

Lessons from Fukushima: Nuclear Safety, Safety, Safety—at a Price

Fukushima was a wake-up call for the nuclear industry, re-shaping markets worldwide over the past 20 months and forcing operators and proponents to evaluate how to secure existing and future facilities against “extreme” events of the natural kind.

“Fukushima was a terrible disaster [but] it forced the industry to look again at designing for extreme events,” said Nigel Thornton, a director of Energy at Atkins (FY 2012 revenues \$2.68 billion; London), one of the world’s leading engineering and design consultancies with 40 years’ experience in nuclear safety.

While the industry has what Thornton terms “a very robust design” process, “Fukushima made us look at designs for very low frequency, but very high-consequence, events—those [with a probability of] less than 1 in 10,000,” said Thornton. And that design vision is not only about reactors but also about what failed at Fukushima: the backup generators. “We’re looking to add further layers of defense.”

As Thornton noted, extreme natural events are akin to a “constantly moving target,” and as a result, “beyond design” is more than an industry-specific technical term: today the new reality is planning for accidents once considered beyond the pale of design-process probability.

Building plants and reactors to withstand the newly recalibrated risks of natural disasters is one thing. The other is ensuring that what’s already in place is fortified adequately—and the cost to do so will be hefty. Estimates in Europe are in the \$30 billion range. In the United States, home to the world’s largest nuclear fleet with 104 reactors, one nuclear energy provider, Xcel Energy, told a Twin Cities newspaper that post-Fukushima safety recommendations from the Nuclear

Regulatory Agency (NRA) (see below) could cost the utility \$25 million to \$50 million.

Nearly two years after Fukushima, the industry continues to assess what the full impact will be going forward. One observer told CCBJ that the consensus in the Japanese power industry is that Fukushima was a lesson in complacency. “We had convinced ourselves that [our facilities] were safe,” he said. To contemplate a disaster on the scale of Fukushima “was seen as an irrational fear.”

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Rush to Assess the World’s Reactors

The rush to assessment following Fukushima was immediate, with the Nuclear Energy Agency reporting on actions in 23 nuclear power nations, among them South Korea, which has plans to not only dramatically build its internal nuclear presence but to export its technology.

Among the actions the government there has put in place post-Fukushima: increasing the height of the sea wall at its Kori plant as a defense against large tsunamis and safeguards to ensure that both electric power and auxiliary back-up power is available to secure reactor cores in case of station blackouts. Yet as 2012 came to a close, controversy over the safety of South Korea’s 23 nuclear reactors led to an admonishment from the International Energy Agency (IEA).

The IEA’s concern, reported in November 2012, was in part a reaction to an investigation into fake safety documents for parts, which in turn led to the shutting

down of two reactors, with another later shut down after microscopic cracks were detected. In its report, the IEA cautioned that South Korea needs to “rebuild public trust” by “boosting transparency and improving regulation.”

China, a nuclear powerhouse in the making, also took action on post-Fukushima safety concerns. Its first step was to place a moratorium on new nuclear construction shortly after Fukushima and lifted 19 months later in October 2012. The time was spent, according to the Hong Kong-based *South China Morning Post*, reviewing the country’s regulatory framework and inspecting 16 operating reactors. The latter resulted in a government proposal to spend upwards of \$12 billion in safety improvements and also in a paring down, by one-third, the number of new plants on the drawing board.

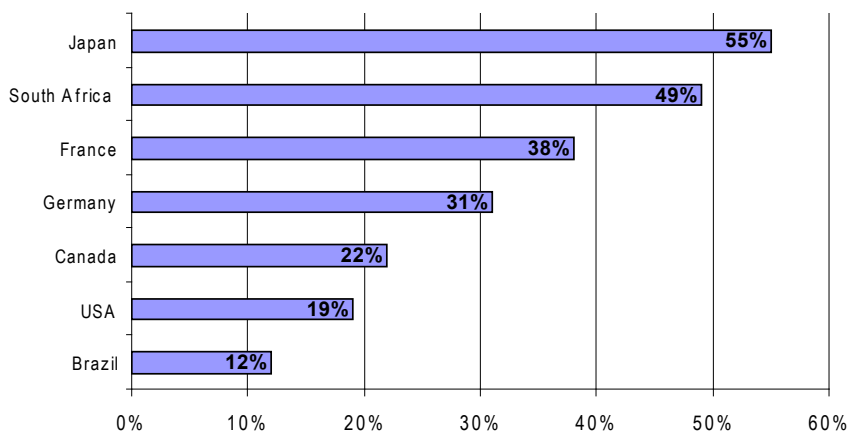
EU Stressed by Stress Tests

The European Union also launched its review of nuclear plants shortly after the Fukushima disaster, with leaders of the 27 EU Member States calling for comprehensive stress tests on active reactors in 15 EU nations, with two neighbors also agreeing to participate: Switzerland (with four operating plants consisting of a total of five reactor units) and Ukraine (with four operating plants consisting of a total of 15 reactor units).

The aim of the tests was two-fold, as identified by the Commission: to assess the “safety and robustness” of nuclear power plants if extreme natural events cause “normal safety functions” to shut down and also to assess the ability of the plants to deal with severe accidents.

The findings of the draft report were released in October 2012, and the results are not encouraging. Nearly every reactor—134 of the 145 tested—was cited as needing additional safety improvements for coping with earthquakes, floods and power outages—the factors that felled Fukushima. And the report embeds the

Share of Nuclear In Government Energy RD&D Spending, 2010



Source: International Energy Agency's Directorate of Sustainable Energy Policy and Technology

Group. "The U.S. response to Fukushima has been "straightforward and methodical. The industry and the NRC came together [creating uniformity] in our approach."

In the near-term, the work to be done is specific to the NRC Fukushima Task Group's recommendations but also to safeguards identified by operators. These include, said Brister, "seismic and flooding [issues], emergency planning and offsite power loss. Longer term, we'll continue to do detailed analysis to ensure that our safety level is where we want it to be."

Hardened by 9-11

For Brister and Genoa and others within the U.S. industry, there is no comparison between what happened in Japan and the U.S. industry's capabilities. "The two industries are not the same," said Genoa, who noted, "Japan didn't take action on seismic and tsunami information from a decade ago; it didn't take action on flooding" concerns. More specifically, and a point of industry pride, he added, "We withstood Three Mile Island and September 11," the latter considered "a defining moment" for all involved.

The 9-11 terrorist attack in 2001 was a challenge for nuclear facilities and operators, said Genoa. "There was a concern that terrorists would use planes and bombs to damage plants in ways we couldn't anticipate. We had to fall back

into flexible response." As a result of the post-9-11 planning, "we had already taken a lot of steps, our plants were safe. Fukushima just added another layer to what we had already been looking at."

The "flexible response" that marked the industry's defense against the threat of terrorist attacks has been revived post-Fukushima as FLEX, a voluntary program initiated by NEI and the U.S. power plant owners and operators that addresses the layer of safety enhancements now required by the vicissitudes of nature. Redundancy is the catchword, here specific to the availability of crucial emergency and operational equipment needed if a facility loses power, as Fukushima did.

Generators, pumps, hoses, fittings and cables, are crucial back-up energy supplies, said Atkins' Thornton, "which are permanently available in a purpose-built facility located nearby, but not too close."

Exelon Chief Operating Officer and NEI Fukushima committee chairman Charles Pardee told reporters that the price tag for the FLEX safeguards could average more than \$1 million per plant.

NRC Weighs In

In July 2011, the NRC used data and information from its Fukushima Task Force to rule on three safety items, among them disaster planning that "considers

emergencies affecting multiple reactors at the same plant" and improved instrumentation in spent fuel pools. The third was directed at "hardened" venting systems at General Electric boiling water reactors with Mark I or Mark II containment—the same technology used at Fukushima. According to NBC News, 23 U.S. reactors are "very similar" to Fukushima's Mark I systems.

The NRC's safety items are to be in effect by 2016. Additionally, the task force created a three-tier list of recommendations, tier one containing those to be started "without unnecessary delay" and including re-evaluating seismic and flood hazards, strategies for mitigating beyond-design events, installing the hardened vents for Mark I and Mark II containments and strengthening guidelines and procedures that deal with emergencies, accidents and damage mitigation.

Tier two recommendations include evaluating capabilities of spent fuel pools, emergency preparedness and re-evaluating the impacts of other weather and climate-related events, such as tornadoes, hurricanes and drought. Tier three recommendations are more detailed, some requiring further study for possible regulatory action. Among them, a heightened focus on emergency preparedness related to prolonged station blackouts, radiation monitoring, potassium iodine storage and transferring spent fuel to dry cask storage.

Third Generation Reactors: Building for the Future

The best defense is a good offense, and for the NEI's Genoa, that strategy focuses on advances in reactor technology, like the Westinghouse AP1000, he said, which requires half as many safety-related valves, far fewer safety-related pipes and one-third fewer pumps—a passive approach to safety engineering that sees less as being more safe and stable. The four new reactors under construction in the United States today are AP1000s.

