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Atomic Balm?

For the first time in decades, increasing the role of nuclear power in the United States may be starting to make political, environmental and even economic sense.

By Jon Gertner

A Nuclear Renaissance?

Workers at the Alvin W. Vogtle nuclear-power generating station sometimes describe it as being in the middle of nowhere, and in many respects they're right: situated on a bend in the Savannah River, in the thick pine forests of central Georgia, the plant is an hour south of Augusta and a two-hour drive, if you disobey the speed limit, from the outskirts of Atlanta. On the final approach to Vogtle, a narrow country road cuts through vast stretches of undeveloped land punctuated with small ranch-style homes; in some places, you can still discern remnants of convenience stores and cheap motels set back from the pavement, all now shuttered, some barely standing. When Vogtle (pronounced VOH-gull) was being built in the 1970's and 80's, it was more aptly described as the middle of everything, a bustling, improvised city of engineers and tradesmen, some 14,000 workers in all, many of whom lived nearby in tents and trailers. It was one of the largest construction projects in the history of Georgia. An entire concrete factory, now defunct, was built here during that time; so was a factory to manufacture ice, a necessary ingredient in making the superdense nuclear-grade concrete required for the reactor-containment buildings. To Ellie Daniel, a local man who has worked as an administrator at Vogtle for more than two decades, only two significant things have happened in the history of Georgia's Burke County. "One is the Civil War," he told me. "The other is Plant Vogtle."

The boom that swept through the region as Vogtle rose from the forest floor — its immense cooling towers are each 548 feet tall — ended somewhat badly, however, at least in a financial sense. The plant took almost 15 years to move from blueprints to being operational. And by the time it began producing electricity in the late 1980's, its total cost, $8.87 billion, was so far overbudget that Vogtle became yet another notorious example of the evils of nuclear energy. In the public mind, the issue was safety. For the industry, the larger concern was economics. Indeed, as originally designed in the early 1970's, Vogtle was intended to generate a total of around 4,500 megawatts of electricity, enough power to serve the needs of several million homes. The grand plan was to have four reactors. Instead, it was scaled back to two, Vogtle Unit 1 (finished in 1987) and Vogtle Unit 2 (1989). Today these reactors together produce about 2,400 megawatts, satisfying about 15 percent of the state's power needs.

One day this May, on a brisk morning so clear that I could see its cooling towers from 20 miles away, I visited Vogtle on one leg of a tour to assess what many in the energy industry are calling a nuclear renaissance. Thanks partly to large government incentives and to market forces that have pushed the price of other electric plant fuels (especially natural gas) to historic heights, the prospect of starting a new nuclear reactor in this country for the first time in 30 years has become increasingly likely. By early summer a dozen utilities around the country had informed the U.S. Nuclear Regulatory Commission, which oversees all civilian nuclear activity in this country, that they were interested in building 18 new facilities, nearly all of which would be sited next to existing nuclear reactors. Vogtle was in this group of 18. In fact, the Southern Company, the large utility that runs Vogtle, also announced that it would formally apply to the N.R.C. next month for an early site permit, the first step in readying the community for a nuclear project that would complement the existing reactors. Whether Vogtle will turn out to be the 1st, 5th or 10th next-generation plant to break new ground is difficult to say; trying to predict which utility will be able to overcome formidable obstacles — public approval, regulatory scrutiny, billions in financing and complex engineering challenges — is akin to predicting the winner of a presidential election years in advance. Still, if things move smoothly (a rarity when it comes to nuclear power in this country), the Southern Company will receive a license to build and operate a new plant in 2010. Construction will take five years. Electricity will begin to flow to the residents of Georgia in 2015.

Over the past year, the debate over nuclear power has increasingly been framed as an environmental one, as several commentators — most notably Patrick Moore, a founder of Greenpeace (and now estranged from the organization); the British conservationist James Lovelock; and the Whole Earth Catalog founder Stewart Brand — have stepped forward to assert that global warming requires an embrace of new nuclear plants, because unlike gas- or coal-powered plants, nuclear reactors produce electricity without emitting greenhouse gasses. The nuclear industry, in turn, has capitalized on the chance to adopt a green tinge, or at least greenish one; among its recent slogans is the exhortation to "Go nuclear: because you care about the air." Most environmental groups have not softened their opposition, however. "This is more a propaganda exercise than a serious discussion of the viability of the industry," Jim Riccio, the nuclear policy analyst at Greenpeace, told me. By using global warming, he added, "the nuclear industry is trying to find some fear greater than the nuclear fear to be their selling point."

Nonetheless, whether any new nuclear plants are built in the United States depends less on the sentiments of the American public than on the country's individual utilities. And for conglomerates like the Southern Company, which runs Vogtle as well as two other nuclear plants in Georgia and Alabama, the determining factor is not air quality. It's money. Over the next 12 to 24 months, as utilities like Southern determine what to do, their fundamental concern is the bottom-line cost. And the feeling among many in the industry is that the financial prospects are almost certainly looking up.

One afternoon at Vogtle, Ellie Daniel took me just west of the plant. The reactors here sit amid 3,150 acres of wilderness; the snap of pine in the air and the low hills that roll toward the riverbank lend it the serenity of a fine vacation spot. We drove past the old concrete factory, past the crumbling foundation of the ice works and halted by a clearing at the side of the road. At the edge of the clearing, small pine trees had been planted in neat lines, stretching like vineyard rows up the hill to Vogtle Units 1 and 2. The ground beneath our feet was covered in a carpet of fallen needles. It's all part

Jon Gertner, a contributing writer for the magazine, last wrote about student-loan forgiveness.

of the effort to preserve the area as a pristine environment, Daniel explained to me: "We're trying to return the area to how it looked before we built here."

