ANS ANNUAL MEETING

Developing a nexus of public support

THE 2006 AMERICAN Nuclear Society Annual Meeting, held June 4–8 in Reno, Nev., featured the promising theme, *A Brilliant Future: Nexus of Public Support in Nuclear Technology*, and an attendance of 1269. Introducing the meeting's opening plenary session, Jim Reinsch, president of ANS and of Bechtel Nuclear, noted that ANS was formed in 1954 to support the men and women working in the nuclear field through knowledge exchange, professional development, enhancing public awareness, and other means. That mission has never been more important, he said, nor has the society been more relevant to the industry, given today's complex global issues.

Reinsch

Reinsch also noted that it was his privilege to present an ANS Presidential Citation to Nils Diaz, chairman of the Nuclear Regulatory Commission since 2003, whose term on the NRC would end on June 30. Diaz's "steady hand on the rudder" guided the NRC through "very interesting times," Reinsch said, including the push for plant life extensions and power uprates, the 9/11 terrorist attacks, and the needed streamlining of the licensing process. The commission's communication with the industry and with the public was never stronger than under Diaz, Reinsch said, adding that he had retooled the staff, bringing in new people who will sustain it through the coming renaissance. "We have been blessed to have that leadership," Reinsch said.

Reinsch then turned the session over to Vic Parrish, of Energy Northwest, who cochaired the meeting with Louis Pardi, of Washington Group International. Parrish introduced the first speaker, Spencer Abraham, former U.S. Secretary of Energy, who, like Diaz, played a leading part in the country's response to 9/11. Upon taking the stage, Abraham reminded meeting attendees of what a surprising choice he had been for President George W. Bush's first cabinet, with his having sponsored a bill to abolish the Department of Energy when he served in the Senate.

Abraham

At the time of his arrival at the DOE in 2001, Abraham said, he found little optimism. Few people were going into the fields needed for developing nuclear power. University research reactors were being decommissioned or programmed for closure. There was a virtual standstill in the Yucca Mountain project. Even on the day of his departure, February 1, 2005, Abraham felt that while the department had moved forward programmatically, things had not changed very much in terms of where the country was. But since then, he said, the situation has changed in ways that could not have been forecast 15 months ago.

The whole energy industry is moving forward, he said, with profits for well-run energy companies at record levels. The media are focusing on energy in a more constructive way, and many environmentalists are changing their attitude about nuclear power.

Abraham also noted, however, the outcry over energy prices and the impact they are having on other parts of the economy. The reasons are simple, he said—supply and demand. There are very tight markets with

Meeting session coverage:

- *The brightening prospects for new power reactors*
- *The Global Nuclear Energy Partnership (GNEP)*
- *Nuclear energy and the hydrogen economy*
- *Training the workforce for a reviving industry*
- *Designs that anticipate DD&R*

Smyth Award goes to Robinson

At the opening plenary session, the Henry DeWolf Smyth Award, established in 1972 by ANS and the Nuclear Energy Institute (then known as the Atomic Industrial Forum), was presented by Skip Bowman, president and CEO of NEI, to Ambassador C. Paul Robinson, president emeritus of Sandia National Laboratories. The award was given in recognition of his outstanding and statesman-like contributions to nuclear energy activities. The citation reads: "For four decades of significant contribution to U.S. national security, arms control, proliferation prevention, and the peaceful use of nuclear energy throughout the world."

Robinson

An important part of Robinson's work has been his involvement with the U.S.-Russian Lab-to-Lab program on joint arms control and initiatives that have helped to secure weapons of mass destruction throughout the former Soviet Union and enabled the transition of materials, infrastructure, and people from weapons development to peaceful applications of technology.

Robinson was appointed by President Ronald Reagan as the chief negotiator and head of the U.S. delegation to the U.S./USSR Nuclear Testing Talks (1988–1990). Those talks culminated in the unanimous ratification of the Threshold Test Ban Treaty and the Treaty on Limiting Nuclear Explosions for Peaceful Purposes, both of which remain in force today. The Joint Verification Experiment of 1988, a unique endeavor within those negotiations, laid the groundwork for nuclear cooperation, which is now carried out under the Lab-to-Lab program.

Robinson's efforts with his laboratory director counterparts in the United States and Russia have contributed to several important initiatives over the last decade. Under his leadership, seven U.S. lab directors met with nine of their Russian counterparts in Vienna in 2004 to draw up "Principles in Common for Future Nuclear Power Technologies," which have been embraced by the governments of both countries. Taken together, said Bowman, Robinson's contributions to the foundation for the next nuclear era make him a most deserving recipient.

In accepting the award, Robinson spoke of the current crisis with respect to proliferation. The Non-Proliferation Treaty has not fulfilled its promise, he said. It was originally a "gentlemen's agreement," with all parties having to show their fulfillment of the conditions of the treaty rather than verify that they were not cheaters. A number of countries have since cheated, Robinson noted, finding ways to do so within the fabric of the treaty. The lab directors, he said, believe that this could not be corrected by adding on proliferation protection to the present fuel cycle. This mistake must not be repeated with the future fuel cycles we develop, Robinson said.—*D.K.*

very limited production capacity worldwide. The amount of oil that can be pumped is being pumped, while demand keeps growing. This makes many countries very vulnerable to political events, as well as to natural disasters and terrorist threats and actions. Instability in the Middle East and elsewhere can have a chilling effect on energy resources, he said, adding, "We have seen President Putin turn a quarrel with Ukraine into a question of energy supply being provided across pipelines to many countries as a political tool. This sets up a new calculus on energy supply." Now individual countries have the sort of power previously enjoyed only by the OPEC cartel.

The demand side, Abraham said, is driven not only by economic growth, but by the desire of people to achieve a higher standard of living. Millions of people in China and India who had never before contemplated owning a car now believe that owning one is indispensable for their own advancement.

On the supply side, he said, many Western countries are doing things that make it more difficult to meet the growing demand, from resource limitations to political opposition and regulatory considerations. The "not-in-my-backyard" (NIMBY) syndrome, he noted, is credited with preventing the building of a new oil refinery in the United States since the 1970s, or a new liquefied natural gas regasification terminal for decades.