The AP1000 is an advanced, third-generation 1,100-megawatt pressurized water reactor (PWR) built to standards the U.S. industry put into effect post-September 11, 2001, including fortified structural strength to withstand an airplane crashing into it. The AP1000 is also designed to cool down automatically over a 72-hour period, even if external power is lost, a safeguard whose worth was underscored by the Fukushima disaster.

Passive safety features and other enhancements are “evolutionary improvements,” said Genoa. “We’ll simplify [reactor] design over time. We have bright people looking at elegant solutions.”

The industry may feel secure about the safety now and in the future, but the public remains skeptical. And even though Genoa assured that while “public opinion took a serious hit in the United States, within a year it had bounced back to pre-Fukushima levels,” there remains one notable exception: California’s San Onofre Nuclear Generating Station along the Pacific Coast near San Clemente.

Shut down by operator Southern California Edison (SCE) in January 2012 due to a possible radiation leak, controversy has dogged San Onofre since the late 1970s. Fukushima revived public concern due to similarities between the two reactors, including San Onofre’s coastal location, earthquake risk and current problems related to the facility’s generators, including leaks and general “wear and tear.” According to the NRC, San Onofre has logged more safety concerns—22—by employees than any other U.S. plant. PPL’s Susquehanna Steam Electric Station in Lucerne County, Pennsylvania, has logged 21.

SCE is determined to reopen the plant in the short term and reportedly has been meeting with the NRC to get the go-ahead. If nuclear can continue to get the go ahead at San Onofre in Southern California near the iconic surf spot Trestles, near a corridor where numer-

Nuclear Nations

Country	2011 Nuclear % of Elec.	Operating Units	Capacity (MW)	Units In Construction	MW In Construction	Planned Units	Proposed Units
France	77	58	63,130	1	1,600	1	1
Slovakia	54	4	1,816	2	782	0	1
Belgium	54	7	5,927	0	-	0	0
Ukraine	47	15	13,107	2	1,900	2	11
Hungary	43	4	1,889	0	-	0	2
Slovenia	41	1	688	0	-	0	1
Switzerland	40	5	3,263	0	-	0	3
Sweden	39	10	9,326	0	-	0	0
Korea Rep.	34	23	20,671	3	3,640	6	0
Armenia	33	1	375	0	-	1	0
Czech RP	33	6	3,766	0	-	2	1
Bulgaria	32	2	1,906	0	1,906	1	0
Finland	31	4	2,736	1	1,600	0	2
Spain	19	8	7,567	0	-	0	0
U.S.	19	104	101,465	5	5,565	11	19
Taiwan	19	6	5,018	2	2,600	0	1
Romania	19	2	1,300	0	-	2	1
Japan	18	50	44,215	2	2,650	10	5
Germany	17	9	12,068	0	-	0	0
Russia	17	32	23,643	11	9,270	17	24
U.K.	15	18	9,703	0	-	4	9
Canada	15	18	12,604	0	-	3	3
South Africa	5	2	1,830	0	-	0	6
Argentina	5	2	935	1	692	2	1
Pakistan	3	3	725	2	630	0	2
India	3	20	4,391	7	4,824	16	40
Netherlands	3	1	482	0	-	0	1
Mexico	3	2	1,300	0	-	0	2
Brazil	3	2	1,884	1	1,245	0	4
China	1	16	11,881	26	26,620	51	120
Iran	0	1	915	0	-	2	1
Total		436	370,461	66	59,218	1312	2612

Sources: International Atomic Energy Agency and World Nuclear Association. Japan’s future nuclear energy policy still under debate and review since the Fukushima accident and no firm decisions have been announced. Totals only include countries that have existing nuclear capacity. Another 29 units are planned and 68 units proposed in countries without operating nuclear plants.

ous attempts to permit a new highway have been thwarted and with an affluent, environmentally aware population nearby, it seems likely to get the go ahead almost anywhere else in the U.S. in the post-Fukushima era. At least for existing sites that is. The real test may still be years off

when new reactors on existing facilities, or even new facilities come up for community consideration. If nuclear aspires to contribute an increasing share of the U.S. electricity mix, it better be sure nothing else happens in the next few years in the U.S. or around the world. ⚙

1-in-10,000-year natural-disaster planning equation for natural events such as earthquakes and flooding.

When released, the Commission noted, in a most understated manner, that the scale of the problems identified “may amplify public concerns about the safety of nuclear power on the part of Europeans, who are already deeply divided over the technology and whose governments still zealously guard control over energy policy at the national level.” That assessment of the controversy to come is equally true of probable reaction to the estimated cost to make the repairs detailed in the draft: upwards of €25 billion.

Moving forward, peer review methodology will be applied to the action plans cited in the draft report in early 2013, “in order to verify that the stress tests recommendations are consistently implemented in a transparent way throughout Europe,” according to the Commission, which will report on the implementation of recommendations in June 2014.

But for now, the onus of the findings lies heavily on a handful of EU nations, among them Finland and Sweden—the latter re-emerging as a nuclear power champion after years of fence-sitting—where concerns focus on the crucial ability of operators to restore safety functions if either cooling systems or electric power are downed. The report also found that 10 reactors in countries including Spain, the Czech Republic and France lack “adequate equipment” to detect earthquakes.

Among the specific findings of the EU stress test:

- Earthquake risk: 54 EU reactor units (37%) did not take modern standards for earthquake risk calculation into account. The risk calculation should be based on a 10,000-year time frame.
- Flooding risk: 62 reactors (43%), did not take modern standards for flooding risk into account. The risk calculation

should be based on a 10,000-year time frame.

- The internationally recommended minimum seismic hazard level, “regardless of any lower apparent exposure to seismic hazard,” has not been used for the seismic hazard studies of 65 reactors (45%).

- On-site seismic instruments to measure and alert of possible earthquakes need to be either installed or improved in 121 reactors (83%).

- In the case of 81 reactors (56%), equipment to fight severe accidents is not stored correctly and is not located where it can be “quickly retrieved.”

- Five reactors (3%) cannot cope for more than an hour after a station blackout without intervention in order to prevent reactor core heat up.

- Forty reactors (28%) do not have passive measures (such as those that do not require initiation by system or human intervention) in place to prevent hydrogen explosions or of other combustible gases in case of a severe accident.

- Thirty-two reactors (22%) do not have containment filtered venting systems in place to allow safe depressurizing of the reactor containment in case of an accident.

- Twenty-four reactors (17%) do not have backup emergency control rooms if the main control room becomes uninhabitable due to radiological releases, fire or other damage from “extreme external hazards.”

Fukushima Changes the World: U.S. Now Expecting the Unexpected

“Fukushima changed the world,” said Paul Genoa, senior director of policy development for the **Nuclear Energy Institute** (NEI), the U.S. industry’s policy group. “We were rocked by what we saw. It went way beyond what was anticipated.” Accidents on the scale and scope of Fukushima, or Chernobyl 26 years ago impact the entire industry. “We believe

our reactors are safe, but how safe is safe enough?”

Joining its global nuclear-power counterparts, both the United States’ nuclear industry and operators and the **Nuclear Regulatory Commission** (NRC) jumped into reaction mode to consider, as Genoa related, protection scenarios that can “withstand what’s expected but also what can happen from the unexpected,” for example “severe flooding, coastal as well as [from] upstream and downstream reservoirs and dams.”

It wasn’t only Fukushima that drove the probability of extreme flooding home. In 2011, the U.S. Northeast experienced record flooding from Hurricane Irene, and a 300% increase in normal rainfall in parts of the Ohio Valley caused historic flooding along the Mississippi River and its tributaries.

The industry rode out those 2011 floods remarkably well. NEI, citing data from the **World Association of Nuclear Operators** and the **Institute of Nuclear Power Operations**, reported that the 62 unplanned shutdowns in 2011 represented “the lowest yearly total in more than a decade.”

Superstorm Sandy in October 2012 affected 34 nuclear facilities along the Atlantic coast, according to the NEI. Twenty-four nuclear facilities remained online, seven facilities were already shut down for refueling or inspection. Three units—Indian Point 3 and Nine Mile Point 1 in New York and Salem 2 in New Jersey—“safely shut down, as designed,” NEI reported, because of storm conditions or grid disturbances.

Combined, said Genoa, “2011 and 2012 were just amazing. We have to anticipate more risk.”

“An accident anywhere is an accident everywhere,” noted Jay Brister, vice president of Global Business Development, **CH2M HILL** Nuclear Business

The U.S. Nuclear Industry; Making the Best of Uncertain Times

High build costs, a recession and a jerky recovery, competition from cheap natural gas as well as time-outs for Fukushima-safety assessments—all have rained down on the U.S. nuclear power industry over the past two years like a perfect storm, causing a 10% drop in installed generation and putting projects on hold.

