "right" to reprocess uranium to supply other GNEP countries. The problem is that reprocessed plutonium is easily weaponized. The 250 metric tons of plutonium already produced world-wide are sufficient to build 40,000 atomic bombs. Under GNEP, the amount of additional plutonium from reprocessing U.S. spent fuel would top more than 500 metric tons.[212]

The Bush Administration announced plans to build a new $80 billion reprocessing plant to handle at least 2,000 tons of spent fuel a year but the U.S. has tried, and failed, to build reprocessing plants on three previous occasions. The first facility in West Valley, New York, was shut after six years (taxpayers have so far spent $4.5 billion to clean up its contamination) and the other two plants were declared inoperable.[213] Ending the threat of nuclear proliferation requires the closure of all enrichment and reprocessing facilities.

In June 2009, the DOE cancelled critical funding for GNEP, explaining that the Obama White House was "no longer pursuing domestic commercial reprocessing, which was the primary focus of the prior Administration's domestic GNEP program."[214]

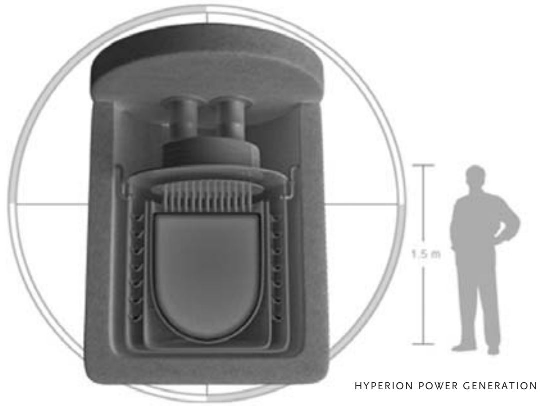
Nuclear disarmament would be a long-overdue step towards a more peaceful and secure future. It would also liberate a wealth of national treasure and scientific expertise that could be redirected toward the promotion of smart and sustainable carbon-free energy technologies. However, as long as the U.S. continues to plan for "winning" a nuclear war, maintains plans for pre-emptive nuclear strikes, and works to expand its nuclear arsenal, other countries will have an incentive to pursue their own nuclear options.[215]

LUCIE CHOCHOLATA

Anti-nuclear and disarmament activists rally at the start of the Non-Proliferation Treaty conference in New York on May 2, 2011.

NINE

"NEW, IMPROVED" REACTORS WON'T SAVE U.S.



The nuclear lobby promises a new generation of "cheaper, safer, greener" reactors (including the 68-MW liquid-metal module pictured above) but these new designs are neither risk-free nor waste-free. Nuclear technology still remains "history's most expensive and dangerous way to boil water."

Nuclear proponents frequently talk about the promise of a new generation of reactors that will overcome the cost, safety, waste, and other problems that have plagued the industry so far. The most important thing to grasp about these so-called "Generation IV" reactors[216] is that they *do not exist*. (The government of South Africa cancelled work on a Gen IV Pebble Bed Modular Reactor in February 2010, explaining it "could no longer justify putting more money into the project.")[217] It would be decades (if ever) before most of these designs could be built.

THE VERY HIGH TEMPERATURE REACTOR (VHTR, also known as the Next Generation Nuclear Plant) might be completed by 2021 but none of the other designs would be even available for commercial construction until 2045 (according to estimates by the French government, which has the greatest experience with state-supported nuclear power.)[218] While it is unwise to write off new technologies entirely, the possibility that Generation IV reactors could offer a timely solution to the world's climate or energy problems remains extremely remote.

THE GAS-COOLED FAST REACTOR is helium-cooled and uses novel core configurations aimed at increasing efficiency through very high operating temperatures. It presents control problems, durability problems and heavy waste impacts after decommissioning.

THE LEAD-COOLED FAST REACTOR could be built in various sizes, with modular components having a long refueling interval. It would supposedly be cooled by natural convection. It has component compatibility problems, extreme pressure and temperature characteristics, uncertain maintenance, and the possibility of environmental contamination with lead.

The Molten Salt Reactor uses nuclear fuel dissolved in molten fluoride salt flowing into a graphite core. It requires super-durable structural materials and poses proliferation risks.

The Sodium-Cooled Fast Reactor would breed plutonium and retain it within the reactor. Overheating would cause the chain reaction to slow down. Sodium is highly corrosive and reacts explosively in contact with water or air, making this design very demanding. Sodium coolant problems, combined with uncontrolled costs and recurrent shutdowns, led to the abandonment of France's Superphénix reactor.

The Super-Critical-Water-Cooled Reactor. Operating at much higher temperatures and pressures than current reactors, this design would theoretically offer modestly better thermal efficiency (albeit with greater accident risks) and lower electricity costs—although not to the point of being competitive with renewable sources, much less gas or coal.

Traveling Wave Reactors. TWRs are unlike traditional reactors that require enriched uranium to operate. They are being promoted as "a financially and socially attractive emission-free energy that is safe and sustainable." [219] A TWR only needs a small initial amount of enriched uranium as a trigger, after which a chain reaction begins to slowly consume a core of depleted uranium. TWRs are "breeder" reactors capable of making and consuming their own fuel. Since the major feedstock would be the "nuclear garbage" created by traditional reactors, TWRs are presented as offering a "solution" to the problem of stored nuclear waste.

The technology received a major boost in 2010 when Microsoft Chair Bill Gates publicly praised "traveling wave" breeder reactors and became a major investor in TerraPower, a TWR pioneer. TerraPower's backers claim that computer simulations demonstrate that "a wave of fission moving slowly through a fuel core could generate electricity continuously for well over 50 to 100 years without enrichment or reprocessing."[220] The proposed benefits of TWRs include: reduction of stockpiles of stored nuclear wastes; tapping a freely available fuel that could supply energy "for thousands of years;" elimination of enrichment and reprocessing; reduction of proliferation risks associated with uranium enrichment; and extended reactor service-life.

But TWRs still carry many of the basic flaws of traditional and New Generation reactors: they produce nuclear wastes that need to be removed at the end of the plant's working life; the designs have not been built or tested; it will take a decade before the first TWR could be built; and a single reactor could cost $4 billion. Given these impediments, it's not surprising that billionaire Gates and his other TerraPower partners are lobbying the Department of Energy for billions of dollars in R&D subsidies.[221]

BOX VII

MINI-REACTORS TO THE RESCUE?

With hopes for a Nuclear Renaissance waning, the American Nuclear Society (ANS) has proposed a mini-renaissance of Small Modular Reactors. SMRs (small enough to fit in a garage) could power homes, factories and military bases. Unlike large reactors, SMRs would be cheaper to build and easier to site. They would have no "footprint" because they could be installed underground. After a working life of 7-10 years, the buried module would be replaced with a new unit. The old unit would become a disposal risk (after a suitable cooling-off period).

In February 2010, the Nuclear Regulatory Commission invited companies to bid for $39 million in federal funds set aside for mass-producing "mini-nukes." At the same time, Energy Secretary Steven Chu followed up with an op-ed in the *Wall Street Journal* praising SMRs. South Carolina's Savannah River National Laboratory (SRNL) is working to see that the state becomes a pioneer in SMR technology and has announced plans to collaborate with New Mexico's Hyperion Power Generation to build 10-700 MW mini-reactors at a plant employing as many as 500 workers. SRNL has announced it is "taking a leadership role" by establishing a demonstration project for a small reactor to be built by GE-Hitachi.

An international SMR conference held in Columbia, South Carolina, in April 2011, attracted scores of companies and agencies ranging from Westinghouse, AREVA and GE to the International Atomic Energy Agency, the China National Nuclear Corp. and the Iraq Energy Institute. Also attending were Senator Lindsey Graham, three members of Congress, and representatives from the DOE, NRC, the U.S. Army and many U.S. utilities.

Conference organizers hoped the event would "cement the Midlands and South Carolina as a center for the development and production of the mini-reactors." Mini-reactor proponents envision new markets in Third World countries that cannot afford traditional nuclear plants.

But mini-reactor detractors note that SMRs would still depend on a costly, inefficient and hazardous fuel cycle that generates intense heat loads, employs dangerous materials (like helium and highly reactive sodium) and produces nuclear waste. Building mini-nukes would decentralize and scatter all the operational risks of supplying, maintaining, safeguarding and dismantling nuclear reactors. A larger, aboveground "pocket-reactor" would still require its own control room operators and security personnel and, because of "economies of scale," smaller reactors could wind up costing more than large plants. Tom Clements, a nuclear power critic with Friends of the Earth, charged the proposal to develop SMRs at Savannah River was simply a ploy by the nuclear industry to avoid licensing oversight from the NRC. The Department of Energy, which runs the site, denies the charge.

TEN

BETTER OPTIONS EXIST

SOLAR LIGHTING

The 162,000 solar panels at Spain's 62 MW Olmedilla Solar Park (the world's largest photovoltaic power station) produce about 87.5 gigawatt-hours of electricity a year—enough to power more than 40,000 homes. The Olmedilla plant was constructed in just 15 months at a cost of $350 million.

Where do we go from here? How do we start the process of change? If nuclear energy is not the answer to the global energy and resources crises, then what is the best course to fashion an economy that provides for the long-term welfare of people and the preservation of nature? Instead of continuing to fantasize about a "nuclear rebirth" it's time to accept the fact that this ailing industry suffers from a long list of incurable maladies. Instead of prolonging the lives of reactors well past their designed age of retirement, we need to pull the plug on these aging artifacts. We need to demand that reactors be closed at the end of their operational lifetime of 35-40 years.