Much of this will be swept away, though, if plans progress the way the Southern Company hopes. In the clearing, some engineers at Vogtle had painted a green circle, about 60 feet in diameter, to mark the location and size of the planned reactor building. And in the center of the circle was a pole, also painted green, to mark the hot reactor core. This would be Vogtle Unit 3, Daniel said. Not far off, perhaps a few hundred yards, was another pole and another green circle. If you can imagine it, he added, this would be Vogtle Unit 4.

Hard Times After T.M.I.

On the evening before my visit to Vogtle, the prospect of new reactors at the site was the subject of a public meeting, convened by the Nuclear Regulatory Commission, at a technical college in Waynesboro, Ga., a small town about 30 minutes from the plant. Anyone intrigued or appalled by the idea of new construction could come to ask questions. These kinds of community gatherings have become a frequent occurrence around the country over the past year as utilities have shown a renewed interest in building reactors. "We're in what's called the preapplication space for Plant Vogtle," David Matthews, the head of new-reactor licensing at the N.R.C., told me as people milled about before the evening meeting. Matthews brought a dozen colleagues with him — engineers and science advisers, mainly — to address any technical points that might arise after he made a few brief remarks explaining the N.R.C. licensing process. But some attendees had come not so much to ask questions as to encourage the Southern Company to build Units 3 and 4. "Can you do it any quicker?" asked one representative from the local chamber of commerce. Meanwhile, a number of antinuclear advocates wanted to quiz the commission officials about the possible hazards of a new plant design and the plant's radioactive (and highly toxic) spent fuel; some had even set up tables to distribute brochures alongside the agency's own informational pamphlets. The rancorous debates that defined these sorts of public meetings two decades ago were largely absent: the exchanges followed a protocol that kept tempers in check while lending the meeting a formality that N.R.C. representatives, all dressed in formal business attire, tried to promote. Vogtle Units 3 and 4 were serious business.

The received wisdom about the United States nuclear industry is that it began a long and inexorable decline immediately after the near meltdown, in 1979, at Three Mile Island in central Pennsylvania, an accident that — in one of those rare alignments of Hollywood fantasy and real-world events — was preceded by the release of the film "The China Syndrome" two weeks earlier. To be sure, the events at T.M.I., as those in the industry invariably refer to it, as well as the radioactive steam explosion at Chernobyl seven years later, galvanized public opinion against nuclear power as never before. In the case of Long Island's Shoreham plant, steadfast community opposition eventually stopped a newly finished plant from ever operating. But the fortunes of the nuclear business have been defined by many factors that aren't so conspicuous. Several years before T.M.I., the growing expense of new nuclear projects, coupled with the realization that many predictions for future electricity demand were overblown, had already hobbled the business. New orders for plants had fallen off drastically by 1978. "The industry was in a depressed state," says J. Samuel Walker, the historian at the Nuclear Regulatory Commission. "And what T.M.I. did was finish things off."

In fact, T.M.I. didn't kill the industry. It killed the *growth* of the industry — ensuring, in a way, that nuclear power would not assume more than a fraction of the U.S. electric business. The last year a plant was approved for construction by the N.R.C. was 1978. But interminable construction schedules meant that many facilities approved before T.M.I., like Plant Vogtle in Georgia, were finished long after the accident. Some didn't even start generating power until a few years ago; the last was the Watts Bar plant in eastern Tennessee, which began operations in 1996. Since then the contribution of nuclear energy to our electrical grid has remained fairly steady. All told, the 103 active nuclear reactors in the United States supply about 20 percent of our electricity. And in some places the contribution is much larger. New York gets 29 percent of its power from nuclear energy, New Jersey 52 percent. Abroad, nuclear energy has its hot spots too — in France, for instance, 78 percent of the electricity comes from nuclear energy. There are currently 337 working reactors in 30 countries outside the United States, and there may soon be many more, as India and China embark upon ambitious plans to build dozens over the next decade to satisfy their thirst for electricity.

In the U.S., each of the commercial nuclear plants has been granted a 40-year operating license by the N.R.C. This life span was originally based upon the hypotheses of engineers and physicists in the early 1960's who weren't sure how long a large nuclear plant could safely operate, because none had ever been built before. While there have been numerous incidents of mechanical defects over the past few decades, the 40-year projection has by and large proved a conservative estimate, and in the past few years, the N.R.C. has been granting 20-year extensions so that some older plants that pass workplace inspections can run for a total of 60 years. Even with such licensing renewals, though, it's doubtful the current fleet of plants will run for, say, 80 years. When I visited Nils Diaz, the longtime chairman of the Nuclear Regulatory Commission, who retired at the end of June, he pointed out that even if one passed muster for safety, a plant that old might require so much upkeep as to make it uneconomical.

That means the industry, in a way, is in a race against time. Recently, Paul Joskow, a professor of economics at M.I.T., sent me a chart that looks ahead to the output of America's reactors over the next half-century. As the current 103 nuclear reactors continue to generate electricity for the next few decades, the line on the chart remains mostly flat. But then the plants' electricity production falls off a cliff. "I think this is the first time in many years, perhaps 20 years, that the combination of government policy, economic conditions and environmental constraints are reasonably favorable for nuclear," Joskow told me. "If they can't move forward now, it would be very difficult in the longer run." It may even be more urgent than that. One conclusion to be derived from the chart is that nuclear power in this country is dying. Unless someone starts building soon, it will begin to disappear in 15 or 20 years, as one plant after another exhausts its operating permit and goes dark. And it will effectively be extinguished as an energy source by around 2050.