Demand for electricity dropped during the recession and has yet to bounce back to levels needed to “sustain a robust industry,” said Paul Genoa, senior director of policy development for the **Nuclear Energy Institute** (NEI), the U.S. industry’s policy group. The U.S. Energy Information Administration cautions that low population growth and “greater energy efficiency” should continue to dampen demand over the next 20 years.

In short, it’s not the best of times for the U.S. nuclear power renaissance, but no one is hanging up “closed” signs yet. “We’re a resilient industry,” said Nigel Thornton, a director of Energy at **Atkins**, a leading engineering and design consultancy with a long-term presence in nuclear power. “We all recognize that nuclear has a significant role in the future of the renewables era.” Besides, there is encouraging news. For the first time since the Three Mile Island accident in 1979, two projects are under construction, each with two new advanced Westinghouse AP1000 reactors.

It’s About Money, Honey

Still, even with some market movement, future builds are looking less viable. The barrier to growth is directly related to the balance sheet. As **CH2M HILL**’s Jay Brister underscored, nuclear is a market driven “by the desire of utilities who have a responsibility to deliver cost-effective products to the consumer.” And

Christofer M. Mowry, president of **Babcock & Wilcox** (B&W) mPower, Inc., advised, there’s the risk factor that nuclear’s high initial capital costs introduces to the business decision on new-build. Until the market gains momentum, “many investors are not willing to make major bets on the generation portfolio,” he said.

The same is true for utilities where, as NEI’s Genoa noted, “operators are not making long-terms decisions on what to buy for long-term energy.” As a result, “We’re not building a lot of nuclear plants today,” he said.

Exelon’s decision to delay expenditures for three to four years is one example. “The rationale is that [they’re] waiting for demand to match generation needs,” said Brister. Exelon, which finalized its merger with **Constellation Energy** in March 2012, is the largest nuclear provider in the United States with nearly 20% of U.S. nuclear capacity, 10 plants and 17 reactors in Illinois, Pennsylvania and New Jersey.

“When the existing nuclear fleet is retired, what will we replace it with?”

At **Duke Energy** (2011 revenues \$14.5 billion; Charlotte, NC), the second-largest nuclear power generator with 10 units—and following the \$26 billion merger with **Progress Energy**, the largest U.S. utility with 7.1 million customers—going nuclear “is a financial decision, that also incorporates the need to continue to maintain diverse fuel sources at our utilities and also be able to economically meet expected carbon and other air regulations,” said Duke Energy’s Thomas C. Williams, director of external relations. “There is a degree of financial risk, that we balance with the costs and long-term benefits of fossil and renewable asset decisions. Nuclear plants are expensive to build.”

At present, Duke Energy, with two new reactors in its sights, is “maintaining its nuclear options,” said Williams. Nuclear “is the backbone to our system in the Carolinas and provides about 30% of the utility’s overall generation mix in six states. And it provides crucial baseload power for our industrial demand, “where we need a certain type of plant to meet demand from a large industrial load that doesn’t ramp up or down. Demand is steady twenty-four seven.”

Existing nuclear power capacity, said Williams, also contributes to the relatively low electricity prices that Duke customers enjoy. “Nuclear is why our rates are so low in the Carolinas. [Our plants] operate very efficiently. ... We’re not saying no to new nuclear, but rather being very careful as we make each decision to advance the permitting aspects of the projects.”

The company still plans to proceed with permitting of new AP1000 reactors at the William States Lee facility in Cherokee County, South Carolina—cost is estimated at \$12 billion. “We’re committed to building and to getting permits to maintain our option to build.”

It’s a wait-and-see holding pattern that others are following, noted **Bechtel**’s John Atwell, manager of operations, New Nuclear. Bechtel, which has conducted seven of the 18 combined operating license (COL) applications received by the NRC as of March 29, 2012, is seeing a pattern of companies going through the process to get licenses, then “putting projects on the shelf until the situation is right for building the plant.”

Citing competition from natural gas, Atwell allowed that “natural gas in the United States is extremely cheap at this point in time,” which causes operators to “look at the economies of building nuclear versus a gas plant. But utilities need to have portfolio diversity—and just because natural gas is cheap now doesn’t mean it will remain so.”

Still, it's "hard to justify" the high cost of nuclear at a time when natural gas prices are at historic lows, said Duke Energy's Williams. "It's much cheaper to build natural gas plants, but they can be more expensive to operate," he said, noting another advantage: "We're already meeting 20 percent of our carbon reduction goals for 2020 because of lower priced natural gas and our excellent nuclear capacity factors in the Carolinas."

"Natural gas has had a huge impact on decision-making," conceded CH2M Hill's Brister, with most of the attention now directed at using gas to replace aging coal plants. This is happening across the industry, especially in regions with a high proportion of coal in the power mix. For example, in September 2012, the Progress Energy Carolinas subsidiary announced the closure of the coal-fired H.F. Lee Power plant in North Carolina, which will be replaced with a 920 MW natural gas facility to be constructed on property nearby.

But it is the longer-term future that Williams said Duke Energy is considering, in terms of how the market for natural gas plays out versus nuclear costs. "When the existing [nuclear] fleet is retired, what will we replace it with?" he asked.

It's a question Duke Energy is grappling with now as it considers the future of the Crystal River nuclear plant in Crystal River, Florida, acquired through the Progress Energy deal. With three years left on its 40-year license, the decision on what to do with the plant, idle for the past three years after the building cracked during routine maintenance, is based solely on the numbers—depending on the scope of the repair work, costs could range from \$1.3 billion to \$3.4 billion, said Williams. By comparison, constructing a new natural gas facility there of similar size costs less than \$1 billion.

Without Crystal River, Duke Vice President Chris Fallon told attendees at a nuclear industry event in October 2012, "76 percent of Duke's Florida energy production would come from natural gas." Putting all its eggs in one fuel basket is the kind of move that industry insiders like Bechtel's Atwell would discourage, based on the unknowns of future natural gas pricing.

A natural gas plant has a lifespan of 30 years, close to that of a nuclear plant. But the major difference is in the cost of the fuel—natural gas plants require a steady stream of fuel to keep going, which impacts the cost to customers when gas prices fluctuate. Nuclear, on the other hand, said Babcock & Wilcox's Mowry, "is a more concentrated form of energy. One megawatt hour of nuclear fuel costs much less than either coal or gas."

"It's hard to justify the high cost of nuclear at a time when natural gas prices are at historic lows."

Reactors in the News

There are currently 10 applications for 16 new nuclear units under active NRC review. Five others are under construction, including two AP1000 reactors each at the Southern Company's Alvin W. Vogtle Electric Generating Plant in Burke County, Georgia, and South Carolina Electric & Gas' (SCANA) Virgil Summer Nuclear Generating Station in Jenkinsville.

A Gen II PWR reactor is also under construction at the Tennessee Valley Authority's Watts Bar plant 50 miles outside of Chattanooga, an on-again, off-again project that began in 1973, took a hiatus in 1985 and resumed again in 2008. Scheduled for completion in 2015, costs have nearly doubled, from the \$2.5 billion

estimate in 2008 to today's target of \$4.2 billion.

Cost for the Summer project is estimated at approximately \$9.8 billion, covering the AP1000 units, the transmission facility and financing. SCANA will reportedly pay 55% of the estimated cost and is looking to raise customer rates. South Carolina's largest power producer, Santee Cooper, is responsible for the remainder. The first reactor is scheduled for completion in 2017. (Due to loss of a large wholesale customer and lack of demand growth, Santee Cooper is seeking to sell all but 20% of its equity in the project; see page 33.)

Of the two AP1000 builds, the Vogtle project is feeling the brunt of public and official scrutiny. The first project to be approved by the NRC in 2008, it's also the first to receive a conditional federal loan guarantee for plant construction from the Department of Energy—garnering more than \$8 billion of the \$14 billion price tag. Both put Vogtle's expansion into the limelight, focused on how Southern grapples with what has become an industry norm: cost overruns. The estimated cost did go up in November 2012 by \$900 million, when the Shaw Group and Westinghouse, the project's contractors, sued Southern for that amount, citing design changes and licensing delays.

Yucca Mountain Aside, Hopes for Friendly Politics

The DOE loan guarantee was seen to portend a nuclear-friendly Obama Administration, and Atkins' Thornton believes it has been, to a point. "Yucca Mountain is obviously something the industry has to find a solution for," he said. In the ongoing nuclear waste storage debate, Obama rankled the industry when Secretary of Interior Ken Salazar shelved the Nevada repository site. "The key thing with a repository isn't the engineering solution, it's about the difficulty getting

a community to accept one” in their own backyard, said Thornton, adding that the debate itself is making the industry “an easy target for people concerned about nuclear energy.”

