ANS/ENS INTERNATIONAL MEETING

Making the nuclear renaissance real: What will it take?

IN THE FOUR years since the 2003 ANS/ENS International Meeting, the nuclear power community in the United States has gone from an almost exclusive concern with the present—improving plant performance, making use of power uprates and license renewal, trying out immediate decommissioning of closed reactors—to a forward-looking "nuclear renaissance," with perhaps 30 reactor license applications on the way and actual reactor orders seeming imminent.

At the 2007 ANS/ENS International Meeting, held November 11–15, 2007, in Washington, D.C., the broader perspective offered by the involvement of the European Nuclear Society helped point out that the prospect of new reactors is not so radical. David Bonser, of British Nuclear Fuels plc, the ENS honorary cochair, reminded attendees at the opening plenary session that power reactor construction in Asia never stopped.

The theme of the meeting was "Making the Renaissance Real," an acknowledgment of the widespread belief that nuclear power is about to expand in the United States, and also of the fact that none of the activity to date has led to a firm commitment to build new reactors. The speakers at the plenary session addressed what have become, in recent years, familiar topics related to whether the renaissance can happen and what needs to be done to ensure it.

The first speaker was Jeffrey R. Immelt, chair and chief executive officer of General Electric, who said that he never thought he'd be speaking to this audience. In 2001, GE had considered selling off its nuclear business—Immelt's predecessor, Jack Welch, had not been a nuclear power enthusiast. Speaking for himself, Immelt said that he wanted GE to be seen as a stable partner for the nuclear industry, supporting the installed base of boiling water reactors and commercializing the advanced Economic Simplified Boiling Water Reactor (ESBWR) design, which he said has been designated the 52nd product in GE's "ecomagination" line.

Looking ahead at the energy picture in general, he said he foresees a 2300-GWe increase in electricity supply worldwide in the next 20 years. He also sees weaknesses in infrastructure, such as transmission and distribution, and in the sufficiency of personnel. He added that he sees opportunities for efficiency improvement in gas turbines, and also in wind energy. On the nuclear side, Immelt said that it was his decision that GE would not bid for the Olkiluoto -3 project in Finland, now under construction, which is based on Areva's first European Pressurized water Reactor (EPR).

Immelt

Continued

Meeting session coverage:

- *Workforce development for new and existing reactors*
- *Lessons learned from the old construction era as the new one begins*
- *Fuel cycle options within GNEP*
- *Meeting the higher demand for fresh fuel*
- *Developments in nuclear imaging*

On whether there would be a renaissance, Immelt said he didn't know. He stated his belief that it would depend on whether fossil-fired generation would be taxed on the basis of its carbon dioxide emissions, and he noted that his overall approach at GE is based on an assumption that there will eventually be laws or restrictions on CO_2 effluent. He said that nuclear power's prospects are already good, but would become much better if carbon taxation goes into effect.

Presenting a European perspective was Adolfo Garcia Rodriguez, CEO of Empresarios Agrupdaos of Spain and a member of Euratom's panel on Generation IV reactor designs. He described a widely varied set of nuclear situations, with Finland and France building EPRs, Romania bringing Cernavoda-2 on line, Bulgaria buying reactors from Russia, the United Kingdom actively preparing for new-build proposals, and Germany not acting to end the previous government's nuclear phaseout. He noted that even in countries where new reactor construction is not planned, the electricity providers are looking to invest in new reactors elsewhere.

Because wind and solar power are intermittent and there is no proof that carbon sequestration is feasible, the facts favor nuclear, despite the opposition of some environmentalists.

Despite the extent to which the European Union has advanced (such as the establishment of the common currency, the euro), Garcia Rodriguez noted the lack of Europe-wide nuclear regulations, which in his view weakens efforts to standardize new nuclear power, as with the joint European utility requirements document. As for how new construction will be financed, he said he believes the only way it will happen is if "risk is shared by the main players,"—meaning that a reactor vendor would have to hold a stake in a new plant, rather than getting paid entirely in cash.

Eileen Claussen, president of the Pew Center on Global Climate Change, indicated that the use of the term "renaissance" was appropriate, because the first renaissance was based on reason, fact, and knowledge, all of which are on the side of nuclear power now in response to global warming. She said that there is a need to reduce worldwide greenhouse gas emissions by 60 to 80 percent by 2050. Power generation and heating produce 42 percent of the CO_2 generated by modern society, and for nuclear power to provide one of the "wedges" of carbon-free energy needed to meet the need, there would have to be 700 GWe of new nuclear power—about twice the world's current installed nuclear capacity.

Because wind and solar power are intermittent and there is no proof that carbon sequestration is feasible, Claussen said, the facts favor nuclear, despite the opposition of some environmentalists. She said that interim storage of spent fuel should be discussed, because even if the high-level waste repository at Yucca Mountain is built and opened, decades will pass before spent fuel is shipped there. She also noted that the National Academy of Sciences is opposed to the Bush administration's Global Nuclear Energy Partnership (GNEP), which would use burner reactors to transmute some waste and reduce the total volume.

On the cost of new nuclear, Claussen cited a projection by the Keystone Center that it would be about $80 to $100 per megawatt. Coal is around $48/MW without carbon capture, but would be about $80 to $90/MW with capture. She said that nuclear advocates must focus on the advantage available from climate policy, cap-and-trade, and other comparative cost issues.

Sen. Thomas Carper (D., Del.) began his talk with what may be his standard opener for any audience: a humorous explanation that he is the only U.S. senator who is not running for president. "I'm running for vice president," he said. Turning to the subject for this specific audience, he said that he believes that loan guarantees for nuclear power projects, authorized in the Energy Policy Act of 2005, will ultimately be funded by Congress at $25 billion in total Treasury obligation. (At this writing, Congress had not yet finished work on loan guarantees or on the fiscal year 2008 federal budget related to them.)


Carper

Carper said that one of his friends in the Senate, who *is* a presidential candidate, surprised him recently by saying that the United States should return to nuclear power. This is the view of most of the candidates in both parties, and also on both sides of the aisle in Congress. Carper said that the biggest impediment to new nuclear in the minds of officialdom is waste management. Following on a point Immelt had raised, Carper said that he expected to see legislation to set up a "cap-and-trade" scheme that would limit fossil-fired generation, creating the impetus to build more reactors. Returning to humor in his conclusion, Carper quoted Thomas Edison, who said that opportunity is often missed because it arrives wearing overalls and looks like work.

Future impacts

John H. Sununu pulled no punches in his talk during the honorary cochairs' special session titled "Government Policy's Impact on Nuclear's Future: What Every Voter Needs to Know." While nuclear power is on the verge of a renaissance, Sununu said, he is concerned that the industry "may blow it again" by not understanding what it takes to craft government policy.

Sununu, the former governor of New Hampshire and chief of staff for the first President Bush, explained that the existing fleet of nuclear plants in the United States was built by a dedicated group of people that understood the technical aspects of the process, but not the economic and political issues involved. "Energy is a political issue, as all important issues are," he said, "because that is just the way it is."

Sununu is now president of JHS Associates and a partner in Trinity International Partners, a private financial firm. He also cohosted CNN's nightly "Crossfire" on cable television from March 1992 until February 1998.

Sununu related his experiences in helping to bring the Seabrook nuclear plant online in 1990 when he was governor of New Hampshire, where the plant is located. The construction permit for the plant was granted in 1976, and construction was completed in 1986, but local opposition delayed its opening for years. While safety was thought to be the main issue keeping the plant from operating, Sununu said that the real issue was the cost of electricity to be produced by the plant. He pleaded with the plant's then-owner, Public Service Company of New Hampshire, to make a statement guaranteeing that electricity rates would hold to a slight capped increase when Seabrook went on line. The utility, however, would make no such concession. Sununu said he is convinced that the company's stance caused the four-year delay in the plant's construction and licensing schedule and the ultimate bankruptcy of the company.


Sununu

The lesson learned from the Seabrook experience, he said, is that the industry should be trumpeting a message about economics to the general public. "We have to tell the voter, in clear terms, how much nuclear power has saved them over the last 20 years," he said, "and we have to quantify it."

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Once Seabrook came on line, it became the anchor of energy supply in New England. Today in New England, which has a good history of using nuclear power, the message should focus on how much the technology has saved—and is saving—the region, which once used imported oil as the primary alternative. "That's easy arithmetic to do when you have $100 barrels of oil," Sununu said. "But don't expect the voter to do the calculation. Don't expect the politicians to do your homework. Don't expect them to carry your message." He advised nuclear utilities to send pronuclear messages in the same envelopes in which electric bills are mailed. Unfortunately, he said, the utilities have been afraid to do that.

