Nuclear News

August 2020

In This Issue:

Two decades of DOE investment lays the foundation for TRISO-fueled reactors

Regulatory history of non-light-water reactors in the U.S.

26th Annual Vendor/Contractor Profile Issue

AMERICAN NUCLEAR SOCIETY


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Westinghouse EnCore® fuel is a game-changing accident-tolerant fuel solution that is intended to provide design-basis altering safety and significant economic benefits, as well as greater uranium efficiency.

As the leading supplier of nuclear fuel globally, Westinghouse has access to a world-class network of research, design and manufacturing partners. We are collaborating to deliver EnCore fuel on an aggressive, accelerated schedule. The pursuit of accident-tolerant fuel is being carried out by an international, multidisciplinary, world-class network of research, design and manufacturing partners. Leveraging the breadth and depth of our resources, combined with U.S. Department of Energy awards, as well as utility funding, we are collaborating with respected industry partners to deliver EnCore fuel to the market. In the spring of 2019, we became one of the first companies to insert lead test rods with accident tolerant fuel manufactured into lead test assemblies into a commercial nuclear reactor.

Learn more about how Westinghouse EnCore Fuel is changing nuclear energy at westinghousenuclear.com

August 2020 | Volume 63, Number 9

Alien landscape? Exotic food? Nope, just a cross-section of a TRISO fuel compact. See page 66 for an in-depth look at TRISO.

Special Report

Special Section

Features

Every Issue

The Utility Working Conference Virtual Summit

This year marks the 26th anniversary of ANS's Utility Working Conference. What is usually a three-day meeting will instead be a one-day online event, held on August 11. To register, go to ans.org/meetings. This will allow for participation the day of the conference, as well as access to videos of the sessions afterward. "Change is inevitable, and we continue learning valuable lessons," said Dan Churchman, general chair of the UWC. "No matter how we spin it, the theme of this year's meeting is now more relevant than ever."

The UWC's theme this year, "It's Go Time: Creating Momentum Toward Transformational Change," speaks volumes about the need to adapt in this time of pandemic. Like many other organizations' conferences, the 2020 ANS Annual Meeting in June was held virtually, and it met with great success, with more than 2,300 attendees participating remotely. And so the UWC will adapt, too.

Churchman, engineering director at Southern Nuclear Operating Company, noted that canceling the annual UWC was not an option because of lessons to be learned and discussions to be had that simply could not wait. He said that while a virtual meeting sacrifices in-person networking, it still allows for bringing some of the best and the brightest together for lively discussions, panel sessions, and presentations.

The UWC's opening plenary session, scheduled from 9:00 a.m. to 11:30 a.m. (EDT), will feature the following speakers:

- Chris Hanson, commissioner, Nuclear Regulatory Commission
- Jeff Place, executive vice president of industry strategy, Institute of Nuclear Power Operations
- Tim O'Connor, senior vice president and chief nuclear officer, Xcel Energy
- Maria Lacal, chief nuclear officer, Arizona Public Service
- Scot Greenlee, senior vice president of engineering and technical support, Exelon

The schedule for the educational sessions throughout the day is packed. One of the major benefits of a digital meeting is that when sessions that interest you are presented simultaneously, you can participate in one of them and go back later to watch the recordings of the other sessions.

We hope that next year's UWC can take place live and in-person at Marco Island, Fla. Meanwhile, we hope to "see" you at the virtual UWC!—*Rick Michal, Editor-in-Chief*

UWC Educational Session Schedule

12:00 p.m.–1:30 p.m. (EDT)

- A Not So Random Walk Down Nuclear Industry Operating Cost Data
- Innovative and Historical Approaches to Decommissioning
- XCEL Energy/DOE/INL Transformational Project
- Digital Implementation (Part 1): Evolving Digital Modification Strategies for Significant Cost and Risk Reduction
- Automated Work Scheduling
- Inventory Management Workshop
- Equipment Operator and Initial License Operator Training Program Redesign Workshop
- Performance Data Analytics and Visualization
- Subsequent License Renewal (SLR): Is 80 the New 60?
- Incorporating FLEX into PRA Models
- The Democratization of AI: Using AI/ML to Assess Risk, Perform Inspections, and Make Decisions

2:00 p.m.–3:30 p.m. (EDT)

- SOUL Knowledge Management Platform
- Status of Decommissioning Projects in Progress and Completed to Date
- Exelon/DOE/INL Transformational Project
- Digital Implementation (Part 2): Evolving Digital Modification Strategies for Significant Cost and Risk Reduction
- Optimized Procurement Descriptions Workshop
- Artificial Intelligence: Improving Corrective Action Program and Work Order Generation and Screening
- NRC Transformation
- Insights into DOE Research, Human Factor Engineering Strategy for Phased Main Control Room Modernization, and Cutting Edge Technology

4:00 p.m.–5:30 p.m. (EDT)

- Capital Investment Analyses from Fukushima to Today
- Nuclear Industry Security Transformation to Reduce Costs
- Expanding the Use of Monitoring and Diagnostics Centers to Integrate with Work Management
- Diversity in Nuclear Supply Chain Workshop
- Use of e-Learning Workshop
- Contemporary INPO Performance Improvement Efforts
- Advanced Reactors: Innovation in Nuclear Technology Needs Agile, Efficient, and Predictable Regulatory Framework

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to continue to provide safe, reliable nuclear energy.

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Palo Verde Generating Station

NEI Awards

Arizona Public Service
Palo Verde Generating Station

Ameren Missouri
Callaway Energy Center

Dominion Energy
Surry Power Station

Exelon Nuclear Generation
Corporate

Southern Nuclear Operating Company
Alvin W. Vogtle Electric Generating Plant

Vendor Awards

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PSEG Nuclear LLC
Hope Creek Nuclear Generating Station

GE Hitachi –
Tennessee Valley Authority
Browns Ferry Nuclear Plant

Westinghouse –
American Electric Power
Donald C. Cook Nuclear Plant

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Arizona Public Service
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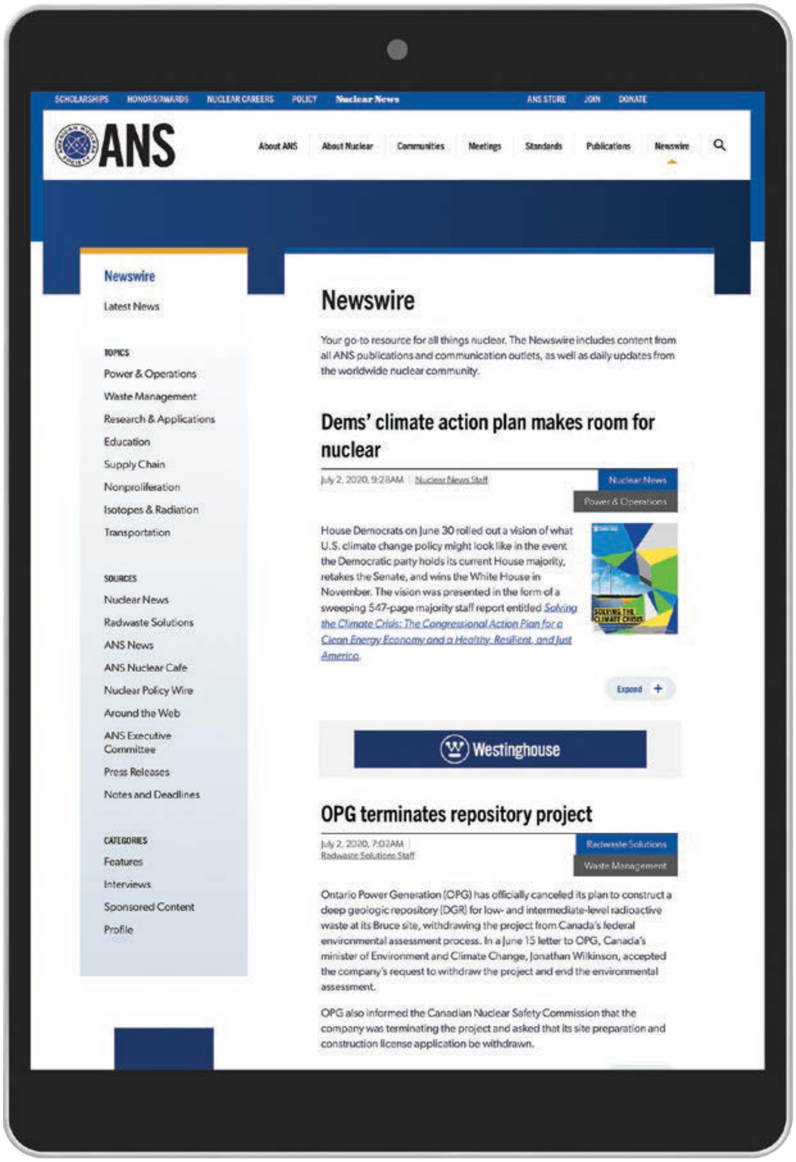
News flash!

As part of our promise to offer new membership benefits, we created ANS Newswire, a daily news feature to get you up to speed on nuclear news in this 24-hour news cycle.