For those with deep misgivings about the safety and expense of nuclear plants, life without them may indeed be a cause for celebration. Yet their absence would probably pose tremendous challenges for the United States. The first is where 20 percent of our power would come from; the second is whether a substitute fuel for that power would emit carbon dioxide. It is, in many ways, a long-term dilemma, one closely related to global warming, and one that is poorly suited to a society that focuses on short-term results. For Wall Street, which concerns itself with our publicly traded utilities' quarterly earnings, the primary worry is whether companies (and investors) that choose nuclear power will quickly be saddled with burdensome debts. For elected officials, the main concern is whether support for nuclear energy will hurt or help their standing in the next election cycle. Yet to spend a few months listening to those who study the earth's energy resources is to get the feeling that we are in for a very difficult century — and one that depends on an immediate future of difficult and unpleasant choices. "If you want a different energy system in 2050, you really have to start changing it now," says John Holdren, a Harvard professor and one of the country's most esteemed thinkers on energy and the environment. "You can't get there and say, 'Oh, I want a different energy system.' "

Pick Your Poison

When it comes to America's future energy needs, one of the larger points of confusion is the somewhat tangled relationship between fossil fuels and electricity. Current prices at the gas pump, for instance, or the possibility that we are approaching a moment of "peak oil" — the point at which the global supply of crude peaks and then diminishes forever, with cataclysmic consequences for transportation, trucking and the economy in general — actually have little to do with the future supply of power. Making electricity is generally about creating a source of heat and steam, and using that steam to turn giant turbines and generate power. Less than 3 percent of our electric power is generated from oil. Besides the 20 percent contribution from nuclear power, 50 percent of our electricity comes from burning coal, 18 percent from burning natural gas and (in a heat-free method that is often the cheapest) 6.5 percent by harnessing the energy of water moving through dams. Wind and solar power make up less than one-half of 1 percent of what we use on a typical day. In part because the wind doesn't always blow and the sun doesn't always shine (and in part because wind turbines and solar cells are expensive to build) neither technology is yet good enough to generate large, reliable quantities of inexpensive electricity, or what utility companies call "base load" power. At at some point in the future, oil and electricity may fight for supremacy: Toyota recently announced it is developing a plug-in car in addition to its hybrids, for instance, and electricity has the potential to help manufacture clean-burning fuels like hydrogen for the future.

Over the past few years, the executives at Georgia Power, a division of the Southern Company as well as the utility that owns the majority share of the Vogtle plant, have tracked the population growth of the region and tried to look ahead, as all utilities do, at what the demand for electricity might be several decades from now. At the moment, the company's 20-year projections suggest that power needs in the region will grow by 30 percent. So that's one consideration. Another is that some outmoded plants in their system will need to be replaced. Building Vogtle Units 3 and 4 would, essentially, be a bet that a nuclear power plant will be superior to a new coal or gas plant in the long run. "I think based on what we know today, it would be the best option, but there's still a lot of work to be done," Oscar Harper, a vice president at Georgia Power, told me. Yet even if Georgia Power makes a decision in favor of nuclear, it still needs the state's public utility board to agree that it's in the best interest of Georgia residents.

None of this is assured. Moreover, what makes the choice of fuels such a knotty problem is that something that is cheap now, like coal, may not be so cheap in 10 years. This isn't because we're running out; we probably have at least a century's worth of coal reserves in the United States alone. But if the government were to impose a tax or a cap on carbon emissions, something that almost everyone I spoke with in the energy industry believes is inevitable, or if new laws mandate that coal plants must adopt more expensive technologies to burn the coal cleaner — or to "sequester" the carbon-dioxide byproducts underground — the financial equation will change: a kilowatt-hour generated by coal suddenly becomes more expensive. There are other contingencies at play, too: fuels, like natural gas, could experience a supply interruption that leads to enormous price spikes. As for the hope that wind and solar power will generate large amounts of clean, affordable electricity in the near future? I encountered great skepticism inside and outside the utility companies. "Maybe in 40 years," Paul Joskow, of M.I.T., told me.

Meanwhile, nuclear power has several appealing factors: the cost of uranium is fairly low, the supply is abundant (and mostly found in countries friendly to the United States) and big plants like Vogtle can generate large amounts of inexpensive electricity. The fuel, which takes the shape of thousands of pellets that are loaded inside long metal tubes and then placed into the reactor core, is strikingly potent; just a few pellets stacked together to resemble the size, shape and color of a black crayon can generate enough electricity for an entire family for a year. On the other hand, the list of negatives is long. Uranium mining is a messy business, and some Western states are still cleaning up the detritus of mines and mills from a half-century ago. A catastrophic reactor accident here or abroad — one that could be the equivalent of a so-called dirty bomb, killing thousands and rendering hundreds of square miles of surrounding land uninhabitable — would immediately destroy any revival of the industry. Then there are byproducts and proliferation. Until the Yucca Mountain underground repository in Nevada is completed (and the site probably will not be approved for construction before 2011), spent fuel has to stay on the site of nuclear facilities. And the possibility of irradiated fuel in the hands of a terrorist or rogue government has become increasingly worrisome in recent years.

The most immediate challenges, at least for the utilities, are the capital costs of building new plants, which when factored into the cost of the electricity, as they need to be, have a history of striking terror into the hearts of public-utility board members. A coal plant costs significantly less than a nuclear plant — as much as 50 percent less — and a gas plant is much cheaper than a coal plant. When I asked David Ratcliffe, the C.E.O. of the Southern Company, about the choice he's facing at Vogtle, he explained: "When you line up the three fundamental technologies — gas, coal and nuclear — you're lining them up from lowest capital cost and lowest construction time to greatest capital cost and greatest construction time. You're also lining them up from greatest fuel-price volatility to least fuel-price volatility." Probably the best comparison of gas, coal and nuclear energy was

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done with Joskow’s help in 2003, when the Massachusetts Institute of Technology published an exhaustive analysis of the future of nuclear power. The M.I.T. study concluded that nuclear energy is competitive, but only under certain circumstances. One instance is if the costs of building a plant are significantly reduced (by shortening the length of construction, for example). Another is if coal and natural-gas plants are taxed on carbon emissions. Because nuclear plants don’t produce carbon dioxide and wouldn’t be taxed, their electricity could conceivably cost no more to generate than that from coal and gas, or even less.