Beyond that, we need to accept that we live on a finite planet with limited resources: Earth's oil, water, minerals, soils, and oceans are all showing troubling signs of devastation and depletion. On a finite planet, the pursuit of continuous, ever-expanding economic growth—the primary goal of the prevailing U.S. economic system—is a recipe for disaster. By itself, even the creation of new "clean energy systems" will not enable us to maintain our current unsustainable rates of industrial-economic growth. We need a Renewables Revolution that supports a Steady State Economy driven by a Conservation Imperative.

The United Nations' Millennial Assessment Report (undertaken by the largest body of social and natural scientists ever assembled to evaluate human impacts on the planet's ecosystems) found that 60% of Earth's 24 most critical ecosystems have been seriously degraded over the past 50 years to the point that the planet's ability "to sustain future generations can no longer be taken for granted." The Report called for "substantial changes in institutions and governance, economic policies and incentives, social and behavior factors, technology, and knowledge."[222]

As Richard Heinberg eloquently demonstrates in our IFG report, "Searching for a Miracle,"[223] there is no way to sustain an economic system built on a false assumption of endless resources, inexhaustible energy and infinite expansion. Even if we could manage to switch totally to renewable energy systems —which we certainly advocate—no combination of these systems could sustain an economy built on the mad premise of endless growth, and the projected rise in the human population only compounds the dangers. The good news is that thousands of groups around the world are already far ahead of their governments in planning for a Post-Oil, Post-Growth, Conservation Economy. There is no shortage of good ideas, only a shortage of ability to make them manifest.

Even if all of the world's current energy output could be produced by renewables, this level of energy consumption would still inflict terrible harm on Earth's damaged ecosystems. In order to survive, we need to relearn how to use less. It is critical that we adopt a Conservation Imperative.

Faced with the inevitable disappearance of the stockpiles of cheap energy we have used to move and transform matter, we need to identify society's fundamental needs and invest our limited energy resources in those key areas. A Post-Oil/Post Coal/Post-Nuclear world can no longer sustain the one-time extravagances of luxury goods, designed-to-be-disposable products, and brain-numbing entertainment devices. The long-distance transport of raw materials, food and manufactured goods will need to decline in favor of local production geared to match local resources and needs. Warfare—the most capital-, resource- and pollution-intensive human activity—must also be diminished. Neither the costly inventory of nuclear arms nor the Pentagon's imperial network of 700-plus foreign bases is sustainable. There will doubtless still be wars but, in the Post-oil World, they will be either be waged with solar-powered tanks or fought on horseback.

Modern economies insist on powering ahead like competing steamboats in an upstream race. We have become addicted to over-consumption on a planet that was not designed for limitless exploitation. As the late environmental leader David Brower noted: "In the years since the Industrial Revolution, we humans have been partying pretty hard. We've ransacked most of the Earth for resources…. We are living off the natural capital of the planet—the principal, and not the interest. The soil, the seas, the forests, the rivers, and the protective atmospheric cover—all are being depleted. It was a grand binge, but the hang-over is now upon us, and it will soon be throbbing." [224]

On the eve of India's independence, Mahatma Gandhi was asked whether his new nation could expect to attain Britain's level of industrial development. Noting that "it took Britain half the resources of this planet to achieve its prosperity," Gandhi famously estimated that raising the rest of the world to British levels of consumption would require "two more planets." The United Nations Development Program recently reconsidered Gandhi's equation as it applies towards "a world edging towards the brink of dangerous climate change."

Working from the assumed "sustainable" ceiling of climate-warming gases (14.5 Gt CO_2 per year), UNEP confirmed that "if emissions were frozen at the current level of 29 Gt CO_2, we would need two planets." Unfortunately, UNEP noted, some countries are producing more CO_2 than others. Fifteen percent of the world's richest residents are using 90 percent of the planet's sustainable budget of shared resources. According to UNEP's calculations, just sustaining the current lifestyle of Canada and the U.S. would require the resources of 16 planets—eight planets each. [225]

In this final chapter, we have bundled some of these ideas into four broad categories: Technological Efficiencies; Alternative-Renewable Energy systems; Public Policy Options; and most importantly, The Conservation Imperative—*Powering Down*. A combination of these efforts, enthusiastically embraced, will have a good chance of saving the world by embracing new, sustainable lifestyles that eschew the bizarre notion that happiness can only come from never-ending consumption and accumulation. A new level of appreciation for "sufficiency" and "equitability" will be the ultimate answer.

The "Net Energy" Challenge

When it comes to the question of "net energy," the laws of physics are clear and immutable. In order for an organism (or a technology) to succeed, it cannot expend more energy than it consumes. In order to survive, a migrating salmon needs to expend no more than one calorie of energy to acquire three calories of food energy—a 3:1 ratio. Prehistoric hunter-gatherers burned one calorie of energy in the pursuit of every 4-5 calories of berries or deer meat. Preindustrial farmers and the nomads of the Kalahari could subsist successfully with a 10:1 Energy Return on Investment (EROI). However, with the discovery of coal and oil, humans were able—for the first and only time in history—to tap an EROI of 100:1. In order to match the energy potential of a single barrel of oil, a single human worker would have to labor 8.6 years—without pausing to sleep.[226]

The one-time gift of fossil energy (representing 500 million years of captured solar energy) sent human beings into unprecedented overdrive—building, traveling, flying, planting, logging, polluting and toying with weapons of mass destruction. Human "progress" was fueled by the profligate combustion of fossilized biomass—consumed at rate of about 5 million year's worth of solidified sunlight every year. But today, as Richard Heinberg has famously observed, "The Party Is Over." As the most easily accessed reservoirs of cheap oil have been exhausted, the EROI for oil has plummeted towards 10:1, forcing industry to undertake costly, high-risk deep-ocean drilling and to scrape desperately after tar sands, an unattractive carbon resource with an EROI of only 4:1.

Efficiency: The "Fifth Fuel"

Energy efficiency has been called "the Fifth Fuel."[227] According to energy expert Amory Lovins: "Each dollar invested in electric efficiency displaces nearly seven times as much carbon dioxide as a dollar invested in nuclear power, without any nasty side effects."[228] It is clear that a serious international commitment to promote energy efficiencies would yield spectacular paybacks—not only by reducing global warming, energy consumption and pollution, but also by lowering the costs of economic productivity. But we begin with a daunting task. Consider the current state of affairs:

Each day, on average, human activity pours 16 million tons of CO_2 into the atmosphere. The average citizen of the world contributes about 12 tons of CO_2 a year: The average American contributes 23 tons.[229] The U.S. burns about 17 million barrels of oil a day—seven million barrels of which are imported. The U.S., with only 5% of the world's population, generates 23 percent of all energy-related global carbon emissions. The U.S. consumes nine times the electricity used by the Earth's average resident while more than 1.6 billion people live without electricity.

Surprisingly, it's not cars but buildings that are the greatest sources of planet-cooking emissions. Homes and offices consume around 50% of U.S. energy. Globally, buildings consume 76% of the world's electricity.

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Co-generation "peaker" plants can be used to provide power in times of high demand, such as on hot summer days.

Since 1980, the size of the average U.S. home has ballooned 45%, a trend that must be reversed since this increase in rooms and windows requires more energy for heating, cooling, lighting and added electrical appliances.[130] The average U.S. home produces 11 tons of CO_2 annually. An average home uses 26 plug-in appliances (including multiple TVs and set-top TV boxes that consume half as much energy as a refrigerator) and videogame consoles that require twice the power of a fridge.[231]

Since developing countries use only 30% of the world's generated energy, it is clear that the ultimate solution to our energy future largely rests in the hands of the industrialized nations.

If the U.S. were to reduce its industrial energy use by 1%, that seemingly small step would save about 55 million barrels of oil (and about $1 billion) a year. The energy *wasted* by America's power plants would be sufficient to power Japan. Our automobiles, industrial motors and water heaters are less efficient than those in Japan and Europe. Ironically, many of our "smart, new" technologies are *not* energy efficient. Some modern manufacturing systems consume a million times more energy-per-pound-of-output than traditional industries. For example, it takes more energy to make a microchip than to forge a manhole cover. Production inefficiencies of current manufacturing processes have become a critical factor in determining the lifecycle energy costs of solar panels.[232] This must change and an ever-growing number of sustainable business practices are coming online to make this happen.[233]

On the plus side, since 1973, improved efficiencies have saved more than six times the energy produced by America's nuclear power plants. A global "Green New Deal," like the one proposed by the UN,[234] could create jobs, spur technological development, cut the world's energy demand 20% by 2020 and lower U.S. electricity consumption by 75%.[235] Strong national efficiency standards could replace the need for 450 power plants by 2020. Calling efficiency "the cheapest, cleanest, fastest energy source," President Obama has vowed to cut the government's energy use by 15%. Over the past 30 years, the U.S. has routinely saved far more power through efficiency improvements than it has generated from nuclear power plants.[236] While efficiency investments usually pay for themselves in three years (and thus have been adopted on economic grounds by many U.S. companies), they continue to be dismissed by the corporate interests that stand to profit (in the short term) from the ever-increasing consumption of energy.[237]

The fact is that efficiencies have already had a major impact. In September 2010, a Lawrence Livermore National Laboratory study found that total U.S. energy consumption fell from 99 quadrillion BTUs in 2008 to 94.6 quads in 2009 because of changing economic and lifestyle impacts. The U.S. Energy Information Administration reports that the country's CO_2 emissions dropped nearly 10% between 2007 and the end of 2009.[238] While around one-third of the drop was attributed to the recession and lower natural gas prices, most of the reductions came from efficiency gains and new state renewable energy standards boosted by a federal "clean energy" stimulus.[239] (Note: Part of the "dash for gas" that brought down prices involved the exploitation of "unconventional" sources like shale gas. But the hydraulic fracturing needed to extract the gas can pollute groundwater with toxic "fracture fluids.")