Abraham said that he believes that energy security is probably the biggest challenge we face today. But, he added, the public policy response has not been strong enough. The energy bill took too long to be passed—four years—and is not sufficient to meet all the challenges, he observed, although it probably is a help to the nuclear industry. He said, however, that it does not address nuclear waste or the need for new oil refineries.

The one comprehensive way to address all these concerns is the expansion of nuclear energy, with its obvious benefits, Abraham said. There is no way that the carbon targets are going to be reached without a major expansion of nuclear energy, he noted, and the focus cannot be only on renewables. "You cannot fight nuclear energy and global warming at the same time. It is a self-defeating approach," he declared.

There is a great story to be told and it needs more telling, he said. It is also necessary to remain united, to ensure that the public is informed, and to maintain a focused research and outreach effort. "I think we have the right people in place to do this," he said.

A questioner from the audience asked Abraham about his reasoning behind the Senate bill to abolish the DOE. He said that at the time he saw no clear focus of what the mission of the DOE was, and he thought that most DOE programs could be put into other agencies and departments. He explained that he thinks the bill setting up the National Nuclear Security Administration went a long way to ease his concerns by sorting out the DOE structure, in particular by putting defense and security issues within a semiautonomous agency and providing clear lines of responsibility. By his second year, he said, he realized what the mission of the department was: national security. "If we do not have energy security, our national security is jeopardized. I think the framework does work now."

National, energy, and economic security

National security was also stressed by Nils Diaz, who focused on the nexus of national security, energy security, and economic security. The connections, he said, "are as obvious as they are challenging."

The safe, reliable, and secure operation of current plants, a result of the industry's working together, has enabled the present possibility for new build, Diaz declared. He stressed the importance of continued safe operation of the nuclear fleet, which deserves the best of the NRC and of the entire nuclear community. He also emphasized that people are owed factual and responsive communications on the key issues of safety, security, and economics. Two other key areas for Diaz are risk and communication: "The [risk] standard the NRC uses is a good one that has stood the test of time and the courts: reasonable assurance of adequate protection," he said.

Diaz

Diaz noted that he has worked to ensure the effective use of communications as a management tool for the NRC. "Communication makes the nexus of predictability, connectivity, and accountability visible, usable, and then functional. It makes uncertainty an issue to be managed, not feared.

Uncertainty is a reason for action, not inaction." Although no license application has been received, he said that the NRC could not wait for certainty to act. "We used sound evidence of the industry's intention to submit COL [construction/operating license] applications to launch an aggressive preparation program for new reactor licensing reviews," he observed. "This preparation, costly in manpower and resources, required the support of the Congress and benefited from the seriousness of the industry to do it right this time."

"The NRC is, in its thinking as well as in its structure, more focused, more open, more responsive, and, of course, more risk-informed."

Diaz said that the NRC is working to put in place the regulatory infrastructure necessary to conduct the technical and legal reviews for the anticipated new plant license applications. "We are reorganizing, hiring, enhancing existing programs and processes, and developing new ones to meet the workload. We are breaking the old reactor licensing mold and building a well-planned, rigorous, and disciplined new reactor licensing review organization that befits the needs of our nation and fulfills the responsibility assigned to the NRC. As it changes," he said, "the NRC is, in its thinking as well as in its structure, more focused, more open, more responsive, and, of course, more risk-informed."

He said he is also "convinced that the approaches we're considering today will result in significant benefits not only in relation to NRC's initial licensing reviews, but also in relation to industry's operation and maintenance of the plants and NRC activities during the operation phase."

Diaz said that there is enough experience to ensure that the problems of the past do not happen again. "I submit to you, it is time to wrap up the lessons and have solutions in hand. We are all responsible," he said. "Uncertainty exists . . . and it needs to be managed and resolved, well and on schedule. There is no credible industry without a credible regulator. There is no predictable industry without a predictable NRC. There is a nexus, it is known, and it will be even more open to all. It comes down to using state-of-the art technology and managing the uncertainty, the predictability, the connectivity, of knowing one's role and executing that role. It comes down to accountability. . . . You are accountable. The NRC is accountable. Different roles, one accountability: to one nation, under God, indivisible, with liberty and justice for all."

A vendor's perspective

Andy White, president and chief executive officer of General Electric Nuclear Energy, offered a vendor's perspective of the future and how it is going to be different from the past. Even considering the high capital cost, when costs are levelized over 20 years, and looking at the next generation of designs, nuclear is the best decision from an economic perspective. He provided a list of what customers want in the next-generation plants. This includes simpler designs that are easier to operate and maintain, lower capital costs, faster construction periods, fewer specialized people, fewer security people, fewer maintenance people, lower forced outage rates, improved safety and security, lower dose, and reduced waste. In regard to financing options, he noted, utilities also say that unlike the first time around, they will not take all the risk—industry must take a share.

White

A lot of lessons have been taken on board, White said. The licensing process has been much improved through design prelicensing, early site permits (ESP), and combined COLs, which ensure that once a plant is built, it can be operated. The ability to undertake large projects is now very good, White said, through, for example, maximizing engineering before construction starts; maintaining good collaboration across the project by participant teams; using advanced construction methods such as modularization, which helps take the critical path out of on-site activities; ensuring standardization of engineering designs; and having an efficient global design chain for major components, such as forgings, vessels, and many others.

GE looked carefully at staffing positions across its entire business, White said, focusing on retirements and what level of backup was needed, and undertook a recruiting drive on this basis, not only of college graduates, but also from the pool of experienced people in the industry. White mentioned that moving the nuclear headquarters from expensive California to the East Coast has been positive for recruitment. In 2005, some 250 people were recruited, and the plan is to add about another 150, mainly engineers, this year. He also noted that GE has turned around the age demographics: The average age of GE nuclear engineers was 52.4 in 2003, and last year it went below the 50-year mark. GE is making maximum use of its experienced people to mentor the younger ones, he said.

The renaissance is coming, White said. The only question is who will be first and when.

The role of universities

Speaking on the role of universities, Jose Reyes, head of the department of nuclear engineering and radiation health physics at Oregon State University, looked back to a 1930s talk given by Sir Arthur Eddington, who spoke of a new form of energy (atomic) that would make energy economy unnecessary. It is just such vision and enthusiasm, Reyes said, that drives scientists and engineers.