There is a counterargument to building large new power plants. One view — voiced most forcefully, perhaps, by Amory Lovins, a physicist who runs Rocky Mountain Institute, which advises corporations and utilities on energy efficiency — is that we don’t need to increase our electrical supply. We need to decrease demand by rewarding utilities for getting customers to reduce electricity use by, say, updating their appliances, furnaces and lighting. Lovins, a longtime critic of nuclear power, contends that it remains financially uncompetitive and that the 30-year absence of new plants is proof that the market has rejected nuclear power as a viable technology. When we spoke about whether utilities need to build more big generating plants in this country, he told me no — not now, not in 15 years, not even after that. “I think if you do,” he remarked, “your shareholders and ratepayers will be asking awkward questions that you would really rather not want to answer.” Yet the concern, even among Lovins’s admirers, is that if he is mistaken — that is, if either his estimates on efficiencies can’t accommodate population and industrial growth, or because what is possible in principle for energy efficiency is not possible in the real world — then the utilities will require an alternative plan. And that would entail more supply, likely meaning more big base-load plants (whether they rely on uranium, gas or coal) as well as large investments in renewable sources like wind and solar power.

When I asked John Holdren at Harvard whether the potential for efficiencies is as large as Lovins says, he replied, “The savings could be huge.” Yet Holdren also maintains that creating a clean and reliable energy supply for the future is going to be so daunting that nothing should be taken off the table. Clean coal, renewables, nuclear — we’ll need them all. To those in the electricity business, this is known as creating an energy portfolio: build everything, use everything and rely on nothing exclusively. “I’ll be very happy if Amory’s right,” Holdren added, “but I’d like to hedge my bets.”

For 30 years the debate has been defined by a perfect and almost maddening symmetry, not only in terms of opinion but also of facts. The answer to whether nuclear power is risky can be framed many ways, for instance: you can tally the number of injuries and deaths to citizens from U.S. nuclear plants (zero) or consider the potential number of injuries and deaths in a serious accident (many). Is nuclear power clean because it doesn’t produce carbon? Or is it dirty because it produces radioactive waste? Is it very expensive? Or are the economics competitive over the long run, especially if fossil fuels are taxed for warming the planet?

The AP1000, the Latest Thing in Plant Designs

For a utility that wants to go shopping for a nuclear plant, there are no blueprints floating around to help you do it yourself. If you have access to $2 billion or $3 billion, you pretty much have only three options. You can begin negotiations with General Electric or a French company called Areva for their newest designs, known as the E.S.B.W.R. and the E.P.R., respectively. Or you can start talking with Westinghouse, as the Southern Company has done, and check out its new reactor, the AP1000. If the Southern Company’s Georgia Power division decides to build Vogtle Units 3 and 4, this is the model. Unlike G.E.’s and Areva’s models, the Westinghouse design was approved and certified this year, after a complex multiyear process, by the Nuclear Regulatory Commission. Still, as I was reminded during my tour of Vogtle, an AP1000 has never been built anywhere in the world.

Westinghouse’s offices are about 30 minutes outside Pittsburgh, in a complex of squat, black, glassy modernist boxes that seem to have been dropped gently from the heavens onto a campus of several hundred verdant acres. The company continues to license its all-American name for home appliances, and its switchboard still gets calls every December from homeowners having trouble with their old Westinghouse Christmas lights. But this is now a nuclear company, and a nuclear company only, from top to bottom: Westinghouse services existing plants, sells fuel and sells new plant designs. All its other divisions have been shed, most of them during a corporate fire sale in the 1990’s. “At that point in time, we didn’t anticipate nuclear coming back here in the U.S.,” Steve Tritch, the company’s C.E.O., told me when I met with him in his office. So Westinghouse looked to Europe and Asia for new plants and concentrated on selling fuel and consulting services. “Barring some tremendous technological discovery that was going to produce energy, my own personal belief was that if you looked at the basic situation with fossil fuels, then nuclear was going to be used again here,” Tritch said. Still, in those days he assumed that Westinghouse wouldn’t see much new business in the U.S. until perhaps 2015.

About two-thirds of the plants in the United States are based on Westinghouse designs, including Vogtle Units 1 and 2 and the first commercial reactor ever built in this country, in Shippingport, Pa., which began producing power in 1957. In the mid-1950’s, the Atomic Energy Commission, the forerunner of the Nuclear Regulatory Commission, allowed the development of nuclear power for civilian uses. The fuel was to be far less volatile than that used in a weapon, which is why a nuclear plant can't be detonated like an atomic bomb. Yet it took at least another decade before the industry gained any traction, and much of the early momentum came from government financing and the willingness of companies like G.E. and Westinghouse to sell plants for tremendous discounts. Many utilities couldn't resist. In the early years, most of the engineers who designed plants came out of the U.S. Navy program for nuclear submarines, which explains the industry preference for nautical terminology (the "fleet") and to some extent its nautical design motifs. Walking through the industrial interiors of Plant Vogtle and of Grand Gulf, a nuclear plant I visited in Mississippi, I had the odd sensation of being in the hold of an immense freighter, bound for somewhere.

In retrospect, the nuclear dream of the 1950's and 60's was at least partly delusional. Those infamous predictions from the early days — that nuclear power would be "too cheap to meter," as Lewis Strauss, the chairman of the Atomic Energy Commission, told a conference of science writers in 1954, or that the country was destined to have the nuclear power of 1,000 plants by the year 2000, as the commission predicted in the early 1970's — seem farcical in light of what transpired in building the plants: the billions in overruns, the endless years of construction. Steve Tritch told me that inside the Westinghouse offices in the 1980's, executives kept a list of domestic plants they expected would be decommissioned even before their 40-year licenses expired. The trend for utilities was to get out of nuclear power as fast as possible, not in.

