

# NUCLEAR REACTIONS

Lessons learned from projects in Georgia and South Carolina might determine the course of U.S. nuclear development for decades to come

BY KARL RHODES



*Georgia Power and its partners are building two nuclear reactors at the Vogtle Electric Generating Plant near Waynesboro, Ga.*

Five years ago, Stanford economist Geoffrey Rothwell and Berkeley economist Lucas Davis made a \$20 bet on the cost of two nuclear reactors under construction in Georgia. Rothwell wagered that units three and four at Georgia Power's Vogtle Electric Generating Plant would cost less than \$4,200 per kilowatt of capacity. Davis bet they would cost more.

"I went easy on Geoff and agreed to exclude financing costs and focus only on the 'overnight' cost of construction," quips Davis, who heads the Energy Institute in the Haas School of Business at the University of California, Berkeley.

"I can't remember whether we used 2007 dollars or 2011 dollars," hedges Rothwell, who retired from Stanford University to become principal economist for the Nuclear Energy Agency at the Organisation for Economic Co-operation and Development.

Davis and Rothwell are not the first to gamble on the high upfront costs of nuclear power plants. Nuclear construction boomed in the 1960s and early 1970s, but in the mid-1970s, rising electricity prices triggered increased scrutiny of utilities' capital expenditures. Safety and environmental fears also intensified in 1979 when a film called *The China Syndrome* portrayed a nuclear power plant on the verge of a total meltdown. The movie debuted 12 days before a partial meltdown occurred at Three Mile Island in Pennsylvania. No one got hurt, but the incident created a sense of panic that radiated throughout the nation. Orders for new reactors dwindled to zero in the United States, but most American reactors continued to deliver clean, reliable,

low-cost power for decades with no major problems.

In the mid-2000s, to rekindle nuclear development, the federal government streamlined the licensing process and offered loan guarantees, tax credits, and production incentives. Politicians also started talking about ways to limit carbon emissions substantially after another film — *An Inconvenient Truth* — fanned fears of global warming. In terms of publicity, the movie seemed to give back to nuclear development some of what *The China Syndrome* had taken away. As natural gas prices spiked above \$10 per thousand cubic feet, electric utilities applied for permits to build 24 new reactors, but their enthusiasm faded quickly. The recession of 2007-2009 stunted growth in demand for electricity, natural gas prices fell sharply, and a tsunami slammed into the Fukushima Daiichi Nuclear Plant in Japan.

Today, only four of those 24 proposed reactors are under construction: the two Vogtle units at the crux of Davis and Rothwell's wager and two reactors of the same type at the V.C. Summer Nuclear Station in South Carolina. These two projects are only 55 miles apart as the crow flies; if nuclear construction has come to a crossroads in the United States, this is it.

## Why the Southeast?

Nearly all active proposals to build nuclear power plants are confined to the Southeastern United States for three primary reasons. First, power generation in the region is dominated by large, well-capitalized companies with regulated returns on investment. In other words, if they can

convince their utility commissions that building nuclear reactors is a prudent use of resources, they can pass along the development costs to their ratepayers. Second, nearly all Southeastern states have adopted CWIP (cost of work in progress) accounting, which allows a utility to start passing along some financing costs to ratepayers while a plant is under construction. Third, population growth and the increasing use of air conditioning per capita has continued to increase demand for electricity in the Southeast relative to other regions of the United States that have had significant, positive experience with nuclear power.

Georgia Power expects demand for electricity to rise 27 percent in the Southeast by 2030, with Georgia's population growth driving much of that increase. To help meet that anticipated demand, the company is adding two reactors to its Vogtle plant, a facility it owns jointly with Oglethorpe Power, Municipal Electric Authority of Georgia, and Dalton Utilities. Southern Nuclear, a subsidiary of Georgia Power's parent company, oversees the project. These partners are building the first new nuclear units in the United States in the past three decades. (The Tennessee Valley Authority, or TVA, completed a reactor this year, but the TVA received a construction permit for that unit in 1973.)

