Nuclear Energy

The site of what is arguably the world's leading research program in nuclear energy lies just a short drive from the city of Marseille through the picturesque and romantic countryside of southern France.

At Cadarache, the Commissariat à l'énergie atomique, the French atomic energy agency, operates a complex of research facilities that is soon to be the home of ITER, the International Thermonuclear Experimental Reactor, which will be the most advanced and powerful Tokamak fusion reactor ever built. This reactor is being funded by the EU, China, Russia, the United States, and others.

Though famous as the future site of ITER, Cadarache is also soon to be home to one of the world's most advanced fission reactors. On March 21, engineers began building the advanced Jules Horowitz Reactor (JHR), to be used to test and evaluate advanced technologies. It is expected to operate for 50 years.

Work on the JHR is just one more sign of French dominance in the nuclear energy industry. In the United States, where nuclear energy technology was invented, only 19.4 percent of electricity is supplied by nuclear power plants. In France, by comparison, 78.5 percent of electricity is generated by nuclear power. The situation is much the same in other European nations. Lithuania, Slovakia, and Belgium all generate more than half of their electricity using nuclear power. Other nations producing more than 40 percent of their electricity using nuclear power include Ukraine, Sweden, Bulgaria, Armenia, and Slovenia. Meanwhile, a growing list of nations, including Russia, China, South Korea, Taiwan, and India, have nuclear power plants under construction.

Notably absent from that list is the United States. Hamstrung by irrational fears, miles of red tape, and onerous bureaucratic regulatory obstacles, no new domestic nuclear power plants have been ordered and built in America for over 30 years, even though the United States has the largest per capita demand for energy. The resulting lack of new nuclear capacity in the face of rising energy demand brings on short-term and long-term consequences. Short-term problems caused by a lack of electrical capacity include rolling blackouts, disruptions in daily life like stopped elevators, non-working traffic signals, loss of refrigerated products, etc. Among long-term problems we face rising electrical costs, termination of marginal industries, and no industrial expansion, among many, many others. Those consequences are entirely unnecessary because nuclear power provides an economical and safe method of producing abundant electricity.

Energy Options

Though alternative energy options like solar and wind power continue to get favorable press, their large drawbacks limit their practicality. Both are inefficient and subject to environmental disruptions. Cloudy days substantially reduce output from solar "farms," and wind power is subject to the vagaries of the weather. Moreover, vast swaths of territory must be covered with solar panels and parabolic mirrors or windmills in order to generate large amounts of power. In southern California, for instance, Stirling Energy Systems is building a 500-megawatt solar installation that, according to *Wired* magazine, is expected to cover 4,500 acres of land with 20,000 large, dish-shaped mirrors.

The only really viable alternatives for future large-scale generation lie with the four technologies that already provide the bulk of the nation's power: hydropower, natural gas, nuclear, and coal. Of those, hydropower, providing 6.5 percent of U.S. electricity, has already peaked, and is likely to undergo a slow decline in usage in the future as smaller dams are dismantled to restore the natural course of some rivers. That leaves natural gas, coal, and nuclear power as options.

While natural gas has been highly touted as an energy source because it is considered a relatively clean fuel and because gas plants are relatively inexpensive to build, gas is an unlikely candidate for future large-scale power generation. During the 1990s, construction of gas-fired plants, which now provide 18.7 percent of U.S. electricity, increased because of relatively low fuel prices. In recent years, however, natural gas prices have increased substantially.

Moreover, domestic gas supplies are likely to be insufficient to support long-term expansions in gas-fired generation, even if domestic gas production increases. A recent study by Canada's National Energy Board concluded: "Production increases alone are not sufficient to meet the projected future requirements for natural-gas demand, including power generation. Consequently, any increases in demand for gas-fired generation would necessitate a reduction in gas consumption by other consumers and the development of further sources of gas supply." Those other sources of supply would be foreign, most likely Russian, sources. Already Europe is dependent on Russian gas and in each of the last two years faced supply disruptions at the hands of the Kremlin.

Gas isn't going away any time soon, but it is clearly not the best solution to the nation's long term need for energy. Coal, which already provides almost 50 percent of U.S. electricity, is a better option because the United States holds the world's largest reserves of the fuel. But even coal — though it will remain a useful fuel far into the future — fares poorly in comparison to nuclear energy.