While the positive message on economics should be at the forefront, Sununu added, other issues that should be talked about are the historical safety of the plants and nuclear's place in the global warming environment. These issues are the simple ones, however: "Now we come to the hard part. . . . I know of no important industry in the world as schizophrenically divided on the details of policy as the nuclear industry," Sununu said.

The first "hard" issue regards the Department of Energy's proposed high-level waste repository at Yucca Mountain, in Nevada. Sununu wondered if the industry's policy is that new plants can't be built until the repository project gets moved forward more aggressively, or whether the idea of a repository needs to be put aside for good, or whether surface storage for spent fuel is the way to go for the next 100 years and the issue of Yucca Mountain can be dealt with later. He declared he is unclear on the industry's take on Yucca Mountain "because the industry [itself] doesn't know what the industry policy is."

Sununu said that each time he has talked with the leader of a utility or a vendor company in the industry, a different version of the waste disposal policy is offered up. The result is that nuclear's lawmaking friends are confused. "If we, the informed, are divided on issues, we leave it to the uninformed to make the decision, and that's what we're doing again," he said, with reference to the mistakes made during the construction of the existing fleet.

Carbon is another important issue on which the industry must offer a unified front, and yet all the major players seem to have a different take on it. Sununu scanned the audience before saying, "If there are plenty of utilities represented here, I guarantee you there are 40 different policies on giving credits for carbon, carbon reduction, carbon nonemission tax credits, and carbon tax cap and trade." This mixed bag means that the industry will get a carbon policy driven by someone other than itself. "Once again," he said, "our friends in the administration and our friends on the Hill are saying, 'What do you really want?'"

Sununu stressed that the problem with being splintered on issues is that opponents don't have to fight very hard to support their own positions. "All they have to do is say, 'No.' That's a very simple, unified position," he said.

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An issue on which the industry should come together immediately is that of making recommendations to fill the two vacancies on the Nuclear Regulatory Commission created when Commissioner Edward McGaffigan died and Commissioner Jeffrey Merrifield's term expired. But the industry hasn't offered up a slate of recommended candidates, and that inaction made Sununu proclaim, "Shame on us!"

Sununu wrapped up his talk by making a final plea to promote the renaissance in a manner of solidarity. "We screwed it up last time," he said. "Let's not screw it up this time."

Aligning stars, acting boldly

ANS President Donald Hintz, the session's cochair, who had addressed the audience prior to Sununu's speech, also commented afterward, saying—tongue in cheek—that it is hard to get Sununu to give a firm opinion on anything. That comment drew a chuckle from the audience.

Hintz, in his opening remarks, recalled the optimism he had felt during the years when many people thought the industry might not survive in a deregulated environment. At the time, starting in the late 1990s, he led an effort at Entergy to buy undervalued nuclear plants, and he was known for saying the stars were beginning to align for a nuclear comeback. Today, he said, "the stars are aligned."

Hintz added that the government will play an important role in making the renaissance real. "We recognize the need for public policies that make the playing field more level for nuclear technologies," he said. "As individuals, we must be involved in the political process and demand that our elected officials focus on many of the energy policy issues that are critical to our country's future."

Hintz's cochair for the session, David Bonser, observed that while the industry has to influence government to look favorably on preferred policy, in the United States there is only one federal government that needs to be convinced. In Europe, by contrast, there are 27 governments that are members of the European Union.

"Governments need courage because these are difficult and contentious issues," said Bonser, director of human resources for BNFL Group and president of ENS. "Bold actions are required, and bold actions require courage. These are actions that will result in changes in voters' lives, and these actions will challenge some deeply held and legitimate public concerns—whether it's the safe treatment of nuclear waste, the threat of terrorism, or the continued safe operation of nuclear plants."

Bonser emphasized, as Sununu had, that "nuclear power is and always has been a political business. We need, as an industry, to give good, reasoned information to our policymakers," he said, because "government policy is central to the renaissance."

A very bright future

Another speaker during the session was Under Secretary of Energy Clarence "Bud" Albright, who oversees the DOE's energy and environmental programs, including its portfolio of applied energy research and development activities, nuclear waste management efforts, and environmental cleanup of the nuclear weapons complex.

Albright said that there is no silver bullet for solving energy problems in the United States, but that "there is a huge and very bright future in the nuclear industry if

we work together."

The DOE, he said, is working hard on the GNEP program, which seeks to develop worldwide consensus on enabling the expanded use of nuclear power to meet growing electricity demand. "We believe that working with other nations around the world will ensure the renaissance of nuclear power," he said. "It will ensure that the nuclear materials that are necessary to fuel these plants are used for peaceful purposes and are used to generate electricity and not to generate trouble."

Albright also asked that members of the industry come to the DOE with ideas on how to advance the renaissance.

Inconvenient truths

The session's final speaker, Richard Myers, played off Al Gore's movie about global warming by offering a series of "inconvenient truths" about the future of power generation in the United States. Myers is vice president of policy development at the Nuclear Energy Institute (NEI).

The first inconvenient truth is that the coal-fired plants in the United States are largely old plants. They are less efficient and dirtier than newer models because of a lack of environmental control technology, and they are too expensive to retrofit. To fill the energy void, the nation in the past 15 years has built gas-fired plants because they represented the lowest investment risk. But gas-fired power plants expose consumers to extreme volatility in electricity prices. While coal-fired and nuclear plants represent 70 percent of the nation's electricity supply and provide the greatest forward price stability, very few coal-fired plants and no nuclear plants have been built in recent years.

Myers

This situation leads to the second inconvenient truth. "It's time to pay the piper," Myers said. Because the nation has deferred investment in new, more efficient, and cleaner nuclear and coal-fired baseload plants and in transmission infrastructure, the "electric power industry is pushing a mountain of deferred capital investment in front of it," he said. "How much? More than the entire book value of the existing system." About $1 trillion will need to be spent between now and 2020 for new generating capacity, new transmission, new distribution, demand features, and environmental control technology on the existing capacity, he said. Not included, he added, is the potential cost of carbon controls.

About $1 trillion will need to be spent between now and 2020 for new generating capacity, new transmission, new distribution, demand features, and environmental control technology on the existing capacity.

The third inconvenient truth is that tackling this problem will require innovative approaches to financing, combining all the financing capabilities and tools available to the private sector, the federal government, and state governments. "The loan guarantee program authorized by the 2005 Energy Policy Act was a step in the right direction," he said.

Meeting the energy investment crisis will require the abandonment of many of the "institutional prejudices that color American politics and policy," he said. This—the fourth inconvenient truth—consists of a new financing model, the domestic equivalent of an export-import bank, which should be developed so that it is equipped with the tools necessary to ensure that capital flows to critical infrastructure development in the electric sector. The nation already uses loan guarantee programs to support shipbuilding, steel making, rural electrification, affordable housing, construction of critical transportation infrastructure, and for many other purposes, he said.

Another truth is that realistic expectations must be created about the nuclear renaissance. "Underpromising and overdelivering is better than overpromising and underdelivering. Believe me, we will get only one shot at this," he said, echoing Sununu's message. Myers said that the building of new plants will and should start relatively slowly and wrap up over time. The basic inputs to project development, such as the supply of craft labor, construction management expertise, and the supply of major components, will tend to ensure that.

Myers explained that discussions at NEI have centered on a first-build scenario that will happen in waves. The first wave will consist of five or six new reactors coming on line around 2015, built to cost and schedule and with no regulatory or licensing mishaps. The second wave of new plants will then go into commercial operation with clear evidence of an infrastructure—the workforce, fuel, and supply chain—that is expanding to meet what is clearly sustained and sustainable demand.

The final truth is that things will get worse before they get better. In many parts of the United States, reserve margins have been driven dangerously close to the minimum levels necessary for reliable service. Even if lawmakers provide the policy support necessary to ensure that capital flows to rebuilding the electric infrastructure, it is already too late to catch up. The lights won't go out, Myers said, but more gas-fired generation will be built and the capacity factors of modern combined-cycle plants will be increased to about 40 percent (up from the 35–40 percent range).

Myers said that the nation can limit economic damage "if we start now, if we put in place the institutions, policies, and tools necessary to support investment in a new electric infrastructure. Unless we take steps now to rebuild this nation's energy infrastructure, we are at risk of leaving an economy that is weaker, less resilient, and more vulnerable to the unforeseen and unforeseeable shocks to which all nations are subject," he said.

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In closing, Myers returned to the theme of the session. "What every voter needs to know is the truth. What every politician and policymaker needs to know is the truth, no matter how inconvenient that truth may be."