Vogtle also features the U.S. unveiling of the Westinghouse AP1000, a 1,117-megawatt reactor that is designed to be less expensive to build, operate, and maintain. Compared to earlier-generation reactors, the AP1000 has 50 percent fewer valves, 35 percent fewer pumps, 80 percent less piping, 45 percent less building volume, and 70 percent less cable. In addition to Westinghouse, the other primary contractor on the project was Chicago Bridge & Iron.

The AP1000's modular design was intended to facilitate faster construction, but by the time Rothwell and Davis made their wager in 2011, Vogtle's owners and contractors already were arguing over who would pay for design changes and licensing delays caused in part by Nuclear Regulatory Commission actions. (The project is now running about three years behind schedule.) The owners and contractors finally settled their differences in late 2015 by agreeing to add \$915 million to the construction contract, bringing the cost forecast to \$11.9 billion — up about \$2.2 billion from the company's original estimate — not including financing costs. Also related to the settlement, CB&I sold its nuclear construction business to Westinghouse Electric, which then hired Fluor Corp. to manage the construction workforce.

These new arrangements also apply to the AP1000 reactors that South Carolina Electric & Gas Co. (SCE&G) is installing at its Summer Nuclear Station. The company owns 55 percent of the project with 45 percent belonging to Santee Cooper, South Carolina's state-owned utility. The cost forecast for the new Summer reactors has increased to \$10.1 billion in 2007 dollars — up about \$1.8 billion from SCE&G's original forecast, not including financing costs.

In addition to this cost overrun, one of the units at Summer is about 19 months behind schedule as of mid-2016, while the other unit is more than three years behind.

## Watching and Learning

Charlotte, N.C.-based Duke Energy and Richmond, Va.-based Dominion Resources appear to be next in line with proposals to build reactors in the Southeast. But executives at both companies say they are happy to watch and learn from the Vogtle and Summer projects and from similar reactors under construction in China and Japan.

By the end of this year, Duke expects to receive combined operating licenses (COLs) from the Nuclear Regulatory Commission to install two AP1000s in Levy County, Fla., and two AP1000s in Cherokee County, S.C. But the company would not break ground immediately on these units.

"We want to see what happens in China since Westinghouse is building four of these same units in China," says Chris Fallon, Duke's vice president for nuclear development. "I think they are targeting loading fuel sometime at the end of this year or the beginning of next year. And we'll see how the projects are delivered at Vogtle and Summer."

Duke collaborates with the owners of the Vogtle and Summer projects as well as with Florida Power & Light (FP&L), a subsidiary of Juno Beach, Fla.-based NextEra Energy, which has proposed building two AP1000s at its Turkey Point Nuclear Power Plant south of Miami.

"We work together in a group called APOG, which stands for AP1000 Owners' Group," Fallon explains. "We follow the construction and operational readiness activities at Vogtle and Summer very closely. We partner with them on both resolving licensing-type issues that are needed by both applicants and license holders as well as working through construction issues. So if Duke and FP&L decided to move forward, we've captured those lessons learned and know how to apply them."

Dominion Resources is not part of APOG because it has selected a different nuclear technology to expand its North Anna Power Station in Louisa County, Va., where the company already operates two reactors. Instead of the AP1000, Dominion plans to install a GE-Hitachi ESBWR (economic simplified boiling-water reactor). "The GE-Hitachi design fits the North Anna site better, and we have the cooling capacity to accommodate a somewhat larger reactor," explains Mark Mitchell, Dominion's vice president for generation construction. The GE-Hitachi reactor would add 1,470 megawatts of capacity — about 32 percent more than an AP1000 unit.

Even though Dominion is pursuing a different technology, Mitchell remains keenly interested in the Georgia and South Carolina projects. "We are sharing lessons learned with Georgia Power and with SCE&G," Mitchell says. "We have had people onsite at Vogtle." Dominion also is sharing lessons learned with Detroit-based DTE Energy, which has obtained a COL for a GE-Hitachi ESBWR in Michigan, and with companies that are installing similar GE-Hitachi reactors in Japan.