Meanwhile, the Department of Energy notes that 75% of home electricity is wasted—consumed by "stand-by" appliances that continue to draw power even when "turned off." While modern refrigerators use two-thirds less energy than they did 20 years ago, a proliferation of "vampire appliances" with always-on dials, clocks, and displays are costing U.S. homeowners $1 billion a year in added energy bills.[240] Redesigning or eliminating the "standby" option can tap significant energy savings. In the meantime, homeowners can drive a stake through these energy vampires by plugging them into surge protectors so they can all be turned off at one time at night or when leaving the house. This would accomplish a significant gain in "negawatts."

Negawatts not Megawatts

"Negawatts" are watts saved from one application and made available for another. For example, replacing one 75-watt incandescent bulb with one long-lasting, energy-efficient 20-watt compact fluorescent bulb creates 550 kWh of saved energy over the new bulb's lifetime—and keeps 1,300 pounds of CO_2 out of the air.[241] Here's another form of negawatt: When electricity demand rises, large users can be paid for creating "negawatts" by cutting back on consumption.[242] Taking full advantage of off-the-shelf energy-saving devices can cut the costs of heating, cooling and lighting U.S. homes and offices by as much as 80%.[243]

The Zero-CO_2 Economy

Transition to a truly Zero-CO_2 industrial economy may be possible—but it won't resemble the kind of extravagant industrial dystopia we now inhabit. This can be achieved with a combined array of old and new technologies including photovoltaic panels, solar thermal, passive solar, wind turbines, wave power, biomass, geothermal, hydrogen, ultracapacitors, solar light pipes[244] and other options. Because oil-dependent industrial agriculture generates as much as 30% of the world's climate-changing greenhouse gases, a Zero-CO_2 economy will also require replacing large-scale, mechanized farming with organic and agroecological practices that actually capture and return excess atmospheric CO_2 to the soil.[245]

A Green Transition by 2050

Greenpeace and the European Renewable Energy Council have published a detailed blueprint for the transition to a sustainable and just energy future by mid-century. Given the recent trend of double-digit growth in renewable energy options, the "Energy [R]evolution" plan would close all nuclear reactors by 2020 while stabilizing both the climate and the economy.[246] As homeowners go off-grid, producing their own rooftop power and backyard food, this transition to "micropower" promises to propel a fundamental efficiency revolution.[247] Taking the lead in North America, the Canadian province of Ontario has passed a Green Energy Act while the university town of Berkeley, California, has fashioned a Climate Action Plan that the United Nations has praised as "the best in North America."[248] The following sections detail these and other possibilities.

The Power of Renewables

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SMUD's Solano Wind Project in Rio Vista is on track to generate more than 39 megawatts of clean, renewable power.

In 2007, the fast-growing renewables sector received $71 billion in private capital investment while the nuclear industry received nothing.[249] At the same time, the world invested $100 billion more in renewables than in fossil fuels, adding 40 billion "green watts" to global output. Nuclear power added zero watts.[250]

While previous studies predicted renewable wind, water, sun and geothermal (WWSG) energy would be supplying 12% of the world's electric power by 2030, new research by the International Scientific Congress projects wind and photovoltaic technologies could provide 40% of the world's electricity by 2050—if renewable alternatives receive adequate financial and political support.[251] Investing in existing and innovative green-tech energy and efficiencies also would prevent the release of 38 billion tons of greenhouse gases a year.[252] Each month, a single home with a one-kilowatt PV system prevents the release of 300 pounds of CO_2 into the air, keeps 150 pounds of coal from being mined, saves 150 gallons of water and avoids the release of nitrous oxide and sulfur dioxide. While solar and wind power provide energy on a variable rather than a constant basis, they can become collectively reliable when integrated with steady-output renewables like geothermal, small hydro and wave resources.

Solar[253], wind[254], biomass [255] and geothermal[256] are all projected to be competitive with "cheap, dirty" coal as early as 2015. There is an added advantage to replacing carbon-combustion energy with renewable power—because WWSG is more efficient, meeting the world's projected global demand for 16.9 TW of electricity by 2030 could be accomplished with only 11.5 TW of WWSG.[257] To understand why this is the case, we only need to look at the automobile. Only about one-fifth of the gas burned in a car is actually transformed into motion—most is wasted as heat. By contrast, in an electric-powered vehicle, as much as 86% of the energy is converted into motion.[258]

Hopes to replace "dirty coal" (which is responsible for 86% of the country's stationary CO_2 emissions) with "clean coal" technology have been dimmed by warnings that this new techno-fix could add as much as 70% to the cost of turning coal into electricity.[259] In another sign that "clean coal" is no panacea, major utilities are starting to drop out of the industry's multimillion-dollar lobbying group, the American Coalition for Clean Coal Technology.[260] The clean-coal cause was further damaged when a report in the journal *Science* condemned the process of using "mountaintop removal" to extract coal. *Science* reported "the preponderance of scientific evidence is that impacts are pervasive and irreversible and that mitigation cannot compensate for losses."[261]

With many renewables already cheaper than nuclear, U.S. utilities in the Southwest are signing purchase agreements for wind power at 4.5–7.5 cents per kWh—one-third the cost of nuclear power.[262]

According to a Duke University study, 2010 marked a "Historic Crossover" in North Carolina—it marked the year that electricity from solar PV panels became cheaper than nuclear power. Electricity from the state's nuclear reactors cost 16 cents per kWh while electricity from photovoltaic panels was only 14 cents per kWh—a rate that continues to fall. (The data only covered PV power, not concentrated solar systems, which can lower costs even more.) The study factored in the hidden costs of government subsidies for both power sources, but concluded that—even if all subsidies were removed—solar power would still be cheaper within a decade.[263] (While capturing even a small percent of the sun's potential could, in theory, more than meet the entire world's power needs, there are many limiting factors that will still require that we learn to live more responsibly with less available energy.)

Renewable energy is now competitive with nuclear power. According to a July 2010 study by NC WARN, a nonprofit nuclear watchdog group, the cost of solar energy has dropped to roughly 15.9¢/kWh, while the cost of nuclear power has risen to nearly 20¢/kWh (and that's at the plant site, before any transmission charges). The Energy Information Administration's March 2011 *Monthly Energy Review* reports that the production of renewable energy in the U.S. jumped by 5.6 percent in 2010. Energy derived from renewable sources rose to 10.92 percent in 2010 while the amount of energy produced by nuclear power fell to 11.26 percent (down from 11.48 percent in 2009).

What would it take to move to a self-sustaining WWSG economy by 2030? According to a blueprint offered by two California researchers, more than 50% the world's power needs could be met by building 3.8 million large wind turbines. (Not an impossible task given that the world's automakers build more than 50 million cars and light trucks each year.) [264] Another 40% would be generated by rooftop solar panels and concentrated solar power stations with the remainder coming from geothermal, wave and 900 hydroelectric stations (70% of which already exist).[265]

President Obama's 2009 stimulus package routed at least $70 billion to renewable energy R&D—triple the DOE's baseline budget and more than the annual budgets of the Labor and Interior Departments combined. The stated goal was to double renewable energy capacity in three years. (Reality check: while this is a lot of money, it's less than the world's three major oil companies spend in a single year. And Obama's stimulus only lasted two years.)[266]

In 2006, for the first time in history, micropower—which embraces small renewables, co-generation and other efficiencies—out-performed nuclear reactors, producing one-sixth of all the world's electricity (and one-third of all *new* electricity).[267] In China, the country with the world's most ambitious nuclear program, electricity from distributed renewables charged ahead of atom-powered electricity by a factor of seven.[268] The amount of new nuclear capacity added between 2000 and 2007 was six times *less* than the 13,300 MW of wind power added during the same period. In 2008, 20,301 wind energy installations in Germany generated 40.4 TWh—as much power as six large nuclear reactors.[269]

Compared to these vibrant new developments, nuclear power is a stodgy and obsolete technology. We need to move past the old "dig-it-up-and-burn-it" energy technologies and focus our attention on fashioning a sustainable green future. Here's a brief rundown of some of the most promising technologies.

Wind Power

Wind power is the world's fastest-growing energy source. In 2009, new installations soared 31.7%, as wind capacity continued to double every three years. Wind capacity for 2010 was expected to exceed 200 GW and is projected to produce nearly 2 TW by 2020. Wind power is on track to create one million jobs by 2012. [270] The potential for wind power over land exceeds 72 TW—20 times the world's current electric power production. DOE's National Renewable Energy Laboratory recently estimated that the potential for offshore wind power tops 4,000 GW—four times the entire electricity demand in the U.S.. In 2007, 94.1 GW of wind power were installed worldwide. Leading countries were Germany (22.2 GW), the U.S. (16.8 GW), Spain (15.1 GW), and Denmark, which generates about 19% of its electricity from the wind.