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Advertising in *Nuclear News* over the decades

Our latest Vendor/Contractor Profile issue presents the perfect opportunity to recognize our advertisers: the vendors, contractors, and other nuclear community members whose tremendous support over 60 years has helped us fill the pages of *Nuclear News*. Let's take a closer look at the numbers behind the ads.

1960

First advertiser

Central Research Laboratories

1961

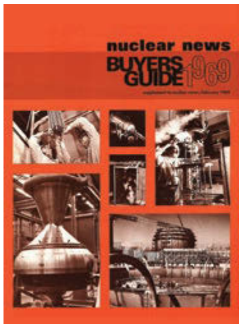
First two-color ad

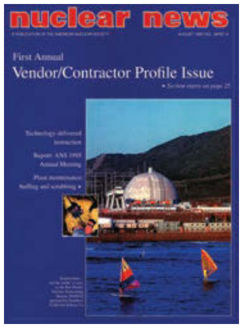
Technical Measurement Corporation

1969

First Buyers Guide with 556 companies in 242 categories

Our 2020 Buyers Guide had 700 companies in 483 categories.





1995

First August Vendor/ Contractor Profile issue

The 2011 and 2012 issues set a record with 90 advertisers each.

Nearly

$75 million

Lifetime advertising revenue

A much larger total than typical association publications generate.

1,600+

Unique advertisers

Nuclear News proudly partners with vendors and organizations to help keep the worldwide nuclear community informed about their products, services, courses, conferences, trade shows, and employment opportunities.

38,415

Total ad pages sold through August 2020

1981 had the highest number of ad pages, with a total of 1,731.

206

Total number of advertisers over the last 24 months. Thank You!

Establishing a collaborative culture of innovation

By Kurt Mitchell

A company's leadership drives its culture, and a company's culture can drive it to lead an industry. Curtiss-Wright, like many other suppliers, has supported the nuclear power industry since the first commercial plant in the United States came on line more than a half-century ago. Since then, these corporate leaders have played a key role in helping to shape the industry itself.

Kurt Mitchell is vice president and general manager of Curtiss-Wright's Nuclear Division.

Today, the nuclear industry is at an inflection point. Low natural gas prices and reduced energy demand illustrate the challenging market conditions facing both plants and suppliers. Subsequent license renewals and next-generation nuclear plants could soon pave the way for a much brighter future; however, this revival will be realized only if the nuclear community succeeds at developing new plant equipment and technologies that enable the transformation needed to sustain the industry. As existing reactors gain approval for life extensions and next-generation nuclear plants move closer to licensing and operations, the nuclear industry must find solutions to both new and ongoing challenges, such as obsolescence and equipment aging, streamlining operations and maintenance, and reducing generating costs—all the while sustaining reliability, safety, and efficiency. I believe the key to the future of nuclear is innovation, and having the right company culture to drive innovation is critical.

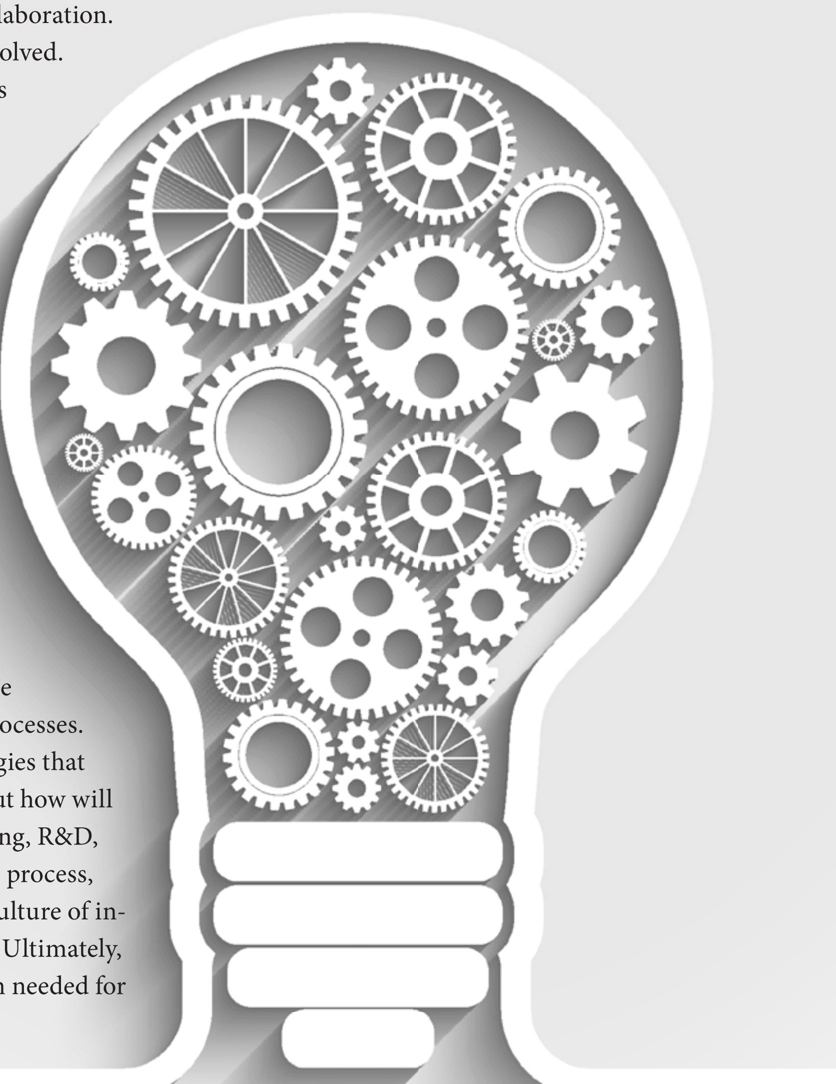
My own company owes much of its success to its history of innovation and entrepreneurship. We can trace these elements back to Curtiss-Wright's namesakes. Glenn Curtiss and the Wright brothers were pioneers in aviation thanks in no small part to their successes in innovation. This spirit of innovation and entrepreneurship has continued over the years, illustrated by my division's growth through the acquisition of private companies. Despite each possessing its own business philosophies and values, these legacy organizations all shared a common thread: innovation-centric company culture that led to their leadership in the market.

Innovation cannot thrive in a bubble. Success requires involvement from all levels of an organization. Innovative concepts and solutions don't just come out of R&D labs. Successful ideas for innovation can come from the people that manufacture, install, and service equipment, too, often inspired by firsthand experience with a problem and unique insight into potential solutions. In other words, many great innovations come from people whose primary role is not to innovate. Our responsibility as leaders is to reinforce a culture where all employees have the opportunity to learn, share ideas, and solve problems. Is the team that's building widgets encouraged to generate ideas for new widgets and think of better ways to make widgets? Leaders can empower their employees to develop new ideas by creating a company culture that promotes, nurtures, and rewards innovative thinking.

Many companies have established internal structures and processes to drive innovation at the leadership level and throughout their entire organization. Innovation should be a key performance indicator in management's performance goals. For example, at Curtiss-Wright, our corporate leadership team champions CW Innovation, an internal platform that facilitates company-wide collaboration and the generation of ideas for new products, process improvements, and efficiency drivers. The program also creates an internal framework to take an initial concept through to development or implementation. But that isn't enough: The bigger goal is to carry this culture of collaboration and innovative thinking beyond the organization and into the nuclear industry.

Innovation and new product development in the nuclear power industry bring unique challenges. Development life cycles are both lengthy and costly, and future demand is uncertain. Investing in a new product for five to 10 years without knowing if it will be commercially successful takes patience, commitment, and vision. For this reason, it is important that the nuclear industry embrace a culture of not just innovation, but collaboration.

Customer-supplier collaboration benefits all parties involved. Nuclear plants identify specific challenges and pain points and collaborate with suppliers to develop brand-new products—or adapt existing technologies—that solve those problems. The plants are able to leverage the suppliers' capabilities and resources while reducing their share of the risk. The suppliers, in turn, gain valuable insight into the plants' needs—information that they can use to better align product portfolios and production. Many of the most widely adopted nuclear power products developed by corporations are the result of customer-supplier collaborations. Within the Curtiss-Wright Nuclear Division, we have a structured Innovation Cooperative Program that utilizes lean methodology and rapid prototyping principles to accelerate problem solving and identify effective solutions for our customers.



As mentioned, our industry is at an inflection point. The future of nuclear requires transformative products and processes. Nuclear power needs innovative equipment and technologies that enable safe, efficient, and reliable long-term operations, but how will these products and solutions be realized? Strategic planning, R&D, and investment capital will all play significant roles in the process, but company leaders must create, reinforce, and affect a culture of innovation and collaboration between plants and suppliers. Ultimately, this culture will drive the innovations and transformation needed for the nuclear industry to thrive.

ANS's Professional Engineering Examination Committee

By Joshua Vajda, Steven Arndt, and Nathan Carstens

The American Nuclear Society's Professional Engineering Examination Committee (PEEC) is responsible for developing the national professional engineering examination for nuclear engineering. This activity provides a path for those educated and experienced in nuclear engineering to qualify for a professional engineer (P.E.) license. PEEC conducts all interface activities between ANS and the National Council of Examiners for Engineering and Surveying (NCEES), which administers the exam.

The committee is composed of 30 members, each of whom is required to be licensed as a professional engineer in at least one state.

Why become a nuclear P.E.?

