The Case for Terrestrial (a.k.a. Nuclear) Energy

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There have been a host of debates this year between the Democratic and Republican candidates for president. Many of these candidates believe that among our top priorities is to address global warming by reducing carbon emissions. All or most seem to agree that decreasing America's energy dependence is another. Yet not one of the candidates has mentioned the idea of nuclear energy—or, as I prefer, terrestrial energy--which could serve both these ends.

Right now there are 103 operating nuclear reactors in America, but most of these are owned by utilities (which also own coal plants). The few spin-offs that concentrate mainly on nuclear—Entergy, of Jackson, Mississippi, and Exelon, of Chicago—are relatively small players. As for a nuclear infrastructure, it hardly exists. There is only one steel company in the world today that can cast the reactor vessels (the 42-foot, egg-shaped containers at the core of a reactor): Japan Steel Works. As countries around the world begin to build new reactors, the company is now back-ordered for four years. Unless some enterprising American steel company takes an interest, any new reactor built in America will be cast in Japan.

This is an extraordinary fate for what was once regarded as an American technology. France, China, Russia, Finland, and Japan all perceive the enormous opportunity that nuclear energy promises for heading off global warming and relieving the world's energy problems as reflected in recent soaring oil prices. Yet in America, we remained trapped in a Three Mile Island mentality, without even a public discussion of the issue. As folk singer Ani DiFranco puts it, the structure of the atom is so perfect that it is "blasphemy / To use it to make bombs / Or electricity."

It is time to step back and question whether this makes sense.

Fossil Fuels

Almost all our energy—and we should remember that all living things exist by drawing energy from their environment and discarding part of it as "waste," so there is nothing inherently shameful about energy consumption—ultimately derives from the sun. Plants store solar energy by transforming it into large carbon-chain molecules (the process we call photosynthesis). The entire animal kingdom draws its energy from this process by "eating." About 750,000 years ago, early humans discovered that they could also draw on solar energy by starting or continuing a chain reaction we call fire. When heated, the stored energy in carbon chains is released. This heat energy can break down other carbon chains, which causes combustion. This has been the principle source of energy throughout most of human history. When historian William Manchester wrote a book about the Middle Ages called *A World Lit Only By Fire*, he was describing the world of only 700 years ago.

All this began to change about 400 years ago when human beings discovered an older source of stored solar energy—coal. Our most common fossil fuel, coal is the compressed remains of vegetable matter that covered the earth 300-400 million years ago. Coal is superabundant and we will probably never run out of it. It was the fuel of the Industrial Revolution, and it is still the world's largest source of energy. It is also the most environmentally destructive substance ever utilized. The EPA estimates that it kills 30,000 Americans each year through lung diseases (and in China it is doing far worse). It is also the world's principal source of carbon dioxide emissions.

Oil, another fossil fuel, is rarer and is believed to be the remains of organisms that lived in shallow seas during the age of the dinosaurs. It was first drilled in 1859, but was used only for lighting and mechanical purposes until the invention of the automobile. Now it constitutes 40 percent of our energy consumption and is perhaps the most difficult fuel to replace. American oil production peaked in 1970 and is now declining rapidly—a fact that explains much of the story of our subsequent foreign policy. The Arab oil embargo occurred three years following the peak, when the producing states realized we were vulnerable. The question now is whether world production will reach a similar peak and decline. As Matthew Simmons has written: "We won't know until we see it in the rear view mirror." If it does come, it may not look much different from the tripling of oil prices we have witnessed over the last six years.

Natural gas is generally considered the most environmentally benign of the fossil fuels. It gives off little pollution and only about half the greenhouse gas of coal.

Natural gas was put under federal regulation in the 1950s, so that by the 1970s we were experiencing a supply shortage. Deregulation in the '80s led to almost unlimited supplies in the '90s. Then we began the fateful practice of using gas to produce electricity, resulting in a price crunch and the loss of many gas-dependent industries, such as fertilizer and plastics factories, to foreign countries. Now American gas supplies seem to have peaked and we are importing 15 percent of our consumption from Canada. Huge gas supplies have been discovered in Russia and the Middle East, but will not do us much good since gas cannot be easily transported over water. Thus China, India and Europe will be able to buy pipeline gas much more cheaply and are already out-competing us on the world market.

Alternative Fuels

Given the precarious state of these fossil fuels, people have begun talking of "alternative" and "renewable" fuels—water, sun, and wind. The term "renewable" is somewhat misleading: No energy is "renewable" insofar as energy cannot be recycled (this is the Second Law of Thermodynamics). The term "renewable" usually describes tapping *flows* of solar energy that are supposedly "free." But coal and oil in the ground are also free. It just takes work—and energy—to recover them. So, too, solar "renewables" can only be gathered at a cost. They are often limited and require the use of other resources—mainly land.

What about water? Hydroelectricity is a form of solar energy. The sun evaporates water, which falls as rain and then flows back to the sea, creating kinetic energy. Rivers have been tapped since Roman times and, beginning in the 19th century, dams were built to store this solar energy. Hydroelectric dams provided 30 percent of our electricity in the 1930s, but the figure has declined to ten percent. And all the good dam sites are now taken.