Not far from my home, one nearby road crosses a rail line that leads to a coal-fired plant. As with most rail lines, trains here seem to be synchronized to run at times of maximum inconvenience. Most of these trains on this line are known as "unit trains," consisting of an engine or two plus *one hundred* 90-ton coal cars. It takes all the coal hauled by one of these trains to fuel a typical 1,000-megawatt generating plant for a single day! And even though the coal itself is cheap at the mouth of the mine, transportation costs mount substantially by the time the unit train reaches a power plant. According to the University of Wyoming, "Coal at the mine mouth is about $5 per ton. By the time it gets to Illinois, the cost is $30 per ton. A train load of coal is worth $50,000 when it leaves the mine. When it pulls into the power plant in Chicago it is worth $300,000! For the user, up to 80% of the cost of the coal is in the transportation."

The Nuclear Option

Even though coal remains an attractive option, nuclear energy is far superior. For one thing, despite the bad press it gets, nuclear is safer. No one in the United States has died as a result of nuclear-power generation.

That can’t be said for coal. Historically, more than 100 lives have been lost annually at train crossings owing to coal-hauling unit trains.

Those tragic accidents are examples of the numerous accidents related to fossil-fuel energy generation that claim many lives each year. According to scientist and acclaimed science-fiction author Ben Bova, “If you count up the number of people killed in coal mine disasters or oil well accidents and the wars being fought over oil, nuclear power looks positively benign. Then there are the natural gas and propane explosions that kill hundreds each year and destroy millions of dollars’ worth of property.”

Finally, and far worse still if we are to believe the Environmental Protection Agency (a practice to be carefully considered), coal-fired plants in the United States annually cause 24,000 early deaths — including 2,800 from lung cancer. According to the EPA, emissions of fine particle pollution (or soot) resulted in an average loss of 14 years of life for the victims, along with 38,200 non-fatal heart attacks and 534,000 asthma attacks each year. (For more on concerns about radiation and the safety of nuclear energy, see article "Myths About Nuclear Energy.")

All things being equal, the economics of energy production also favor nuclear energy over coal. Instead of the 100 or so train cars of coal it takes to run the average coal plant each day, nuclear energy uses a comparatively tiny amount of uranium for fuel, making nuclear energy very efficient by comparison. The relatively tiny fuel requirements of nuclear power plants result in operational cost savings, and new technology developed by a private team of scientists in Australia and leased to General Electric promises to reduce costs even more.

Presently, nuclear fuel is commonly enriched by a clumsy process using centrifuge technology, but the Australian team has found a way to enrich uranium much more efficiently using lasers. “The technology, said Michael Goldsworthy, a nuclear scientist and leader of the project, may halve enrichment costs, which he estimated accounted for 30 percent of the price of nuclear fuel,” the *Sydney Morning Herald* reported on May 27, 2006.

The power stored in uranium fuel boggles the mind. Suppose you have in your hand a penny-sized piece of the uranium isotope U235. It would seem strangely heavy because its density is more than 2.5 times that of the metal in a modern penny. An enormous amount of energy is pent up in the disc, but it is not hot — either thermally or radioactively. With a half-life of over 700 million years it gives up its radioactivity gradually, (A half-life is the amount of time it takes for a radioactive substance to give up half of its radiation.) and being an “alpha emitter,” its radiation is too weak to penetrate your skin. You could wear it as a necklace your entire life without any danger.

Let’s further suppose you are Mr. and Mrs. Joe Average living in the Midwest. The average amount of heat energy necessary to heat your house through the snowy days and clear, still, cold Iowa nights from October to March is 80 million BTUs — the BTU being a measure of energy required to raise the temperature of one pound of water by one degree Fahrenheit. Not only would the energy stored in that penny-sized bit of uranium be enough to heat your house for one heating season, it would be enough to heat the average house *for more than six years*! In fact, a single pickup load of U235 has the equivalent energy of the coal carried in 36,500 large coal cars.

Today, most existing nuclear power plants require uranium fuel that is comprised of about 3 percent U235, with the balance being the more abundant U238 isotope. All told, it takes just six truckloads of uranium to power a typical 1,000-megawatt nuclear reactor for a year.

Breeder Reactors

Clearly, uranium is a much more efficient source of energy than coal. More advanced technologies that are available now compound that efficiency. According to the *Hyperphysics* archive developed by Georgia State University physics professor Carl R. Nave, "Under appropriate operating conditions, the neutrons given off by fission reactions can 'breed' more fuel from otherwise non-fissionable isotopes." The right type of reactor can take advantage of this phenomenon in order to generate *more* fuel while it is operating.