Becoming a P.E. shows a professional commitment that helps distinguish between engineers. Fewer than 5 percent of newly degreed engineers become licensed. Surveys have shown that engineers with a P.E. license have higher average salaries than those without.

A P.E. is held to a high ethical standard that can be enforced by the state licensing boards. While ethics is important for any engineer, nuclear engineering is a high-visibility field where the welfare of the public is always at the forefront. Becoming a P.E. shows a commitment to high ethical standards in a field where retaining the trust of the public is crucial.

Much of the Principles and Practice of Nuclear Engineering (PE) exam builds upon undergraduate academic studies. Many engineers rapidly specialize within their field after leaving academia. This can make taking the broadly based PE exam a more significant investment in review time. Taking the PE exam as early as possible tests you on this technical material while it is still fresh in your mind.

Some states are now relaxing the experience requirements for taking the PE exam (experience is still needed before the P.E. license can be awarded). NCEES recently amended its Model Law, a set of best practice guidelines, to remove the requirement of four years of experience before taking the exam.

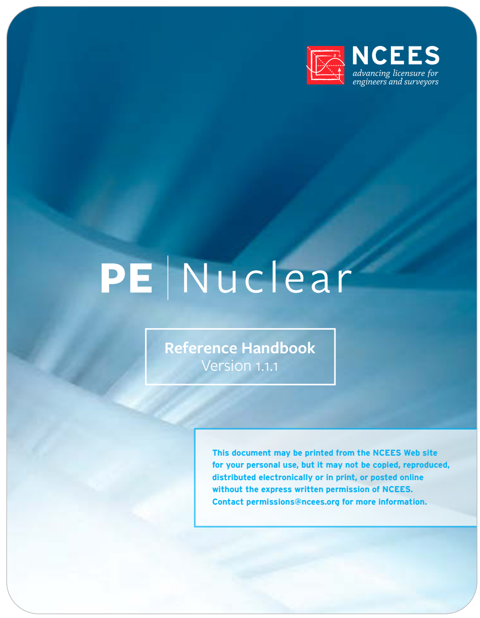
PEEC's meetings

PEEC typically meets three times at each national meeting: an exam development workshop, a new member and/or refresher training session, and a committee business meeting. An additional session may be scheduled on an ad hoc basis to address emergent needs. A subset of the committee also meets twice a year at NCEES headquarters in Greenville, S.C., specifically for exam development activities. For these meetings, NCEES provides funding for 15 PEEC members to attend a two- or three-day exam development workshop.

The breadth of the PE exam and the time required to create and review new questions for the exam dictates a large committee. The care needed in writing exam questions and the limited time available for training new writers and reviewers of exam questions have made recruiting and retention of new members a challenge. Over the past two and a half years, PEEC has aggressively sought to increase diversity on the committee. For example, prior to 2017, PEEC had only one female member. In early 2018, the committee added three additional women, and in 2019, two more women joined the committee, so that now 20 percent of membership is composed of women. PEEC is committed to recruiting underrepresented minorities so that members represent a broad cross section of licensed nuclear engineering professionals.

PE exam

The PE exam is offered in an 85-question computer-based test (CBT) format that was first administered on October 19, 2018, at Pearson VUE testing centers throughout the United States. (The very first PE nuclear exam, which was of the pencil-and-paper variety, was administered in the fall of 1973.) PEEC developed the *PE Nuclear Reference Handbook*, which is the only reference allowed for CBT. Version 1.1.1 of the handbook is available, free of charge, on the NCEES website (ncees.org/engineering/pe/nuclear/). More than 2,500 copies of the handbook have been downloaded as of the end of May 2020.



With the conversion of the PE exam to CBT, ANS and NCEES entered into a formal memorandum of understanding (MOU) that articulates the division of responsibilities for PE examination activities. Starting in fiscal year 2018, NCEES assumed full financial responsibility and liability for exam development activities for the PE exam. Because of exam security requirements, all exam development activities now occur exclusively at NCEES headquarters. Under the new MOU, ANS continues to provide committee leadership and subject matter experts for NCEES's Nuclear Exam Committee, as well as lead all exam promotion and exam preparation activities, such as the maintenance of ANS's PE Nuclear Exam Study Guide and the PE Nuclear Exam Preparation Module Program.

Primary activities

- *Preparing exam questions for use in a unique annual national PE exam.*

Each exam question (also referred to as an "item") requires an author and two reviewers and must be approved by the PEEC chair. A five-hour workshop held in conjunction with each ANS national meeting was traditionally one avenue for supporting exam development activities. However, because NCEES has assumed exam development, all activities requiring access to the entire pool of potential questions (also known as the exam bank) now occur exclusively at NCEES headquarters.

NCEES also provides a secure online collaboration tool between PEEC meetings to support limited exam development activities that do not require access to the exam bank. A workshop conducted at

Spotlight On continues

ANS Annual Meetings continues to be used for exam development activities that can be performed outside of NCEES headquarters, including review and revision of the reference handbook and preparation and maintenance of the PE practice exam.

■ *Promoting participation in the PE exam.*

PEEC actively promotes licensure for ANS members and nuclear professionals in general. At least one PEEC member attends the annual ANS Student Conference to promote licensure at the career fair and presents a lunch-and-learn session when available. The committee publishes articles in *ANS News* and posts reminders of PE exam registration deadlines in ANS broadcasts. Individual committee members also facilitate information blurbs within their places of employment, and at least one PEEC member has published an article on licensure on the ANS Nuclear Cafe blog. This year, PEEC has used social media to promote engineering licensure and to publicize exam preparation workshops and exam preparation materials, as well as important dates for registering for the PE exam.

PEEC worked with the ANS marketing staff to develop a one-page flyer and a bi-fold brochure promoting the PE exam and the ANS-sponsored exam preparation workshop. In addition, the committee worked with staff to develop promotional material for the Fundamentals of Engineering (FE) exam, which is the first examination required for qualification for P.E. licensure. The FE exam is usually taken by engineering students during their senior year.

PEEC promotes engineering licensure and recognizes professional engineers at national meetings by providing a "Professional Engineer" ribbon that is affixed to the name badge of licensed P.E.s.

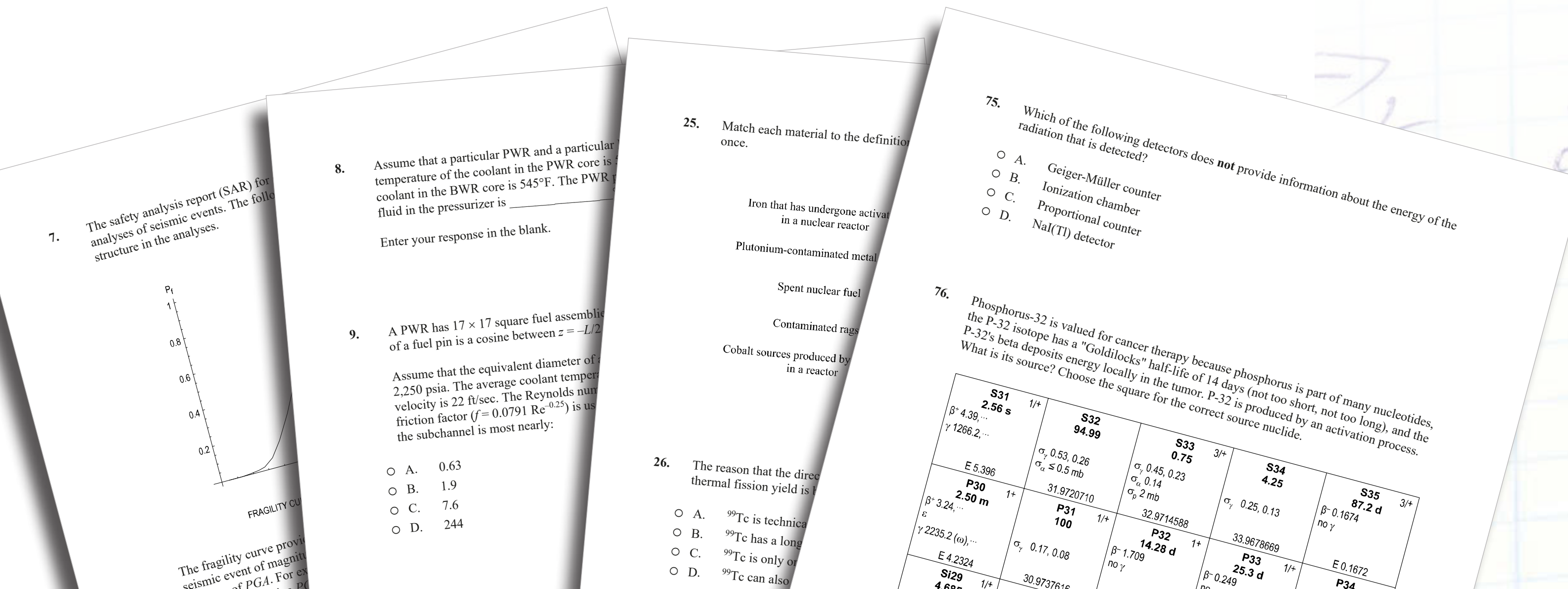
■ *Developing and maintaining the ANS-published PE exam study guide.*

The PE Nuclear Exam Study Guide was revised in 2018 and is available for purchase from the ANS website (ans.org/store/item-690025/). A major overhaul of the study guide is planned to begin in the fourth quarter of this year to better align content with the reference handbook.