Closing the fuel cycle

Researchers at Oak Ridge National Laboratory (ORNL) have been busy evaluating the reuse of reprocessed uranium (RU) in

various reactor designs to see if it could be employed within the context of the DOE's Global Nuclear Energy Partnership. Current GNEP plans call for reprocessing spent fuel so that the amount of high-level waste to be stored in a geologic repository can be minimized. GNEP also aims to recover plutonium for use in mixed-oxide (MOX) fuel. As currently devised, however, GNEP would dispose of reprocessed uranium, something that might not be necessary if it could be reused in light-water reactors, said Lee Trowbridge, a senior staff member in the Nuclear Science and Technology Division at ORNL.

During a session titled "Closing the Fuel Cycle," Trowbridge explained that he had developed a model of the U.S. nuclear fuel cycle as it would be operated under various scenarios—one scenario for GNEP's current plan to dispose of RU, and other assorted scenarios for reusing RU. "We treat in detail only those steps in the fuel cycle that would differ between these alternate strategies," he said. Ultimately, he added, the general conclusion is that "RU reuse appears economically preferable to disposal."

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Trowbridge's model would include natural uranium production, conversion, enrichment, fuel fabrication, fuel burnup in reactors, spent fuel cooling, reprocessing, recycle of plutonium into MOX fuel, disposal of reprocessed uranium, and disposal of fission products and cladding. (Another paper in the ORNL series was presented during a different session by Guillermo "Bill" Del Cul, a senior research and development staff member in ORNL's Nuclear Science and Technology Division. He summarized beneficial fuel reprocessing alternatives, including complete actinide recycling and the recycle of cladding.)


Trowbridge

If the model were altered to reuse RU rather than discard it, most steps would not change significantly in character or magnitude, he said. The ones that would change would be reactor neutronics, RU disposal, RU conversion to fluoride, natural uranium production, enrichment tails disposal, and separative work units (SWU). Only these changed steps were evaluated during his analysis.

Trowbridge said he ran numerous RU-reuse scenarios, varying the age of the spent fuel (three years, five years, and 50 years, the last representing fuel in the current U.S. inventory); the original fuel enrichment (3 percent and 4.5 percent); fuel burnup (33 or 55 gigawatt-days/metric ton uranium [tU]); and number of consecutive reactor passes.

In all of the RU-reuse scenarios, he said, RU displaces a large quantity of natural feed (about 3000 tU), which he said dominates the cost differences of the scenarios. SWU needs were generally slightly higher for the reuse scenarios (80–400 t-SWU) due to the need to compensate for the presence of uranium-236, but enrichment tails generation was always less (140–270 tU). Also, the reuse scenarios avoided disposal of RU (about 2800 tU).

The cost differences of the scenarios were determined using two price sets, he said. The "high" case used recent record prices for UF_6 ($233/kgU), conversion ($12/kgU), and SWU ($140/kg-SWU). The "average" case used earlier prices that Trowbridge said were more representative of historical median costs—UF_6 ($50/kgU), conversion ($7/kgU), and SWU ($116/kg-SWU).

Working only with these costs, he said, the RU-reuse scenarios were always less expensive than the no-reuse scenarios (by $600 million–$700 million/yr for the "high" scenario, and $80 million–$130 million/yr for the "average" scenario). Costs for tails or RU disposal are probably significant, he noted, but are very uncertain, and were not included in his calculations. "Whatever they may prove to be, they would further favor the RU-reuse case," he said.

Providing similar analysis, but for CANDU heavy-water reactors, was Ronald Ellis, a senior R&D scientist in ORNL's Nuclear Science and Technology Division. Ellis selected CANDU's new CANFLEX advanced fuel bundles to perform analyses for assessing RU with respect to the available reactivity and the expected fuel discharge burnup levels. The presence of U-236 in the RU-derived fuel shortens the fuel lifetime, he said, but a means of compensating for this effect, if necessary, is to enrich the fuel to a higher U-235 assay.

CANFLEX is a name derived from CANDU FLEXible fueling. Atomic Energy of Canada Limited (AECL) and the Korea Atomic Energy Research Institute (KAERI) developed the CANFLEX fuel bundle for use in the CANDU reactor. The CANFLEX bundle is made up of 43 fuel pins of two different sizes that increase fuel performance by reducing the power rating of the hottest pins in the bundle, for the same total bundle power output. The design also incorporates special geometry modifications that enhance the heat transfer between the fuel and surrounding coolant. The bundle is about 10 cm (4 in.) in diameter, 0.5 m (20 in.) long, and weighs about 20 kg (44 lb), and it replaces CANDU's 37-pin standard bundle.

During his analysis, Ellis performed reactor neutronics calculations to determine the additional U-235 required to offset the initial U-236 content in the fuel. He also assessed the effects of U-236 (and U-234) on the initial reactivity and discharge burnup for a range of concentrations.


Ellis

To offset the effect of the U-236 in the RU-derived fuel assemblies and to achieve the same exit burnup as if there were none of it in the fuel, he determined that additional U-235 (amounting to approximately 5 percent of the U-236 concentration) would need to be added. "This is only one-fifth of the required increase in U-235 fuel enrichment when compared with that required for pressurized water reactors," he said. He added that it has been reported in RUFIC (Recovered Uranium Fuel In CANDU) project literature that the reactivity effects due to ±50 percent variations in the concentration levels of U-234 and U-236 would be negligible to the operation of the Wolsong CANDU 6 reactors in South Korea. (The RUFIC project is a joint international collaboration between AECL, KAERI, and British Nuclear Fuels plc to assess the use of recycled uranium in CANDU reactors.)

Ellis concluded that for PWR analyses, while the burnup penalty caused by the concentration of U-236 in recycled uranium needs to be offset by additional U-235 enrichment in the amount of about 25–30 percent of the weight percentage of the U-236, the effect in a CANDU reactor is much smaller. He added that because the U-235 content in recycled uranium generally exceeds that in natural uranium, CANDU offers the advantageous option of uranium recycling without reenrichment. "The exit burnup of CANDU RU-derived fuel is considerably larger than that for the natural uranium–fueled scenario, despite

the presence of U-234 and U-236," he said.

The front end

Much attention is focused on closing the back end of the fuel cycle. But a panel session titled "What About the Front End?" turned the spotlight onto the suppliers, converters, enrichers, and regulators involved with front end activities.

ANS past President Harold McFarlane, deputy associate laboratory director for nuclear programs at Idaho National Laboratory, who cochaired the session, noted that the industry trade papers write more about uranium mining and enrichment services than any other topic. "So, I think [the topic] really is the front end of the nuclear renaissance," he said.

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Stephen Turner, chief scientist for TerranearPMC and the session's organizer and cochair, explained that the 10 panelists were representatives of companies or agencies involved with the three components of the front end: mining and conversion activities, enrichment services, and regulation.

While uranium production has decreased from the high levels of the 1970s and 1980s, when more than 150 million lb U_3O_8 were produced annually, demand has skyrocketed. Demand now exceeds supply by more than 50 million lb U_3O_8 per year, and the cost per pound has gone from less than $25/lb earlier in the decade to the current level of over $90/lb. Still, the session's speakers generally were confident that nuclear power plants would not have to shut down because of a lack of fuel, based on current capacity, secondary supply, and uranium yet to be mined.


Turner

Mining and conversion activities

James Dobchuk, vice president of marketing for Cameco Corporation, led off as the first speaker for the mining and conversion activities block. Cameco, a Canadian company, is the largest uranium producer in the world, responsible for unearthing about 20 percent of the world's uranium supplies from its mines in Canada, the United States, and Kazakhstan. "The company has a tremendous reserve base in excess of 500 million pounds, which, roughly speaking, is enough uranium to fuel the entire United States for about a decade or so," Dobchuk said.

Cameco also operates a conversion facility at Blind River and fuel services facilities (conversion and fuel fabrication) at Port Hope, both located in Ontario, Canada. The Blind River facility refines uranium concentrates into uranium trioxide (UO_3), which is an intermediate product in the uranium conversion process. The Port Hope facilities chemically change the form of the UO_3 to either uranium hexafluoride (UF_6) or uranium dioxide (UO_2). Port Hope has the licensed capacity to produce 18 percent of the world's annual requirements of UF_6 used in making fuel for light-water reactors, Dobchuk said.

Dobchuk laid out the process for taking a uranium mine active. It could take five to seven years from the discovery of a uranium deposit to the confirmation of its resources, and another 10 years to secure an operating license and build a mining facility. A mine operates for 10 to 30 years, depending on its size and the grade of the ore.

Don Falconer, vice president of corporate development for Aurora Energy Resources, said that Aurora has been investigating the Michelin and the Jacques Lake uranium deposits, located in Labrador, Canada, in an effort to mine the area. The initiative is called the Michelin Project, he said.