In 2007, the U.S., China and Spain each added more wind capacity than the entire world added in nuclear capacity. The U.S. added more wind capacity in 2007 than was added in coal capacity for the previous five years combined.[271] In 2008, as coal-powered electricity fell by 1.5%, more wind power came online than in the previous two years.[272] In 2009, Europe added 37.5 GW of new wind energy while electricity from oil, coal and nuclear energy fell a collective 32.1 GW.[273]

In 2007, green-tech investments topped $5 billion while spending on global green energy rose 60%. In 2009, global revenues for solar, wind and biofuels reached $139 billion. By 2019, revenues from wind power alone are expected to exceed $114 billion.[274] Global installation of wind power hit a record 27 GW in 2008. The U.S. alone added more than 4 GW—more than 40 percent of all new global electrical capacity—to eclipse Germany as the planet's leader in wind energy. Photovoltaics, which topped 4 GW worldwide in 2008, are expected to become an $80.6 billion industry by 2018.[275]

Around the world, wind power has proven to be recession-proof. In 2009, China doubled its wind power capacity for the fifth year in a row while the U.S. increased its wind power capacity 40%—to 35.2 GW.[276] Wind power projects in 15 U.S. states now generate 28.2 GW—enough to power 8 million homes while cutting 52 million tons of CO_2 per year. Texas, Iowa, California, Minnesota, Washington, Oregon, New York, Colorado and Kansas each generate more than 1,000 MW of wind energy. Texas leads with 7.9 GW but Kansas has the potential to produce 19 GW of wind power by 2030.[277] California has the largest number of installed units with three massive wind farms hosting more than 21,000 turbines.[278]

Wind power has the potential to supply at least 20% of U.S. electrical needs at an affordable price since power-friendly wind speeds have been found to exist in 17% of U.S. land and coastal regions.[279] The U.S. National Renewable Energy Lab (NERL) estimates the wind in North Dakota alone could generate one-third of the country's electricity. Some studies suggest that adding the wind-energy potential of Kansas and Texas could provide all our country's needs for clean, affordable electric power.[280]

NREL projects that offshore wind turbines could supply at least 20% of all electricity for U.S. coastal cities[281] and U.S. Interior Secretary Ken Salazar believes wind turbines off the East Coast could produce 1 million MW—enough power to replace 3,000 coal-fired power plants. New Jersey plans to triple its wind power resources to 3,000 MW by 2020.[282] In 2010, Google announced it was investing in the Atlantic Wind Connection, an offshore power project that would plug wind turbines into a submerged transmission cable stretching 350 miles from New Jersey to Virginia. This $5 billion project is expected to produce 6,000 megawatts—sufficient to power two million U.S. homes.

Replacing all U.S. vehicles with electrics powered by wind-generated electricity could cut CO_2 emissions by a third and prevent 15,000 auto-exhaust-related deaths. However, this would mean building and installing as many as 144,000 huge 5-MW turbines—just to power the existing number of autos. We would be better off using the electricity to power mass transit systems while we work to develop more compact and energy-efficient cities.[283] Meanwhile, the 158 GW of clean electricity flowing from the world's wind turbines is preventing the release of 204 million tons of CO_2.[284]

Wind turbines aren't immune from criticism, however. Turbines in California's Altamont Hills were implicated in the deaths of endangered raptors and dozens of YouTube videos document some of the friction-caused fires that have destroyed 149 turbines around the world. Nearby buildings have been damaged by broken blades that have flown as far as 4/5^{ths} of a mile.[285] While accidents may increase with the expansion of wind farms, the overall dangers remain statistically small. Wind energy is also inconstant, with more wind activity in the winter months than in the summer and the greatest wind-loads found in mountains, open plains and at sea. Shipping wind-generated power hundreds of miles over power lines means sustaining significant transmission losses. Still, the average Energy Returned on Energy Invested (EROEI) ratio for wind power is 18:1, which is competitive with conventional power technologies (and more efficient than nuclear, at 11:1 EROEI).[286]

Surprisingly, 2010 was a bad year for the wind industry. The American Wind Energy Association (AWEA) reported the lowest figures for new capacity and new installations and new investment in years. AWEA projected that 2010 installations would likely fall 25-45% below 2009 figures. While 10 GW of new U.S. wind energy was added in 2009 (up 20% from 2008), growth in 2010 was expected to range around 6 GW. "The problems," reports *Power Magazine*, "are found in Washington." Passage of a strong national renewable energy standard and expansion of federal loan guarantees (like the billions offered to the nuclear industry by Republican and Democrat leaders) would boost demand. "We have a historic opportunity to build a major new manufacturing industry," AWEA cautions, but if the new 112th Congress fails to provide critical federal support (a serious likelihood given the increased power of oil-and-coal-backed Republicans), AWEA fears "manufacturing facilities will go idle and lay off workers."

Solar Photovoltaics

Land-based photovoltaic potential stands at around 1,700 TW worldwide. California, alone, boasts 354 MW of installed solar electric power. Two more large photovoltaic sites (one proposed for the Mojave Desert and another in Antelope Valley) would add another 783 MW. California's $3 billion Solar Initiative has helped install more than 50,000 rooftop-mounted generating facilities statewide, accounting for 60% of the entire U.S. solar energy market.[287]

Concentrated Solar

Large tracts of mirrors can be used to focus the sun's heat on centrally mounted tanks that create steam to spin turbines and produce electricity. Spain plans to have 50 concentrated solar power (CSP) plants generating 500 MW in 2011 and NREL expects to see 4,000 MW of CSP installed by 2015.[288] California has plans for four CSP facilities with a total capacity of 2,660 MW. With Egypt, South Africa, Australia, Libya, Algeria, India, Israel and Morocco also installing CSP plants, global production is expected to hit 36,859 MW by 2025—the equivalent of 36 nuclear power plants.

The sun's light can also be trained on photovoltaic cells, some of which have attained record-setting efficiencies topping 40 percent.[289] High Concentration Photovoltaic (HCP) systems do not contain the toxic cadmium telluride found in current PV panels. HCPs also maintain their efficiency better than standard PV panels. A downside: Large CSP facilities—planned for the Mojave Desert, the Sahara Desert and elsewhere—have raised environmental concerns over the disruption of animal migration routes, the destruction of habitat and displacement of flora and fauna if the land is graded, sprayed with chemical herbicides, shaded from sunlight, wind and rain, and subjected to human presence, vehicles and trash.[290] A far less disruptive approach is "distributed solar power."

Distributed Solar

Widely distributed wall- and rooftop-mounted photovoltaic and thermal collectors can provide homes and offices with power and heat. Unlike centralized electricity plants, distributed power sources are located right where the energy is used. Homes and cities in the U.S. occupy about 140 million acres. According to NREL, placing PVs on 7% of our rooftops and parking lots could "supply every kilowatt-hour of our nation's current electricity requirements," leaving "a landscape almost indistinguishable from the landscape we know today."[291] An important bonus: using distributed solar would also bypass fragile electric transmission grids, greatly improving reliability and resilience.

Solar Thermal Water Tanks

With water heating constituting a home's third largest energy cost, solar water heating provides a simple and affordable means to chop hot water bills in half. A single home equipped with a passive thermal water heater (a common sight on Southern California rooftops during the '30s and still widely used in Greece, Turkey, Israel, China and India) can prevent the release of more than 50 tons of CO_2 over the course of 20 years.[292] In January 2010, the California Public Utilities Commission launched a $350 million incentive program to install 300,000 solar water heater systems on the Golden State's rooftops by 2018. The move is expected to eliminate 100,000 tons of greenhouse gas emissions each year.[293] In February 2010, Senator Bernie Sanders (I-VT) followed California's lead by introducing the "10 Million Solar Roofs and 10 Million Gallons of Solar Hot Water Act," which would provide rebates to cover up to half the cost of 10 million solar power systems and 200,000 solar water heaters.[294]

Passive Solar

Buildings designed for passive solar heating employ south-facing glazed windows, insulation, sunspaces and Trombe walls to capture the sun's free light and heat. Thick, south-facing Trombe walls and floors built from heat-absorbing materials capture solar heat during the day and slowly release the stored heat to warm the house at night. Day-lighting of north-facing rooms and upper levels can be accomplished with a *clerestory*—a row of windows near the peak of the roof—or solar pipes that collect and redirect sunshine throughout the building.[295]

Thin-film Solar

Traditional rooftop solar panels may soon become passé, thanks to new thin-film solar coatings. Available on polymer sheets that can be easily applied to windows and walls, these "power sheets" have the potential to provide enough electricity to power entire buildings.[296] Nanosolar PowerSheet cells may cut production costs from $3 per watt to 30 cents per watt, marking a historic point where solar power becomes cheaper than coal.[297] Stimulated by new "feed-in" laws that pay homeowners for electricity generated from rooftop panels, a Canadian firm in Ontario is gearing up to build a $500-million manufacturing plant capable of producing 150 MW of thin-film solar a year.[298]

Thin-film photovoltaics are positioned to become the fastest growing part of the solar module industry because they promise to dramatically reduce production costs while generating more power under a wider range of light conditions. Thin-film photovoltaics can be incorporated into solar farms or installed on city rooftops and building facades. Requiring only about 1/200 of the crystalline silicon used in traditional solar cells, thin-film modules promise quicker energy payback.[291] The façade of the Technology Place at the British Columbia Institute of Technology incorporates sufficient thin-film solar panels to provide 100% of the building's lighting.[300]

Light Emitting Diodes

Around 20% of global electricity is used for lighting. Australia, Brazil and Switzerland have banned incandescent bulbs (which waste 95% of their electricity as heat). These bulbs will be phased out in Europe and the U.S. by 2012. Even though energy-efficient compact fluorescent bulbs use 75% less power and last ten times longer, they contain tiny amounts of toxic mercury and some produce an unsteady ultraviolet light that can trigger epilepsy and cancer. The better bet is Light Emitting Diodes (LEDs), which are 80% efficient, can mimic the color of natural daylight and—with a lifetime of 45,000 hours—will outlast a nuclear fuel rod by two years.[301] Unlike Compact Fluorescent Lights, LEDs do not contain mercury, which can be released if the lamps are broken. The DOE estimates switching to LEDs would save more than $30 billion in energy costs and reduce energy consumption for lighting by one-third—the equivalent of 44 1-MW powerplants.[302]

Tidal Energy

Large underwater turbines that can turn the ebb and flow of ocean tides into electricity are being built in Scotland, Ireland and Australia. France has successfully operated a 240 MW tidal plant at La Rance for more than 40 years.[303] A commercial-sized system is already in operation in Nova Scotia while the Philippines plans to build a tidal fence in the San Bernardino Strait.[304] In the U.S., tidal power systems have been proposed for New York's East River, the Mississippi and California's Golden Gate. The caveat is that these technologies remain largely experimental and—like ocean-based wind turbines—are susceptible to formidable corrosion and battering from salt-water and waves.