The Administration’s Blue Ribbon Commission on America’s Nuclear Future is looking at the where, the when and the hows of managing a repository with a 2020 deadline for resolution. Described by NEI CEO Marvin Fertel as a “chronic source of frustration,” the lack of federal action is the target of a \$750 million lawsuit filed against the DOE in 2011 by the NEI and 16 of its member companies for the money utilities are paying (through customer rates) into the Nuclear Waste Fund, “a program that doesn’t exist,” said Fertel.

Storage aside, there’s an expectation by Thornton and also Babcock & Wilcox’s Mowry that the Administration’s attention means it believes “nuclear continues to have a role to play in the U.S. power mix.” Obama, said Mowry, is “pro-environment and is genuinely concerned about the climate. That’s how we can help—by reducing emissions.” Added the NEI’s Genoa, “the industry will be challenged by natural gas in \$4-\$6 range” unless nuclear is seen as a solution for carbon-free generation.”

Utilities still consider future carbon costs in sensitivity analyses despite current policies. “Utilities take the broader approach and look at greater diversity of fuel types for the long term,” said CH2M HILL’s Brister.

With new coal power capacity essentially banned by the Environmental Protection Agency’s performance standards for greenhouse gases, utilities essentially have two choices for new baseload capacity: gas or nuclear. Paul Lorenzini, CEO of NuScale Power and an industry professional since the 1970s, acknowledges nuclear’s current disadvantage against inexpensive natural gas. But he says some

Recommendations of the Obama Administration’s 2012 Blue Ribbon Commission on America’s Nuclear Future

- 1) Consolidated interim storage facilities and permanent deep geologic storage should be developed and programs started to prepare for large-scale transport to these facilities;
- (2) A new management entity should be created to manage the federal government’s high-level waste program;
- (3) The new management entity must have full access to the nuclear waste fund and the monies being collected through the nuclear waste fee;
- (4) The approach to siting and developing new nuclear waste management and disposal facilities in the U.S. should be adaptive, staged, consent-based, transparent, and standards- and science-based;
- (5) The U.S. government should provide stable, long-term RD&D (research, development, and demonstration) support for advanced reactor and fuel cycle technologies; and
- (6) The U.S. should demonstrate international leadership on global non proliferation concerns and improving safety and security of nuclear facilities worldwide.

utility executives are still motivated to include nuclear in their portfolio. “Because of the potential price volatility of gas supplies they want nuclear in their portfolio as a hedge,” said Lorenzini.

Exporting Policy: SMR Gaining Foothold and Going Global

NuScale was one of the four competitors for the second DOE loan guarantee—making available \$452 million in funding over a five-year period to develop and receive regulatory “Design Certification” for small modular reactor (SMR) technology. The winner, announced in late November 2012, was B&W mPower, beating out NuScale (majority owned by engineering and construction services giant Fluor of Wisconsin), Westinghouse and Holtec. The B&W mPower SMR project with the DOE, named mPower America, will receive a portion of the \$452 million—the exact amount of the award is being negotiated.

More than an incubator for new-tech development—up to four B&W mPower reactors will be constructed at Tennessee Valley Authority’s Clinch River Site in Oak Ridge, TN—the DOE’s SMR program is part of nuclear energy’s geopolitics. SMRs are now seen as the next

big step forward for nuclear power worldwide. Small, modular—they’re almost “plug-and-play”—and one-fifth the cost of its big-megawatt siblings, SMRs “are practical and more affordable—there’s a market for them,” said Lorenzini.

The market is the world. “SMRs are scalable to local requirements,” said B&W’s Mowry. “Bigger plants are limited by the places where you can build,” near large sources of cooling water for example. SMRs are buried underground beneath thick, reinforced concrete walls. And SMRs, added Lorenzini, “can go into any market.” And because they’re so much smaller than the typical 1000-MW size of the existing nuclear technology—the B&W mPower units are 180 MW each—they can be integrated into existing grids with much less investment in new transmission capacity.

Both the DOE and the industry hope government support will help ensure American technology leadership in SMRs and drive a strong export market. The DOE funding was specific to development within the United States, and NuScale, for one, promoted its entry as “U.S.-based and U.S. manufactured.” Noted Lorenzini, “If you create the industry, you create the U.S. market for it, and U.S. jobs.”

The NEI sees SMRs as another way for the United States to ensure that it continues to keep its prominent seat at the nuclear proliferation table, particularly now, as the U.S. build market remains flat. “International nuclear safety is tied to whether the United States is competitive in the global market,” said Genoa, and what that takes is “a transfer of knowledge.” The DOE loan guarantee for SMRs and also the 2010 loan to help build Southern’s Gen III AP1000 reactors, are indicators, said Genoa, that “the Obama Administration is realizing that nuclear exports and our security are tied together.”

“If we’re not sitting at the table together transferring information and technology, then we have no global influence,” said Genoa. Exporting technology is the lifeblood of the U.S. industry as nuclear energy demand grows and spreads globally, and for the NEI, a major barrier to garnering a good-sized share of that world market is what Genoa describes as bureaucratic “stove piping.”

Government agencies entrusted with nuclear policy “don’t talk to each other,” said Genoa, who cited the Pillsbury report, released in October 2012 by the Pillsbury Winthrop Shaw Pittman law group. The report’s summation: the U.S. regulatory process “is more complex, restrictive and time-consuming” than its counterparts in Russia, Japan, South Korea and France. This creates “a competitive disadvantage” for U.S. exporters.

In specific go-to-market terms, said Genoa, “it can take up to two years to get approval for exporting [products] here as opposed to four months in other countries.”

What can be exported barrier-free, however, said Genoa, is “the gold standard of safety” that the NRC represents, a U.S. regulatory-based advantage that companies including Mitsubishi Heavy Industries are eager to obtain.

Mitsubishi Close to Permits for Two Giant APWR Plants

Mitsubishi Heavy Industries is seeking—and close to receiving—that coveted prize with two deals for its Advanced Pressurized Water Reactor (APWR), one with Luminant for the Comanche Peak facility in Glen Rose, Texas, and the other with Dominion’s North Anna plant in Louisa County, Virginia. Both are under active NRC review, with the Dominion project receiving its early site permit (ESP) in November 2007.

The Dominion APWR facility in northern Virginia will be big even by the nuclear industry’s standards: 1700 MW. Michael Ivey, assistant general manager of Mitsubishi Heavy Industries America’s Washington Office pointed out that the region has the “mature grid and huge demand” needed to create a market for such a large plant.

“Because of the potential price volatility of gas supplies power utilities want nuclear in their portfolio as a hedge.”

The two APWR deals are in keeping with Mitsubishi Heavy Industries’ post-Fukushima goals, among them to “accelerate the development of global business” to realize, as Shigero Masamori, head of Mitsubishi Nuclear Energy Systems outlined in a June 2012 business update, an increase of “400 billion yen [about \$4.9 billion] through overseas new build and alliances” by fiscal 2014.

In May 2012, Mitsubishi Nuclear Energy Systems officially opened an engineering center office in Charlotte, North Carolina, to help support its U.S. expansion strategies for both building new nuclear plants and selling replacement components for existing facilities. The company said in a release that it will invest \$4.1 million in the facility and hire

135 engineers and other employees over the next five years.

Obtaining NRC design certification (DC) and combined license (COL) applications from the NRC is the icing on Mitsubishi Heavy Industries’ world expansion cake. As Ivey said, echoing Genoa, NRC certification “is the gold standard. With it, we can take [our products] anywhere.”

The Proof is in the Nuclear Pudding

For NEI’s Genoa, all talk of nuclear energy’s future in the United States comes down to one basic ingredient: the proof in the pudding. The United States remains, he said, the world leader in nuclear generation, with 104 reactors that have “consistently provided one-fifth of the nation’s electrical needs.”

While the majority of America’s fleet is vintage late ‘70s and early ‘80s design, 70 have been approved for another 20 years of operation, said Genoa, a testament, he added, to the U.S. industry’s focus on maintenance. “We’ve been keeping [plants] in excellent condition” through upgrading and refurbishing equipment. Over the past two decades, the U.S. nuclear industry “has spent \$86.6 billion on improving and upgrading plants, the equivalent of building 10 new plants,” said Genoa.

While one may rightfully suggest that the long-awaited nuclear renaissance may have been put on hold following Fukushima, in Genoa’s opinion, “The renaissance is more than building more plants, it’s about operating more efficiently. [In the United States] we’ve been near 90 percent capacity as fleet average for a decade.” ☼

Babcock & Wilcox Takes Early Lead in Small Modular Reactor Development

In electrical power generation, large facilities are generally preferred for their efficiency and economies of scale, but for many applications of nuclear generation technology, small might be a better fit to deliver clean, reliable, carbon-free—and reasonably priced—electricity. A powerhouse veteran of the nuclear industry has recently been tapped by the **U.S. Department of Energy** to prove that point, and perhaps also to blaze the trail for U.S. exports and potential market dominance.