The combined deposits of the project contain a measured resource of 5.34 million lb U_3O_8, an indicated resource of 52.54 million lb U_3O_8, and an inferred resource of 38.03 million lb U_3O_8. In the Michelin Project, "Aurora has created, we feel, a new uranium district that is significant," he said.

If Aurora does proceed with mining the Michelin Project, a mill will be built at the site to process the ore into uranium concentrate. The company's goal, Falconer said, is to bring the project into operation by 2013.

James Graham, president and chief executive officer of ConverDyn, drew a chuckle with the title of his presentation, "Between You and SWU—Where We Are." A SWU (pronounced swoo), is a function of the amount of uranium processed, the composition of the starting material, and the degree to which it is enriched.

ConverDyn is a uranium conversion company owned jointly by Honeywell International and General Atomics. ConverDyn operates a plant in Illinois where U_3O_8 is converted to UF_6. "It's a gas at elevated temperatures; it's a solid at ambient temperatures," Graham said.


Graham

Other major converters in the West, he said, are Cameco, Areva (in France), and Springfields (in the United Kingdom). Graham said that ConverDyn and its competitors are studying their conversion facilities to figure out how to expand them to handle the coming nuclear renaissance. "Presuming the U_3O_8 people produce all the uranium they say they are, we will have to have facilities in place to convert it and send it out for enrichment," he said. "Likewise, the enrichment people will have to plan ahead, too."

ConverDyn's new conversion plant will be in Europe, and will potentially be operational by 2013, he said.

Gary Fox, executive vice president of uranium services and products for Areva, said that uranium conversion is the step in the fuel cycle that is often overlooked or ignored. Areva is involved in all phases of the nuclear fuel cycle and in the reactor side of business as well.

Fox said that there has been little investment in conversion activities over the past 20 years. Last summer, however, Areva launched a €610 million (about $898 million) project to replace the Malvési and Pierrelatte conversion facilities in southern France. A new conversion plant, Comurhex 2, will be located near the company's new Georges-Besse II enrichment production site, which itself is currently under construction. Work on building Comurhex 2 will start in 2009, with first production planned for 2012.

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Fox also mentioned Areva's plan to build a new uranium enrichment plant in

the United States. The NRC has been notified of the plan, and site selection and the preparation of an NRC license application are under way. He said the new enrichment plant, which would employ Urenco's gas centrifuge technology, would have a capacity of about 3 million SWU.

The means of bridging the supply-demand gap include moving material out of inventory, substituting enrichment for uranium, running shorter fuel cycles, and recycling spent fuel.

Enrichment services

Introducing the enrichment services part of the session was John Donelson, vice president of marketing and sales for USEC Inc. The company was once part of the Department of Energy but was privatized about 10 years ago. USEC operates the Paducah Gaseous Diffusion Plant, which currently is the only uranium enrichment plant in the United States.

Donelson

Donelson said that the U.S. enrichment industry for years has been in a protracted decline, and imports account for 88 percent of the enriched uranium used in the United States. That should change by 2011–2013, however, when new enrichment plants will use gas centrifuge technology instead of the more energy-intensive gaseous diffusion method. In the United States, USEC and Urenco have started construction on new enrichment plants, and Areva and General Electric are considering new facilities as well.

Donelson said that USEC's American Centrifuge plant, planned for Piketon, Ohio, will feature "low-cost production, higher efficiency, and modular expansion capability." The company has been testing a lead cascade—a series of centrifuge machines—as a demonstration of the technology.

Kirk Schnoebelen, president and CEO of Urenco, explained that Urenco provides about one-third of the enriched uranium demand for the U.S. fleet. The company operates enrichment facilities in Germany, the Netherlands, and the United Kingdom. Urenco's gas centrifuge technology will be used at the $1.5-billion National Enrichment Facility (NEF), which is currently being built by Louisiana Energy Services (LES), in New Mexico.

Since September 2006, Schnoebelen said, LES has grown from an organization of 12 individuals to one that has more than 171 full-time employees. "It's interesting and may be a good indicator for nuclear power plants that LES, in spite of its somewhat remote location, has been fairly successful in attracting a very well-qualified staff from across the country and in Europe," he said. The goal is to have 200 workers start training for NEF operations by the second quarter of 2008.

Schnoebelen said that global enrichment capacity is currently growing, along with the significant investments in capacity. The transition to a largely centrifuge-based enrichment process "will be a beautiful platform," he said, on which to base the technology's incremental growth and "to fuel a nuclear renaissance."

The final presentation on enrichment services was provided by Tammy Orr, president and CEO of GE Hitachi Global Laser Enrichment. The company is a wholly owned subsidiary of GE-Hitachi Nuclear Energy, which is 60 percent owned by GE (the former GE Nuclear) and 40 percent by Hitachi Nuclear.

GE-Hitachi plans to build an enrichment plant in the United States that will use the Silex process, which is a laser isotope separation technology that was developed in Australia. In late 2006, GE entered into an agreement with Silex Systems, Ltd., that gave GE the exclusive rights to develop and commercialize the laser enrichment process for uranium. Now GE-Hitachi owns those exclusive rights.

Orr said the laser enrichment process uses cylinders of natural UF_6 gas that are met with a laser that selectively excites the U-235 atom. A mechanical separation process then separates out an enriched stream of UF_6 from a depleted stream of UF_6. "That's it in a nutshell," she said.

GE-Hitachi is currently developing an NRC license application for a commercial facility. "We anticipate submitting the application in 2008, along with an environmental report," she said. Initial operation of the plant is targeted for about 2012. "From that point forward, we will ramp up to either 3.5 or 6 million SWU," she said regarding the plant's capacity level, which will be decided in the 2009 time period.

Orr said that 12 engineers and scientists who came from Australia and are still part of the Silex organization have come to work on the GE-Hitachi project in Wilmington, N.C.

Regulatory matters

Leading off the regulatory part of the session was Joseph Giitter, deputy director of special projects for the NRC. Giitter reviewed the agency's recent activities in connection with enrichment plants: USEC's American Centrifuge plant, near Piketon, Ohio, was issued a license on April 13, 2007, and is under construction; LES's NEF, near Eunice, N.M., was issued a license on June 23, 2006, and is under construction; GE-Hitachi submitted a license amendment for the Silex test loop on June 29, 2007, and the company plans to submit an application for a full-scale facility in 2008; and Areva is expected to submit a license application for a facility in mid-2008.

Giitter

Regarding GE-Hitachi's application, Giitter said the NRC was currently reviewing the Silex test loop, the purpose of which is to provide a pilot test of the laser enrichment process. "This is a similar approach to the one that USEC took with the lead cascade facility, whereby they're not actually enriching uranium but pulling samples to verify the efficacy of the process," he said.

The NRC is also doing the licensing review for the Department of Energy's planned mixed-oxide fuel facility in South Carolina, he said.

Suzanne Phelps, senior project manager of fuel supply for NEI, said that it believes that uranium supply can be expanded to meet demand. "The market is tight now due to inactivity in the uranium mining business from the early 1990s to the 2000s," she said. The means for bridging the supply-demand gap, she continued, include moving material out of inventory, substituting enrichment for uranium, running shorter fuel cycles, and recycling spent fuel.

In 2005, she said, the International Atomic Energy Agency did a uranium study that determined that the supply should be adequate to last until 2050. After 2050, she said, additional sources will have to be identified, reprocessing and recycling will be in place, and fast reactors will be in operation, reducing the demand for new production.

The session's final speaker was Jeff Combs, president of Ux Consulting, a company probably best known as the publisher of nuclear fuel market prices and uranium prices. Uranium is now about $93/lb, but Combs noted that in 2004, uranium prices


Combs

were near $14.50/lb.

"I think because the price was so low, people thought uranium supplies were plentiful," he said. "As a consequence, there wasn't much exploration or investment in production, and there wasn't much forward contracting being done by the utilities."

Workforce development

With the nuclear renaissance moving from hope to reality, one of the main concerns is having the workforce in place—in terms of numbers and expertise—to deliver. The problem has, in fact, been well defined over the past few years. This panel session, "Status of Workforce Development for the Renaissance," was led by Ken Ferguson and was made up of representatives from utilities, vendors, manufacturers, and others, who described what their organizations are doing to attract and retain the people they need.

Lisa Stiles, who was on loan to NEI's Government Affairs Division from 2005 to 2007, is now the project leader of strategic staffing and knowledge management in the nuclear business unit of Dominion Resources, where she is responsible for the development and overall execution of a workforce planning strategy. Stiles remarked that her career has allowed her to focus on the critical issues facing a resurgence of nuclear energy. From her past interest in waste management and public outreach, she said, she is now "passionate about infrastructure—both physical and knowledge- and skill-based."