■ *Providing PE exam preparation materials via online modules.*

In 2019, PEEC members developed a new study aid to help prepare engineers who are interested in becoming licensed in nuclear engineering. The PE Nuclear Exam Preparation Module Program is a comprehensive study resource. The video-based online program replaces and expands on the PE exam study workshop formerly held each June at the ANS Annual Meeting. Each module presents content that follows a list of learning objectives and is aligned with the PE exam specifications. Study modules are available for purchase at ans.org/pe/modules. The module program is divided into four specification areas:

1. Nuclear Power Systems covers steam, fluids, pumps, heat exchangers, and probabilistic risk assessment.
2. Nuclear Fuel Cycle covers fuel enrichment, fuel bundle design, transmutation, fuel burnup, waste storage, and waste disposal.
3. Interaction of Radiation with Matter covers buildup factors, radiation effects on materials, shield-



ing design, dose assessment, and personnel safety.

4. Nuclear Criticality/Kinetics/Neutronics covers criticality safety, point kinetics, and reactor core analysis.

A General Knowledge module provides an introduction, general information, and science background material.

In addition to the ANS online modules program, NCEES offers a PE practice exam that was developed by PEEC members and was completed in April 2020. The practice exam contains 85 questions from past exams; simulates the format, style, and level of difficulty of exam questions; and provides solutions to enhance examinee understanding for each topic area. The practice exam is available for purchase through a link provided on the NCEES website (account.ncees.org/exam-prep/).

PEEC's goals

PEEC has set the following goals for the next three years:

- Continue to fulfill its commitment with NCEES to produce a unique and high-quality PE exam annually.
- Maintain and revise the *PE Nuclear Reference Handbook*, as necessary.
- Continue to provide exam preparation material, such as the online modules program, to prepare candidates for the exam.
- Maintain and update the PE Nuclear Exam Study Guide, as needed. A major revision of the study guide will begin in fourth-quarter 2020 to align material and content with the recently approved new NCEES exam blueprint.
- Continue to recruit new members to PEEC, with a focus on recruiting newly licensed P.E.s and underrepresented groups.
- Continue to actively promote the PE exam to increase participation.

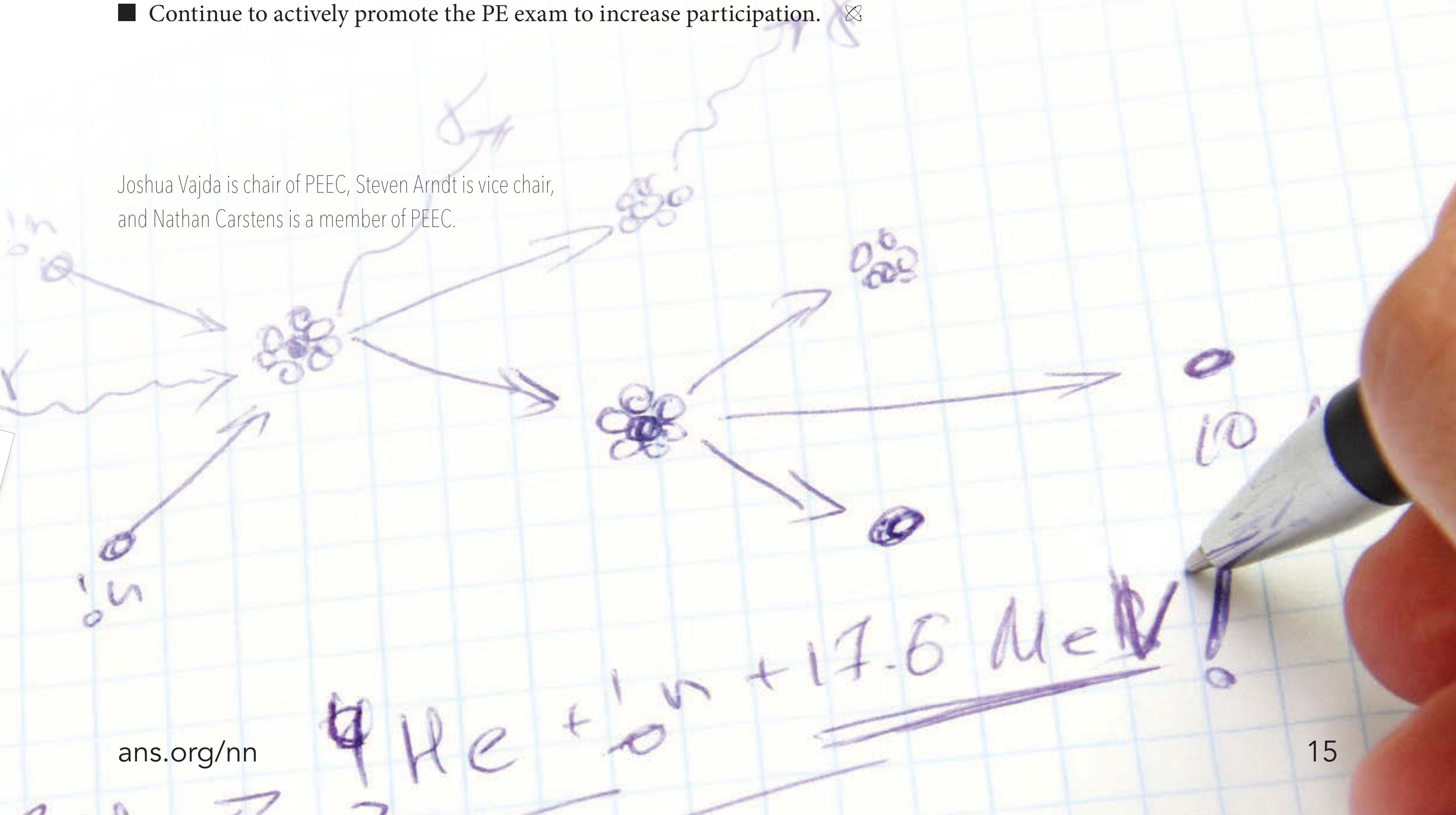
Joshua Vajda is chair of PEEC, Steven Arndt is vice chair, and Nathan Carstens is a member of PEEC.

Want to become a nuclear P.E.?

The Principles and Practice of Nuclear Engineering exam takes place once a year in October. The date of this year's exam is October 22. Candidates may reserve their seat up to a year in advance at a Pearson VUE test center once they are registered with NCEES and approved by the NCEES board. Candidates are encouraged to reserve their seat for the exam as early as possible.

ANS and NCEES offer materials for purchase that prepare candidates for the exam:

- PE Nuclear Exam Study Guide (ans.org/store/item-690025/).
- PE Nuclear Exam Preparation Module Program (ans.org/library/item-pemodules/).
- PE Nuclear Practice Exam (account.ncees.org/exam-prep/384).
- *PE Nuclear Reference Handbook*, available free of charge. (Register or log in at account.ncees.org/login to download the handbook.) For more information, visit ans.org/peec.



Equal by 30 has a partner in ANS

Achieving gender equality in the clean energy sector by 2030 is the goal of Equal by 30, a campaign of the Clean Energy, Education and Empowerment (C3E) International Initiative. ANS joined the campaign on June 25 and is now one of over 145 public and private sector organizations committed to taking concrete action toward achieving equal pay, equal leadership, and equal opportunities for women in the clean energy sector by 2030.

"As the voice of nuclear engineers and scientists, ANS is committed to taking action for achieving gender equality in the workforce," said ANS President Mary Lou Dunzik-Gougar. "Women must be encouraged and recognized for the contributions they make in nuclear science and technology."

Equal by 30 was launched in May 2018 at the Clean Energy Ministerial (CEM) in Copenhagen. It operates under the banner of C3E, which is a joint initiative launched in 2010 by the CEM and the International Energy Agency to encourage greater gender diversity in clean energy professions.

ANS's commitment to Equal by 30 is not the Society's first public pledge to support gender equality. Immediate Past President Marilyn Kray joined Gender Champions in Nuclear Policy in 2019, and Executive Director/CEO Craig Piercy now represents ANS as one of more than 50 Gender Champions.

For more on the Equal by 30 initiative, visit equalby30.org.

ANS backs DFC move to permit nuclear investments

The U.S. International Development Finance Corporation (DFC) has proposed eliminating legacy prohibitions against financing international nuclear power projects, and ANS Executive Director/CEO Craig Piercy lodged his support for the move in a letter submitted to the DFC on July 2.

"Supporting nuclear power projects abroad is essential to help the world achieve a low-carbon future and to help the U.S. solidify its place among the world's energy leaders," Piercy said. "I urge you to remove the legacy prohibition on support for nuclear energy projects in developing countries."

The DFC's change to its Environmental and Social Policy and Procedures, proposed and

ANS backs DFC continues on page 18

ANS PRESIDENT'S COLUMN

What does "clean" mean to you?

Have you wondered why, in this age of climate alarmism, nuclear isn't considered *the* choice for clean power production? You seldom hear nuclear mentioned in the same context as wind, solar, and hydropower. Yet nuclear is the cleanest and safest form of energy today that is both reliable and scalable.