Wave Energy Converters

Installing wave energy converters could potentially harness 2 TW of ocean power. Agucadoura, the world's first wave farm, built off the coast of Portugal, uses three Wave Energy Converters to produce 2.25 MW.[305] One challenge is to perfect converters that can withstand continual pounding by corrosive seawater.

Hydroelectric

Hydropower represents more than 92 percent of all renewable energy generated worldwide. The world's total hydro potential is nearly 14,370 TWh/year but, at the present time, only about 8,082 TWh/year is economically attainable. About 700 GW of hydropower is already installed, with another 108 GW under construction.[306] Norway generates 98.9% of its electricity from dams, followed by Brazil (83.7%) and Venezuela (73.9%).[307] Since 1980, Iceland has more than doubled its hydroelectric production which, in 2006, stood at 7.88 billion kWh.[308] The U.S. is the world's hydropower leader, with 92,000 MW providing 9 percent of the nation's electricity (and 49 percent of the country's renewable energy). Pumped storage provides a way to increase shifting peak demands. During periods of low demand, off-peak electricity is used to pump water uphill into reservoirs. The stored water is then used to produce hydroelectricity during periods of peak need.[309]

However, with climate change reducing precipitation in the over-subscribed Colorado River watershed, major dams in the Southwest (including Lake Mead and Lake Powell) are nearing "dead pool" status—i.e., where water reserves fall to such low levels that they are no longer able to produce power. Another downside is that large dams can become environmental nightmares. In addition to the GHGs produced during construction, forests and vegetation buried beneath a dam's impounded water can decompose to release global-warming CO_2 and methane into the atmosphere. (In 1990, the rate of GHG-emissions-per-kW produced by the Curuá-Una dam in Brazil, was estimated to be three times greater than that of a comparable oil-burning power plant.)[310]

The massive weight of dammed water has even been known to cause regional earthquakes. Globally, the concentration of vast hydroelectric reserves has had a measurable impact on Earth's rotation. NASA estimates the 42 billion tons of water rising behind China's Three Gorges Dam will move the planet's axis two centimeters and lengthen the day by 0.06 microseconds.[311]

Small Hydroelectric

Small village-sized hydro projects are less destructive to the environment. Small and "micro" turbines can be effective where river flows are strong and constant year-round. "High head" turbines require water falling from a height greater than ten feet. "Low head" turbines can provide mechanical or electrical power with a vertical fall of two-to-ten feet. In the U.S., small-hydro projects require the approval of the Federal Energy Regulatory Commission and the U.S. Army Corps of Engineers.[312]

Cogeneration

Conventional coal-fired electric generation is only 33 percent efficient, while cogeneration has the ability to perform at 75-90 percent efficiencies.[313] Burning fuels to generate electricity creates heat that can be captured for space or water heating. Combined Heat and Power (CHP) plants generate electric power and harvest the otherwise lost heat to warm homes and buildings. Capturing the lost heat from U.S. steel mills and oil refineries could produce 100 GW of electricity while eliminating about 400 million metric tons of CO_2 emissions.[314] The U.S. currently derives only 6 percent of its electricity from cogeneration or distributed renewables. In 2003, Denmark met 52% of its energy needs with CHP.

Geothermal

As of 2006, worldwide geothermal capacity was estimated at around 10 GW.[315] In certain spots, hot water beneath the Earth's surface can be tapped. In Iceland, 89% of home heating is provided by geothermal resources.[316] U.S. hydrothermal resources are estimated to be in the range of 2,400 to 9,600 exajoules.[317]

The 15 turbines driven by steam wells at The Geysers site in northern California generate about 725 MW—enough to power a city the size of San Francisco. In southern California, a half-dozen new energy projects are preparing to tap the geothermal potential of Imperial Valley—estimated to approach 2,500 MW.

In addition, low-temperature direct heat can be tapped anywhere on Earth using a heat pump with pipes bored only a few meters into the ground. In the colder regions of Europe, Asia and Canada, heat pump installations have been growing 30-40 percent annually.[318] Enhanced Geothermal Systems (EHS) are a promising alternative that would produce electric power by running turbine fluids through superheated rocks 3-10km underground. While water is a limiting factor, many of the world's poorest regions (in Africa, South America, the Caribbean and Pacific Islands) are rich in geothermal potential. Another advantage: sustainably managed, geothermal is the rare renewable resource that provides constant, rather than intermittent, power.

Home/Office Fuel Cells

Small, cost-efficient fuel cells now coming on market offer to clip energy bills in half while cutting CO_2 emissions by nearly 40%. A suitcase-sized 5kW unit installed outside the house can transform natural gas from existing utility lines into heat and electricity for the home. In addition to being 11 times more efficient than solar panels, stationary fuel cells are a form of distributed power—they can produce power directly where it's needed, 24 hours a day, without sustaining the transmission losses endemic to electricity delivered over the power grid. As a combined heat and power system, these home-office fuel cells are predicted to reach efficiencies ranging from 60 to 90 percent.[319]

Wind Hydrogen

Using wind-generated electricity to electrolyze water produces hydrogen that can be banked for later use. This stored hydrogen can be used in an engine or a fuel cell to generate electricity on demand—even when the wind isn't blowing. Hydrogen is traditionally produced by stripping hydrogen atoms from natural gas or fossil fuels, a process that generates greenhouse gases. Wind-hydro creates no greenhouse gases or other harmful byproducts. In a September 2009 wind-hydro demonstration, NREL drove a fuel-cell-powered Mercedes Benz 110 miles on four pounds of compressed hydrogen. [320] (Of course, the more Earth-friendly option would be to park the Mercedes and walk, bike or take mass transit.)

For both the near term and the distant future, renewable technologies—wind, wave, geothermal, solar, etc.—offer safer, cheaper and quicker energy options than risky, costly, cumbersome nuclear power.[321] Renewable technologies, when combined with energy efficiency, can provide *half* the planet's electricity by 2050, making it possible to cut CO_2 emissions by 50% by 2040. The European Renewable Energy Council estimates that investing $11.3-$14.7 trillion to transition the world's energy sector to renewables (at an annual investment of just 1% of global GNP) could cut fuel costs by a quarter and save an estimated $750 billion a year.[322] But despite these impressive figures, it appears unlikely that renewables-plus-efficiencies can sustain industrial society at its present levels of consumption and waste.

Currently, turbine blades and PV panels must be manufactured, delivered and maintained by drawing on ever-declining reservoirs of cheap oil, dirty coal and poisonous uranium. While the sun, wind, and tides will still be here 2,000 years from now, renewable energy sources cannot sustain an industrialized economy operating on the current scale. Compared to the 100:1 energy wallop of a barrel of oil, the best EROI for a windfarm is 18:1. The EROI for nuclear power is around 11:1.[323] At some point, we will face the real test: Can renewable energy alone build the *next* generation of solar mirrors, photovoltaic panels, fuel cells and wind-turbine towers?

Further transformations in economic and social priorities are required, as we discuss in the following sections.

Public Policy Reforms

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The Premiere Gardens "solar subdivision" in Rancho Cordova, Calif. The 100 building-integrated PV "Zero Energy Homes" are among the first of their kind in the nation. They combine solar panels with improved energy efficiency.

The Industrial Revolution of the 19th Century gave us the Age of Coal. In the 20th Century we entered the Age of Oil. The second half of the 20th Century saw the dawn of the Nuclear Age. The 21st Century promises to become the Age of Renewable Energy and Conservation—but only if we have sufficient public determination to resist the vested interests that would keep society hooked on the debilitating addiction to costly oil, dirty coal and deadly atoms. Political options must quickly change so that appreciating Earth's limits becomes a constant factor in the way energy policy decisions are made. Aggressive efforts must be made by all levels of government, business and society to adapt to the realities of a planet being pushed to its limits—and that means applying the Conservation Imperative first and foremost.

The struggle has become titanic. President Obama's economic stimulus plan included $80 billion for Green Energy, the Energy Department has promised $150 billion for renewables research and the U.S. Interior Department has established a task force to accelerate development of large-scale, renewable energy projects on federal lands.[324] This is a good beginning, but it's not nearly enough. Large-scale "solutions" may prove to be a luxury that is no longer available in the era that we are now entering. In a Post-Carbon world, we will need to focus more on solutions that are local, small-scale and sustainable.