The **Babcock & Wilcox Company** (B&W) of Charlotte, N.C., beat out three other teams, consisting of six formidable industry contenders, to win the DOE's blessings and a share of \$452 million in a public-private partnership to build and commercialize its small modular reactor (SMR), the B&W mPower reactor. B&W will do so with **Bechtel**, its partner in a joint-venture company, **Generation mPower**, formed in 2010 to develop and promote the B&W mPower SMR.

The DOE made its decision in late November 2012, following an announcement at the beginning of the year that it would invest approximately \$452 million to “assist the industry in advancing SMR technology to full commercialization.” It is the second recent major DOE investment in nuclear energy deployment. The first, in 2010, provided an \$8 billion loan guarantee to install two new Westinghouse AP1000 reactors at the Southern Company's Alvin W. Vogtle Electric Generating Plant, now under construction.

B&W has not publicly indicated how much the five-year mPower project is estimated to cost. In the days following DOE's award, it announced a supply agreement with **Lehigh Heavy Forge** of Bethlehem, Pa. The two will jointly

participate in designing and making the large forgings needed to manufacture mPower SMRs. Also standing by: reactor suppliers in 36 states, who have collectively formed more than 150 MOUs with B&W since work on the B&W mPower program began in earnest in 2009.

B&W, which in 2011 reported nearly \$750 million in U.S. government contracts for nuclear decontamination, decommissioning and remediation, heads up the B&W mPower project. Bechtel, of San Francisco, is exclusively providing the engineering and procurement of key components and will build the plant. The **Tennessee Valley Authority** (TVA), another early project partner, is in the process of securing a license from the **Nuclear Regulatory Commission** (NRC) to construct up to four B&W mPower reactors at the TVA's Clinch River site in Oak Ridge, Tennessee.

Petite but Powerful

SMRs are the hottest new thing in the 50-year-old nuclear industry—and for Christofer M. Mowry, president of B&W mPower, it's technology that “feels like a better path forward. There's a lot of energy and excitement here,” said Mowry. “We really believe we can make a fundamental change [in the nuclear industry], to make it more practical and to address public concerns.”

Even before the DOE announcement came down, Mowry was adamant that “moving forward” would not stop if the B&W mPower team lost the competition. “We believe that if you look in the crystal ball, you'll see that [for the future] the industry needs more than one form of clean baseload power generation. There are plenty of technology providers for big [reactors]. Small is a nice complement—and there's a market for them.”

That market is global and growing, made up of countries interested in nuclear but without the grid—or the money—to spring for a full-blown plant.

Based on advanced pressurized water reactor (PWR) technology (as are most nuclear reactors worldwide), B&W's mPower is “one fifth the size and cost” of its conventional nuclear cousins; it provides a 180 MW of electrical power capacity compared to an average 1000 MW for the typical nuclear units. Smaller output allows SMRs like the mPower to “scale to local requirements,” according to Mowry, a key selling point for SMRs in nations and areas that lack the needed infrastructure, but want access to clean, reliable carbon-free energy.

SMRs will be able to repower legacy power generation assets, predicts Mowry. “Many old power plants are scaled to the size of mPower,” he said. By replacing an older similarly sized power plant with an mPower reactor a utility “could continue to use the existing grid and site infrastructure, saving money, time, and jobs.”

Despite current low natural gas prices, Mowry predicts that in the long-term SMRs will offer a competitive complement to gas-fired power generation for utilities. “Seventy to 80 percent of the cost of electricity [from a gas-fired plant] can be the cost of the natural gas fuel,” he said. “With nuclear energy, it's only 10 percent.”

Less Risk and NIMBYism

From the perspective of community acceptance and regulatory permitting, SMRs offer “an absolute reduction in risk, not only in terms of nuclear safety but also in terms of project financing and deployment,” said Mowry. “It makes nuclear construction look like combined cycle construction—and 70 percent of [the work] is done in the factory, not the job site.”

Modular design is a key element of SMRs, making them “almost plug and play,” he said. The B&W mPower reactor can be built in factories, shipped by rail or truck to construction sites, and then assembled onsite. The entire reac-

tor, measuring 83 feet high by 13 feet in diameter, is buried underground beneath thick reinforced-concrete walls, enhancing safety from all internal and external threats – technical, environmental and human. “Underground is inherently more secure,” he said.

Visually, all one sees of the nuclear reactor is a one-story building that sits in the middle of the 40-acre plant site. “It ‘looks like a WalMart. With trees around, you wouldn’t even see it,” said Mowry. The low-profile appearance is important: “It will help get local communities to accept the facility as a neighbor – one that provides them with energy and jobs in a safe, clean manner. B&W mPower needs to be a non-intrusive part of the local [growth] equation.”

Back to the Future

SMRs like the mPower bring nuclear technology almost full circle, according to Mowry. “The U.S. pioneered the nuclear industry in the 1950s. Those first reactors were much smaller, on the order of B&W mPower,” he said. They got bigger because the idea was that “cost efficiency would increase” with size.

But with a history of cost overruns and financially challenging delays in permitting, “The industry hasn’t consistently managed these cost and schedule risks during construction for big reactors.”

Still it has taken many years, decades in fact, for mPower to get to this stage. Prior to developing mPower, B&W already had a background in supplying compact “integral” reactors in which the components are self-contained within one steel vessel, not distributed and connected by pipes. In the 1960s, “we pioneered [the technology] on the commercial side, building a [SMR-style] reactor” for use on a German merchant ship – the Otto Hahn,” according to Mowry, who added that B&W cut its teeth on nuclear as the reactor supplier for the first U.S. nuclear submarine, the Nautilus.

Nuclear Strategy & “Market States”

Market State Type

Nuclear Strategy	Mercantile	Managerial	Entrepreneurial
Rollback	Japan (pre-2011)	Germany, Italy, EU	[none]
Renaissance	China, Korea, Russia, Taiwan	France, Finland	Canada
Restructuring	UK, Japan (2012)	Sweden, Spain	USA

Source: EBI/Verdigris Capital presentation by Andrew Paterson; Market State types adapted from *Marketing the Future of the State* by Philip Bobbitt.

Bobbitt imagined three principal versions of Market State: The Entrepreneurial Market State reflects a broadly libertarian view, tending to keep state intervention to a minimum and confining itself to nurturing tangible and intangible (for example, education) infrastructure. The Managerial Market State is more sensitive to egalitarianism, and attempts through long-range planning to give more weight to the interests of posterity. The Mercantile Market State is more consensual and more protectionist, keeping

control over capital both monetary and human – e.g. through immigration control. For entrepreneurial states [USA, Canada], sovereignty is transparent, a function of the state’s adherence to human rights norms. For managerial states [EU], sovereignty is the translucent creation of international institutions and can be pierced only with the endorsement of those institutions. For mercantile states [Asia], sovereignty is opaque, and cannot be breached for any reason by any state except as a response to an attack.

The commercial integral reactor technology, said Mowry, “percolated on paper after that [and was] reinvigorated in 2008, with more focus on a practical power generation design ready for formal project launch.”

The mPower team and its development members employ more than 400 workers, said Mowry. Mowry said that the “completeness of our design” was a plus for entering the DOE competition. “We were much farther along in development and the ability to deploy a lead plant before the 2022 goal set by the DOE,” he said of rivals NuScale Power (majority owned by Fluor), Hyperion Power Generation, Toshiba, General Atomics, General Electric and TerraPower, which counted Bill Gates as an investor.

Interestingly, B&W has a consortium of utilities “actively interested in our design,” including Old Dominion Electric Cooperative, PowerSouth Energy Cooperative, Nebraska Electric G&T Cooperative, FirstEnergy, TVA and Oglethorpe Power Corp. Members of the project’s advisory council also include more traditional large electric utilities like Dominion, Duke Energy, Entergy, Exelon and Vattenfall.

A ‘Little’ Bit of Export Prowess

The DOE’s intent with the SMR program is to establish U.S. nuclear leadership, or, as the DOE advised more specifically when the competition was formally announced in March 2012, to position “America as the leader in advanced nuclear energy technology and manufacturing,” both for export opportunities and to establish a “competitive edge in the global clean energy race.”

It’s also about ensuring that the United States remains an influential nuclear power on the political front and specific to nonproliferation, a position at the world’s table “that only works when you have a globally competitive nuclear technology,” said Mowry. “We need nuclear technology that is ubiquitous, a technology that is broadly adopted and installed by other countries around the world,” he said.

At its core, SMR development is therefore “also a national security issue,” said Mowry. “If we’re not involved in export of safe nuclear energy, it’s harder to be involved in the conversation. It’s the geopolitical dimension to nuclear energy that matters as well,” he said, adding that if the United States doesn’t build and spread SMR technology, someone else, maybe France or China, will. ⚙

Redefining the Nuclear Energy Market, Post-Fukushima

No amount of safety features will change the current course of the nuclear energy market in Germany. After the March 2011 Fukushima earthquake, tsunami and nuclear disaster, Germany's leadership has firmly moved to a policy of *energiewende*, or energy transition: a polite term for giving nuclear the boot.