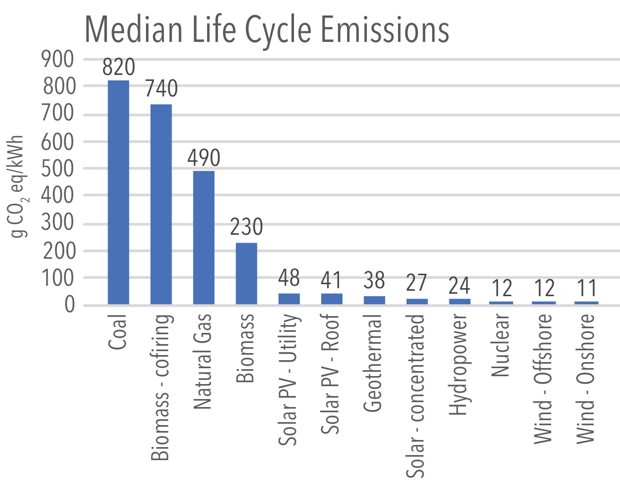
The answer to the "why" question has many facets, but I would like to focus on one area in which we all can make a difference: the public perception of nuclear. Most people, including policy-makers, don't consider nuclear a clean source of energy. As nuclear professionals, we have an opportunity to raise the level of public understanding about the many benefits of the technology. Over the next few months I will address specific benefits of nuclear, with supporting facts and figures (we scientists and engineers love our data!), to empower every ANS member to proudly and confidently raise nuclear to the forefront of discussions about clean energy.

This month, the topic is "clean." Clean can mean something different for each audience. If carbon is your concern, nuclear is as clean as wind power and cleaner than all other power types, when you consider emissions across the entire life cycle of the energy source.

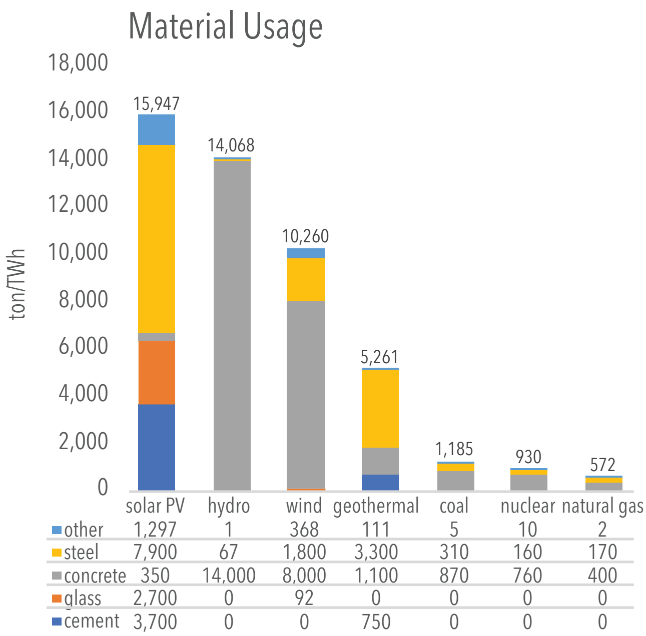
As data from the U.S. Department of Energy and the Breakthrough Institute confirm, nuclear is also a winner in terms of land usage, fuel footprint (inverse energy density), and material usage.

Because of low material and land usage (for both power plants and fuel production), it follows that the amount of waste produced by nuclear is also the smallest. Higher-energy-density fuels release higher-density waste streams, but *all* energy production creates some sort of harmful waste.

According to data from the Department of Energy and the U.S. Energy Information Administration, for one year of generation, a 1,000-MWe nuclear plant produces about 20 tons of spent nuclear fuel, about 175 tons of depleted uranium, and about 500 m³ of low-level waste. By contrast, a 1,000-MWe coal plant produces about



Source: Climate Change 2014: Mitigation of Climate Change – Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Table A.III.2 (ipcc.ch/report/ar5/wg3/)



ANS President's Column continues on next page

ANS President's Column continues

300 tons of SO_2 and about 5 tons of fly ash *per day*. Production of 1,000 MWe for a year from wind results in about 36,000 tons of used turbine blades, and that's assuming all other turbine components are recycled. The same amount of electricity from solar photovoltaics results in about 10,700 tons of used solar panels, which leach cadmium into the environment both during and after use when exposed to rainwater. While waste from nuclear power plants is well managed, the same standards do not apply to waste from other power sources.

I'll have more to say about waste in future months, along with other attributes of safe, reliable, and scalable nuclear energy. Talk to you then!—*Mary Lou Dunzik-Gougar (president@ans.org)*

ANS backs DFC continues

opened to 30 days of public comment on June 10, was based on a recommendation from the U.S. Nuclear Fuel Working Group's April 2020 report on "Restoring America's Competitive Nuclear Energy Advantage."

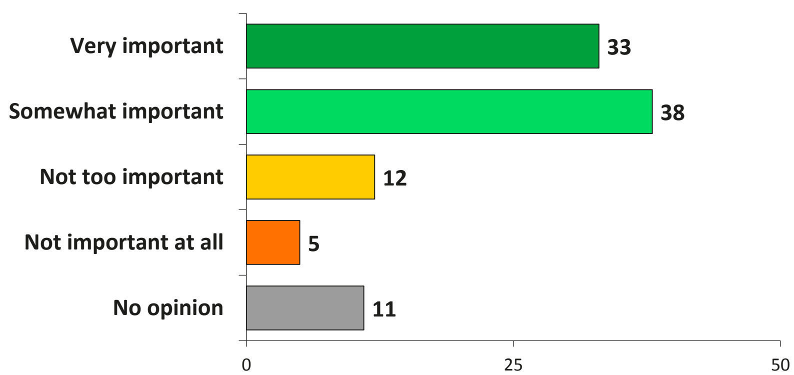
Investment in nuclear development overseas will promote U.S. goals in foreign policy and advance global safety standards, Piercy said, since state-owned enterprises in Russia and China currently dominate the global nuclear market. With that market valued at $500–$740 billion over the next 10 years, nuclear exports could be an engine for U.S. job growth.

"Sustainable economic development abroad depends on access to clean and reliable electricity, and nuclear energy—in tandem with wind, solar, and other renewables—can effectively meet this requirement without adding to global pollution levels and harming public health," Piercy said.

Visit ans.org/policy to read the letter and for more information about ANS's participation in U.S. and international public policy discussions.

Polling shows substantial support for nuclear energy

Sixty percent of respondents in a recent national survey from Bisconti Research favored the use of nuclear energy, with only 25 percent opposing its use. When asked what the primary focus for the United States should be in meeting the nation's electricity needs, 75 percent of respondents chose an energy mix that included nuclear energy.



Importance of nuclear energy in meeting U.S. electricity needs. Graph: Bisconti Research Inc.

These data and more were gathered in an online survey of over 1,000 U.S. adults conducted by Bisconti Research in mid-June, together with Quest Global Research. Ann Bisconti, president of Bisconti Research, has tracked public perception of nuclear power using a consistent set of questions since 1983 and has seen the favorability of nuclear grow since the mid-1990s.

"Reliable and affordable electricity and clean air are top considerations for electricity production, and Americans believe we should make

Polling continues on page 20

The U.S. nuclear supply chain: Time to start the climb

Dear reader:

Let's face it. The U.S. nuclear manufacturing and supply chain is not what it once was. In the 1960s and '70s, America was the dominant player in the global nuclear industry. Under the auspices of Atoms for Peace, U.S. companies successfully provided reactor systems and associated services to countries across the world and held significant sway over the course of future nuclear development in the international arena. America was at the top of its nuclear game.

Then came a series of rogue waves. Cost overruns, India's "peaceful" nuclear explosion, Three Mile Island, public opposition, increasing international competition, advancements in wind and solar technology, cheap natural gas, paralysis in nuclear waste policy—take your pick: all have conspired to fundamentally harm the vitality of our nuclear "Team USA."

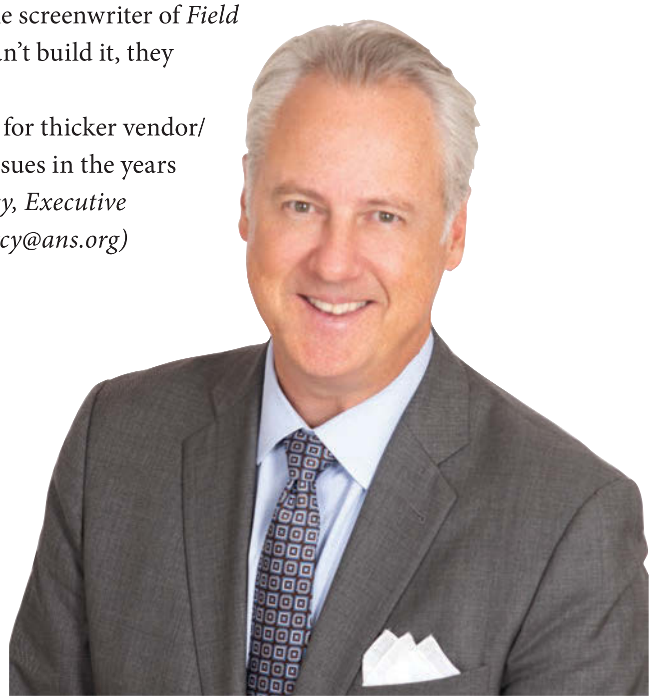
Today, the U.S. sector is clearly much smaller as a result; you need only look at the decreasing thickness of recent *Nuclear News* vendor/contractor profile issues for confirmation. Buffeted by utility cost-cutting domestically, well-funded state-owned competitors internationally, and now a global pandemic and widespread economic disruption, many U.S. suppliers are holding on for dear life.