What about wind? Wind energy has captured the imagination of the public and is touted by many as the fastest growing energy source in the world. All of this is driven by government mandates—tax credits and "renewable portfolio" laws that require utilities to buy non-fossil sources of power. The problem with wind is that it is completely unpredictable. Our electrical grid is one giant machine interconnected across the country, in which voltage drops must be carefully limited in order to avoid damaging electrical equipment or losing data on computer circuits. Wind irregularities can be masked up to around 20 percent, but after that they becomes too disruptive. At best, therefore, wind will only be able to provide the 20 percent "spinning reserve" carried by all utilities. In addition, windmills are large and require lots of land. The biggest now stand 65 stories tall—taller than New York's Citicorp building—and produce only six MW, or about 1/200th the output of a conventional power plant.

Most are found on mountaintops, since that is where the wind blows strongest. Amory Loins, the guru of “soft energy,” has suggested covering all of North and South Dakota with such windmills.

What about the sun? Solar energy is very diffuse. A square-meter card table receives enough sunlight to run only four 100-watt electric bulbs. At best, solar could provide our indoor lighting, which consumes about ten percent of our electricity. But keep in mind: storing this solar energy requires huge lands areas.

Sunshine can be harnessed *directly* in two ways—as thermal heat or through photovoltaics, the direct production of electricity. In the 1980s, California built a Power Tower that focused hundreds of mirrors on a single point to boil water to turn a turbine. The facility covered one-fifth of a square mile and produced ten MW. It was eventually closed down as uneconomical. Last year, when Spain opened an identical Power Tower in Seville, *U.S. News and World Report* ran a cover story hailing it as a “Power Revolution.” That facility, of course, is completely subsidized by the government.

Photovoltaic cells have more promise. They are thin wafers where solar radiation knocks the electrons off silicon atoms, producing an electric current. At present, an installation about half the size of a football field could power one suburban home—when the sun shines, of course. The problem is that photovotaics are enormously expensive: Enough of them to provide one-quarter of an average home’s electricity requires investing around $35,000. Their greatest benefit is that they are able to provide electricity precisely when it is most needed—on hot summer afternoons when air conditioning produces peak loads.

Nuclear or Terrestrial Energy

There is one other form of alternative energy often mistakenly grouped with solar: geothermal energy. Geothermal is produced when the natural heat of the earth comes in contact with groundwater. This can produce geysers and “fumaroles”—steam leaks that are harnessed to produce electricity.

Where does this heat come from? Temperatures at the earth’s core reach 7,000 degrees Centigrade, hotter than the surface of the sun. Some of this heat comes from gravitational pressures and the leftover heat from the collisions of astral particles that led to the formation of the earth. But at least half of it (we don’t know the precise percentage) comes from the radioactive breakdown of thorium and uranium within the earth’s mantle.

This is “terrestrial energy,” and a nuclear reactor is simply the same process carried out in a controlled environment. When we harness terrestrial energy in the form of uranium isotopes, we mine it, we bring it to the surface, we concentrate it, and we initiate a chain reaction that releases stored energy in the form of heat—the very same process as that used to harness solar energy from coal.

When Albert Einstein signed the letter to President Roosevelt informing him of the discovery of nuclear energy, he turned to his two fellow scientists and said: “For the first time mankind will be using energy not derived from the sun.” The possibility emerged in 1905, when Einstein posited that energy and matter are different forms of the same thing and that energy could be converted to matter and matter to energy (as reflected in the famous equation $E = mc^2$). The co-efficient, c^2, is the speed of light squared, which is a very, very large number. What it signifies is that a very small amount of matter can be converted into a very large amount of energy. This is good news in terms of our energy needs and the environment. It means that the amount of fuel required to produce an equivalent amount of energy is now approximately two million times smaller.

Consider: At an average 1,000 megawatt coal plant, a train with 110 railroad cars, each loaded with 20 tons of coal, arrives every five days. Each carload will provide 20 minutes of electricity. When burned, one ton of coal will throw three tons of carbon dioxide into the atmosphere. We now burn 1 billion tons of coal a year—up from 500 million tons in 1976. This coal produces 40 percent of our greenhouse gases and 20 percent of the world’s carbon emissions.

In contrast, consider a 1000 megawatt nuclear reactor. Every two years a fleet of flatbed trucks pulls up to the reactor to deliver a load of fuel rods. These rods are only mildly radioactive and can be handled with gloves. They will be loaded into the reactor, where they will remain for six years (one-third of the rods are replaced at each refueling). At that point they will be removed and transferred to a storage pool inside the containment structure, where they can remain indefinitely (three feet of water blocks the radiation). There is no exhaust, no carbon emissions, no sulfur sludge to be carted away hourly and heaped into vast dumps. There is no release into the environment. The fuels come out looking exactly as they did going in, except that they are now more highly radioactive. There is no air pollution, no water pollution, and no ground pollution.