Reyes

Universities have always played an important role in the development of nuclear technology, he said, adding, "We have a brilliant future because it has been powered by a noble cause." Universities are being called upon to supply the workforce for the nuclear renaissance and are making significant headway, Reyes said. Undergraduate enrollment in nuclear engineering has tripled since 2000, and this is being followed by a similar wave of graduate student enrollment, he said, noting that funding is a big part of that. The DOE has put more than $120 million into its university programs since 2000, he observed, and during that same time, the NRC put in $23 million in support of its mission. He also pointed to the growth of minority groups in nuclear programs.

To produce the workforce needed, he said, universities are having to add value to their degrees and are developing new ways of cooperation with industry and government. According to discussions he has had with industry, companies are looking for a lot of strengths in new hires, with communication and interpersonal skills at number one. Next are skills such as the ability to work independently on specific tasks, to work in multidisciplinary teams, to have talent for problem definition and the development of paths to problem resolution, and the ability to work in a matrix organization.

There are also opportunities out there now for students to develop these skills, including internship programs at national labs, the DOE, and the NRC, Reyes said. In addition, Oregon State is piloting an "apprentice" program that will provide men-

toring for student leaders by industry and government leaders. There will be a competition among students to spend a summer program under a mentor.

Universities also provide the industry with access to people and research loops. Reyes said that he led a project for Westinghouse to build an experimental facility to undertake tests of the design and performance of the AP600 and then of the AP1000. This was a huge project for the university, he said, and required some new ways of operating. After Westinghouse completed its testing program, it was used by the NRC for its assessment.

A brilliant future

Whoever came up with the conference theme, said Frank L. (Skip) Bowman, president and chief executive officer of the Nuclear Energy Institute (NEI), "got it just about right. There is indeed a very brilliant future for our nuclear industry in this country." In the mid-1990s, Bowman said, common wisdom held that nearly half of the plants operating at that time would by now be shut down because of competitive pressures. Instead, the industry is thriving and profitable, consistently recording average capacity factors in excess of 90 percent. A decade ago, he said, who would have guessed that by 2006, three-quarters of our nuclear fleet would have obtained 20-year extensions, or plan to do so; that the president and Congress would approve Yucca Mountain; that a bipartisan Congress would provide financial incentives and risk insurance to stimulate investment in new nuclear capacity; and that states and local communities would be competing to build new nuclear capacity in their backyards.

Bowman

A decade ago, who would have guessed that by 2006, three-quarters of our nuclear fleet would have obtained 20-year extensions, or plan to do so.

Bowman added that he believes that nuclear power is becoming a unifying factor rather than a divisive one. The public, he said, is unwavering in its support, as is the highest level of our executive branch. "President Bush unveiled his global nuclear energy partnership, a long-term vision of the global promise of nuclear power, borne out of a conviction that substantial expansion of nuclear energy is the only way that the world can meet its electricity needs in a stable way while protecting our environment." There is an exceptional and unprecedented support from Congress on both sides of the aisle, he said, and a growing acceptance from the financial community.

This unmistakable trend is due, he said, to nuclear power's three distinguishing characteristics: It produces large volumes of low-cost electricity around the clock at high levels of safety and security, the electricity is generated at a stable price without the punishing volatility of gas-powered capacity, and it helps maintain air quality. Other sources of electricity may have two of those attributes, but no others have all three.

"We have worked hard to earn the trust [of a wide range of stakeholders]; we must work equally hard to maintain that trust," Bowman said, adding that it will not be possible to build new reactors in this country unless there remains that consensus among stakeholders that today's nuclear plants are safe and reliable. Continued excellent plant performance is an unconditional imperative, he declared.

To continue to earn the public's trust, the industry must move quickly and proactively to address emerging issues such as the recent tritium releases at some nuclear plants, Bowman said. Although the tritium releases will not cause any harm to public health and safety, he continued, they came as a surprise to the public and community leaders, and such surprises can erode public confidence. The industry took the initiative to disclose voluntarily any releases, even those that fall way below the regulatory reporting line. "Full transparency in operations should be our goal."

With the Energy Policy Act of 2005, the federal government has provided the tools to undertake the massive capital investment that will be required to build new plants, Bowman said, noting that there are some items of unfinished business, however, including used fuel, which he called "the elephant in the room." In particular, there is no plan to move used nuclear fuel from plant sites either to a central repository or to on-site storage facilities.

To deal with this issue, Bowman said, the NEI Executive Committee established three priorities last February. The highest priority is for the government to fulfill its statutory obligation to take title to and begin moving used nuclear fuel from plant sites. The number-two priority is to develop a statutory "finding of waste confidence," to ensure that used fuel policy issues do not stand in the way of continued operation, license extensions of existing plants, or new-plant licensing. Number three is to freeze the nuclear waste fee at 1 mill/kWh and to ensure that all funds collected for the program are made available, as Congress intended, for the development of this repository.

The momentum for nuclear power is now insurmountable, and its global warming advantages will make it very difficult to stop.

Bowman also said that the momentum for nuclear power is now insurmountable, and that its global warming advantages will make it very difficult to stop. "What could cripple us more is an accident," he stressed. "That is why we cannot drop our guard. We cannot become complacent.

"Now it is up to us to finish the job. We have an awful lot left to do, but we can and we will get it done. Failure is not an option."

GNEP and fuel

There are those who say that nuclear power's future is tied to closing the fuel cycle. Perhaps with that connection in mind, two sessions with related topics were combined in an effort to provide more information to a wider audience. The sessions were titled "Long-Term Sustainability of Nuclear Fission Energy" and "Implementing the Spent Fuel Recycling Initiative: Fuel Cycle Requirements and the Role of the Nuclear Power Utilities."

Vic Reis, senior advisor to the secretary of energy, started off the session by saying that the so-called nuclear renaissance is really a nuclear crisis, if the word crisis is defined as danger plus opportunity. "Much of what people have been talking about over the past years is concentrating on the dangers of this nuclear stuff," he said. "I think the time now is to concentrate on opportunities."