Dominion "has been a victim of its own success," she said. Its nonretirement attrition is extremely low—about 1.8 percent. Its workforce is committed, and people are delaying retirement. Workers come to Dominion, she said, but there are warning signs of possible future problems. There is a much higher attrition for new hires, she noted, both experienced and young people, as well as a shrinking labor pool. Furthermore, some locations are becoming extremely difficult to staff. Having purchased the Kewaunee plant in Wisconsin, Dominion is now having trouble finding people willing to spend their winters there.

This "new reality" requires a coordinated fleet-wide workforce planning strategy, Stiles said. Dominion had been using an average retirement and attrition formula for defining needs, which, she said, was not nearly accurate enough for planning purposes. A better planning process is now being used that allows a manager to add his or her knowledge about specific people. Stiles said, however, that she wants a more robust forecasting tool that incorporates attrition probabilities of different disciplines and populations.

Another problem being encountered is that of knowing what the ideal staffing levels should be. She defined three different levels of staffing: a *minimum* staffing level, which provides safe operation of the plant today, but does not provide support for continuous improvement; an *optimum* staffing level, which will also support improvements and changing standards; and a *margin* staffing level, which provides safe operation, supports improvements, and prepares for the future. The idea of "margin staffing," she said, is not yet Dominion policy, but she is working to convince the board of its suitability.

Planning, she said, also requires the identification of critical positions, which she defined as those that are difficult to fill, require considerable time to become proficient, or serve as a feeder group to other critical positions. Examples she gave were radiation protection chemistry technicians and supervisors, senior instructors, and quality inspectors.

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On the recruiting side, Stiles said that Dominion is now expanding its successful university partnership process, which began targeting nuclear engineers for the nuclear analysis and fuel department, corporate-wide. Furthermore, she said, instead of a shotgun approach, the strategy is now to focus on a few universities, with an emphasis on the quality of their nuclear engineering programs and other factors, such as location, which can be important in retaining people. She said that Dominion also wants each site to develop partnerships with community colleges and high schools to reach out to students early on, get them excited about nuclear, and convince parents that it is a good career option.

Recruiting worldwide

For Bernie Copsey, manager of new plants engineering at Areva NP, the workforce issue is one of those "wake-up-in-the-middle-of-the-night-with-a-cold-sweat" problems. Over the next eight years, he said, Areva needs to add 2000–3000 people worldwide in order to support the nuclear renaissance.

The good news, he said, is that the old talent, many of whom are eligible to retire today, are willing to stay on longer and to even come back from retirement because of their passion to build something. But, he noted, that can only last for so long. Copsey said that he has had success in hiring experienced people with a non-nuclear background. It takes good interviewing skills, he said, to identify the people with the right competencies who can be trained and mentored in the areas where they are lacking—notably, the nuclear safety culture.

Since starting in his current job, Copsey said, about one-third of his hires have come from universities, a proportion he thinks will probably go up to one-half. These people have to be brought up to speed very quickly, he said, and this requires an understanding of generational differences. Copsey pointed to four generational groups: "matures, baby boomers, Generation X, and millennials," each with a different take on what turns them on to come to work every day. Each, he said, has their own way of working and priorities. The millennials are used to multitasking—they can instant message, talk on cell phones, e-mail, and play video games all at the same time—and they work in the same way. This is not a problem, he said, but for matures, communicating with them can be difficult. About one-third of the millennials he hires are women, and another third were not born in this country. "That is not how it was 30 years ago," Copsey said, and so both the mentors and the mentees have to be trained how to communicate.

Areva works with local colleges and universities to support and develop engineering courses, provide internships, and undertake other activities, Copsey said. He also noted that the ANS Student Conference is a good place to recruit. Five years ago, he said, about 100 people attended the conference; in 2008, Texas A&M expects about 500. Areva also supports the North American Young Generation in Nuclear (NA-YGN), noting that the attrition rate for people involved in NA-YGN is very

low. The company holds "brown-bag" seminars for this group covering a variety of subjects that are presented by key people, including Tom Christopher, president and chief executive officer of Areva NP. Young recruits who are involved in mentoring and rotational programs and join NA-YGN will see where their career is going and are less likely to leave, Copsey said.

The success of the nuclear renaissance, Copsey concluded, hinges on the ability of the vendors to develop their workforce. Managers must be creative in recruiting, mentoring, leadership development, and training. And since the vendors are doing things "worldwide," the workforce must also be worldwide, he added.

A new perspective

Mark Barlow, director of operations for Washington Safety Management Solutions, a subsidiary of Washington Group International, gave another perspective on workforce development for the nuclear renaissance. For Barlow, the "war for talent" is not new. When he started his career with Westinghouse, the company was hiring hundreds of engineers across all disciplines, many right out of college. Barlow believes that talented individuals will come when the business becomes attractive and is viewed as an exciting opportunity—unlike during the late 1970s and the 1980s. Successful organizations, he said, will attract and retain new talent by offering accelerated career opportunities for personal growth and a chance to make a significant contribution.

Barlow

Barlow put forward a proposal for dealing with an expanding construction program, suggesting the replacement of the traditional owner-supplier transactional structure that is used for construction projects with what he calls life-cycle alliances. This would involve two interrelated aspects: a change in perspective and a change in roles. The first, he said, would demand that investors, suppliers, and regulators move away from just being participants with their own individual objectives to being team members with long-range, mutually beneficial objectives. The second aspect would involve the creation of the owner's agent (OA). The OA would not be simply a services contractor, Barlow said, but a technology-savvy management advisor and "trusted partner" whose goals and objectives would be shared by the owner. An OA could be expected to provide the owner continuity, efficiency, and an understanding of the plant's situation throughout the project.

Barlow explained that the OA's staff would be expected to have experience and expertise through the complete nuclear project life cycle. This would include the technical side of reactor design, engineering, licensing and regulatory management, construction, and, in the future, fuel recycling and waste optimization and disposition. The staff, he said, would also have to have proven skills in areas such as project development, stakeholder relations, project cost and schedule control, risk management, supplier management, and operations, to name just a few.

"So where is this experience and expertise to be found?" Barlow asked. When the previous round of nuclear power plant construction ended, he said, much of the talent migrated to the Department of Energy nuclear complex, where it continues to work today. The talent, he said, was initially focused on complex projects such as the K Reactor restart, the New Production Reactor Program, and nuclear material reprocessing and production facilities. With the end of the cold war, the focus shifted to complicated environmental management projects involving waste processing and treatment, Barlow said. He noted that the large management and operations contractors used by the DOE could satisfy his concept of owner's agents because they already deal with projects of great scope, take on huge responsibilities for the DOE, and are used to performance-based financial incentives.

Successful organizations will attract and retain new talent by offering accelerated career opportunities for personal growth and a chance to make a significant contribution.

To move forward, Barlow concluded, the industry must address the structural factors that hampered it in the past. The dynamics have changed, he said, and new approaches such as the new alliance model he proposes must be employed.

Employee retention

Rick Wilkinson, vice president and corporate manager of operations systems in Parsons' Infrastructure and Technology Group, said that the workforce crisis hit Parsons "like a ton of bricks" some 18 months earlier, when the company realized that in the prior six months, it had hired about 10 percent of its total domestic workforce—with a net gain of about zero. He said that he doubted that any organization could afford that sort of staff turnover and succeed, and so Parsons started a number of initiatives to address these issues.

Wilkinson

While attracting new graduates and early career professionals is the current focus of the company, Wilkinson said, retaining them is another priority. To develop and motivate its people, Parsons has instituted a number of in-house programs in areas such as project management, project controls, engineering, quality management, construction management, and operations. For example, a model of excellence for project management is the foundation for an in-house training and certification process. This model was developed by methodically interviewing a number of the company's most successful project managers to determine their common attributes and competencies. A Parsons-specific guidebook was prepared from this effort for use in a certification process. Candidates are required to pass online quizzes on the guidebook and take a comprehensive written exam that takes some eight hours to complete. The exams are assessed by project managers worldwide and graded by an in-house group of experts.

This process has made a difference to the business, Wilkinson said. Company metrics show that the number of projects with negative performance has been dramatically reduced, he said, adding that more recently, Parsons also started a collaborative Web-based degree course in project management with a national university.

The discipline of project control is another area Parsons is struggling to fill, Wilkinson said. The company recently developed an in-house training and certification process, also using a company-specific best practices guidebook. It is a multiyear program, he noted, with mentoring and field training, and rotational assignments in cost estimating, planning and scheduling, and cost engineering.