Both Mitchell and Fallon emphasize that their companies are strongly committed to nuclear power, but they decline to speculate about when their companies will start

pouring concrete to build their proposed units.

“I personally think that we will build a third reactor at North Anna, but I don’t know what the timeframe will be,” Mitchell says. “But certainly, it makes sense to obtain the license and have the option.”

### Putting Fears Aside

The possibility of a costly accident has factored into the development of nuclear power plants since the very beginning. In 1957, for example, the federal government passed the Price-Anderson Act to encourage nuclear investment by capping the total liability a nuclear operator would face in the event of catastrophic failure.

“Nuclear power has long been controversial because of concerns about nuclear accidents, storage of spent fuel, and about how the spread of nuclear power might raise risks of the proliferation of nuclear weapons,” Davis wrote in a 2012 article in the *Journal of Economic Perspectives*. These concerns are real and important, but nuclear construction costs are so high that it is “difficult to make an economic argument for nuclear even before incorporating these external factors,” he contended.

In his article, Davis compared the “levelized costs” of electricity generated in the United States by nuclear, coal, and natural gas plants. Using a model developed by economists at the Massachusetts Institute of Technology (MIT), he estimated these costs by calculating long-term expenses for construction, operation, maintenance, and fuel and then discounting those combined costs back to a present value for each type of power plant. The results are equivalent to the real price per kilowatt hour of capacity that each plant would need to break even over its lifetime.

In the MIT model’s baseline comparison from 2009, coal was the cheapest option, natural gas was a close second, and nuclear was a distant third. When Davis updated MIT’s assumptions regarding construction costs and fuel costs, natural gas surged ahead. When he added a hypothetical tax of \$25 per ton of carbon dioxide, natural gas still finished first and nuclear still finished last, but nuclear moved much closer to coal and somewhat closer to natural gas.

In the years since that article was published, natural gas prices have gone down even more and nuclear construction costs have gone up, “so a utility would be crazy to build anything other than a combined cycle natural gas plant right now,” Davis concludes. The owners of Vogtle and Summer, he quickly adds, “could not have guessed that natural gas would be as cheap as it is now.”

Executives at Georgia Power and SCE&G declined to be interviewed for this story, but Georgia Power provided written answers to questions about the company’s choice between nuclear and natural gas: “Completing the new Vogtle units remains the best and most economic option for meeting the needs of our customers, over the next best option, which would be combined cycle natural gas — this has been demonstrated repeatedly in detailed semi-annual analyses of the economics of the Vogtle project. We absolutely appreciate the

value of natural gas as part of a diverse fuel mix. ... However, we have to be prepared for natural gas prices to increase in the future.”

SCE&G makes similar arguments on its parent company’s website. “SCE&G’s customers are enjoying the benefits of lower cost gas that shale gas fields and fracking technology has made available recently,” the company said, but “wholesale natural gas prices are currently unregulated, and many question the long-term impacts of fracking.” Also, “gas producers are working on strategies to export their natural gas to overseas markets, which may place upward pressure on price.”

Making a multibillion-dollar decision between expanding nuclear capacity or natural gas capacity boils down to how much value you place on fuel diversity, says Mitchell at Dominion. “From where I sit, fuel diversity is a really good thing. It pays dividends in the long run.”

### Managing Construction Costs

The vagaries of natural gas prices and the politics of carbon restrictions are impossible to predict, but the other key variable in Davis’s model, construction costs, has been trending upward since 1970 — especially in the United States. Davis was banking on a continuation of this trend when he made his bet with Rothwell.

Davis blames some of this cost escalation on a “rapidly evolving” regulatory process. “A joke in the industry was that a reactor vessel could not be shipped until the total weight of all required paperwork had equaled the weight of the reactor vessel itself,” he says.