An opportunity at hand, he said, is the Global Nuclear Energy Partnership (GNEP), a program that aims to develop worldwide consensus on expanding the use of nuclear power while resolving waste and nonproliferation issues. GNEP would de-

velop integrated advanced reactors to create more energy, dramatically reduce the amount of waste, and eliminate nuclear byproducts that unstable regimes could use to make weapons.

GNEP is the brainchild of President George W. Bush, according to Reis. Bush sent Energy and State Department officials to London, Paris, Vienna, Moscow, Tokyo, and Beijing to gauge interest in GNEP, Reis said, and the international response was "extraordinarily positive." It spurred on the development of the program. "It helped set the tone with GNEP," he said.

A first step of the program is to determine policies based on current national strategies. "We'll be developing [international] cooperative programs in scientific research, technology demonstrations, personnel exchange, and so on," said Reis, who noted that the United States would take a leadership role in cultivating GNEP.

Buzz Savage, research and development director for the Department of Energy's Office of Nuclear Energy, said he is an "implementer" of programs such as GNEP, while Reis is a "vision guy, the long-term strategy developer."

Savage remarked that the current strategy for the U.S. portion of GNEP "is to bypass thermal-recycled plutonium and other transuranics in light-water reactors and go directly to fast reactors." Based on the maturity of current technology, he said, the sodium-cooled fast reactor is the best fit.

Under GNEP, the DOE wants to demonstrate the ability to separate and deal with the components of spent fuel. "We would take the uranium and separate it at high purity, then store it as either a low-level waste or store it in some kind of a location where it could be reused later and recycled in fast reactors," Savage said. Cesium and strontium, fission products with 30-year half-lives, would be put into decay storage for up to 300 years before being disposed of as low-level waste. The transuranics would be separated as a group with the remainder of the fission products and would provide the fuel for the advanced burner reactors.

Savage noted that the fission products and any process losses from the various processes would make up the high-level waste that would still have to go to a repository. This requirement, then, ties GNEP to the Yucca Mountain program. "The Yucca Mountain project must go forward," he said. "We need the high-level waste repository. The industry looks to [the DOE] to fulfill our obligation to take their spent fuel. That's the bottom line. We're going to do it."

The cost for GNEP demonstration facilities is in the wide range of $4 billion to $10 billion, Savage said, with possible startup of facilities in the 2010 to 2020 time frame.

Emory Collins, manager of the advanced fuel cycle program at Oak Ridge National Laboratory, said that the United States needs to start recycling spent fuel as soon as possible in order to stop the growth of its spent-fuel inventory. Currently, 50 000 tons of spent fuel are stored domestically, with an additional 2000 tons generated each year, the storage of which costs the industry about $560 million per year, he said.

Mike Sellman, president and chief executive officer of Nuclear Management Company (NMC), said that CEOs for most utilities "have been spoiled over the last 25 years regarding the nuclear fuel cycle. Fuel has been inexpensive and available."

Sellman

But things have changed, he noted. In preparing for his remarks on a utility's perspective of the fuel cycle, Sellman said he went to NMC's fuel buyers and expected them to say everything was going to be fine, like it always has been. They didn't say that. "In fact, what they said was that they do not see how we can have the nuclear renaissance that's been predicted and not have a gap where we don't have enough fuel for a number of years," he said.

Not too long ago, Sellman continued, NMC's nuclear plants (Duane Arnold, Kewaunee, Monticello, Palisades, Point Beach-1 and -2, and Prairie Island-1 and -2, although Arnold and Kewaunee are no longer operated by NMC) spent 50 percent of their fuel costs on enrichment. Now they spend 50 percent on uranium.

The United States needs to start recycling spent fuel as soon as possible in order to stop the growth of its spent-fuel inventory.

Sellman noted that world demand in 2006 requires 170 million pounds of uranium for nuclear plants. "If you look forward to 20 years from now, you see the demand is pretty darn close to being doubled," he said. That demand forecast is based on the assumption that the world will be adding 151 gigawatts of electricity in the next 20 years.

Looking at reprocessing to fill the gap, Sellman said that recycling facilities in the United States would not likely exist in time to deal with the U.S. fuel shortage. Today in the Western world, he said, the reprocessing that exists is equivalent to a uranium mine that produces 5 million pounds per year. He added that all the world's spent fuel would equal a "rich uranium mine with 300 million pounds."

Sellman said that while he sees advantages for recycling and would like to see it happen, the owners of the plants that are managed by NMC have their eyes on one thing: The bottom line. "My owners just care about the price of the fuel," he concluded.

The hydrogen economy

The ANS President's Special Session was titled "The Hydrogen Economy: Partnering with Nuclear for the Future." Introducing the session, President Jim Reinsch called the attendees' attention to the new Nuclear Production of Hydrogen Working Group formed last November within the society's Environmental Sciences Division and encouraged their participation.

Reinsch then introduced Dan Keuter, vice president for Nuclear Business Development at Entergy Nuclear, who served as the session's moderator. He in turn introduced Jeff Serfass, president of the National Hydrogen Association, who delivered brief remarks mainly intended to show that a hydrogen industry already exists. Serfass said that his organization (a trade association) has existed for 17 years and includes 103 businesses as members.

Keuter

Keuter then gave his own presentation on what he called the Freedom Reactor: a 288-MWe modular high-temperature gas-cooled reactor for the production of hydrogen and electricity, with four units installed at a site. He noted that the same electrolysis that extracts hydrogen from water also yields pure oxygen, which is useful in clean-coal technology. The sale of the oxygen would provide another economic benefit. Keuter proposed this design for a demonstration reactor at Idaho National Laboratory, as the Next Generation Nuclear Plant.

Donald L. Paul, vice president and chief technology officer of Chevron Corporation, provided the perspective of the petroleum industry, which would be replaced if the hydrogen economy were to emerge. He expressed skepticism about hydrogen's actually replacing gasoline to any great extent in the near or medium term, mainly because of infrastructure issues. The existing distribution system for petroleum products could

not readily be used for hydrogen, and Paul said that he sees storage as a "major challenge"—which, if not overcome, would bring hydrogen fuel to a dead end. He noted that 105 kilograms of hydrogen, pressurized to 6000 pounds per square inch, needs 1078 cubic feet of storage space, and that an equivalent-energy amount of gasoline needs only 8 cubic feet.