Outside the company, Parsons is working with schools at all levels, Wilkinson said, starting with the public education sys-

tem, which, he noted, is having a tough time keeping kids in school, let alone getting them interested in math and science. The company is involved in local education foundations that support public education in ways that the school board cannot fund, he said, and he described some successes in developing math and science in the school system.

Parsons also partners with community colleges through internships and scholarships and has developed relationships with universities, notably those near the company sites and projects or that have company, management, or alumni relationships, Wilkinson explained. The company uses its projects for field trips, offers senior engineers as guest lecturers, and provides intern projects and assignments. Parsons has also been asked to consult on curriculum development.

The nuclear base—a unique national asset

The session's final speaker was Megan Rossi, senior legislative analyst with Babcock & Wilcox, the largest nuclear manufacturer in the United States. After serving on the USS *George Washington* as a reactor controls division officer from 2003–2007, she left the Navy in 2007 to join B&W. Rossi said that she sees the workforce challenge as a great opportunity for national jobs and economic growth, for the development of the next generation of energy technology, for reducing carbon emissions, and for repatriating the nuclear industry and gaining true energy independence. Her question, she said, is how the industry can come together to attract and develop the workforce needed to take the nation into the next nuclear age.

Rossi called the handful of companies that stayed in the nuclear market after the downturn and now make up the country's nuclear base a unique national asset. They manage the nation's nuclear weapons and labs complex, provide heavy nuclear components to the U.S. government, and operate and maintain the U.S. fleet of nuclear reactors, she said. The success or failure of this industrial base is a matter of national security and independence, she added, and it is now necessary to invest in it and nurture it.

To accurately define workforce requirements, Rossi said, a clear goal for nuclear power is needed. She suggested an ambitious target of meeting 30 percent of the nation's electric power by 2030. She noted, though, that given the world situation, just maintaining the status quo—which would mean building six 1000-MWe plants a year starting in 2013—would not be good enough. To increase that to 30 percent, the number would nearly double she said, and added that right now, the industry could probably produce only one or two a year.

To plan for its future workforce, B&W has identified key critical skills through the analysis of retirements and retention trends, and is also developing a succession planning program, Rossi said. It is also supporting the development of new skills for its current employees "to ensure we take care of the talent we already have," she added.

For recruitment purposes, Rossi said, B&W uses state-wide career and employment resources to promote job opportunities, keeps area schools informed of its needs, partners in education programs, and is involved in engineering mentoring programs and career fairs. It supports education programs at the community and university levels through scholarships and education foundations, training grants for nuclear technicians, and internships. B&W is enhancing its college recruiting program while also developing company-sponsored programs for engineers and technicians with select engineering schools and community colleges.

On Rossi's list of things for the industry to do is to work with national labor organizations to increase the visibility of the demand for skilled trades. She said that studies now show a steep downward trend of high school students taking trade- or industry-related vocational or technical courses. She also stressed the need to fight the stigma associated with blue-collar manufacturing jobs. The stigma is still there and it is strong, Rossi said. "We need to change that image." There are great opportunities for employment and for earnings, she said, and the industry needs to communicate that, particularly to teachers and guidance counselors. She also called for reaching out to women and minority groups.

As for government, she was somewhat critical of its "singular focus" on building new nuclear reactors. Incentives should also go to support the industrial base needed for these efforts. Tax credits to help finance worker training and technician programs, not just for utilities but the entire nuclear industry, would be an easy and effective way to stimulate workforce growth and expand the pool of skilled labor.

New construction quality

Inevitably, thinking about new reactor construction recalls experiences from the earlier generation. The session on new construction quality and inspection dealt as much with ways to avoid repeating the delays and cost overruns of the 1970s and 1980s as it did with establishing new techniques that are geared specifically to new reactor designs, construction methods, and regulation.

Consultant Brian Grimes hearkened back to a 1984 report to Congress by the NRC, which listed factors in the success or failure of reactor construction as seen at that time. These factors included prior experience by owners and vendors; the degree of design completion before the start of construction; regulatory stability; licensee control of the projects; management commitment to quality; the role of financial incentives; practices for procedures and records (now referred to as configuration control); and the NRC's approach to quality issues.


Grimes

Failure is possible, and success requires planning and involvement, and because risk cannot be passed on to someone else, it must be managed.

Grimes noted that configuration control had been a factor in the cancellation of the Zimmer plant in Ohio, on which construction was essentially complete. When the time came to show that the plant had been built properly, the records were in such disarray that this was not possible. Grimes noted that more recently the industry has had success with major projects, suggesting that new reactor construction would not repeat the mistakes of the past. He cited the replacement of large components (i.e., steam generators and vessel heads), conversion to digital instrumentation and controls, power uprates and their related plant modifications, and the Browns Ferry-1 restart as signs that the industry can now manage major projects effectively.

Charles Hess, chief nuclear engineer at Burns and Roe, did not disagree with Grimes, but he pointed out changes in the nuclear scene since the first construction era that pose problems. Most notable is that most nuclear utilities once had considerable engineering experience on the payroll, and some went so far as to handle their own architect-engineering. No U.S. utility today could fill that role, and most utility engineer-

ing staffs are so small that the companies will be "outsourcing the risks" on the project. Current engineering staffs are working on combined construction and operating license (COL) applications, but not on quality assurance for construction. This is especially an issue at the beginning of a project, he said, with new reactor designs that must undergo first-of-a-kind engineering.

Hess recommended early planning, risk-based project management, an integrated management team, a firm financial basis, a technology choice that matches corporate goals, fixed-price contracts, leadership of project management by the owner, extensive training, stakeholder involvement, and development of what he called "active intervenor mitigation plans." In sum, he said that failure is possible, and success requires planning and involvement, and because risk cannot be passed on to someone else, it must be managed.

After the two paper presentations, Grimes and Hess were joined in a panel discussion by Glenn Tracy, director of construction inspection and operational programs in the NRC's Office of New Reactors; Marvin Smith, of Dominion's North Anna-3 project; James Carter, of Navigant Consulting; Russ Bell, of the Nuclear Energy Institute; and Raul Baron, of TVA Nuclear. Tracy also presented material provided by Petteri Tiippana, of the Finnish nuclear regulatory agency STUK. The gist of this presentation was that the construction problems encountered thus far at Olkiluoto-3 illustrate what can happen when previous warnings are ignored.

Grimes, who also chaired the session, noted during the panel discussion that he had hoped to include a representative from the Institute of Nuclear Power Operations (INPO), but that organization had indicated that it was not yet ready to make a presentation on this subject. Bell noted that INPO is leading a lessons-learned activity within the industry on training and accreditation for construction inspection.

A session attendee asked the panel who owns the schedule on a new reactor project. Smith said that everyone involved does, and added that Dominion has invited other expected ESBWR licensees to work on North Anna-3 if it is the reference COL application for that reactor model. (Two weeks later, North Anna-3 did indeed become the R-COL for the ESBWR when its application was submitted to the NRC.) Another question from the floor concerned progress on official documentation to cover limited work authorizations for new reactors. Tracy replied that the documentation has not been completed.

From the audience, Ted Quinn asked how the NRC is preparing its staff to carry out construction inspection. Tracy said that there is a program whereby individuals can be qualified as inspectors in about two years, and noted that the agency is trying to set priorities based on when COL issuance is expected to take place. It is necessary for the NRC to work within the limits of its available budget, he added.


Quinn

In a brief presentation, Smith showed a schedule for North Anna-3, but it did not include a date for signing an engineering, procurement, and construction contract that would formally commit Dominion to building the reactor. Asked during the panel discussion what that date would be, Smith said that it would have to be no later than mid-2009 in order to remain on schedule for reactor startup in 2015.

Nuclear-based imaging

At the session on nuclear-based imaging techniques in biology and medicine, Keith Rogers, of Cranfield University in the United Kingdom, briefly traced the history of X-ray use, pointing out that early on there was a divergence into radiography, which depends on direct beam absorption and the removal of scatter from the image, and diffraction, which depends on just the opposite. Now, about a century later, the separate tracks may be brought together again for work on the new technique of coherent scatter.

While radiography has given rise to computerized tomography (CT), diffraction has led to the development of small-angle X-ray scatter (SAXS) derived from synchrotron radiation. SAXS is one example of the molecular-specific imaging that is possible with synchrotron radiation. Rogers noted, however, that in general the techniques that may become possible are not now in clinical practice, and may not be any time soon.

B. W. Jakoby, whose affiliations include Siemens Molecular Imaging, compared the architectures of positron emission tomography (PET) scanners that employ three and four scanning rings. (Siemens is a manufacturer of PET scanners.) In tests with "phantoms" (artificial constructs with shapes or densities similar to human body parts), Jakoby said that scanning sensitivity was increased by about 80 percent with the addition of a fourth ring. The other option for increasing sensitivity—increasing the thickness of the lutetium oxyorthosilicate crystals used in detection from 20 mm to 30 mm—provided a sensitivity improvement of only about 40 percent.