Germany is the most notable of the countries that reacted to Fukushima by just saying "no"—notable because it will be dismantling all 17 of its reactors by 2022. And of course there's Japan, which remains deadlocked in debate over the who, hows and whats of both Fukushima and the nation's once-robust plans for continued reliance on nuclear. Japan is also reeling from the escalating price tag for cleanup costs: currently \$125 billion, according to Fukushima nuclear plant operator **Tokyo Electric Power Co.** (Tepco).

"The government announced that it is basically aiming at making the country nuclear free by 2030, but there's a lot of controversy about how they announced it and whether it's as firm as it appears and whether it will be extended to 2040," said Anne Hung, head of major projects at the Tokyo office of global law firm **Baker & McKenzie**. "But the trend is there and we see changes in the market already."

According to Hung, although industry groups and some government officials are concerned about Japan losing its international competitiveness without nuclear power—not to mention falling behind on climate commitments—the post-Fukushima public opposition to nuclear power is profound.

"Japanese people are really very angry with the nuclear power operators," said Hung. "In Japan, we just don't see this degree of protest, with old people, moth-

ers, all sorts of people who are upset going into the streets to protest. That force cannot be ignored." And the fact that the country got through a record hot summer in 2012 without significant blackouts due to conservation measures "has a lot more people saying we can live without nuclear in the future."

Switzerland, Belgium, Italy, Brazil and Lithuania are reportedly pulling back on nuclear energy plans. Even France, after the United States the world's second leading nuclear nation with 58 reactors powering 74% of its electrical needs, is cooling on nuclear. According to the *New York Times*, French President François Hollande said his government would "scale back," which prompted the French nuclear energy sector to remind the government that the sale of nuclear equipment and services there is valued at \$9 billion a year, and that the industry employs 125,000 workers.

Still, those saying "yes" are plentiful, and there are new markets jumping on board. The **International Atomic Energy Agency** (IAEA) estimated in 2012 that global use of nuclear energy could rise by as much as 100 percent over the next two decades. And Jay Brister, vice president of Global Business Development, **CH2M HILL** Nuclear Business Group, anticipates growth to pick up in the United States sooner than that. "We're beginning to see ourselves coming out of the current economic downturn. There's a lot of cash in the marketplace, [people] are beginning to make investments."

Knee-Jerk with a Wallop

In the opinion of many, including Nigel Thornton, a director of Energy at **Atkins**, one of the world's leading engineering and design consultancies with 40 years' experience in nuclear power, Germany's nuclear pullout was "a knee-jerk reaction." As Thornton related, the four operators of Germany's nuclear plants—E.ON, RWE, EnBW and Vat-

Global Nuclear Facts

- 436 nuclear plants operating in 30 countries
- 14 percent of the world's electricity provided by nuclear power
- 66 new nuclear plants under construction in 14 countries
- 160 new nuclear plants on order or planned, with additional 329 proposed

tenfall—took a major hit, reporting at the time that it would cost upwards of \$36.7 billion to tear down their facilities and dispose of the waste. Individually, RWE, Germany's second-largest utility, said the dismantling of the two reactors at Biblis would cost €1.5 billion, excluding storage costs for the nuclear waste. E.ON, the largest utility, told Reuters it expected to spend €1.1 billion per plant for both dismantling and the disposal of radioactive material.

"I fully understand why people have been more critical of nuclear energy since the reactor accident at Fukushima," wrote then-CEO Jurgen Grossman in RWE's 2011 annual report. "However, Germany's taking 40% of its nuclear power capacity offline at once ... leads to a lack of security—of supply. This became evident especially during the cold February [2012] days. To prevent blackouts, the transmission system operators actually had to resort to an old oil-fired power plant in Austria."

Vendors and suppliers were also hit hard. Within months of the May 2011 announcement by Chancellor Angela Merkel that Germany's initial reduction in nuclear capacity would be expanded to the entire fleet, **Siemens**, Europe's largest engineering firm, exited the nuclear-build sector by selling its interest in **Areva NP**. (It continues to deliver systems, such as steam turbines used for power plants, both nuclear and fossil).

Siemens board member Michael Suess told Reuters in January 2012 that

Germany's plan to replace the 23% share of electricity lost from nuclear power with that generated by renewables—and to increase that percentage to 35% renewable-generated electricity by 2020—could cost \$2.15 trillion by 2030. The German Energy Agency has also warned that the abandonment of nuclear energy could increase electric bills by 20% by 2020.

Decommissioning Market Grows

The silver lining in Germany's post-Fukushima policy, as the above figures indicate, is the market for decommissioning work, a segment opening up worldwide and one that Atkins, CH2M Hill, Bechtel and others are targeting.

Announced in September 2012, Atkins and Areva formed the Areva-Atkins Partnership UK (Warrington, Cheshire) to land nuclear fuel management and decommissioning projects primarily in the UK, where Atkins has been involved in nuclear waste cleanup since the 1980s. And also in the UK, Atkins has its sights on the ongoing, massive clean-up work at Sellafield, the legacy nuclear reprocessing site in Cumbria, which also involves the decommissioning of reactors at Wildscale and Calder Hall, the world's first commercial nuclear power station. Together, the decommissioning and containment work at Sellafield is valued at \$1.6 billion pounds a year, Thornton said.

"Sellafield has been part of the nuclear industry since the late 1940's, is the site of the UK's first commercial reactors and is the primary site in the UK for spent nuclear fuel management. All of that has to be dealt with," said Thornton. "From an engineering standpoint, it's very challenging and complicated. We're looking at decommissioning long into the future, perhaps 40 years."

And while the two companies did not name specific projects that they intended to bid on when the partnership was announced, Thornton said the venture is "looking around Europe" as power

companies begin decommissioning their first-generation plants. And then there's the United States, added Thornton. "For now the biggest decommissioning [work is] around legacy military facilities, but the 104 reactors will need to be decommissioned after closure."

CH2M HILL is also watching the decommissioning market, its expertise honed by work at the DOE's Rocky Flats Closure Project in Colorado, a former nuclear weapons arsenal. "Globally, the oldest plants were built in the late '60s, early '70s. With 40 years or so the average lifespan, it's an ageing asset base and decommissioning will be more and more in the forefront over time," said Brister.

Westinghouse and Sweden's Studsvik are eyeing decommissioning opportunities as well, announcing in late summer 2012 that they will be offering a "full range" of decommissioning services for plants in Europe—starting with Germany—under the name **ndcon** (for Nuclear Decommissioning Consortium).

Aside from Germany—where, as Brister added, "the utilities have to work with the German government on [the future] decommissioning and economic compensation," both of which will take time—in the forefront today are two possible bellwethers for the decommissioning bubble to come in North America: **Hydro-Quebec's** decision to shut down its sole nuclear generating plant, Gentilly 2 in Bécancour, Quebec; and Richmond, Va.-based **Dominion's** announcement in the fall of 2012 that it would close its Kewaunee, Wis., plant after failing to find a buyer.

In both cases, said Brister, the decisions were based on refurbishing costs versus the price tag for decommissioning. For Hydro-Quebec, the shutdown numbers added up to \$4.3 billion for refurbishing compared to \$1.8 billion for decommissioning. Gentilly 2, according to a statement by Hydro-Quebec's chief execu-

tive officer, Thierry Vandal, will first be prepared for "dormancy," with dismantling scheduled for "several decades from now." Total decommissioning will take 50 years.

For Dominion, the decision to close Kewaunee rather than refurbish it is related to what the U.S. nuclear industry is grappling with today—flat electric pricing, in large part due to declines in demand growth during the recession and in part due to low natural gas prices.

"Dominion was looking at the economic viability of keeping [the plant] open," said Brister. When Dominion bought the plant in 2005, it was seen as an entry point into operating a nuclear-power fleet in the Midwest. And the agreements Dominion signed to sell the plant's output were based on a strong electricity market. That was then; today, projections that lower electricity rates will continue sealed the shut-it-down deal, with Dominion stating bluntly, "It is uneconomic for Kewaunee to continue operations."

The Kings Are in Movement

Yet even with emerging nuclear nations and optimistic views of the industry going forward, there is no denying that Fukushima rattled the nuclear status quo, and not only in terms of country-by-country reactions. Like so many kings on a chessboard, each seeking to unseat the other, the world's nuclear players are in movement across what Thornton cites as one of the major impacts post-Fukushima, "a new nuclear landscape." And the game began in earnest when Germany bowed out of play.

Germany's nuclear pullout not only opened up a decommissioning market, it is an example of the changing landscape that Fukushima inspired. To wit: German operators E.ON and RWE, stung by the anti-nuclear policy shift, also had to rethink their joint venture in the UK, **Horizon Nuclear Power**, formed in 2009 and aiming to develop up to 6,600 MW of new nuclear capacity.