Byron McCormick, executive director for Fuel Cell Activities at General Motors, spoke on the status of fuel cell–powered vehicles and urged the nuclear community to develop reactors for hydrogen production. Stating that personal vehicles are available now to only 12 percent of the world's population and that he expects the share to rise steadily, McCormick said that the use of the internal combustion engine cannot continue to expand without major degradation of the environment. He said, however, "There is no fuel cell industry today," adding that GM is building it by involving small companies. A hydrogen-powered sport-utility vehicle called the Sequel will be road-tested publicly by GM this fall, and other vehicle designs are in development.

The use of the internal combustion engine cannot continue to expand without major degradation of the environment.

McCormick cited one potential advantage of hydrogen: It's the same fuel everywhere—there is no need for summer and winter blends, specific formulas to meet local environmental laws, etc. He projected that $10 billion to $15 billion could fund the setting up of 11 700 hydrogen fueling stations, with a two-mile separation in cities and a 25-mile separation along highways.

With the high-temperature gas-cooled reactor (HTGR) so frequently mentioned as a prime contender to produce hydrogen, it was appropriate that the session included a presentation by General Atomics (GA), the longtime HTGR vendor. Michael Campbell, senior vice president of GA, said that 500 GWe of new capacity would be needed to produce enough hydrogen to supplant petroleum worldwide, and he argued that only nuclear power would be credible as a source for that much generation. He noted the potential problems with hydrogen storage and distribution, adding that any vast nuclear expansion would depend on resolution of waste and fuel issues. He argued, however, that a split cycle of electrolysis and thermal electricity production can produce hydrogen at $1.60 to $2 per kilogram, but he said that there is a "chuckle factor" there, because nobody will believe this until it is actually done. He also said that the TRISO pebble fuel planned for some HTGRs can have low uranium enrichment, can recycle spent fuel and plutonium, and can be used in a thorium cycle.

Kelly Fletcher, leader of the Sustainable Energy Program for General Electric Global Research, looked at hydrogen essentially as energy storage, and he said he thought it is still a "horse race" between hydrogen fuel cells and high-performance electric batteries as to which might ultimately be preferable. Among other things, GE is looking into megawatt-scale fuel cell electricity generators, reversible to produce hydrogen during off-peak hours. GE has also responded, with some utilities, to the Energy Department's request for proposals on hydrogen production with existing light-water reactors. Fletcher noted, in this context, that HTGRs have materials issues that have yet to be resolved.

GE is looking into megawatt-scale fuel cell electricity generators, reversible to produce hydrogen during off-peak hours.

During the question-and-answer session, an attendee wondered whether the Bush administration might be changing its focus from hydrogen to ethanol and asked if oil companies have come to accept nuclear energy. Paul responded that Chevron's position is to explore all forms of energy. To exploit superheavy tar sands, he said, one needs power, heat, and hydrogen—all of which nuclear power might provide.

Workforce training

If the nuclear industry in the United States is to be successful in bringing a new fleet of reactors on line, it should pay attention to the need for specially trained engineers who would ready those reactors for commercial operation. These skilled technicians, called construction test engineers and startup test engineers, are currently in short supply, said Richard Holman, of the Center for Advanced Energy Studies at the Idaho National Laboratory.

Holman

During the session titled "Training, Human Performance, and Workforce Development," Holman said that 400 construction test engineers will be needed by the industry by 2011, and 120 startup test engineers will be required by 2013. The problem, according to Holman, is that the industry is already behind the curve in having enough of them ready for the "new build" era. (For more information on this issue, see the Q&A interview with Holman in our upcoming September issue.)

One tool that might help develop engineers is the "threaded discussion," facilitated by online computers. Lorraine NewHaven, of Westinghouse Electric Company, explained that discussion threads are a form of conferencing that function like an electronic bulletin board, containing "electronic messages that are posted, archived, and viewable on a Web site."

NewHaven

Discussion participants can view both previous and current messages and respond to them in an asynchronous manner, which means "not in real time," she said.

Using as an example a threaded discussion from Westinghouse's online course *Introduction to the Nuclear Power Industry*, NewHaven said that students were involved in a discussion of the question, "Why does the design of pressurized water reactors provide two different means of reactivity control?" In response over a five-day period, the following individual posts were made by six students and two instructors: eight answer posts by students, six additional information posts by students, 11 information posts by instructors, four question posts by students, three question posts by instructors, and eight encouragement or affirmation posts. "These brief statistics demonstrate that collaborative learning is occurring among the eight people that participated in this one thread," she said.

NewHaven noted that learning has been described as a fundamentally social phenomenon and that an online discussion forum contributes to the learning process in the following ways:

■ It provides the social space online to share and discuss information.
■ Posted replies provide feedback or comments from other students or the instructor.
■ Swapping personal experiences provides collective learning.
■ Posting answers to questions allows students to "become" the instructor.
■ Constructing a post is an act of writing, which is a well-documented and powerful learning method.
■ Reading a post is a form of learning.
■ Reflective learning can be achieved during the writing and reading of online posts.

Online courses also can provide an extended time period for learning, which allows "formative learning" instead of "informative learning," NewHaven said.

Kent Hamlin, of the Institute of Nuclear Power Operations, described a tool used to review training programs. That tool, a "vertical evaluation" (VE), can help determine whether a program is appropriately covering the knowledge and skills a worker needs to competently and independently perform a task.


Hamlin

VE provides a means to review selected portions of the "systematic approach to training" (SET) process, Hamlin said, "namely, the analysis, design, development, implementation, and evaluation phases."

VE begins with the selection of a task for review. In selecting the task, consideration is given to how involved it will be in regard to the following areas: initial training, continuing training, its criticality or safety importance, its relevance to operating experience, whether it is specialized, the need to revise or modify it due to plant changes, the chances that new tasks might have to be created for new equipment, whether it requires higher-order cognitive skills to accomplish, and whether it was developed in response to known personnel performance weaknesses.