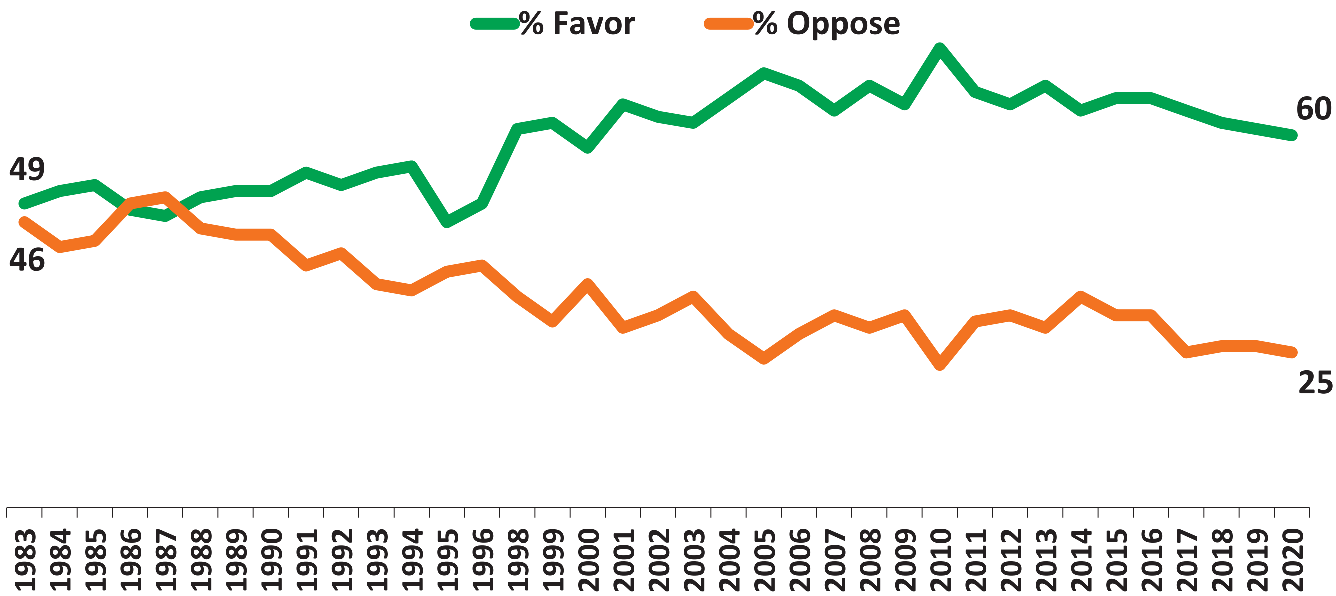
But there is light on the horizon. Almost every major U.S. utility has publicly pledged to aggressively decarbonize their generation portfolios between now and 2050. In the aggregate, those pledges, if honored, would reduce carbon emissions by nearly 90 percent from current levels! From today forward, any utility or state government thinking about closing an existing nuclear plant must face not only the technical feasibility of doing so in a reliable and affordable way, but also the stark climate math of making good on public promises.

There is similar cause for optimism on the nuclear technology front. Advanced reactor designs are making headway through the Nuclear Regulatory Commission's licensing process as I write, raising the chances of real domestic commercialization activity in the latter half of the 2020s. While the supply chains for these systems remain somewhat aspirational for the moment, the idea that public investment can "preheat" the U.S. nuclear manufacturing sector is getting greater recognition in the halls of the Department of Energy and Congress.

Ultimately, as members of a U.S.-based professional society devoted to applied nuclear science and technology and the men and women who advance it, we have a unique responsibility to ensure that the public and its elected leaders see a reinvigorated nuclear manufacturing sector as absolutely essential to the nation's ability to tackle climate change. Put simply, and with apologies to the screenwriter of *Field of Dreams*: "If we can't build it, they won't come."

So here's wishing for thicker vendor/contractor profile issues in the years ahead.—*Craig Piercy, Executive Director/CEO (cpiercy@ans.org)*





Favorability of nuclear power in the United States since 1983. Graph: Bisconti Research Inc.

Polling continues

maximum use of clean air energy," concluded Bisconti. "The finding that 75 percent would give priority to energy mix options that include nuclear energy (the remaining 25 percent would support giving priority only to renewables), indicates that nuclear energy and all energy sources should be considered in the context of how they—together—contribute to providing reliable, affordable, and clean electricity for America."

Bisconti said she is encouraged that "broadly favorable attitudes toward nuclear energy extend across demographic groups, including both Biden and Trump likely voters." Bisconti also noted in her research that communication is essential, because many participants are "fence-sitters, whose attitudes are highly changeable." She also found that "feeling informed is strongly correlated with favorability to nuclear energy."

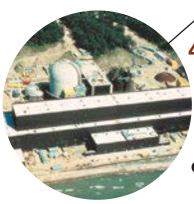
Bisconti reported on the results of last year's survey results in the July 2019 issue of *Nuclear News*, in an article that is now available on the ANS Newswire, at ans.org/news/.

Nuclear Notables—August

Czech landmark
Dukovany, the second nuclear plant in Czechoslovakia and the first in what is now the Czech Republic, entered commercial operation in 1985

On the Eastern Seaboard
New Hampshire's Seabrook saw its commercial start in 1990, more than 14 years after construction began

1970 1980 1990 2000



45 years ago
Cook-1, a PWR in southwest Michigan, had its commercial start

30 years ago
Comanche Peak-1 began commercial operation about 60 miles southwest of Dallas, Texas

1995 A *Nuclear News* first
The Vendor/Contractor profile issue debuted 25 years ago

Did you know?

ANS and NEI are collaborating on advanced reactor standards

More than 400 people attended a June 23 virtual workshop on advanced reactor codes and standards hosted by ANS and the Nuclear Energy Institute. Advanced reactor developers, the Department of Energy, and the Nuclear Regulatory Commission are focused on accelerating joint efforts to support near-term advanced reactor demonstrations. It's against that backdrop that the workshop was convened to ensure the alignment of advanced reactor developers' needs with the priorities of codes and standards development organizations.

Immediate Past ANS Standards Board Chair Steven Arndt, of the NRC, and Marc Nichol, NEI's senior director of new reactors, took the lead on organizing the workshop. Turn to page 132 for a recap of workshop discussions and conclusions.

AMERICAN NUCLEAR SOCIETY ANS

NEI NUCLEAR ENERGY INSTITUTE

I&C vendor insights: safety digital technology selection to win the energy market

Commercial nuclear power plants in the United States (U.S.) face tough competition from sources of alternative generation (e.g., solar, wind, etc.), cheap natural gas, especially in the unregulated market. It is recognized that 35 percent of the U.S. nuclear power plants, representing 22 percent of U.S. nuclear capacity, are at risk of early closure due to economic factors. Plant operators have been reluctant to adopt modern digital technologies for safety-related systems even though these technologies offer many benefits to improve safety and reliability, as well as achieve operating cost reductions.

Significant changes have also been made to improve the U.S. regulatory environment to support the deployment of modern digital technologies through the U.S. Nuclear Regulatory Commission (NRC) digital instrumentation and controls (I&C) Modernization Plans. The changes have sharpened the NRC regulatory review criteria to clearly identify the key safety principles that must be addressed. These improvements were made after a thorough review of lessons learned from recent projects, including the improved review standard used for small modular reactor reviews.

NRC has also improved the processes used to review and approve safety-related I&C modernization projects (i.e., the license amendment review process). The changes were made to address the lessons learned from the reactor protection and engineered safety features actuation system modernization license amendment reviews for several projects, including Duke Energy's Oconee Nuclear Station and Pacific Gas and Electric's Diablo Canyon Power Plant modernization projects.

These recent developments in the industry may open the door for plant operators to adopt modern digital technologies for safety-related systems to address I&C obsolescence and to improve their competitive position. Previous obsolescence management strategies to keep analog safety-related I&C viable as long as possible prevented plant operators from reaping the benefits of modern digital technologies. Plant operators now have the choice to address I&C obsolescence, improve overall plant safety and reliability, and decrease the levelized cost of electricity. There is now a path forward for the operating nuclear fleet to maintain the emission free, always-available electricity as an integral part of the future energy mix.

Plant owners now have to understand how to choose from the many I&C vendors and excellent technologies available in the nuclear market. The choice can be daunting, complicated, and time consuming. Radics LLC, an international nuclear engineering company, develops and supplies advanced customized I&C solutions. Their experience in addressing obsolescence through digital I&C upgrades in Europe, Canada, and Brazil tells us that the choice involves more than just initial cost. Radics LLC has found four additional factors to consider in selecting safety-related I&C equipment.