Germany's move out of the nuclear market "affected their revenues and their ability to invest," said Thornton, and as a result in early 2012 E.ON and RWE put Horizon Power up for sale.

Russia's state-owned **Rosatom** was rumored to have been keen on snapping up Horizon, as was **State Nuclear Power Technology**, a Chinese-government backed nuclear company. But the buyer was Japan's **Hitachi**, which paid \$1.12 billion for the project, finalized October 30, 2012. Hitachi plans to build "two or three" 1,300 MW plants there, the first to be operational in 2020.

For Thornton, the Hitachi buy signals a healthy nuclear market. "That the transfer of ownership took place within six months indicates general interest in nuclear power. It shows positive support" for the industry as a whole.

In business terms, Hitachi's move into the UK market is a post-Fukushima strategy shared by Japan's other two nuclear power brokers, **Toshiba** and **Mitsubishi Heavy Industries**. With work on hold at home, their view now is more extensively global.

Fukushima "has affected all the nuclear manufacturers," said Hung of Baker & McKenzie. "It threw them completely off balance. Their immediate task is to go and clean up Fukushima. But in the long run, I think they are changing their strategy to focus elsewhere" outside Japan.

It's not only Japanese manufacturers seeking markets beyond their shores. South Korean companies are actively looking outward. And so are U.S. vendors, notably GE. According to NEI's Paul Genova, the current flat demand for electricity in the United States, "is not sufficient to sustain a robust industry. We recognize that for the health of the U.S. [nuclear] industry, we have to take a share of the global market, Asia in particular."

South Korea: Targeting a World of Opportunity

According to a May 2012 NEI white paper, 160 new plants worldwide are either on order or planned, with an additional 329 proposed. In short, and in short order, South Korean nuclear players aim to grab a chunk of that market—as well as to keep up with demand at home. Currently with 23 operating reactors, South Korea has ambitious plans to nearly double that number to 40 by 2030, which would also boost its nuclear generation twofold, from 31% today to 59% over the same timeframe.

South Korea's current technology is a source of national pride: though based on the original Combustion Engineering-Westinghouse technology that launched the country's nuclear presence in the late 1970s, South Korea, under the aegis of state-owned **Korean Electric Power Co. (KEPCO)**, has developed its own reactor technology, the APR-1400 now in its third iteration.

In May 2012, construction began on two new APR-1400 reactors, each capable of generating 1,400 MW of electricity, at the Uljin power plant in North Gyeongsang Province. The first reactor is expected to be online in 2017; the second in 2018. The cost, according to the Ministry of Knowledge Economy: \$6.18 billion (7 trillion won).

More than 700 residents attended the groundbreaking ceremony at Uljin, where South Korean President Lee Myung Bak drove the made-in-South Korea point home, noting, "The reactors mark a turning point for South Korea's commercial nuclear energy program because no foreign-made parts are used in the most important areas."

South Korean vendors drove an earlier stake in international market terrain in 2009, when KEPCO, Samsung and Hyundai beat out Areva and an American-Japanese consortium to secure a \$20

billion contract to build four nuclear reactors in the United Arab Emirates (UAE), scheduled for completion between 2017 and 2020. According to the South Korean government, the UAE win is just the beginning—the goal is to export 80 nuclear reactors and secure \$400 billion in contracts by 2030.

The UAE contract is not solely a South Korea win. Atkins is the technical adviser to the lenders, said Thornton, "providing due diligence so that the banks can see that their money is secure."

The **Export-Import Bank of the United States** approved a \$2 billion direct loan toward the construction of the UAE's four reactors specific to the purchase of equipment and services from American-based firms. In a release, the bank said the largest U.S. exporter for the project will be Westinghouse Electric, a subsidiary of Toshiba, providing coolant pumps, controls and other components, as well as services. The work will "create and sustain U.S. jobs in California, Connecticut, New Hampshire, Ohio, Pennsylvania, South Carolina, Texas and other states home to Westinghouse sub-suppliers." It's the bank's first financing for a new nuclear plant since the 1990s.

Middle East Market Heats Up

The UAE provides what Simon Harrison, energy director at **Mott MacDonald**, an design and engineering firm, describes as a "textbook case" for what the new nuclear market is experiencing as more non-nuclear nations enter the fold—how to build in countries without an established regulatory agency or framework.

For a non-nuclear country to develop nuclear power, said Harrison, "they need to set up credible and convincing regulatory arrangements. The IAEA has some quite detailed prescriptions as to what you need to do before you can build a nuclear power station, which is proving to be a helpful template," he said. "The UAE is kind of a textbook case for how to

do it. They've gone from zero to quite an advanced position in a few years."

The UAE and its emerging nuclear neighbors also provide good examples of the factors driving nuclear power in other emerging markets, according to CH2M-HILL's Brister: overall economic growth and consequent increases in demand for electricity. "Where economies are booming, energy is the lifeblood for growth."

The economics of importing oil and gas are also driving more countries to consider "alternative fuel types, like nuclear." And both new and established nuclear nations are increasingly sensitive to climate change, said Brister. "A UAE white paper released in 2008 looked at all the [new energy options] from an environmental standpoint, and nuclear [was found to have] minimized the impact."

Combinations of the above factors are giving rise to nuclear power expansion in other Mideast nations, including Saudi Arabia which, said Harrison, "is keen [on] setting up the King Abdullah City for Atomic and Renewable energy, which will be the focus for developing atomic and renewable power." Also looking at nuclear energy, Jordan, which in April 2012 announced that it had "shortlisted" Russia's Atomstroyexport and an Areva-Mitsubishi Heavy Industries consortium to build the country's first nuclear reactor.

It could take three years to make a decision, and another four to five years to build the plant, the **Jordan Atomic Energy Commission (JAEC)** said in a press statement. In the meantime, Jordan will continue to face what the JAEC described as a "tremendous" energy supply challenge.

China Turns On the Heat

Jordan's need for electricity has nothing on China. "China," said Akins' Thornton, "is progressing rapidly with its new-build program. There's huge demand; the economy is growing so fast, and [the country] is pro-nuke."

Of the 63 plants currently in the works worldwide, 26 are in China, with more to come, although the exact number of projects and the amount of generation planned are both in flux—directly because of Fukushima. New build rules are now in effect, redefining pre-Fukushima goals that had outlined incremental generation growth from 70 GW to 400 GW by 2050. The post-Fukushima changes are the result of China's 19-month safety-inspection moratorium, which ended in October 2012.

Now the only projects that can go forward in China are those that rely on advanced Generation III reactors meeting international standards—and all new reactors have to be located on the coast. "New inland plants are on hold," said Bechtel's John Atwell, manager of operations, New Nuclear. Estimates are that about one-third of the planned projects could be affected.

Still, China is a monster market, and ready to pounce. In June 2012, **China National Nuclear Power Co.**, the country's largest developer, announced an IPO to fund five projects valued at 173.5 billion yuan (\$27.25 billion). According to Reuters, if "all or most" of the planned projects are financed by share sale proceeds, the IPO could be "mammoth."

It's no wonder all eyes are turned in China's direction, and a few are already realizing success, most recently Bechtel, which has a 40-year history in China and offices in Beijing, Shanghai and Taipei. It was tapped by **China Nuclear Power Engineering Corp. (CNPEC)** to "enhance" construction management through training and education. CNPEC is reportedly managing several nuclear projects currently under development.

Earlier in 2012, Duke Energy, the largest electric power holding company in the United States, signed an agreement for nuclear power development with China Power Investment—the day after it had

signed a memorandum of understanding with China **Guangdong Nuclear Power Group** to cooperate in nuclear power investment, nuclear power plant operation management and other clean energy developments. China Power is one of the country's five largest state-owned power producers and one of three companies in the country that can design, develop and operate nuclear power plants.

An Insider's View of the Mammoth

CLP Holdings, a Hong Kong-based energy company with business in China, India, Australia, still owns a 25% share of China's first nuclear power station, the Guangdong Daya Bay Nuclear Power Station in Guangdong China near the border of Hong Kong. "It was a pioneering project," said Peter Littlewood, group director-Operations. "I worked on that project myself for five years in 1980s."

In Littlewood's assessment, there are three issues driving China's nuclear construction strategy. "First, in terms of economics, nuclear power in China is quite comparable with coal. It's a very economical source of electricity, cheaper than wind, cheaper than gas." And that's because China, like South Korea, began with imported equipment and technology, said Littlewood, but "gradually mastered the technology. Virtually all components for a nuclear power station, including the fuel, can be manufactured in China. This has brought the cost down dramatically." (According the NEI, China is also planning to fabricate and supply its own fuel assemblies, develop high temperature gas reactors and fast breeder reactors, and "maximize its domestic nuclear supply chain for construction and eventual export.")

Secondly, said Littlewood, China can build its plants "far more quickly than could be achieved anywhere else in the world," and that reduces the financing costs. Thirdly, China has control over the fuel cycle, including uranium resources.