The next step, Hamlin said, is to review a task-to-training matrix to determine the adequacy of the analysis performed for the selected task. "A complete analysis should result in the identification of the skills, knowledge, and attitudes required" for the safe performance of the job, he said. Next is the design phase, which is examined through a review of learning objectives, tests, and evaluation measures. Continuing along the VE is the development phase, in which the training materials are reviewed for accuracy, quality, clarity, and linkage to the learning objectives.

Following the review of materials comes the implementation phase, allowing the opportunity to observe the conduct of training, instructor performance, and training documentation to determine if they support the previous phases.

The final phase—evaluation—involves the tracking of feedback from "initiation through action" to address training issues and weaknesses, he said.

Hamlin concluded that VE is "a logical, effective, and efficient method to conduct a cross-cutting review of a training program that touches on all phases of the SET process and can provide a sound basis for further in-depth evaluation."

Improving maintenance training through the use of virtual reality (VR) was the topic of Angelia Sebok, a human factors engineer with Micro Analysis & Design in Boulder, Colo. "VR provides a highly visual, interactive environment for personnel to learn the area, the radiation distribution, and to practice their procedures," she said.

Sebok explained that the OECD Halden Reactor Project (HRP), in Norway, has evaluated VR technology for use by the nuclear industry. She said that research indicates that VR technology is effective for teaching the layout of a physical or geographic area and that given sufficient practice, VR-based training of spatial environments is comparable to training in the actual physical environments.


Sebok

Another capability that VR offers is "visualizing the invisible," she said, in that VR allows users to see a physical representation of the radiation distribution in the area. "This type of representation provides a better, more easily understood overview than interpreting individual radiation postings throughout a contaminated area," she said.

Sebok noted that the HRP research also indicates that VR-based training effectively teaches procedural steps and that participants remember this information over time.

She added that VR has two major advantages over procedural training. One is that it can be easily offered immediately before workers perform the tasks, and the other is that a VR model can be easily modified to reflect a variety of situations, unlike physical mockups, which are cumbersome to reconfigure. Sebok summed it up by stating that "VR works."

DD&R issues

A nuclear power plant's decommissioning cost—hundreds of millions of dollars today for an existing reactor—could be cut to tens of millions of dollars if the plant were located underground. During the session titled "DD&R Hot Topics and Emerging Issues," James Mahar, of Idaho State University's College of Engineering, said that the time has arrived to give serious consideration to subterranean plants.


Mahar

The biggest cost saving for such a plant would occur right at the outset: Construction capital costs would be a few million dollars, compared with a few billion for an aboveground plant. Underground plants would be safer, too, both in operation and during decommissioning, Mahar said.

During decommissioning, the plant's highly radioactive metal components could be left in place and a sarcophagus structure built to entomb them. Employing this method would eliminate the associated costs of component transportation and would substantially reduce health and safety risks.

Mahar talked about an idea proposed by Wes Myers and Ned Elkin, of Los Alamos National Laboratory, and before that by Chauncey Starr, the founding president of the Electric Power Research Institute. The idea involves building underground nuclear "parks," each containing multiple reactors, and using superconducting transmission grids to deliver power from these parks (*NN*, Dec. 2004, p. 33). "This concept deserves a more thorough look because of the issues that have arisen lately involving public perception of nuclear power and the concerns for safety from terrorism," he said.

Underground reactors would be built in either thick salt or granite formations, according to Mahar. Costs for excavation in those formations are low. For example, with the cost of excavating 12 000 yd^3 at \$60/yd^3, the price of constructing a subter-

Online courses can provide an extended time period for learning, which allows "formative learning" instead of "informative learning."

ranean plant would be about $2.2 million, he said. Other construction and operational costs could be eliminated because there would be no need for an expensive containment building. Construction costs also could be reduced or eliminated by using existing underground structures, such as empty missile silos and abandoned mineral mines, for most of the containment.

The experience gained from the decommissioning of plants over the past 30 years has shown that little thought was given to that job when the plants were designed.

During his presentation, Mahar displayed an image of a conceptual model of an underground plant. The model contained what he called a "barrier pillow," an area in the mine about 200 feet by 200 feet in size where the reactor vessel would be located, with steam generators placed in neighboring subterranean shafts. "On the ends, of course, you would end up putting in bulkheads in order to restrict access to this area," he said.

The relative inexpensiveness of an underground plant should have utility executives scrambling to sign on because, he said, "If I look at nuclear power plants that cost $2 billion to build aboveground, and I'm looking at about a $2-million investment for an underground plant—that's nothing."

Building new plants that facilitate decommissioning would be a good idea, according to Julia Tripp, of Battelle Energy Alliance. Tripp was making the presentation for Battelle's Richard Meservey, who was not available for the session.

Tripp noted that the experience gained from the decommissioning of plants over the past 30 years has shown that little thought was given to that job when the plants were designed. Because of these design challenges, some decontamination or dismantling activities are difficult to perform, are labor and worker-exposure intensive, and are costly and sometimes dangerous.

Factors to be considered in designing reactors with an eye toward decommissioning are plant layout and access, biological shielding, material specifications, material-handling provisions, surface conditioning and contamination control, and post-shutdown requirements. These design features, Tripp said, could reduce the radiation source and dismantling time, simplify waste management, and provide for safe enclosure and deferred dismantling, if desired.

Tripp stressed that designers should remember the entry/outlet aspect of the plant. For example, a component put into a plant should be able to be removed. "When you put something in, such as a large reactor vessel, that is normally there for the lifetime of the plant, can you get it back out?" she questioned. "In the past, they would sometimes put the vessels in and build a structure around them, and there was no way of taking them out without cutting them up into small pieces."

Tripp suggested that designers look at new plants as if they were workers going in to do a decommissioning job. "There are some slight adjustments that can be made without increasing the footprint of the facility," she said, noting that doing so would make the plant "a lot easier to D&D."

FirstEnergy Nuclear Operating Company's Jim Byrne stressed the importance of maintaining "deep records during the operating life of the plant so you know what you have when it comes time to decommission it." Byrne was involved with the decommissioning of the Saxton plant, in Pennsylvania, which operated from 1962 to 1972 as a research reactor for the nuclear industry.

Byrne said that when Saxton was being decommissioned, radioactive contamination was found in a nearby coal plant. D&D workers did some investigating and were able to find three operators from the coal plant. "Each of these three gentlemen was over 80 years old when we talked to them about how the nuclear plant interacted with the coal plant," Byrne said. "The point is that it's very difficult to find people out there who have clear recollections, so you have to keep good records."