According to Professor Nave, a so-called fast-breeder reactor "can produce about 20% more fuel than it consumes by the breeding reaction. Enough excess fuel is produced over about 20 years to fuel another such reactor. Optimum breeding allows about 75% of the energy of the natural uranium to be used compared to 1% in the standard light water reactor." That is, the same amount of raw fuel could yield 75 times as much energy as it does now!

Split More Atoms

Because nuclear fuel contains such a tremendous amount of energy, incurs relatively little in the way of transportation and fuel costs, and currently is used in reactors built decades ago, electricity generated from that fuel in existing reactors is incredibly cheap. In measurements of economic efficiency that take into account production costs, current U.S. nuclear plants come out on top when compared to coal, natural gas, and petroleum. According to the Nuclear Energy Institute, "In 2005, nuclear power had the lowest production cost of the major sources of electricity, with production cost of 1.72 cents/kWh. Coal had a cost of 2.21 cents/kWh, natural gas 7.51 cents/kWh, and petroleum 8.09 cents/kWh."

The low cost comes from the fact that the initial costs of construction for most existing reactors have long since been recovered. Moreover, new nuclear-power plants carry an initial price tag that is competitive with the cost of new coal-fired plants. The Associated Press reported on March 21 that Duke Energy Corp. "estimated it would cost $1.53 billion to build a single coal-fired power unit at its Cliffside power plant in western North Carolina." That plant would generate 800 megawatts. By comparison, in 1996 General Electric signed a $1.8 billion contract to build an advanced boiling-water nuclear reactor in Taiwan. Under the terms of that contract, GE even agreed to supply the fuel for the 1,350 megawatt facility. Today, according to the Nuclear Energy Institute, a similar plant of 1,450 megawatts "could be built in the U.S. for $1,445 per kilowatt." That works out to approximately $2.1 billion in construction costs. Figured on a per kilowatt basis, Duke Energy's proposed coal facility will cost $1,912 per kilowatt to build. In other words, at present a reactor can be built in the United States for less money than it takes to build a coal-fired plant.

And imagine how much less expensive reactor construction would be if more than a decade's worth of regulatory obstacles were removed from the path of future nuclear construction. Construction of the Watt Bar 1 nuclear plant in Tennessee was started in 1973 and the plant went on-line in February 1996. Nearly 23 years. (This plant, incidentally, set the record of 512 days of continuous operation without refueling or any maintenance downtime.) Meanwhile in China, according to *World Nuclear News*, Westinghouse is building four “AP1000 third-generation nuclear power reactors.” From start to finish, construction of those plants is expected to take only four years.

As good as existing designs have been, the new ones are even better. The major U.S. players have new *passive* reactor designs that take advantage of natural convection and gravity to provide cooling without the necessity of pumps. The Westinghouse AP1000 reactors that are to be built in China are expected to cost only $1,200 per kilowatt installed and have robust safety features. General Electric has developed their ESBWR (the Economic & Simplified Boiling Water Reactor) with similar safety features and economic advantages. European, Asian, and South African developers have offerings that may advance their technologies over those of the United States.

One of the more noteworthy is Toshiba’s 4S (Super Safe, Small and Simple) reactor that is buried in the ground, requires no operator, and provides 10 megawatts of electricity for 30 years without refueling. After 15 years, the neutron reflectors will have to be rotated; otherwise no maintenance is necessary. Toshiba has offered a 4S reactor to the town of Galena, Alaska, at no charge except for the fuel, which would cost less than one-third what the town now pays for diesel fuel. It’s a great deal that, like most nuclear plants, is hamstrung by the cost of paperwork. The next step for this village of 675 souls is to come up with $20,000,000 to pay for an environmental impact statement.

The future is bright for nuclear power. The big question is: will the future be bright for an America that abandons nuclear power? Low-cost energy is essential for the future of all Americans. Climbing energy costs weaken the competitiveness of American industry on the world market. Traditionally, Americans have enjoyed cheap, plentiful power, and that has helped give American industry a competitive edge and led to higher standards of living. Nuclear energy, an American invention, can help keep it that way for decades to come.

It is not too late for U.S. utilities to switch from coal and gas to nuclear power. They did it in France, according to PBS *Frontline*, when the thought of dependence on foreign fuel sources proved intolerable. “A popular French riposte to the question of why they have so much nuclear energy is ‘no oil, no gas, no coal, no choice,’” *Frontline* reported. And it worked. According to *Frontline*, “Today, nuclear energy is an everyday thing in France.” In matters of nuclear power at least, it’s about time for America to follow the French example.

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