Some American businesses, meanwhile, are undertaking massive energy-efficiency moves. Wal-Mart, the world's largest retailer, has realized that its heavy reliance on transportation makes it vulnerable to oil price rises. The Walt Disney Company—which once promoted the false solution of nuclear power—now plans to reduce its carbon emissions 50% by 2012 (and ultimately to zero) by shifting to more efficient clean energy options.[325] According to efficiency advocate Amory Lovins, learning to use energy "in a way that saves money" will mean that "some big problems like oil dependence, climate change, and the spread of nuclear weapons will go away—not at a cost but at a profit."[326] This may be sound a bit wishful—especially for those who recognize that the idea of a "Green" Wal-Mart or "Energy Efficient" Disneyworld is incompatible with the realities of a world that will soon be faced with the need to go on a "power diet."

As the King CONG Economy (Coal-Oil-Nuclear-Gas) flickers toward its inevitable end, the world's industrialized countries are still providing $60 billion in subsidies to support these outmoded and unsustainable industries. Former British Treasury official Nicholas Lord Stern has stated that meeting climate stabilization goals means that "most of the world's electricity production will need to have been decarbonized" by 2050.[327] This would require industrial economies to cut per capita CO_2 emissions by at least 80 percent by mid-century. Developing nations may be asked to cut emissions 20-40 percent by 2020. Only carbon-free renewables like solar and wind can be deployed at a speed likely to accomplish this transition.

Many towns, states and nations are well on the way toward a Renewable Revolution. A report by the Johns Hopkins University's Center for Climate Strategies (based on climate policies already adopted by 16 U.S. states) estimates that a national commitment to just 23 specific policy approaches would reduce CO_2 emissions while creating 2.5 million "green jobs" and adding $159.6 billion to the nation's GDP. [328]

In April 2010, Texas announced it had reached its goal of 10 GW of renewable energy—15 years ahead of schedule.[329] A bill in the California Senate would put the state on course to generate one-third of its energy from renewable sources by 2020, enough to power every home in the state.[330] Hawaii and Alaska have adopted 40% and 50% renewables goals, respectively. The countries of the European Union expect to derive 100% of their power from renewable sources by 2050.[331] Denmark already receives one-third of its electricity from the wind.[332] Sweden has announced its intention to become the industrial world's first "oil-free nation" by 2020 and has challenged the rest of the world to transition fully to renewable energy within the next ten years.[333]

Meanwhile, in the U.S., the 2007 Green Jobs Act, sponsored by Reps. John Tierney (D-MA) and Hilda Solis (D-CA) authorized $125 million to train workers—including low-income youth—to install solar and wind power generators, retrofit old buildings and construct new "green" buildings. The goal is to create 3 million green jobs within a decade. The act's Pathways Out of Poverty provision will assure the benefits flowing to companies in Silicon Valley also will flow to impoverished job seekers in East Los Angeles and the Bronx.[334] As the country's new Secretary of Labor, Hilda Solis is perfectly positioned to promote a Green Jobs program that simultaneously addresses the two major problems of pollution and poverty. Among some of the public policy options now being promoted are the following:

Carbon Offsets/ Cap-and-Trade

Offset schemes give carbon dioxide emitters the opportunity to balance carbon reduction or sequestration against their emissions. They essentially pay other businesses to counter carbon impacts. A similar program, for tradable and gradually decreasing pollution "allowances," was pioneered in the U.S. to minimize acid rain caused by sulfur dioxide emissions from coal-fired power plants. In 2006, about $5.5 billion worth of carbon offsets were purchased in the compliance market, representing about 1.6 billion metric tons of CO_2 reductions.[335]

Identifying actual reductions is tricky and it can also be fraudulent, giving rise to some of the same practices that led to the collapse of the U.S. mortgage market. In December 2009, France reported a $209 million "carbon carousel fraud" and, in January 2010, EU officials announced carbon fraud losses topping 46.7 billion euros.[336] Unlike a straightforward carbon tax, cap-and-trade transactions can lead to economically dangerous speculative "bubbles" that can cause broad economic collapse. The immense and often untraceable sums involved in cap-and-trade systems already appear to be contributing to a new global financial bubble. A more effective—and revolutionary—prescription would be to extend carbon offsets to the world's 2 billion poor who have no access to electricity and should, therefore, rightly represent one of the largest reservoirs of untapped "carbon credits."

Carbon Taxes

The Supreme Court's 2007 ruling that CO_2 was a "pollutant" gave new impetus to advocates of a carbon tax, which economists consider less susceptible to political manipulation and evasion than cap-and-trade systems. Carbon taxes make sense economically and environmentally because they tax carbon directly,[337] using the marketplace to drive change. A carbon tax applied to industries, vehicles and fuels would quickly make renewables competitive, even with heavily subsidized coal, oil and nuclear. It would also provide a powerful motivation for efficiency improvements in manufacturing and agriculture. A carbon tax would not contribute to the creation of speculative markets in trading "pollution credits"—a practice that cap-and-trade systems are already promoting.

Renewable Offsets

Under the Kyoto Protocol's Clean Development Mechanism (which may be renewed in 2012), industrialized countries can gain "renewable" credits to offset their greenhouse gas emissions if they finance and support renewable energy projects (including reforestation) in developing countries.

Feed-In Tariffs

Feed-in tariffs (FITs) reimburse homeowners for the excess electricity their home-based energy systems contribute to the grid.[338] FITs deliver more renewable energy rewards than tax credits or write-offs—and at lower cost. With fixed-rate contracts delivering a 7-9 percent return, FITs make investing in renewable energy almost as attractive as investing in government bonds.[339] FITs favor individuals and small entrepreneurs over large-scale, entrenched corporations.

Germany passed the first feed-in law in 1991 and doubled the country's share of renewable power in nine years. It was the participation of homeowners, local communities and small businesses that accounted for the surprising success of Germany's feed-in program. Germany had hoped to produce 12 percent of its power from renewables by 2010 but it passed that mark in 2007. Germany now expects to produce half its electricity free, clean and renewably by mid-century. (And bear in mind that Germany lacks coastal winds and is cloudy much of the time.) Forty countries—including at least 18 of the European Union's 27 members—are following Germany's example. By 2020, green tech in Germany is expected to account for more than 700,000 jobs, becoming the country's major industry as new businesses spring up to produce solar panels and wind turbines for buyers as far away as New York and Texas.

In Canada, Ontario's provincial power authority has introduced a FIT program that pays homeowners up to 80.2 cents (79 cents U.S.) for every excess, unused kilowatt that goes from their rooftop solar panels into the local power grid. Large multi-megawatt producers also get paid, but at a lower rate of 44 cents per kWh. Community-based wind and solar projects should prosper under this plan.[340] Gainesville, Florida, the first U.S. city to enact feed-in tariffs, requires utilities to buy power generated from local homeowners and businesses at a rate slightly higher than the cost of production. California, Hawaii, Maine and eight other states are moving to enact similar laws. In March 2009, the California Public Utilities Commission proposed a market-based FIT for projects generating between 1.5 to 20 MW. Rep. Jay Inslee (D-WA) has introduced a national FIT law in Congress.

Feebates

A new policy tool to encourage smart market choices is the "feebate." Described as "a cross between a fee and a rebate," it provides rewards for people who choose to purchase more efficient homes and vehicles. People who invest in larger, less-fuel-efficient vehicles or bigger, less-energy-efficient buildings pay an additional "fee" that provides the funds to "rebate" purchasers of more sustainable options. In France, automobile feebates were so successful that the program has been extended to cover a wide range of consumer products. Feebates also work to shift the market towards more sustainable production and have proven more popular than fuel taxes and efficiency standards.[341]

Decoupling and Shared Savings

In 2008, two U.S. states introduced a novel incentive program that allowed electric and gas utilities to keep any profits they realized from *saving* their customers money (usually through improved efficiencies). The experiment proved so popular that, by 2009, 25 states had either adopted or were planning to adopt "Decoupling and Shared Savings" programs. Energy efficiency advocate Amory Lovins argues that "decoupling utilities' profits from how much energy they sell" is one of the best tools policy planners could use to promote the wise use of energy. The policy of rewarding utilities for reducing consumption was actually adopted by the country's state utility commissioners—in 1988.[342]

A Smart Grid

The U.S. electricity grid is a vast patchwork governed by mechanical switches that date from the Analog Era. This aging network is susceptible to unpredictable blackouts and is inherently inefficient since transmission lines lose power for every mile their electrons must travel. Routine outages cost the economy $150 billion a year. Proponents argue that a Smart Grid, resembling the Internet in complex interactivity, could juggle power needs with digital speed—maximizing reliability and minimizing losses, while increasing transmission efficiency by 50%. Improving distribution efficiency is critical since electricity often costs more to distribute than to generate.

But there are drawbacks. Building a national grid could cost as much as $50 billion and—like the Internet—the advantages might not be shared equally by poorer members of society.[343] The "mandatory" installation of Smart Meters in California and Texas outraged customers who discovered errant meters were producing false hikes in their energy bills. Others have complained that the radio-frequency emissions used to broadcast Smart Meter readings have triggered health problems including insomnia, headaches, nausea, heart palpitations, ear pain, memory loss, dizziness, DNA strand breaks, disruptions of the immune, nervous and hormonal systems, and long-term cancer risks.

Smart Meters also raise privacy concerns since detailed monitoring of appliance use can be analyzed to profile residents' behavior (a tempting tool for commercial data-mining). Smart Meter transmissions also can be read remotely by anyone with the proper equipment and the meters are vulnerable to hackers. (One simulation found an attack on a Smart Meter could progressively "infect" 15,000 meters in a single day.) Even a Smart Grid is vulnerable to cyberattacks. Russian and Chinese operatives have successfully installed software in the U.S. grid and, in 2002, 70 percent of U.S. energy providers reported instances of "serious cyberattack."[344]

Smart Meters give commercial utilities the power to control a homeowners' electricity remotely. While this could be useful in rationing consumption during peak use to avoid brownouts, some consumers object to this unprecedented corporate intrusion into their private lives. Instead of a balkanized grid—bankrolled by private industry and guarded by proprietary Smart Meters—the country might be better served by a nationalized grid that is government-run as a public utility.