Records need to be continuously updated, he said. In 1993, after work was completed to put Three Mile Island-2 in storage, information about the plant was put on VHS tapes so that records would exist when decommissioning starts. "I have to go through a process now of converting all those VHS tapes to DVDs because VHS tapes don't last forever," he said. "And it's going to go through a different electronic medium in time, as the DVDs will have to be updated to whatever that new medium is."

The presentations were followed by a brief panel discussion during which John Parkyn, chief executive officer of Private Fuel Storage (PFS), gave an update on what is happening in regard to PFS's proposed independent spent fuel storage installation that would be built in Utah.

Parkyn commented that the Nuclear Regulatory Commission had issued an operating license for the project last February. "So we are at the point now where we have support from the utilities to build the facility at any time," he said, adding that it would take two to three years of construction before startup.


Parkyn

Parkyn noted that some members of Congress have expressed an interest in seeing interim storage for spent fuel, but that option is still a political football. "We are ready to go," he said. "Hopefully, we will have that opportunity."

The Galena project

The panel session titled "The Licensing Process and Status of Small Power Reactors" provided a full update of the Galena project, the plan put forward by Galena, Alaska, to power the city with a 10-MWe 4S reactor, a liquid sodium–cooled battery-type unit developed by Toshiba and Japan's Central Research Institute of Electric Power Industry. The concept features a sealed reactor, located underground, with a 30-year core life. The abbreviation "4S" stands for super-small, safe, and simple, although a recent suggestion was made to add a fifth *S*, for *secure*, to describe the proliferation resistance advantage of this system.

The 4S reactor comes in two sizes, 50 MWe and 10 MWe, with the main market being for remote, industrial, and third-world applications.

The session chairman, Phillip Moore, of Burns and Roe, introduced the first speaker, Marvin Yoder, the city manager of Galena, calling him the driving force behind the project. Since he described the project at the 2005 ANS annual meeting, its pace of development has picked up, Yoder said. Over the past year, a series of white papers on the project sponsored by the state of Alaska has been undertaken, and preparations to enter the licensing process have begun.

Map showing the location of Galena, Alaska, proposed site for Toshiba's 4S reactor

Yoder explained the rationale behind the project: Galena, like many communities in Alaska, is quite isolated. There are no roads to the city, which lies in the middle of the state. Outside of summer, the only way in and out is by plane—about an hour and a half flying time to Anchorage and an hour and a quarter to Fairbanks. For about three months in summer, a barge service up the Yukon River brings in diesel fuel for the city's power generators. With the high cost and environmental problems of this form of production, many towns in Alaska are desperate to find alternative sources. Galena residents are now paying an electricity rate of 33 cents per kWh. The cost from the 4S plant is expected to be about 12 cents per kWh. The plant will also sell its waste heat.

Following a series of fortuitous contacts, Yoder began discussions with Toshiba, which sent a team to Galena in August 2003 to present their reactor concept, which is in fact a development of General Electric's PRISM design on which Toshiba had worked in the 1980s and 1990s. At that time, while many who were involved with PRISM had looked to increase the size of the reactor to improve the economics, Toshiba was interested in a smaller version and continued to develop that concept after work on PRISM stopped.

In 2004, the city made the decision to pursue a possible project. At the time, Yoder said, many people discouraged any sort of nuclear project. The recent turn in fortune of nuclear power, however, has changed attitudes, and the inclusion of small reactors in the announcement of the Global Nuclear Energy Partnership (GNEP) has been particularly encouraging, he said. Since Galena started down this path, four other Alaskan municipalities have expressed serious interest. One of them, the city of Dillingham, had a representative at the session.

Last year, Yoder said, the state of Alaska agreed to sponsor a series of white papers at a cost of about $500 000 to assess the proposal and the many issues raised. Galena hired Burns and Roe to undertake the process, which also involved the law firm of Pillsbury Winthrop Shaw Pittman LLP. With the papers nearly completed, Galena is ready to move forward, with 2010 the anticipated date of groundbreaking.

Moore then described the work his company has done putting together the white papers. The 4S reactor comes in two sizes, 50 MWe and 10 MWe, with the main market being for remote, industrial, and third-world applications. It is a liquid-metal reactor containing a 30-year core, which avoids having to store spent fuel on site. A passively controlled system, 4S can be configured as an actinide burner. The basic design calls for the nuclear components to be placed below grade.

The 4S reactor carries on the tradition of liquid metal–cooled reactors, such as EBR-II, which makes it an evolutionary design.

The 4S reactor carries on the tradition of liquid metal–cooled reactors, such as EBR-II, which makes it an evolutionary design.

There had previously been licensing efforts on liquid-metal reactors, particularly the PRISM reactor design, which had gone through a significant regulatory review. The team used the PRISM safety analysis documents as a guide and reference to identify issues and areas that need further review. The aim was to provide responses to the issues raised, and—as this is a small reactor—to look for exemptions or possible arguments to apply different licensing criteria.

There are seven white papers, Moore said, five of which are completed. The remaining two, one on containment and the other on seismic oscillation, are mostly complete, awaiting some technical information. All are available on the Burns and Roe Web site, <www.roe.com>, and the five that are completed are summarized below.

■ An overview paper provides a description of the technology and the site and considers some financing possibilities. The paper recommends completing the design certification and early site permit (ESP) process before applying for a combined construction/operating license from the NRC. This puts much of the risk up front, before significant money is spent. It also recommends the formation of a limited liability company to own the facility and having the city of Galena contract its output.

■ A second paper covers nuclear liability and property insurance. There are two features of the reactor that will keep down the insurance charges: under Price-Anderson legislation, for reactors under 200 MWe, only primary liability insurance is needed (power reactors also pay for secondary insurance); with regard to property insurance, there is precedence for small reactors to have reduced fees. The white paper calculated what the costs might be.