The so-called renaissance may turn out to be just a brief flurry of enthusiasm, entailing the construction of a few new plants over the next decade. But if nuclear power does catch on again — and there are a number of reasons to think it might, the most obvious being strong government encouragement driven by the attitude that a portfolio of energy options creates a more stable economy — then the seeds of its revival would almost certainly date back to the late 1980's and early 1990's. At that point, it was clear that the industry had massive, intractable problems. Most of the plants in the country were of customized designs, making repairs difficult and efficiencies of scale challenging. Many utilities had no expertise in operating a nuclear plant even after purchasing one. Meanwhile, the process for getting a facility approved by the Nuclear Regulatory Commission was done in two steps: first a construction permit and then, years later, an operating permit. The process all but ensured long delays and wasted resources as N.R.C. regulators identified construction errors and design shortcomings at very late stages and as legal opponents challenged the licensing process over the course of many years.

At around that time, a number of nuclear-friendly groups focused on hammering out a strategic long-term recovery plan for the industry. One of these, the Nuclear Power Oversight Committee, made up of several utility executives, created a blueprint for an industry revival that bears an uncanny resemblance to the way things are turning out today. "They said you have to have a new licensing regime at the N.R.C., because we can never have a Shoreham again," Ed Cummins, Westinghouse's chief engineer, told me. Shoreham, estimated to cost about $260 million in the 1960's, before construction started, was completed in 1984 for $5.5 billion, sold to New York State for $1 in 1992 and immediately decommissioned. Cummins also recalled that the oversight-committee plan listed about 15 other industry and regulatory changes before anyone would again consider building new nuclear plants. Many of the resolutions involved safety features and maintenance. If nuclear power were to ever get another chance, a new fleet of plants had to be standardized in design, easier to build and simpler to maintain. Above all, of course, they had to be far, far less expensive.

The Business of Nuclear Power

No two factors have been quite so important to the revived prospects for nuclear power as the high price of natural gas and large incentives offered by the Department of Energy, amounting to several hundred million dollars, to help finance the first few reactors. But there have been a great number of helpful factors inside the industry too. By the late 1990's, for instance, several utilities, notably Exelon (based in Illinois) and Entergy Nuclear (Mississippi), had developed specialties in buying and operating nuclear plants. With Westinghouse's help, the companies proved that refueling the plants, a complex choreography that occurs every 18 months or so and results in the temporary shutdown of the plant, could be done in about 35 days rather than the customary 60 or 70. The profits in decreasing that refueling period (many nuclear plants take in revenue of about $1 million a day) have been tremendous. Indeed, the companies became so adept at refueling and day-to-day operations that they began acquiring old nuclear plants whose owners either didn't want them or couldn't manage them. And they have proved that building a nuclear plant and buying a nuclear plant are entirely different business propositions. A company like Entergy, for instance, has purchased plants like Indian Point in Westchester County and Pilgrim in Massachusetts, updated them, retrained the work force, sped up the refueling process and reaped a nice financial reward. When I traveled to Jackson, Miss., to meet with Entergy's executives, its C.E.O., Gary Taylor, pointed out that the company's fleet, which now numbers 10 reactors, accounts for about $250 million in annual profits. What's more, it has been companies like Entergy and Exelon that in the 1990's began to give the engineers at Westinghouse and G.E. suggestions for the next generation of nuclear facilities, if they were ever built, rather than the other way around. According to Tritch, the Westinghouse C.E.O., company executives had to listen. "They had been operating plants for 25 years," he says. "It was no longer a core competency of ours. It was a core competency of theirs."

One great challenge in designing nuclear power plants is that making something safer and making something cheaper are often conflicting priorities: the less you spend, the less safe it is, and vice versa. This was what Westinghouse engineers began to wrestle with as they explored designs that could be built more efficiently. For any new project, the same basic technology would still be used to produce electricity: uranium pellets, encased in fuel rods, would undergo a controlled chain reaction in the core, release energy to heat pressurized water and generate steam, and the steam would turn giant, magnetized turbines to generate electricity. But they theorized that if the plant was physically smaller and it used less in the way of materials, it would help reduce costs and construction time. Also, a cheaper plant could be built off site from poured concrete modules and

One scientist points to the 'bathtub curve' that applies to the safety of nuclear plants: statistically, they are most dangerous either when they are first brought online (as with T.M.I. and Chernobyl) or at the very end of their life cycles.

assembled on location, rather than through a huge works project on the scale of the Great Pyramids, as at Vogtle. Most important, perhaps, the engineers began to ponder what's known as "passive" safety features. Years before, the U.S. military had asked Westinghouse to design a small, underground nuclear reactor to power missile silos. The reactor was never built, according to Howard Bruschi, the company's former chief technology officer, but the lessons were not forgotten. Passive safety measures included backup systems that would kick in automatically in the event of accidents or mechanical problems. Hundreds or thousands of working pipes and valves might be replaced by, say, a tank of cooling water mounted high so it could be emptied by gravity rather than by an electric pump. Complexity reduced, money saved. And at least in theory, there was an improvement in safety, too. The company's project was given a name: the AP600. It stood for Advanced Passive reactor; the 600 represented the output in megawatts.