Zero-Energy Buildings

A new generation of self-sustaining buildings that use only the energy they generate is springing up around the world—from America to Zimbabwe. The National Renewable Energy Lab's new 222,000-square-foot office uses passive heating/cooling along with wind and photovoltaic power to service the office needs of 800 employees. The Environmental Studies Center at Oberlin College relies on rooftop and passive solar, natural ventilation and geothermal heat pumps to achieve its Zero-Energy status. The Eastgate Office Complex in Harare, Zimbabwe, uses 90 percent less energy than similar-sized buildings at a savings of more than $35 million.[345] (The savings were accomplished through the application of "biomimicry." The architects incorporated techniques that African termites use to naturally heat and air-condition their mounds.)

More Efficient Eco-Cities

Driving an all-electric vehicle in California will reduce CO_2 emissions but driving that same car in Florida (where electricity comes from coal-burning power plants) will actually *increase* greenhouse gas emissions. While plug-in hybrids are superior to oil-burning autos, the largest energy savings (and greenhouse mitigations) will come from redesigning our cities—replacing urban sprawl with compact communities designed for "access by proximity" that replaces single-driver automobiles with efficient, affordable mass transit. One goal of the New Urbanism movement is to create communities where you can reach everything you need by walking no more than five minutes.

One way to reduce time-and-energy-intensive trips to shop and work is to build more compact and diverse urban centers by narrowing the distances with Infill Building. Instead of building new housing and offices on land far from the urban core, 81 percent of developers who responded to a 2007 poll now favor redeveloping existing neighborhoods[346] with attractive amenities that include integrated shopping, recreation, work, schools and parks. The California Infill Builders Association (CIBA) anticipates that intermingling housing, small commerce and workplaces could cut California's driving miles by one-third and save $4.3 billion in infrastructure costs. Mixed-use neighborhoods could cut commuting by 3.7 trillion miles—a climate-friendly impact that would be the equivalent of removing every car from the state's roads for 12 years. CIBA estimates urban consolidation would save the average household $6,500 in reduced auto and utility expenses.[347]

The 2000-Watt Society

The Swiss Council of the Federal Institute of Technology has proposed that industrialized countries should begin a transition to a world in which every citizen can ive comfortably on a continuous requirement of 2,000 watts (17,520 kWh per year). The average Swiss citizen consumes around 5,000 watts; the average American consumes 12,000 watts. The technologies—energy efficiencies, zero-energy buildings, heat-pumps, renewables—already exist. Since 1983, efficiency advocate Amory Lovins has run his Colorado home and office on 10 percent of the electricity used by the average U.S. household, while using only one percent of the "normal" energy consumed for space and water-heating. What's needed is rapid, well-designed social change directed by sensible public policy goals.[348]

Community Aggregation

Many cities have formed municipal entities to purchase power at discounted rates. Other cities already operate their own municipal power plants. In Aspen, Colorado, 75 percent of the city's municipal electricity comes from renewable sources, mainly wind. At the local level, the nonprofit One Block at a Time encourages aggregation of entire city blocks, a process that brings neighbors together for discounted group purchases, thus bringing down the individual costs of solarization.[349] Traditional commercial utilities naturally see aggregation as a threat. In California, Pacific Gas & Electric Company placed an initiative on the June 2010 ballot to block cities from establishing their own municipal power systems. Despite spending $45 million on the campaign, PG&E's power play was voted down by the people.

Transition Towns

Transition towns, which got their start in the United Kingdom, are now sprouting up in Europe, Asia and the Americas. Discouraged with governments' failure to act on the climate change threat or to begin meaningful preparations for an "Energy Descent Action Plan,"[350] citizens in hundreds of these transition towns have committed to ending their dependency on fossil fuels in 10-20 years. Calling the movement "a social experiment on a massive scale," the Transition Network provides a 12-step guide to a low-carbon economy. "We truly don't know if this will work," the organizers admit. "What we do know is this: if we wait for governments, it'll be too little, too late; if we act as individuals, it'll be too little; but if we act as communities, it might just be enough, just in time."[351]

Meanwhile, other "relocalizing" campaigns are sprouting up around the world. The Post Carbon Institute[352] has been providing blueprints for "a more resilient, equitable, and sustainable world" since 2003. In San Francisco, Bay Localize has created a Community Resilience Toolkit[353] that has been adopted by hundreds of groups around the world.

Powering Down: The Conservation Imperative

To minimize cascading climate calamities and impending wars over shrinking resources, industrialized economies need to formally recognize the limits of the Earth's carrying capacities, put the brakes on growth-oriented economics, and begin a wide-ranging process of "powering down"—learning to live better with less, to unplug from the grid, to simplify our lives, to become more localized and self-reliant. The watchwords for a Brave New Power-Down World are already entering our vocabulary: "Less and Local," "Carbon Footprint," "Slow Food," "Locavore." All have come to mean a change in our values and habits—a rejection of economies based on consumption and growth in favor of solutions that emphasize localization and *less* use of energy and materials in all economic activity.

While the looming inevitability of downsizing poses a challenge for the Industrialized World, the move to Conservation Economies may be more easily negotiated by the "underdeveloped" world where marginal survival—rather than over-consumption—is the norm. Unfortunately, the world's richest nations have offered the false promise of universal prosperity to the entire world. As a result, many in the world's poorest nations feel entitled to experience the questionable pleasures of private automobiles, 24-hour electricity, microwave convenience and processed food.

The harsh reality is that instead of seeing the world's poor majority joining the world's wealthy minority, the damage our over-consumption has inflicted on the planet's forests, oceans and mineral resources means there is now less for everyone to share. Simple justice requires that it is the world's wealthier residents who will need to adjust their lifestyles. Attaining a just and sustainable future will also benefit greatly by efforts to reduce the size of the human population. (It is now clear that educating women is the most effective measure to limit population growth.) We are all in the same boat and that boat doesn't expand with the growing number of passengers—it just gets more crowded and comes closer to sinking.

In a Powered Down world, new homes would be smaller and, hence, cheaper to heat and cool. All new construction would follow green building principles to conserve resources and reduce energy consumption. Insulation requirements would be tripled to match Germany's R70 standard. (The R-value is a measure of thermal resistance used by the building and construction industries. In February 2010, the Department of Energy ordered insulation standards increased from R38 to R60 in the nation's coldest regions.)[354] Food would be grown locally (Beijing's vegetables are raised within 60 miles of the city). Water-intensive lawns would be replaced by gardens and vacant city lots would be transformed into productive urban gardens. Solar-box cookers and solar window-box heaters would cut cooking and heating costs. Instead of replacing aging sewer systems, composting dry toilets could be installed in homes to save billions of gallons of water now used to flush wastes. Rainwater harvesting and reuse of "grey water" from household sinks and bathtubs would save even more.

Achieving a powered-down, reduced-scale, Steady State Economy[355] will require a new economic system that is not based on speculation and ever-expanding debt. Because the banking industry will not voluntarily reform the system, transformation must begin from the bottom up, with the empowering of local economies. Citizens can localize credit by moving funds to locally owned and controlled cooperatives, credit unions, and small banks. Local currencies backed by tangible assets—labor, craft skills, homecare, artistic talents—can help sustain essential jobs that support food, housing and healthcare services.[356]

The Uppsala Protocol outlines a global Power Down Plan featuring equitable sharing of the planet's remaining oil-based energy resources based on a World Depletion Rate, which requires that current and future consumption of oil be limited to the amount of oil extracted in a given year.[357] (Colin Campbell, a geologist with the Hydrocarbon Depletion Study Group at Sweden's Uppsala University, proposed the Protocol in hopes of establishing an international accord to prevent profiteering from the global oil shortage, discourage wasteful consumption and stimulate the development of alternative energy options.)

The world has already seen some examples of successful Power Down economies. Kerala, an unindustrialized state in southwest India, never "powered up." Kerala has a zero-growth economy and one of the country's lowest per-capita incomes. Nonetheless, Kerala's citizens enjoy higher levels of health, education, social mobility, economic stability and gender equality than any other Indian state. Similarly, after the collapse of the Soviet Union, Cuba was forced to Power Down. Without imported petroleum-based fuel, pesticides and fertilizers, Cuban agriculture went organic and community gardens now cover one-third of Havana's urban landscape. Cuban transport largely relies on bicycles and mass transit. The country now enjoys one of the world's highest levels of literacy, health and overall Quality of Life.[358]

On personal, community, national and global levels, our choices in energy policy will determine whether we achieve a stable, durable, peaceful society. Maximum energy and goods consumption cannot guarantee a secure and joyful future.