RadICS-based RPS-ESFAS system

I&C Technology Superiority – It is essential to have clear criteria to differentiate between I&C technologies. Obvious factors often considered include the status of NRC approvals and technical requirements related to input and output device interfaces. It is important to understand the age of the NRC approval and the implementation conditions placed on the technology. It is also necessary to understand what is possible for the upgrade to define additional functionality that provides improvements to safety, reliability, availability, maintainability, and cost of operation.

Best Value with High Impact Return – It is important to look beyond ease of licensing when selecting I&C technologies and developing an I&C system solution. In order to achieve targeted benefits, other factors that should be considered include:

- Reduced hardware board count and inventory requirements with improved protection system reliability with higher functionality digital modules
- Improved plant safety with higher availability for new system with the use of graceful degradation response to faults detected by self-testing
- Used self-testing features to eliminate manual channel functional tests required each calendar quarter
- Used self-monitoring features and alarms to automate manual channel checks each shift
- Digital diagnostic messaging and module human-machine interface design to simplify troubleshooting and corrective maintenance
- Automated end-to-end testing to reduce time and resources required to perform testing during refueling outages
- Optimized architecture within cabinet footprint constraints
- Redundant voters to improve availability

Vendor Experience – It is always about experience, readiness to deal with known project challenges, and the ability to address unexpected problems that can arise during large project implementation. It is important to consider all experience, not just nuclear experience, because it is valuable for a vendor to have familiarity with a variety of nuclear plant digital I&C projects. It is also important to understand the supplier's history of product support and product migration. Past performance is an indication of future performance

Enabling Total Nuclear Plant Transformation – The safety-related digital I&C technology needs to support the plant digital transformation strategy and fit into plant work process and workforce plans. If this is not done, the full potential of the digital modernization will not be achieved.

Radics LLC develops I&C solutions based on the innovative RadICS platform, which is a *Technically Superior* technology. It uses state-of-the-art Field Programmable Gate Array (FPGA) technology, was developed to the most demanding industry standard for safety-critical systems (i.e., IEC 61508) and provides high-reliability at Safety Integrity Level 3. The FPGA technology provides fast and deterministic performance with response times for I&C functions as fast as 5 milliseconds. The reduced operating complexity of the FPGA technology, coupled with the comprehensive self-diagnostics, ensures fail-safe performance through the elimination of systematic faults that cannot be eliminated from microprocessor technologies.

The NRC approved the RadICS platform as meeting or exceeding its regulatory requirements for digital I&C development. Radics LLC was also able to demonstrate that the IEC 61508 design features and internal diversity used to eliminate systematic faults were sufficient to address NRC concerns with digital common cause failure vulnerabilities.

The RadICS Platform provides the *Best Value for High Impact Returns*. The RadICS technology uses extensive on-line self-testing and comprehensive diagnostics at the module, chassis, and system levels. These features can be used to streamline required surveillance activities and reduce burdens on plant personnel, allowing them to focus on other mission-critical activities. These self-diagnostic features can be supplemented with additional engineered test features for a plant retrofit project to achieve greater automation of required testing to provide further benefits.

The RadICS Platform creates a new paradigm for addressing common

Operator-friendly visualization of diagnostic and process information (typical HMI)

cause failure vulnerabilities. The old paradigm relies on the addition of a separate diverse actuation system to address the common cause failure vulnerabilities associated with microprocessor-based systems. The old paradigm adds system complexity along with increased costs and longer schedules for protection system modernization projects. The RadICS Platform incorporates a unique diversity strategy to address the common cause failure vulnerabilities that does not require a separate diverse actuation system to address the common cause failure vulnerabilities. This unique capability eliminates system complexity along with the reduced cost and implementation resources.

Radics LLC has extensive *Vendor Experience* with the RadICS Platform. The RadICS technology has been installed worldwide in more than seventy nuclear plant safety and control applications—most of them safety significant, such as Reactor Protection and Engineered Safety Features Actuation Systems. This experience has been coupled with the experience of the Curtiss-Wright Nuclear Division through a strategic partnership to deploy RadICS-based I&C systems to the U.S. market. Curtiss-Wright has experience and proven mitigation approaches on large-scale I&C modernization projects to deal with digital I&C modernization project challenges.

RadICS technology can *Enable Total Nuclear Plant Transformation.* The technology can support interfaces with other digital technology at the plant to support overall efforts for plant digitalization, migration to data-driven maintenance and, business process optimization. The RadICS technical features can simplify maintenance, troubleshooting, and surveillance testing, and can support operator "mind digitalization" and culture change. Those are important factors for a company's ability to attract and retain new, younger workers.

It is important that nuclear plants continue to provide safe, carbon-free, and reliable sources of electricity. Movement towards I&C modernization will allow plant owners to increase safety and reliability while also reducing operating costs, important considerations in today's competitive energy market. The move to digital can be intimidating but by taking a wide-angle approach and focusing on factors beyond initial cost, today's nuclear plants can set the stage for a promising future.

ANS Virtual Annual Meeting: A huge online success

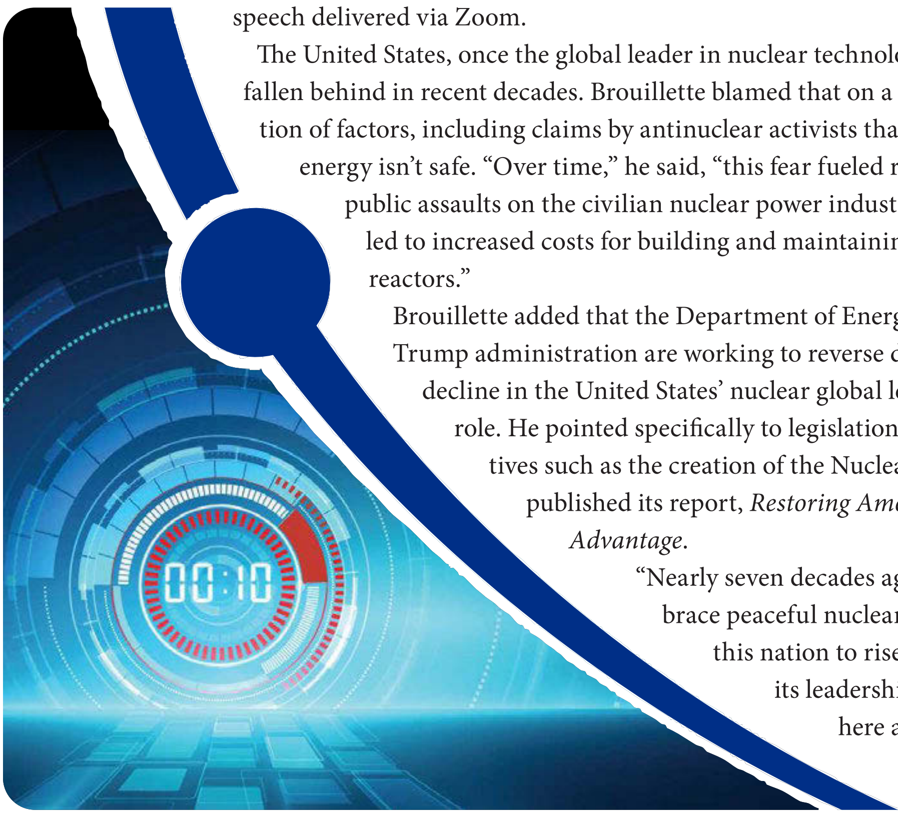
The 2020 ANS Virtual Annual Meeting, which was held June 8–11, was the American Nuclear Society's first virtual meeting and its largest national meeting in terms of attendance, with more than 2,300 participants registered.

The meeting's opening plenary session kicked off with welcoming remarks from Craig Piercy, ANS executive director and chief executive officer, and Marilyn Kray, the then ANS president. The session featured presentations from an all-star cast of federal policymakers, influential politicians, and industry experts.


Piercy


Kray

U.S. Energy Secretary Dan Brouillette delivered the keynote address, in which he noted that nuclear energy and technology has strong allies within the Trump administration. "As we all know, the president remains an extraordinary advocate for this amazing form of energy and for America's nuclear energy leadership," Brouillette said in a prepared speech delivered via Zoom.



The United States, once the global leader in nuclear technology, has fallen behind in recent decades. Brouillette blamed that on a combination of factors, including claims by antinuclear activists that nuclear energy isn't safe. "Over time," he said, "this fear fueled relentless public assaults on the civilian nuclear power industry and led to increased costs for building and maintaining nuclear reactors."


Brouillette

Brouillette added that the Department of Energy and the Trump administration are working to reverse decades of decline in the United States' nuclear global leadership role. He pointed specifically to legislation and initiatives such as the creation of the Nuclear Fuel Working Group, which recently published its report, *Restoring America's Competitive Nuclear Energy Advantage*.

"Nearly seven decades ago, America beckoned the world to embrace peaceful nuclear power," Brouillette said. "It's time for this nation to rise up and recover that vision, to restore its leadership, and to revitalize nuclear energy right here at home."

William Magwood, director general of the OECD Nuclear Energy

Agency, and Kathryn McCarthy, director of the US ITER Project, also gave video addresses. Interspersed among those addresses were video statements from U.S. Sens. John Barrasso (R., Wyo.), Lisa Murkowski (R., Alaska), and Sheldon Whitehouse (D., R.I.).