Westinghouse financed part of the AP600 effort through its research budget, and the company also received a generous grant in the early 1990's from the U.S. Department of Energy. But even those sources of money weren't enough to supply the hundreds of millions of dollars needed to create the large working models to test the efficacy of the safety systems. "So we basically went to other countries that had nuclear programs and invited them to help with their test facilities and engineers," Bruschi says. Within Westinghouse, I heard it said that Bruschi went around the world, hat in hand, looking for help. I asked him how many countries he visited. "Italy, France, Japan, England, Scotland, Spain, Belgium, Sweden, Switzerland, Latvia and Poland," he told me. Eventually he went to China and Indonesia, too. It paid off when the N.R.C. approved the design for the AP600 in 1999.

But there were no buyers. Not one. Ed Cummins, the Westinghouse engineer, says that one major utility executive set him straight on why. Any utility could build a gas plant for far cheaper, he was told, and sell the electricity at a lower rate. So why build this? The AP600 was too small. It generated too little electricity to justify its construction costs. "He was right," Cummins says, and in response, he and his staff spent several years expanding the AP600 into the 1,100-megawatt AP1000. It cost more, but its larger electric output made it more competitive. When I visited Westinghouse in late May, the company was just putting the finishing touches on a simulated control room for the new plant, a sleek space near Cummins's office to demonstrate for buyers and regulators how operators will monitor the plant on just a few computer terminals and one large, central screen. Unlike the control rooms I visited at Vogtle and Grand Gulf, where operators are in charge of literally thousands of buttons, switches and meters, the technology at the AP1000 simulator, like the aesthetic, is modernized, simplified and streamlined.

The look is part of the marketing effort, of course. But the appeal of the AP1000 remains doubtful, even as 11 utilities, including the Southern Company, have expressed interest in the design. Westinghouse maintained to me that the cost will ultimately be somewhere between $1.4 billion and $1.9 billion. "We're negotiating contracts," Dan Lipman, who runs the new-power-plant division at Westinghouse, told me over lunch at the company cafeteria. "We're well beyond the should-we-do-nuclear phase. It's now a matter of, How should we do it?" So I asked Lipman what it would mean to actually cut a deal with a utility for a new plant, the first in 30 years. Would it happen a year from now? Two years? "If your definition of a deal is, when do you first start getting money, then that could happen very soon," he said. "I look for that this year, with big money committed after licensing by the N.R.C." From his continuing negotiations, Lipman said, it's clear that his customers are interested in "off-ramps": clauses in the contracts that allow them to bow out if they hit an unexpected financial or construction snag.

Still, if there is some circumstantial evidence that the price of new plants hasn't hit the point of affordability — the on-ramp, essentially, where utilities stop negotiating and start signing contracts and building — it might be the decision by the Tennessee Valley Authority to refurbish an existing nuclear facility at Browns Ferry in Alabama, rather than sign a contract for a new one. "The fact that the T.V.A. is spending $1.8 billion to fix up an old plant, rather than just spend it on a new plant, suggests that a new one costs well over $2 billion," David Lochbaum, of the Union of Concerned Scientists, told me in Washington. Lochbaum, a nuclear engineer and former consultant in the industry, agrees that carbon taxes could make a new nuclear plant financially viable. For now he says that the AP1000 just costs too much. This is something Westinghouse will not concede, but company executives did say they are fully aware that it isn't passive safety or modular construction that will sell their designs. It's the price tag, as well as proof that for the first time in history, a slew of nuclear plants can be built quickly, smoothly and within a budget.

Achieving Critical Mass

What really keeps the utilities and the nuclear industry up at night is risk — not just the risk that something will break down at one of the existing plants and thus wipe out two decades of improvements in operations, but the risk that the Nuclear Regulatory Commission is a black hole, an organization that will accept the new applications for plants and wait (and wait) before approving a construction-and-operating license. The N.R.C., which has streamlined its review process since the debacles of the 1970's, fields criticisms from both sides. Nuclear-safety advocates like Lochbaum, at the Union of Concerned Scientists, find it too accommodating to the industry; the industry, in turn, finds it too tough, slow and bureaucratic. But no one denies that the agency holds extraordinary power over the fate of the nuclear business in this country. It can shut a facility down, levy fines of $130,000 per incident per day, bar employees from working in the industry and delay and deny licenses. In addition to several thousand employees in its Rockville, Md., offices, the agency places at least two N.R.C. employees at every plant in the country. (They have total access at every plant to review day-to-day operations.) The agency is not known for partisanship; the commission membership is split in party affiliation, and the employees are civil servants. If anything, the engineers I met at the N.R.C. are a kind of hybrid scientist-cop, people of formidable intelligence with very little patience for companies or plants that deviate from the letter of the law.

Nuclear power plants are arguably the most complicated machines in the history of civilization, and the review process for new plants reflects that complexity. Essentially, a utility will need three stamps of approval from the N.R.C. to build a new facility: a site permit, an approved reactor design and a construction-and-operating license. Only then can a utility move forward. In the case of Vogtle, the Southern Company is finishing a site-permit application this month that will explore the suitability of those green circles on the forest floor as future reactor sites. The application will run thousands of pages and include an array of scientific data — "seismology, meteorology, hydrology, just about all the ologies I can list for you," says David Matthews, the head of the reactor-licensing division at the N.R.C. The agency, in turn, will spend two to three years reviewing it. The Southern Company has already said it would use the AP1000, meaning that it has chosen a certified design. So an approval of the site should eventually lead to the next step: a construction-and-operating application that includes detailed engineering data and every possible risk assessment. It will probably run more than 30,000 pages. It will take the N.R.C. at least another three years to review it. The question of whether various utilities are serious about reviving nuclear power might be measured by their seriousness in pursuing such an involved process. They're spending hundreds of millions of dollars to have the chance to build a nuclear plant within a few years. Just for the option of building Vogtle Units 3 and 4 — not for any construction at all — Georgia Power expects to spend $51 million. As David Ratcliffe, the Southern Company's C.E.O., put it: "We're marching down this road."