Objections to Nuclear Energy

What are the potential problems with nuclear power?

First, some fear that a nuclear reactor might explode. But this is impossible. Natural uranium is made of two isotopes—U-235 and U-238 (the latter having three more neutrons). Both are radioactive—meaning they are constantly breaking down into slightly smaller atoms—but only U-235 is fissile, meaning it will split almost in half into two much smaller atoms. Because U-235 is more highly radioactive, it has almost all broken down already, so that it now makes up only seven-tenths of a percent of the world's natural uranium. In order to set off a chain reaction—as in a bomb—natural uranium must be "enriched" so that U-235 makes up a larger percentage. Reactor grade uranium—which will simmer enough to produce a little heat—is three percent U-235. In order to get to bomb grade uranium—the kind that will explode—uranium must be enriched to 90 percent U-235. Given this fact, there is simply no way that a reactor can explode.

On the other hand, a reactor *can* "melt down." This is what happened at Three Mile Island. A valve stuck open and a series of mistakes led the operators to drain the core when it was already short of cooling water. As a result, about a third of the core melted from the excess heat. But did this result in a nuclear catastrophe? Hardly. The public was disconcerted because no one was sure what was happening. But in the end the melted fuel stayed within the reactor vessel. Critics had predicted a *China Syndrome* scenario where the molten core would melt through the steel vessel, then through the concrete containment structure, then down into the earth where it would hit groundwater, causing a steam explosion that would spray radioactive material across a huge area. In fact, the only radioactive debris was a puff of steam with about the same potency as a single chest x-ray. Three Mile Island was an industrial accident. It bankrupted the utility, but no one was injured.

This of course was not the case in Chernobyl, where the Soviet designers didn't even bother building a concrete containment structure around the reactor vessel. Then in 1986, two teams of operators became involved in a tussle over use of the reactor and ended up overheating the core, which set fire to the carbon moderator that facilitates the chain reaction. (American reactors don't use carbon moderators.) The result was a four-day fire that spewed radioactive debris around the world. (More fallout fell on Harrisburg, Pennsylvania, from Chernobyl than from Three Mile Island.) With proper construction such a thing could never happen.

Another objection to nuclear power is the supposed waste it produces. But this is a mischaracterization. A spent fuel rod is 95 percent natural uranium—U-238. This is the same material we can find in a shovel full of dirt from our back yards. Of the remaining five percent, most is useful, but small amounts should probably be placed in a repository such as Yucca Mountain. The useful parts—uranium-235 and plutonium (a manmade element produced from U-238)—can be recycled as fuel. In fact, we are currently recycling plutonium from Russian nuclear missiles. Of the 20 percent of our power that comes from nuclear sources, half is produced from recycled Russian bombs. Many of the remaining isotopes are useful in industry or radiological medicine—now used in 40 percent of all medical procedures. It is only cesium-137 and strontium-90, which have half-lives of 28 and 30 years, respectively, that need to be stored in protective areas.

Of course, federal regulations require *all* radioactive byproducts of nuclear power plants to be disposed of in a nuclear waste repository. As a result, more than 98 percent of what will go into Yucca Mountain is either natural uranium or useful material. Why are we wasting so much effort on this useless task? Because in 1977, President Carter decided to outlaw nuclear recycling. The fear then was that other countries would steal our plutonium to make nuclear bombs. (India had just purloined plutonium from a Canadian-built reactor to make its bomb.) This has turned out to be a false alarm. Countries have either built their own reactors or—as Iran is trying to do now—enriched their own uranium. Canada, Britain, France and Russia are all recycling their nuclear fuel. France has produced 80 percent of its electricity with nuclear power for the last 25 years. It stores all its high-level “nuclear waste” in a single room at Le Havre.

Conclusion

The U.S. currently gets 50 percent of its electricity from coal and 20 percent from nuclear reactors. Reversing these percentages should become a goal both of global warming advocates and anyone who wants to reduce America’s dependence on foreign oil. Contrary to what some critics charge, this would not require massive subsidies or direct intervention from the government. Indeed, the nuclear industry has gone through an astounding revival over the past decade. The entire fleet of 103 reactors is up and running 90 percent of the time. (Most shut down only once every 22 months for refueling.) Reactors are making money hand-over-fist—so much so that the attorney general of Connecticut recently proposed a windfall profits tax on them! The industry is poised for new construction, with proposals for four new reactors submitted to the Nuclear Regulatory Commission and almost 30 waiting in the wings.

The rest of the world is rapidly moving toward nuclear power. France, Russia and Japan are not only going ahead with their own nuclear programs, but selling their technology in the developing world. America, which once dominated this technology, is being left behind. The main culprit is public fear. Nuclear technology is regarded as an illegitimate child of the atomic bomb, a Faustian bargain, a blasphemous tinkering with nature. It is none of these. It is simply a natural outgrowth of our evolving understanding of where energy can be found in the universe. The sun has been our prime source of energy throughout human history, but energy is also generated in the earth itself. It is time to avail ourselves of this clean and safe source of energy.