Claude Nahmias, of the University of Tennessee, reported on the combination of PET (which detects metabolism, including that of cancer cells) and CT (which reveals structure, helping to specify the location of an image return) in the management of patients with cancer. He noted that in some cases, the combination of techniques has shown little or no improvement over PET alone, with mediastinal and cervical lymph node detection lacking good sensitivity. Nahmias said that improvement in the sensitivity and specificity of PET is more likely to result from new, improved biomarkers than from advances in PET/CT instrumentation.

Status of small power reactors

The session on the status of small power reactors included, as expected, an update on the efforts of the 800 inhabitants of Galena, Alaska, to host a Toshiba-designed 10-MWe 4S reactor to supply heat and electricity. The 4S reactor is a liquid sodium-cooled "battery"-type reactor that has been under development since the late 1980s.

Session chair Christopher Lapp, of Lapp Consulting Services, reported that the Galena team held its first pre-application talks with the Nuclear Regulatory Commission on October 23. Unfortunately, because the team must be back in Washington in a few weeks, Lapp said, Marvin Yoder, the Galena city manager who is in charge of the 4S project, could not come to this meeting. Other Galena team members were there, however, to give an update on the October meeting.

Replacing 24 percent of the gasoline used in the United States with ethanol would have a significant positive impact on the U.S. energy situation.

Before the panel discussion began, Lapp brought up one of the heavily promoted alternatives to imported oil—bio-fuels, and in particular ethanol—to replace gasoline. He said that there is a possible role for small reactors in the production of ethanol. Although there are a number of drawbacks to ethanol, he said, its potential can be seen in Brazil, where 24 percent of the fuel used is ethanol (the rest being gasoline). Lapp pointed out that replacing 24 percent of the

gasoline used in the United States with ethanol would have a significant positive impact on the U.S. energy situation.

In the United States, he said, about 18 percent of domestic corn production goes toward ethanol production. Since this is already having an impact on the foodstuff market, Lapp said, it is clear that something other than corn will be needed, and switchgrass is seen as the most likely replacement. Switchgrass, which would yield a more efficient net energy product than corn does, needs little water and can be grown all over the Great Plains.

Welter

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Most ethanol production plants, Lapp said, rely on natural gas, which does not make it a very "green" process. Using the waste heat from large nuclear power reactors is certainly possible: Ethanol has been produced at the Bruce plant in Ontario for several years. He noted, however, that while there are a number of nuclear plants in the corn-growing regions, the cost of undertaking the necessary modifications to existing nuclear plants would not generally be economical. As for switchgrass, the use of process steam from large reactors would not be viable in the Great Plains because of a lack of large transmission systems or large water supplies. Small grid-independent reactors could be deployed there much more easily, he said. These reactors could also provide electricity for rural systems and district heating in the colder climates of the upper Great Plains.

The lack of ethanol stations is another problem, Lapp noted, a result of gasoline pipelines' not being able to transport ethanol. Most states have few ethanol stations, with the lowest density of them in the Northeast. Minnesota has about 50. In 2005, Lapp, wondering if it would be possible to drive across the country on ethanol, converted his 1957 Cadillac to use ethanol. He drove from Washington, D.C., to the ANS Annual Meeting in San Diego, Calif., and back to Washington on ethanol. His conclusion about ethanol, however, was that it could be only part of the picture, because "you still don't want cars sitting in traffic, burning up ethanol."

Kent Welter, acting chief of the NRC's code development branch, noted that the NRC was already looking at several small reactors, such as the Iris design, the pebble bed modular reactor design, and Hyperion, a new reactor whose developers (including one who was on the panel) have asked for a pre-application review. Welter also mentioned that the regulatory process allowed various routes for obtaining a reactor license, which is one of the things usually discussed at pre-application meetings. For example, he said, the recent meeting on the Toshiba design included a discussion on the relative merits of design certification versus design approval.

Two members of the Galena team were also on the panel: Matias Travieso-Diaz, of the law firm Pillsbury Winthrop Shaw Pittman, which advises on regulatory and licensing matters, and Philip Moor, of Burns and Roe. The two are the principal authors of seven white papers commissioned by Galena that cover the most important aspects of the project.

Galena is a community in the middle of Alaska whose only source of power is diesel generation, which is becoming prohibitively expensive. A review of other options, including nuclear, led them to Toshiba's battery-type 4S reactor, which can operate for some 30 years on a single core.

Travieso-Diaz explained that Toshiba had been planning to meet with the NRC for quite some time, but for various reasons it did not happen until last October. This was unfortunate, he said, because if the meeting had been held in 2005 as first planned, the NRC would have had more resources available to look at the 4S design. Now it is in competition with a number of major licensing reviews.

If the meeting had been held in 2005 as first planned, the NRC would have had more resources available to look at the 4S design.

Travieso-Diaz explained that Toshiba has two possible routes to license a reactor: going for design certification, or for design approval. He added that the way NRC staff review the technical merits of a design is much the same in both cases, and that it is later in the licensing process that the differences show. A design that is certified, he said, is the subject of a rulemaking procedure and once granted cannot be challenged, unlike a design approval. And so, from the standpoint of someone who applies for a COL, it is far better to have a certified design.

Travieso-Diaz

Toshiba, he said, is now planning to seek design approval, although this does not preclude applying for certification later. Travieso-Diaz did not elaborate on why Toshiba made this decision, but he did say that the approval route is simpler and less expensive.

Toshiba plans to undertake further general meetings with the NRC to see if there is anything that might be a major obstacle to progress, and will then submit technical reports on the design before actually applying for design approval. Travieso-Diaz said that the initial series of meetings will be like the one in October, aimed at familiarizing the staff with the design. These meetings are expected to take place over the next few months if the NRC agrees. The submission of a formal application is planned for early 2009. Toshiba would expect to obtain design approval by the end of 2011, and if all goes well, a COL application will be submitted in 2012.

Burns and Roe's Moor recapped the Galena story, starting with the town's initial meetings with Toshiba in 2003. In 2004, the Department of Energy undertook a study, "Galena Electric Power—A Situational Analysis," that looked at energy alternatives. The results of that study, he said, were pivotal to Galena, concluding that a small nuclear plant was a real possibility. The city council then passed a resolution to pursue this option, and in 2005, Galena held an initial meeting with the NRC, clearly stating that it wanted to host a nuclear facility. In 2006, Galena received a grant from the state of Alaska to prepare a set of seven white papers setting out the technology and examining the implications of siting a 4S reactor in Galena. The white papers, which are available to the public, cover the following topics: general

overview, nuclear liability, emergency planning, physical security, decommissioning, containment, and seismic isolation.

Moor said that one of the things that makes the 4S special is that it has reached a level of maturity that puts it at the front of the pack of new reactor designs. Among the reactor's distinguishing features, he noted, are modular construction, a 30-year core life (which is longer than most others), inherent safety features, underground siting, no need for fuel storage outside the reactor, and proliferation resistance.

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Galena is also looking at possible financial strategies and is actively seeking a third party, such as a major nuclear operator, to be owner-operator of the facility. He added, however, that the city is ready to fill that role itself. If there were a third party involved, Galena would provide a purchasing agreement to anchor the project.

John Deal, of Purple Mountain Ventures, presented a new small-reactor concept called Hyperion, developed at Los Alamos National Laboratory. Hyperion, he said, uses a uranium hydride fuel with hydrogen acting as moderator, is self-regulating, and has no moving parts. Sealed at the factory, the reactor would not be opened until its return to the factory to be refueled, approximately every five years. Deal said that he prefers to call it a "chemical" rather than a "nuclear" battery. The design capacity is between 60 and 70 MW thermal, with production at 20–27 MW electrical.

Purple Mountain Ventures was spun out of Los Alamos a few years ago after legislation was passed that allowed DOE lab operators to license their technologies. Deal explained that he and his associates realized that nuclear may soon be "out of the closet" and looked into the marketing possibilities for small reactors.

Deal said that rather than developing a small-reactor concept first, the group started by looking for likely commercial applications, identifying the supply of heat and power for oil and gas exploration and desalination, as well as for the military and remote communities. What people wanted, they found, was a reliable, relatively inexpensive source of heat with minimal complexity and a reliance on fairly simple concepts. It also had to be portable, safe, and proliferation-resistant, be able to use existing infrastructure, and produce little waste.

A likely candidate technology was sought, and the result was the Los Alamos solution, which Deal described as a battery based on nuclear science.