I asked many people in the industry whether the N.R.C. can grant licenses with the kind of speed that would preserve the integrity of its safety reviews and still satisfy the utilities. Nils Diaz, the recently retired chairman of the commission, told me that with new management procedures and employees — the N.R.C. is hiring hundreds of scientists and engineers to ready itself for the blizzard of work — the agency is up to the task. But most of the utilities, and many financial analysts who cover the electricity business, maintain a more guarded attitude. In fact, the industry has tried to create several cushions to insulate itself from potential hang-ups, since a delay doesn't mean only that it will take longer for a plant to produce revenue but also that a utility will have to pay interest on any money it borrows to finance a plant. (At Vogtle, for instance, nearly $3 billion of the final $8.87 billion cost was the finance charge on debt.) For starters, the Department of Energy has created a kind of risk insurance available to utilities that are the first movers in building a new plant. If one of the new plants hits regulatory delays during construction, the D.O.E. will reimburse the utility for at least a part of those costs.

The second cushion is the creation of an industry consortium, called NuStart, to test the licensing process. NuStart is filing several applications for nuclear plants, on behalf of its members, with the Nuclear Regulatory Commission. These applications — for the Grand Gulf plant in Mississippi and the Bellefonte site in Alabama — have preceded all others and may end up being built first. One goal of NuStart is to prove to Wall Street that utilities can get a license in a timely manner. Another goal is to establish a way for the industry to pool risk and information. If NuStart's construction-and-operating applications for its two sites are approved, in other words, any utility in the consortium (including Entergy, Exelon and Southern Company) can copy huge parts of the approved application for its own use, thus saving time and money. The Southern Company would do this for Vogtle.

The hypothetical nuclear plant then hits the next set of obstacles. In the South, at least, there appears to be little in the way of community opposition. When I spent the day in Port Gibson, Miss., the tiny town next to the Grand Gulf plant, the local politicians were adamant in support of any new reactor. "We've not been able to prosper like other communities," James Miller, the country administrator, told me. "We see this as our golden opportunity." The industry seems more concerned about the logistics of building a plant — that is, the actual construction. Several executives told me that they worried most about finding enough craft labor to work on the special aspects of plant construction. They also worried about steel orders, since the domestic industry that long ago forged the massive reactor vessels no longer exists. Only Japan Steel Works, these executives say, has such capacity now. "This country hasn't built really a lot of whole infrastructure in 20 years, and it hasn't licensed a new nuclear plant in 30 years," Gary Taylor, the Entergy Nuclear C.E.O., told me. "Most of the hard manufacturing moved offshore. In many ways that may be a bigger challenge than anything else."

Then there's the question of safety. The performance of American plants in this regard has improved markedly over the past 10 years; the industry, moreover, has gone to great lengths to help operators at plants around the world share information on mechanical or safety issues. Yet the specter of an accident has never really disappeared — nor will it. Nils Diaz told me that the role of the National Regulatory Commission is not to regulate the industry to a "zero-risk factor." That would be impossible, he said. It's to make sure there is the "reasonable assurance of adequate protection." Many industry critics wonder if even this goal is achievable. David Lochbaum, of the Union of Concerned Scientists, has pointed out the existence of a "bathtub curve" that applies to the safety of nuclear plants: statistically, they are most dangerous either when they are first brought online (as was the case with T.M.I. and Chernobyl) or at the very end of their life cycles. Many of our existing plants, Lochbaum points out, are edging closer to old age. As for the next generation of plants, the risk assessments on the AP1000 suggest its design is between 10 and 100 times safer than existing models. But until one is actually built, this remains a hypothetical. Engineers at the N.R.C. told me they will retain a healthy skepticism for passive safety until there's a track record in a working plant. They also noted, as a separate concern, that design safety (in any plant) does not necessarily translate into operational safety. "It's difficult to model and predict human action," Jerry Wilson, an N.R.C. analyst, told me. "It's much easier to model the technical details."

Finally, what about a wild card — that is, the remote possibility of an attack on a plant? It is not easy to get into a nuclear facility these days. It took me several weeks just to gain access to report this article, and I was first subjected to a thorough background check. At the gates of both Vogtle and Grand Gulf, I was met by heavily armed guards; later, I was escorted through many phalanxes of protective structures — razor wire, concrete blocks, fences, steel turnstiles, security doors, explosives sensors and so on — before ever getting near the reactor. At Grand Gulf, guards even patrolled inside key buildings with AR-15 semiautomatic rifles. Walking unescorted was out of the question. At least from the ground, the plants seemed impregnable. And the reactor-containment buildings, where the core resides — the small domed buildings that are the heart of a nuclear plant (the high cooling towers carry no radioactivity) — are some of the strongest man-made structures in existence. They're engineered to withstand earthquakes, fires, floods, internal explosions.

Yet the details of the N.R.C.'s own security reviews of plants (the agency periodically stages "force on force" mock attacks) have not been made public since 9/11 for reasons of national security, so there is no way to know how some facilities, if any, are deficient in protective measures. In 2000 and 2001, the last set of statistics the N.R.C. made public, 6 of 11 plants that were tested failed to prevent reactor damage when defending against the simulated attacks.

A Different Sort of Wedge Issue

To John Holdren of Harvard, the essential problem with nuclear power is that it is "too unforgiving of either human error or human malice." At the same time, Holdren points out, every source of electricity has its negatives. In the case of oil and gas, the question is whether there are enough reserves. For other fossil fuels like coal and tar sands, the question is whether our atmosphere can tolerate the emissions. For ethanol, the question is whether there is enough land to grow the necessary crops. For wind and hydropower, the question is whether there are enough good sites. Enough sunlight hits the planet to power civilization 2,000 times over, Holdren says, but solar power from photovoltaic cells is too expensive. "I can design a world that runs on photovoltaics," he says, "but at current costs, electricity would be three or four times what it costs today." That would wreak havoc on the world economy.