“They’re getting control of imported uranium as well [and] they have the ability to enrich uranium.”

After the Fukushima disaster, the Chinese government put the nuclear program on hold to investigate safety at existing reactors and those in development. The **World Nuclear Association** reports that an October 2012 directive by the State Council indicates “future pace of approvals will be reduced ... only new plants at coastal sites will be approved up to 2015 [and] new reactors will have to comply with new-generation safety standards.”

Littlewood sums up the take-away: “The result of [the post-Fukushima review] is they’ll make a more rapid transition from second-generation to third-generation technology which has been developed by Westinghouse and other technology providers and is inherently safer.”

“We all believe that second-generation technology, which is virtually every nuclear reactor operating in the world now, can be safe, but there’s definitely an issue of perception, so the sooner they move to third-generation technology, which can be called inherently safe, the better,” he said.

While a variety of foreign and domestic technologies will be used, the key third-generation technology will be Westinghouse’s AP 1000 pressurized water reactor (PWR) design. According to the WNA, Westinghouse won a competition with AREVA/EDF and other bidders for the first third-generation plants in 2007. “This trend was given impetus by the reappraisal of safety following the Fukushima accident,” notes the WNA.

After an initial tranche of four reactors are constructed by Westinghouse and Shaw, technology transfer agreements will allow domestic nuclear contractors to build the units, according to WNA. Eventually, Chinese companies “will manufacture [third generation technology] on their own,” affirmed Littlewood. ☼

U.S. Onshoring of Uranium Enrichment Creates New Market Opportunities

Welcome to New Mexico, the Land of Enchantment—but also for the uranium fuel industry, which has found a home along the eastern strip of the state nicknamed the “nuclear corridor.” The founding father is the Department of Energy’s Waste Isolation Pilot Plant (WIPP), an underground, 10,000-year storage facility for radioactive transuranic waste—the equipment, clothing and other materials contaminated during nuclear weapons research and development. With WIPP as the trailblazer, the state that put the atomic age on the map has also become the go-to destination for two companies that represent firsts on U.S. soil: commercial operations that process uranium on the front end of the nuclear power fuel cycle.

International Isotopes (INIS), a medical radiochemical company located in Idaho Falls, Idaho, is the latest of the two nuclear newcomers, with plans to open a first-of-its-kind uranium deconversion plant west of Hobbs, the principal city in Lea County, oil and gas country bordering Texas. INIS’s end products, are various fluoride compounds that will be sold to an already-hefty installed customer base that includes the use of those products for pharmaceutical, semiconductor, solar photovoltaic and refrigerant industries.

Licensed by the NRC in October 2012, the INIS project—officially described as a “uranium tails recovery” operation—is a heartbeat away from finalization and all systems are just about ready to go. With help from 10-person environmental firm **G.L. Environmental** (Las Vegas, NM), INIS recently secured its air permit from the State of New Mexico; it is starting final work on a groundwater permit from the state as well. The last item on the to-do list before construction begins on the \$115 million facility

is “to secure funding,” said INIS President and CEO Steve Laffin. And while Laffin admits that “it’s a tough [funding] market out there,” he’s also not fretting. The project is “flexible,” he said. “We have the option to build something smaller to reduce capital” needed. Overall, “I’m quite optimistic, based on the business model and the market opportunities.”

The market opportunities, as noted above, are compelling: U.S. industries use 400 million pounds of some fluoride products each year and the market “has maintained a steady 5%-to-8% growth rate over the past 25 to 30 years,” said Laffin.

Then there’s INIS’s business model, which includes an envious production bonus: It will be paid to take the raw product it needs to make its fluoride by-products. That raw material comes in the form of uranium tails—the by-product of the uranium enrichment—and supplied from INIS’s neighbor, **Urenco USA**, a division of the global uranium enrichment company, Urenco based in the UK.

Urenco USA’s National Enrichment Facility in Eunice is the first commercially developed uranium enrichment plant in the United States. “We’ve signed a contract with Urenco,” said Laffin, “which is already producing and stockpiling [the tails]. There will be a reserve” when INIS opens its nearby facility, which adds to Laffin’s optimism: “There’s no lack of material.”

From Stockpiles to Business Models

Urenco’s presence in New Mexico could be a harbinger of what’s to come elsewhere: more enrichment plants in the United States spurred by two key changes in the landscape: the Megatons to Megawatts program, which supplied nuclear power plants in the United States with Russian-enriched uranium from the decommissioned nuclear weapons stockpile, ends in 2013. And new rules now limit the amount of imported enriched

uranium to no more than 20% of what the U.S. reactors need for fueling, said Laffin.

What America's nuclear reactors need is about 4 million pounds of enriched uranium annually in the form of UF₆. The enrichment process that produces those 4 million pounds of enriched uranium also produces about 50 million pounds of leftover depleted uranium tails, a 10:1 ratio. In other words, it takes 10 pounds of natural uranium to produce one pound of enriched uranium that can be used for fuel, said Laffin. The other 9 pounds of leftover by-product is the depleted uranium that is INIS's raw material. "That's a tremendous volume of material to be dealt with."

Urenco's \$3 billion facility in New Mexico is the first to address the need for domestically enriched product. Others in the queue include a partnership between General Electric and Hitachi, which received NRC approval in September 2012 to build what would be the first laser-based enrichment plant. The laser technology enriches the uranium through "photoexcitation," according to company announcements.

The Urenco operation uses traditional centrifuge technology, which is also the preferred technology for two other companies—**Areva Enrichment Services**, a division of the French nuclear energy company, which has received a license to build a facility in Idaho, and the **United States Enrichment Corp.** (USEC), which has received the okay to construct a test and demonstration facility in Piketon, Ohio, on the site of a now-closed military-grade uranium processing plant.

(USEC, created as a government corporation under the Energy Act of 1992 and privatized in 1996, operated the government-built reprocessing facilities in Piketon and also Kentucky, both using gaseous diffusion technology to supply uranium for the weapons program and nuclear power reactors. USEC also

OECD Estimate on Uranium Fuel Supply

In 2006, world uranium production of 39,600 tons provided about 60% of world reactor requirements for the 435 commercial nuclear reactors in operation. The gap was made up by secondary sources such as the dismantling of nuclear warheads and the re-enrichment of uranium tails. Most secondary resources are now in decline and the gap will need to be filled by new production. World nuclear energy capacity is expected to grow 40-80% by 2030.

administered the Megatons to Megawatts program.)

Good News for the Lab Guys

Opportunities in the United States for the enrichment side of the uranium business "are enormous," said Laffin, who added jokingly of the 150 employees anticipated for the INIS New Mexico facility, "We're the guys with the white hats"—the lab guys who know how to handle the "toxic and reactive" tailings INIS will be paid to haul away from Urenco. (Those tailings, according to the state of New Mexico requirements, will be housed in 5,018 cylinders, each holding up to 14 [short] tons of material, the amount the plant would produce over eight to 10 years, if running at full capacity.)

INIS received a patent in 2004 for its fluoride separating technology and opened a pilot plant at its Idaho Falls facility to "see if we could scale up," said Laffin. By 2007, "it was clear to us that we were in a unique position to address the whole waste issue."

NRC licensing was both the easy and the challenging portion of the planning process. Easy, because INIS had already worked with the NRC: Its medical business, which in 2011 reported \$10 million in gross revenues, relies on radioactive products for isotope development. "It was a skill set we already had," which appealed to the NRC and which extended to INIS's safety record. The challenge was waiting for the license: that took nearly five years, he said. The next step was to find a location for the new business. "The last thing we wanted to do was build a plant where it would not be wildly ac-

cepted by the community," said Laffin. So INIS conducted a "competitive" search, in the end lining up a handful of communities that were interested in the project. "We met with everyone and presented our project, and local economic development groups sent bids to us, with incentives. [The winning bid] was based on an extensive scoring process, and New Mexico won hand's down."

Laffin credits Urenco for "opening a path for us." Its presence in Lea County inspired the local community college to offer an associate degree for nuclear technicians, providing INIS and Urenco with a pool of future talent, said Laffin, and both companies "are creating an avalanche of high-skilled jobs" for the Hobbs and Eunice communities, where 8% of the population is employed in what makes up one-third of the industry there: oil and gas and mining extraction.

"It's very exciting to see the development going on down there," said Laffin, a boon that's not been ignored by the nuclear energy industry. In the spring of 2011, a gathering of industry players arrived in Hobbs for a national energy conference aptly titled "The Uranium Fuel Cycle."

On hand, **Babcock & Wilcox**, which presented its case for the deployment of small modular reactors in eastern New Mexico, specifically its mPower SMR. Babcock & Wilcox, through its technical services group, and URS are the new managers of WIPP, winning the \$1.2 billion contract from the DOE. Services will be rendered through a joint company, Nuclear Waste Partnership, which has tapped Areva Federal Services as the major subcontractor. ⚙