Ingredients for a New Sustainable Economy

In his 2009 IFG report, "Searching for a Miracle," author and futurist Richard Heinberg outlined some of the steps required to craft an emerging economy of sufficiency, equity, sustainability and peace. Here is a brief overview of some essential goals:

A rapid transition from carbon-based energy by adopting an "Oil Depletion Protocol" [359] ***(aka the Uppsala Protocol).*** Scaling down the "King CONG" (Coal-Oil-Nuclear-Gas) Economy. We must reject dangerous and unsustainable "alternatives" such as "clean coal," "new generation nuclear," "industrial-scale biofuels," and "waste-to-fuel incineration." We need to place global limits on the expenditure of declining fossil fuel reserves and place sufficiency standards on manufactured goods to safeguard sustainability goals while assuring the equitable reallocation of dwindling resources. The annual per capita energy required for human well-being is believed to be 50 to 70 gigajoules (Gj). Beyond 100 Gj, there is no appreciable improvement in one's personal sense of well-being—nor in any *objective* measures of well-being. In North America, current annual per capita energy consumption stands at around 325 Gj.[360]

Swift adoption of small-scale, locally owned, ecologically sustainable renewable energy systems to accelerate the process of "powering down" by dramatically increasing conservation and efficiency. Additionally, adoption of the "Precautionary Principle" (which requires initial evidence that a technology, product or practice is safe—not that it is "not known to be unsafe") will protect the public against the introduction of goods, services or practices that could harm humans, societies or the environment.

Reparations. Much of the West's inordinate wealth stems from an oft-times brutal colonial history. Nations have grown rich and powerful by occupying other nations—extracting their resources for profit and leaving them impoverished and in debt. In a world of diminishing resources, this historic misappropriation of wealth needs to be addressed. Avoiding a grim future of local and global "resource wars" will require moving from a world of "haves and have-nots" to a world of "share and want not." A reallocation of global resources will be needed to achieve an equitable balance between nations.

Rejection of the main driving forces of economic globalization: These include: hyper-growth; export-oriented food, energy and commodity production; deregulation of corporate abuses; profit-based privatizing of the shared public commons; privatization of public services; the promotion of global economic goals over local needs. A new generation must be taught to reject the Market's invitation to indulge in excessive consumption. Spending less time working for cash to acquire nonessentials will buy more time to spend with family and friends and to engage in social, recreational, cultural and spiritual pursuits.

Transition to reviving "Import Substitution" on a national level, while advancing work toward "local solutions to local problems." Seek regional and home-based production of economic necessities, such as food, clothing, transportation and shelter. The production of essential goods and services must be determined by democratic consensus, not by the imperatives of global capitalism. Wall Street must yield to Main Street with prohibitions on economic speculation and debt-based finance. Growth-based economies must be replaced by no-growth, steady-state economies that function within natural limits.[361]

Relocalization. The agenda of economic globalization serves to sustain the growth of global corporations at the expense of the planet's environmental carrying capacity and to the detriment of local communities and businesses. The inevitable passing of the Age of Cheap Oil will require the creation of "survival economies" that rely on less long-distance trade and less movement of capital across time zones. Society will need to become more self-sufficient by "relocalizing" the creation of essential goods and services. Government, industry, agriculture and commerce will benefit from investment rules that favor local ownership and mandate community participation on all corporate boards.

Redesign existing urban and non-urban living environments into compact, self-sufficient, pedestrian-friendly EcoCities[362] built to accommodate—and transcend—the limitations of a post-carbon world. Land removed from traditional agriculture must be converted back to croplands, cultivated under local community ownership. Post-carbon re-ruralization will rely on renewable and natural inputs rather than fossil fuel byproducts and manufactured chemicals. The depletion of cheap oil will require the de-industrialization of agriculture and the adoption of organic, climate-wise, and locally sustainable agroecology and micro-farming. The strategies of "permaculture"[363] will reconnect agriculture with natural ecologies to create productive, stable and resilient systems. While petroleum-dependent industrial agriculture pours Greenhouse Gases into the atmosphere, organic farming practices actually capture excess carbon from the air and return it safely—and productively—to the soil.

Adoption of the principle of "Polluter Pays." At all levels, the full ecological and social costs of production must be identified and born by the producer.

The old models used to measure economic wellbeing, Gross Domestic Product (GDP) and Gross National Product (GNP) must be abandoned. New measurements must emphasize the satisfaction of basic human needs (rather than economic wealth) and securing "economic sufficiency" for all people—including shelter, food, education, health, and access to healthy environments. Rather than worshiping exponential growth, corporate profit and the accumulation of personal wealth, societies will need to focus on economic and environmental sustainability, the preservation of "natural capital," and the collective wellbeing of all members of the community. Population growth must be addressed by supporting women's education and social emancipation. Green economists have proposed a Genuine Progress Indicator (GPI) to evaluate the degree to which a country's economic performance improves the overall welfare of its people and the environment.[364]

Finally, Heinberg lists five fundamentals that can serve to gauge a successful Survival Society: "Ecological sustainability; degree of 'net energy gain' or loss; degree of social equity, well-being and 'sufficiency' (rather than surplus consumption and wealth); democratic decision-making processes; and nonviolent conflict resolution."

"A deliberate embrace of limits does not amount to the end of the world," Heinberg writes, "but merely a return to a more normal pattern of human existence. We must begin to appreciate that the 20th century's highly indulgent, over-consumptive economic patterns were a one-time-only proposition and cannot be maintained."

CONCLUSION

SRS ENERGY

SRS Energy's Solé Power Tiles (pictured above) are designed to resemble Spanish tiles, slate and shake roof tiles. Each tile contains a flexible solar panel (produced by United Solar Ovonic) encased in lightweight, recyclable polymer. These solar tiles can outperform flat PV panels in some high-heat conditions.

When President Jimmy Carter called energy conservation "the moral equivalent of war" and challenged citizens to "put up with inconveniences and to make sacrifices," the energy-powers-that-be pounced, memorably reframing Carter's wise admonitions as a prescription for "shivering in the dark." In response, "conservation without sacrifice" became a widespread corporate mantra. Advertisements now assure us that, by resorting to "greensumption," we can shop our way to an environmental Nirvana where we can continue to enjoy "warm showers and cold beers"—only with less energy: our "sacrifices" limited to the choice between driving a Prius instead of an Escalade.

A more realistic view of our energy future—and the lifestyles it will support—requires a complex analysis. Traditional energy planning (like planning for land use and transportation, the biggest factors in energy demand) has been predicated on the assumption that populations will continue to grow and that humans have a right to make continually greater demands on the world's resources. But since we live on a finite planet, designing solutions to "sustain growth" are not ecologically sustainable and hence fail as solutions. They are merely mechanisms for sustaining the *problem*.

Rather than allowing food shortages, wars and social breakdown to control population, today's leaders should be looking at ways to restrain population growth. And they should help us to reframe human happiness as a goal that is not dependent on the ever-growing consumption of goods.

What we need is a society of resilience, a society of sharing and mutual support. Disasters will come. Even a "smart grid" will remain vulnerable to massive outages caused by everything from winter storms to solar flares to computer hackers disrupting the grid via the Internet. Such vulnerability can be minimized through the decentralization that comes with widely distributed generation. Once millions of off-the-grid homes and businesses are equipped with stand-alone power-generating systems, massive blackouts will no longer be a threat. Community-based generation will provide depth and redundancy that can improve power reliability and reinforce national, as well as local, security.

President Obama's decision to follow George Bush's policy of using public money to stabilize a banking and investment culture judged "too big to fail" is an unfortunate throwback to a financial paradigm that has brought economic peril to the entire global economy. Establishing state banks would be a proven way to lessen Main Street's dependence on high-flying Wall Street financiers. Keeping money near home, rather than trying to revive the national economy by stimulating credit spending on new cars and 3D TVs would put an end to the speculative practice of pumping new air into old bubbles.

Switching energy sources and "going green" is only part of the solution. After all, a pistol redesigned to fire biodegradable bullets is still a weapon. If the Age of Industrial Solar produces a legacy of "green tailings"—choking landfills with cast-off batteries and PV panels leaking heavy metals, acidic fluids, and caustic chemicals into our groundwater—we will have failed to address the fundamental issues of sustainable survival. Our goal must be total closed-loop recycling, where every industry's waste becomes another industry's raw material—imitating nature's wise and economical use of resources.

Many of the sicknesses of contemporary America and the rest of the "developed world" stem from excess: too many calories, too many miles driven, too many ostentatious living spaces, too much throwaway stuff. Instead of globalization's promise of "More from Everywhere," a better watchword for the future will be "Less and Local." Our long-term survival in the 21st century depends not on consumption but on social solidarity, cooperation, sharing, resourcefulness, knowledge and health. The future belongs to those whose basic needs and wellbeing can be sustained locally, in low-impact, self-supporting communities.

We need decentralized solutions and ground-up, community-based alternatives. Instead of bailing out speculators, we should be investing to create small-scale, decentralized, sustainable and democratic communities supported by millions of small, local, organic farms. We will need to respond to massive changes and had better be flexible and agile. In the Brave New Post-Oil World, old ideas about energy will disappear. We will need to understand the economic advantages of owning a mule rather than a pick-up. Someone who knows how to make and repair a boot could become more valued than someone who knows how to boot up a computer. Many capital-intensive, extractive centralized industries will collapse, leaving us to care for our polluted air, damaged land, chemically poisoned croplands, and the broken oceanic food chain.

Turning away from the false promises of nuclear power is not only good in itself, it will help us focus on the real necessities for a better future. We will have to redesign our technologies to be smarter and more efficient and our cities to be compact, convenient and congenial. We will need to learn to live within our means—doing without extravagance, just as our thrifty forebears did—living better with less, more in tune with each other and our shared planet. If we can escape the easy temptations of the consumerist mentality, we will be able to address the inequality that threatens the fundamental stability of our nation and our world. The old Combustion Economy promoted massive inequities in the distribution wealth and power. What the world needs now is a sustainable Compassion Economy that will usher in a new era of stewardship and sharing.

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