What complicates things further is the specter of great climate changes. This month, Jim Hansen, a NASA scientist, declared that we have, at most, 10 years to alter the trajectory of global greenhouse emissions. Holdren, similarly, says he believes that the problems from global warming could become so acute so quickly — as in a few years, rather than a few decades — that there really isn't much time to decide which way to go.

Among the most influential ideas these days about how to change the system are those from the research of two Princeton professors, Stephen Pacala and Robert Socolow, who wrote an academic paper in 2004 on what they called "stabilization wedges." It is an encouraging document, in that it presents a manageable way to think about how to address global warming — basically, to approach it on many fronts simultaneously — without suggesting we need one big, magical fix. Pacala and Socolow looked at what we can do now, using current technologies, and barring any sort of startling new scientific developments, to freeze carbon dioxide production and thus slow down global warming. They assert that we could reduce carbon emissions incrementally. In pursuing one of these "wedges," we would reduce carbon emissions slightly; but in pursuing all of them, we could succeed in flatlining the growth of carbon emissions entirely by the century's midpoint.

There are 15 different wedges. These include increasing vehicle efficiency, reforestation, improving the efficiency of buildings, capturing carbon in power plants, replacing some coal power with wind power and replacing some coal power with solar power. Nuclear power is a wedge, too. It is curious, though perhaps unsurprising, that to various advocates some wedges have proved more appealing than others: supporters of nuclear power, for instance, stressed its environmental wedge potential to me while playing down the viability of wind and solar power. The opposite is true as well. In the film "An Inconvenient Truth," Al Gore refers to the Pacala and Socolow research, citing several wedges, but not the nuclear one. He stresses renewable energies.

To consider nuclear energy in the environmental framework, though, may be the same as asking whether the utilities that pursue new plants might be giving us a valuable wedge. Because without the environmental contribution from new nuclear plants, we may need to find a wedge somewhere else. And ultimately, the essential, agonizingly difficult question of nuclear power is not whether it's good or bad, or whether it's worse than wind and better than coal, but whether we will have a better future with or without it. "By 2015, I think everyone in the world will be convinced that our interventions in climate are going to be intolerable," Holdren says. "I'm often asked, 'Can you solve the climate problem without nuclear energy?' And I say, 'Yes, you can solve it without nuclear energy.' But it will be easier to solve it with nuclear energy." Of course, that does not necessarily address the questions of plant security, proliferation and operational safety. Or economics. But it does suggest, as the M.I.T. economist Paul Joskow told me, that "there is a value" in the development of at least a few new plants and in keeping the nuclear option alive. This line of thinking might ultimately bring you to a cautious support for nuclear power simply because allowing it to die seems more dangerous than keeping it alive. You are against its demise, rather than for its advancement.

There are many in the nuclear industry, meanwhile, with far grander visions. Gary Taylor, for instance, the C.E.O. of Entergy Nuclear, says he believes a doubling of the number of nuclear plants around the world is inevitable, both to satisfy energy demands and to counter global warming. As Taylor puts it: "The reality is, what is scalable in the time frame that addresses the issues? If it isn't this technology, I don't know what it would be." Diaz, the former head of the N.R.C., told me he sees a similarly bright future for nuclear. "The world is going to go nuclear, because they do not have any other real alternatives," he says. I met plenty of other engineers within the industry who went even further. Their feeling about nuclear power is close to evangelical, in that they seem to approach the technology with moral certitude while being loath to acknowledge any of its many negatives. Would that include the utility executives who will ultimately decide if — and what — to build? I'm not sure it would. To those I spoke with in the uppermost ranks, nuclear power isn't a belief system. It's a business. And to them, what might come out of, say, Vogtle Units 3 and 4 — the waste and the power and the profits — would be nearly identical to what comes out of Units 1 and 2.

At least that was my conclusion in Georgia, where Jeff Gasser, the Southern Company's chief nuclear officer, took me through a long tour of the plant. He was smart, meticulous and intensely committed to the obscure safety protocols that go on at nuclear power facilities. Most of all he was forthright about the advantages and disadvantages of the nukes business. When we went to visit the spent-fuel pool in Vogtle, where the used fuel-rod assemblies are stored under 20 feet of protective water, Gasser let me know that we would die if we pulled one of the fuel assemblies out of the pool. "We would receive, before we could get to the exit door a few feet away, a lethal radiation dose," he said. I quickly had to check the radiation dosimeter I was wearing — another legal requirement of the N.R.C. — to see if I was already glowing. (It read zero.) "The communications people hate it when I use words like 'lethal' and 'irradiated,' " Gasser continued. "But the fact is, there is no perfect way of generating electricity. There are byproducts for every type." Like many others, he went through the positives and negatives of coal, gas, solar, wind and nuclear. In his opinion, he added, with Vogtle's engineering, redundancy of safety systems and its trained operators, it was a safe, reliable and efficient way of making electricity. That was his sales pitch.

We had already passed through the containment buildings, where the reactors heat the pressurized water. So Gasser took me through the turbine building, an enormous room the size of a soccer field, where the steam turns the fan blades. Eventually, we went out a back door into the sunlight. The deafening sounds of turbines and machinery subsided to a dull thrum. We removed our earplugs and walked over to a small forest of electrical transformers, our backs to the plant. The electricity from the turbines inside comes out here, Gasser explained, its voltage is transformed, and it is then put into the grid.

Gasser made a pushing motion toward the green hills before us.

"Once the power is sent out of here, it can go everywhere," he explained. And I could see that it did go everywhere. The high-tension wires stretched away from where we stood, in several directions, through deep cuts in the pinelands, as far as I could see. ■