Hyperion, Deal said, is not expensive. A complete reactor, including siting, would cost about $20 million and would generate electricity at about 4.5 cents per kWh. He said that he has the customers and the money to develop the product.

During the question-and-answer session, the panel was asked to address a critical issue for small reactors: the huge cost of licensing a nuclear plant and providing staff, notably security personnel.

Travieso-Diaz replied that the cost of the first unit may be high, but that this would be offset by selling in quantity. An important thing to remember, he said, was that because the reactors would be identical, the cost of licensing subsequent units would be very low. He also noted that the NRC should take into account some of the important safety features of the 4S, and that it should not require the same level of security or the elaborate emergency response plan of a conventional large reactor. Nor should it need a large number of licensed operating staff, he added. If the NRC ultimately does not accept those basic principles, the Hyperion, and any other small reactor, is dead in the water, Travieso-Diaz said. He also mentioned that for the 4S, Toshiba has already undertaken a substantial amount of the work that will be needed for licensing a reactor, and has shouldered a lot of the cost as well.

Moor noted that staffing requirements for the 4S should be less than 30 people, including security, taking shift work into account.

Deal answered from a slightly different perspective. Having been around government and the DOE for many years, he said, he does not think that the NRC is going to change its regulations, and so it might be necessary to spend $100 million for the first license. He added that he expects to sell thousands of the Hyperion reactors. In addition, he said, oil and gas companies could save billions using them at an oil field, rather than conventional fossil fuels.

Welter added that having been involved in planning and budgeting for the review of a variety of reactors, there is no single dollar figure. The cost of licensing will depend on many factors, he said, such as the technology and the size of the reactor, adding that he does not think that the NRC will need to change its rules in order to license small reactors.

Releases to groundwater

Starting in late 2005, first at Braidwood and then at other nuclear power plants, it was learned that tritium-bearing water was less under control than had been previously believed. So far there have been no significant consequences, but the fact that contaminated water has been migrating in quantities and concentrations greater than previously believed has driven licensees and regulators to look more closely at the subject, and this panel session, "New Construction Quality and Inspection," provided a discussion on the latest developments.

The panel was chaired by Thomas Nicholson, a project manager in the NRC's Office of Nuclear Regulatory Research. He cited the agency's task force on tritium and other releases, which in September 2006 concluded that public health has not been affected but the potential exists for unplanned, unmonitored releases beyond plant boundaries and into inhabited regions. He noted that some leaking components are not subject to surveillance, and that there is now an NEI initiative to encourage voluntary reporting of on-site leakage in excess of the Environmental Protection Agency standard for public drinking water. Also, he said, there is no NRC requirement for groundwater monitoring on a plant site.

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While the main focus of attention from the public has been on tritium, Nicholson said it is not the only radionuclide that could figure in releases that are partly or completely unmonitored. There could also be strontium-90, cesium-137, cobalt-60, nickel-63, and others, all of which would have migration paths different from that of tritium. One response by licensees has been the addition of extra monitoring wells, but Nicholson

warned that these wells might themselves become release pathways, allowing contaminants to reach the water table.

In a presentation making a case for an observational method for conceptual site modeling development, Matthew Barnevik, of GZA GeoEnvironmental, showed that the installation of a crane in the spent fuel storage yard at Indian Point required excavating 30 feet down alongside the Unit 2 spent fuel pool wall. The digging exposed a shrinkage crack in the pool wall and moisture indicating leakage. Later drilling on the site led to the detection of the fission product strontium in the groundwater. The mapping of water flows at the site showed the effects of grade-level modifications during construction, and so, Barnevik said, it is necessary to consider construction impacts on groundwater movement, a subject that is not always included in a site's final safety analysis report.

A clearer view of the state of a site, in terms of contaminant releases, may be available after the end of a plant's operation, rather than during it.

David Scott, of Radiation Safety and Control Services, expanded on Nicholson's list of radionuclides by giving his own ordered ranking of the most important ones in releases—actual and potential—from nuclear facilities. He ranked tritium fourth, behind Sr-90, Cs-137, and Co-60. The rest of his top 10, in order, are Cs-134, iodine-129, Ni-63, carbon-14, plutonium-238, and americium-241. He noted that tritium and gamma-emitters migrate differently, in that tritium can be bound in the unsaturated zone, and then emerge whenever the water rises.

A clearer view of the state of a site, in terms of contaminant releases, may be available after the end of a plant's operation, rather than during it. Gerry van Noordennen, now with UniStar Nuclear, was with Connecticut Yankee Atomic Power Company during the decommissioning of Haddam Neck. He said that all plant buildings are now gone except those related to the storage of spent fuel. The state government has given its approval for unrestricted use of the site, and NRC approval is pending. Water monitoring will continue for another four years.

Van Noordennen said that the refueling water storage tank had leaked, and two repairs made during the plant's operating years had not been completely effective. Because Sr-90 is known to be migrating toward the Connecticut River, $75 million will be spent to remediate soil and bedrock ($10 million of that will be used for groundwater monitoring). Van Noordennen said that lessons learned from the decommissioning that could apply to new plants are to consider including raceways in spent fuel pool construction to allow access in case repairs are required later, and to put underground piping in duct banks, concrete trenches, or encased pipe.

During the panel discussion, a question from the audience addressed a point raised by Nicholson: Should a well be monitored while it is being dug in order to determine whether the well itself might cause migration? Scott said that at the decommissioning of Yankee (in Rowe, Mass.), strata were isolated while a well was being drilled. Some techniques allow for taking a continuous sample along the direction of drilling. Then at each change in material, the drilling is stopped and the hole is pressure-grouted. Barnevik commented that this works in soil, but not in bedrock.

The applications arrive

The ANS Operations and Power Division's New Construction Working Group has been meeting regularly at the past several national meetings, holding what amounts to a technical session open to all interested parties rather than a committee meeting. The session is essentially an update on the status of new reactor projects and developments that might influence whether reactor orders and construction will actually take place.

Tom Miller, of the DOE, expressed the raised expectations that exist even within the agency. The DOE's Nuclear Power 2010 cost-sharing program was seen as ambitious in 2004, with its project to demonstrate the licensing process by recruiting partners to apply for real licenses, without orders actually being placed (or even firmly planned) for reactor hardware. In late 2007, Miller said, "licensing demonstration's not going to cut it."

NP2010 would be a nominal success if the licenses are issued, Miller said, but in the environment that has since developed, without real financing and decisions to build, NP2010 would not be a real success. Asked what ANS members could do, Miller said they should lobby Congress, not just for NP2010, but for nuclear deployment overall, stressing climate change and energy security. He also noted the need for growth in the skilled workforce, and asked rhetorically how many parents would encourage their children to make their careers in craft labor.

The NRC has been observing a landscape of new reactor possibilities that changes so frequently that Joseph Colaccino, chief of the EPR projects branch in the agency's Office of New Reactors, declined to provide a comprehensive update because it might have already been outdated. Looking ahead to the license application for Calvert Cliffs -3 (part of which was submitted last summer) and the design certification application for the U.S. EPR, he said that this parallel approach was "a challenge" because of the possibility of rework on one needing to be reflected in the other. Among the recent developments that may make new reactors possible, he cited the revision of the standard review plan. He also noted that some participants in the nuclear debate are bothered that the NRC seems to interpret its mission as "enabling" the licensing of new reactors.

The organization that has probably come the closest to declaring outright that it intends to build new reactors is STP Nuclear Operating Company, now with merchant electricity provider NRG Energy as its largest single owner. Greg Gibson, NRG's manager of regulatory affairs, summarized the company's approach to licensing, in particular its adoption of the Advanced Boiling Water Reactor (ABWR), a reactor design that has been used in plants that have actually been built and operated. He noted that South Texas-3 and -4 would be the world's 12th and 13th ABWRs, adding that these would differ somewhat from the original standard design, mainly in the area of instrumentation and controls. The digital technology that is now available was not when the ABWR went through the design certification process.


Gibson

The license application for the two reactors was submitted in September, but NRG is apparently not going to leave the rest of the project dormant while pursuing the license. Gibson said that he expects to place the order for the nuclear steam supply systems and other major components during 2008, perhaps as early as January. Asked if the procurement of large forgings through Toshiba, rather than GE-Hitachi, meant that the two vendors would bid competitively for the order, Gibson said no. He said that Toshiba had gained the lead on winning the order, and that GE-Hitachi was currently negotiating for a part of the contract. (Gibson said that GE-Hitachi was negotiating with Toshiba; in an interview the following day, GE-Hitachi President and CEO Andrew White said that his company was negotiating with NRG, not with Toshiba.)—*E. Michael Blake, Dick Kovan, and Rick Michal* NN