■ A third paper focuses on emergency planning (EP). With a passive design, and with all the nuclear components located below grade within the reactor vessel, which is surrounded by a guard vessel, there are very limited pathways for materials to escape. The study concluded that an EP zone of about 800 m was adequate for this facility and gave the justifications for that. There are several locations in Galena, Moore said, with that much distance available. The analysis also concluded that from an emergency response perspective, it would be

possible to cross train people on site—for example, combining maintenance functions with EP functions—to reduce the number of people needed.

■ The fourth paper covers security issues, including proliferation and terrorism. As with EP, the possibility of multitasking roles would help here. The paper also discusses how first responders could be from the local law enforcement agency. It also makes some recommendations regarding equipment and tactics.

■ Having experience doing decommissioning estimates, including one for the Fast Flux Test Facility, Burns and Roe was able to provide some in-depth cost estimates for decommissioning the Galena 4S, coming up with $33 million–$53 million, depending on the level of contamination of the secondary side and some other contingencies. The paper also looked at funding possibilities that are straightforward—in other words, what the ratepayer would pay. While not exactly side-stepping the spent fuel and recycling issues, the team did assume that there would be some resolution by the time the Galena facility would need to dispose of its first reactor.

Burns and Roe was quite positive about the possibility of limiting the impact of uncertainties and concerns normally raised when licensing a new design. The team has been trying to obtain GNEP funding to pursue ESP environmental work. Yoder had recently testified before a congressional committee on that subject. They are also trying to raise private funding for furthering the licensing process.

The next speaker, Joe Williams, a senior project manager in the NRC's division of new reactor licensing, stressed that the NRC has not had much interaction with the project other than a couple of introductory meetings. He said that he could not speak directly to the technical merit of the design, only on the licensing process. He called the proposed schedule very aggressive. The review time for a design certification is nominally 42–60 months. With regard to the ESP, the review time should be on the order of 30 months, including issuing an environmental impact statement.

For new technology like this, Williams noted, substantial NRC resources would be needed, on the order of 100 FTE (full-time equivalent), he guessed. The AP600 expended over 130 FTE for the design review and cost several million dollars. The NRC review effort, he remarked, is not proportional to the power level, nor inversely proportional to the safety claims, but is governed by the need to verify the claimed level of safety. In a situation where the staff is unfamiliar with the technology, while experience from previous work can be taken into account, the scope of work will be large, and people have to be mindful of that.

Williams also pointed out that the 4S review would compete with other activities. "Frankly," he said, "Galena is going to have an uphill battle, although that is my opinion." He also noted that presently there is no money in the NRC budget for this review.

Matias Travieso-Diaz, from the Pillsbury law firm, explained that it is not only necessary that an ESP procedure be successfully carried out, but that the plant considered is technically and economically viable for the site. If a plant requires 150 people to run it, he said, it will not be viable. Galena will lead the way for discussions with the NRC on a host of issues that will have an impact on economics, such as how big a security force or operating force is needed and how large an EP zone is needed. Galena is doing missionary work for the rest of the industry, he said.

During the discussion period, Moore was asked what the chances were of the project's meeting its planned schedule. He said that Galena wants to get the plant on line by 2015, when the existing diesel generators need replacing. He acknowledged how difficult this may be and that many discussions with the NRC will be necessary before any more schedule planning is possible. He emphasized, however, that "we are planning for success." If the project should get behind schedule, the plan is to install the plant's back-up diesels, which can then be used until the reactor plant is in operation.

As for how many people will be needed on site to operate the plant, he said that by taking advantage of remote-sensing systems, probably about 25 per shift. The white paper actually puts forward a smaller number, as the plant requires little operational or maintenance support and people can multitask. But licensing issues may force the number higher.

Asked for more information on security, Moore noted that 4S was designed originally for use in the developing world and focused on proliferation resistance. Some of the relevant features include the following:

■ Nuclear components are below grade.
■ No spent fuel is stored on site.
■ The pressure vessel head is welded on.
■ A guard vessel surrounds the pressure vessel.
■ A heavy concrete cap is placed over the guard vessel.
■ Liquid sodium is very difficult to handle.

Accessing the reactor would be difficult, he added, as heavy equipment would be needed and any strangers would be noticed in Galena.

As for the project's current status, Toshiba has now prepared the Preliminary Safety Information Document, which is now undergoing an internal review. Burns and Roe will then complete its own review before taking it to the NRC. An important goal for the first meetings with the NRC, Moore said, is to explain the safety bases of this reactor and to convince the NRC that it need not take some six years to complete the licensing process. Toshiba has designed what is substantially a small version of PRISM. This is a brilliant design, he said, with few moving parts, and it should be possible to expedite the licensing process.

Other sessions

Kevin Phillips, mayor of Caliente, Nev., and a supporter of the Yucca Mountain repository project, commented during the session titled "Focus on Communications: Pronuclear Communications" that the way to gain public support in Nevada for nuclear would be to build nuclear power plants in the state. These plants could provide inexpensive electricity to Nevada, subsidized by the sale of power to energy-starved California. As a secondary benefit, the plants' waste heat could be used to desalinate sea water, which could be piped in from the Pacific Ocean. The resulting potable water could then be piped out to farmers' fields across Nevada, turning desert areas into crop-producing lands. These actions, Phillips maintained, would put public support fully behind nuclear. The key, of course, is convincing Nevada politicians to build the nuclear plants.


Phillips

In the session titled "Education and Training: General," Prabhar Munshi, of the Indian Institute of Technology (IIT) at Kanpur, declared that India needs nuclear engineering professors. The problem, he said, is that graduate students often go to work in other industries that offer higher salaries than does the nuclear industry. Munshi told how seven IIT graduate students were hired recently by IBM. "I don't know what they're going to do," he said, "but the higher salaries were enough to lure them away."

IIT, which offers India's only civilian nuclear engineering (NE) program and the country's only master's degree and Ph.D. NE programs, employs only four NE faculty members for its 18 students. The size of the student body could grow, Munshi said, if there were an increase in faculty numbers. Another problem, he said, is that there is a lack of research reactors in India.

Munshi explained that India has another provider of nuclear engineering education—the government's Department of Atomic Energy (DAE)—but that DAE is interested only in running the nation's power reactors. DAE, he said, "doesn't want to have anything to do with radiation outside of government control."—*E. Michael Blake, Dick Kovan, and Rick Michal*