Georgia Power echoes that comment in less colorful terms. “Nuclear is a complex, highly regulated process in general — construction is tied to specific, stringent safety and design standards,” the company says. Georgia power also highlights another cost factor that is unique to its current construction: “The Vogtle project is the first new nuclear to be built in the United States in more than three decades and required the re-establishment of a nuclear supply chain that has not existed in the United States in a generation.”

Robert Rosner, the founding co-director of the Energy Policy Institute at the University of Chicago, agrees with Georgia Power’s supply chain argument. “Nuclear power is experiencing renewed learning after the decline in supply chain experience,” he wrote in a forward to Rothwell’s 2016 book, *Economics of Nuclear Power*. “The build rate of nuclear reactors over the past few decades has been low in North America and Europe; as a consequence, the requisite highly trained workforce for building reactors is no longer in place. This is a situation that leads to considerable risks in construction cost estimates.”

The supply chain established to build the Vogtle and Summer projects should significantly benefit Duke Energy and FP&L if they decide to install their proposed AP1000s. But Davis questions whether the collective experience of building four reactors of the same type will generate

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4 percent of traditional consumer lending, but by 2015 their share had jumped to more than 12 percent.

These many changes highlight the uncertainty of banking's future. Will new bank entry bounce back as interest rates eventually rise? And if it does, will those new banks look like the community banks of previous generations?

Marshall says blueharbor is sticking with the old model. "We're just a good old-fashioned, general consumer community bank. If we tried to specialize in any one thing, we wouldn't be serving our community," he says. At the same time, he recognizes the environment is changing. His daughter is studying banking and finance in

college (he hopes she will be the fourth-generation banker from his family), but he says many of the young bankers he meets or works with have expressed frustrations with current regulatory and economic conditions. "There are a lot of folks who say it's just not worth it to start a bank today," he says.

Mahan thinks the future is bright for new banks — if they're willing to adapt to changing consumer demands. "You've got to be focused on technology and deliver products and services with a beautiful user experience," he says. "Because at the end of the day, who wakes up and thinks about their bank?" **EF**

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**WEB EXCLUSIVE:** See sidebar "Opening Your Own Bank."

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substantial cost savings from learning-by-doing. "It's not that there is no learning," he says. "It's just that it's hard because we are not building enough of these anywhere to really get down the cost curve — not in the United States, not in Asia, not in France, not anywhere."

Davis admits, however, that he is intrigued by the 20-plus nuclear reactors currently under construction in China. "It's a huge priority to figure out how China is able to do this," he says. In addition to lower labor costs, he suspects that the Chinese nuclear program benefits from a more favorable regulatory regime.

### Settling the Bet

As of May 2016, Vogtle's projected cost per kilowatt of capacity was \$5,327 — well above Davis and Rothwell's over-under threshold of \$4,200.

So it appears Davis will win the bet. He also is sticking with the conclusion of his 2012 article: "In 1942, with a shoestring budget in an abandoned squash court at the University of Chicago, Enrico Fermi demonstrated that electricity

could be generated using a self-sustaining nuclear reaction. Seventy years later, the industry is still trying to demonstrate how this can be scaled up cheaply enough to compete with coal and natural gas."

Rothwell vehemently disagrees. "Nuclear power plants have an expected lifetime of 60 years. So even though there are low gas prices now, there is no reason to believe they will stay low for the next 60 years," he says. "And if you use standard discount rates, you make the value of electricity inconsequential from years 31 through 60. So if you are trying to provide for generations of consumers, then you have to come up with a way of valuing electricity for future generations."

As for the bet, Rothwell concedes that he *might* someday owe Davis \$20, but he's not quite ready give up the cash. "We still need to determine the 2007 overnight costs in 2007 dollars," he insists, "because it is likely that the \$5,327 value is in 'as-spent' dollars. We won't know until the plant is producing electricity, all the costs have been identified for the regulators, and the economists have analyzed the data. Let's not be hasty in our judgments. Our work is not yet done!" **EF**

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**WEB EXCLUSIVE:** See sidebar "Nuclear Power and Global Warming."