Magwood

Magwood said that nuclear energy advocates need (1) to accept that the economic model is changing, which means moving away from light-water reactors in the future, (2) to change the perception that nuclear waste is dangerous, and (3) to understand that nuclear energy is global, so the path to success will involve deployment in many countries at the same time.

"We here today are very fortunate to be in the nuclear energy business at this time," Magwood said. "The uncharted future will tell the tale, but whatever the conclusion of that story is, the key chapters will be written now. . . . Your success contributes to a better, cleaner, more prosperous world for everyone and will do so for generations to come."


McCarthy

McCarthy provided background on the ITER project in France, as well as a look at where it stands now, and how it will affect the future. She said that ITER's mission is to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes and to produce and study burning plasma—the next major step for fusion energy development.

The investment from the United States is 9 percent of the hardware design and fabrication; 9 percent of the central team budget for integration, assembly, and commissioning; and 13 percent of the central team budget during operations. In return, the United States gets full access to research and all of the ITER-developed technology and scientific data.


Barrasso

"This is a highly leveraged investment for the United States," McCarthy said. "By partnering with multiple countries, the cost is shared, the risk is distributed, and the benefits accrue to all."

Barrasso, chair of the Senate Environment and Public Works committee, stressed the importance of implementing pronuclear policies in the coming years and of building a resilient nuclear fuel supply chain.

"Now more than ever, Washington must advance policies to preserve and expand the use of nuclear energy," said Barrasso, who cosponsored the Nuclear Energy Innovation and Modernization Act (NEIMA). "Nuclear power is reliable. Nuclear power is resilient. Nuclear power is critical to meeting our clean-energy goals. And nuclear power is fundamental to protect our energy and our national security interests."


Whitehouse

Whitehouse was introduced by Piercy as "probably the most tireless advocate for climate change legislation in the U.S. Senate." Whitehouse said that he feels optimistic about nuclear energy. One reason for his positive outlook is the passage of bipartisan legislation such as NEIMA.


Murkowski

Murkowski, who chairs the Senate Energy and National Resources committee, was also hopeful about nuclear energy's future. "As we look a decade ahead, know that I'm excited about the future of nuclear energy," she said. "By 2030, I'm hopeful that we will have demonstrated a number of new nuclear energy technologies. I'm also hopeful that we would have worked together to bring the United States into first place globally as a leader once more for the nuclear industry."

Special Report continues

A still image from the Utility Roundtable; in the top row are, from left to right, panelists Patrick Burke and Alan Scheanwald, and moderator Bruce Hallbert. In the bottom row are, from left to right, panelists Michael Green and Scot Greenlee, and moderator Alison Hahn.

Hydrogen roundtable

The plenary session speakers were followed by a roundtable discussion titled "U.S. Leadership in Sustaining Clean, Competitive Power and Hydrogen." The production of hydrogen, in addition to electricity, from the current fleet of nuclear reactors is garnering a lot of interest from stakeholders, according to representatives of four nuclear utilities that together operate about one-third of the U.S. nuclear fleet. The panelists represented utilities that have been awarded funding through the DOE's Light Water Reactor Sustainability (LWRS) Program to demonstrate hydrogen production at existing LWR plants in Ohio, Arizona, and Minnesota.

Alan Scheanwald, of Energy Harbor, Patrick Burke, of Xcel Energy, Scot Greenlee, of Exelon Nuclear, and Michael Green, of Pinnacle West Capital Corporation (representing Arizona Public Service), talked about how the program fits into their long-term plans. Bruce Hallbert, director of the LWRS Program's Technical Integration Office at Idaho National Laboratory, and Alison Hahn, of the DOE's Office of Nuclear Energy, moderated the panel.

The panelists agreed that it will take more than interest to turn the potential for large-scale hydrogen production into an economic boon for the nuclear power industry. Technical and economic challenges remain. Hydrogen resources must be flexible and dispatchable, and storage and cost are key factors, as are scaling up demonstrations and creating a distribution network.

"Natural gas prices are the threat for Energy Harbor," Scheanwald said, adding that small, single-unit plants are most at risk. He explained that as the lead applicant with Arizona Public Service (APS) and Xcel Energy on the LWR Integrated Energy Systems Interface Technology Development and Demonstration project, Energy Harbor hopes to have a low-temperature electrolysis unit in operation at the Davis-Besse plant in the spring of 2022. Among the prime goals of hydrogen demonstrations, Scheanwald said, are finding industrial partners interested in using hydrogen gas and reducing the capital cost of equipment.

Burke said that Xcel Energy, one of the first utilities to announce a commitment to carbon-free energy, has become the largest wind energy–producing utility in the country. On windy days, Xcel "flex-operates" its nuclear plants, Monticello and Prairie Island. "Today, for example, it's going to get up to 90 degrees in Minnesota," Burke said. "The wind is blowing, so tonight we'll end up flexing the operating units down to 80 percent at Monticello and down to 75 percent at Prairie Island. That leaves us a unique challenge."

Xcel Energy is developing a technical and economic analysis for hydrogen production in the Minnesota area as part of a Phase I plan and has submitted a proposal for a Phase II plan for high-temperature electrolysis at Prairie Island.

Green said that APS and its three-unit Palo Verde plant experience peak demand in the summer, when utility-scale and distributed solar meet much of that demand but leave a steep ramp rate in the afternoon. Green said that APS and other organizations in Arizona recognized that it doesn't make sense to "downwardly dispatch" high-performing reactors like those at Palo Verde while the utility works toward meeting its self-determined clean energy goals. "Hydrogen presents a great opportunity to meet our aspirations," Green said. APS is performing a technical and economic analysis and is looking to scale up hydrogen production using demos at existing fossil fuel plants.

> **"From what we're seeing at Exelon, there's absolutely an opportunity going forward to produce hydrogen on a large scale."**

Exelon has been assessing hydrogen as an option to support the continued operation of its nuclear plants, according to Greenlee, who emphasized the economic pressures that Exelon nuclear plants are facing in competitive electricity markets. The company has been assessing hydrogen as an option to meet its goals, including the self-supply of a plant's hydrogen needs and peak power generation, and it received LWRS funding under a separate project to add a 1-MW electrolyzer to one of the utility's plants for on-site hydrogen needs. Exelon will soon announce the selected plant—a boiling water reactor—and plans to complete the project in April 2023.

"From what we're seeing at Exelon, there's absolutely an opportunity going forward to produce hydrogen on a large scale," Greenlee said, adding that electricity price is the dominant factor in the cost of hydrogen production, followed by scale of production and the efficiency of the electrolyzer.

As the roundtable drew to a close, the panelists agreed that much work remained to be done to make hydrogen production from nuclear assets viable. "Are we going fast enough to make the current fleet viable?" Greenlee asked rhetorically. To that, Burke commented, "It's going to take a lot of work, and we've got to get cracking on it."

President's Special Session

Organized by ANS's Young Members Group (YMG) and Student Sections Committee (SSC), the President's Special Session featured a group of nuclear policy luminaries who discussed the influence of nuclear technology on U.S. national security and where the nation stands with regard to leadership of the future global nuclear industry.

The session featured some breaking news as well. In introductory remarks, Marilyn Kray announced the signing of a memorandum of understanding calling for increased collaboration between ANS, the North American Young Generation in Nuclear, the Nuclear Energy Institute, and U.S. Women in Nuclear.

Kray also presented a presidential citation to the YMG and announced the recipients of

Special Report continues

three awards—ANS's Distinguished Service and Distinguished Leadership awards, and the Henry DeWolf Smyth Nuclear Statesman Award, jointly awarded by ANS and NEI. More about these awards and this year's recipients can also be found on Newswire, at ans.org/news/source-ansnews.

Session moderators Kelsey Amundson, YMG secretary and incoming treasurer, and Kelley Verner, SSC chair, introduced the panel, which included Rita Baranwal, assistant secretary for the DOE's Office of Nuclear Energy; Laura Holgate, vice president for materials risk management at the Nuclear Threat Initiative; Maria Korsnick, president and CEO of NEI; and Siegfried Hecker, professor emeritus in the Department of Management Science and Engineering at Stanford University.

The following are selected remarks from each of the panelists.

Korsnick: "Simply put, the world is safer when the United States is the preferred partner for nuclear energy development happening around the globe. That, I regret to say, is under threat. Domestically, the U.S. nuclear fuel cycle is in a precarious position, particularly when it comes to uranium mining, conversion, and enrichment. Putting aside the direct energy security benefits of the domestic fuel cycle, a lack of growth in our industry endangers our ability to lead abroad.


Korsnick

"We need a holistic approach that leverages the ingenuity of the domestic industry, invests in advanced nuclear technologies, and increases our competitiveness abroad by leveling the playing field for nuclear here at home. That's the way forward to achieve both strong national security and a thriving domestic industry."

Baranwal: "New advanced reactors have the potential to solve diverse challenges across the nation, as well as across the globe. And at DOE, we're focusing our efforts around four major priorities. First is to sustain the existing fleet here in the United States. Next is one of my top priorities, and that's to get advanced reactor technologies across the finish line. Third is to establish and maintain a critical fuel cycle infrastructure, and fourth is to enhance the global competitiveness of the United States.


Baranwal

"My office took action on [the Nuclear Fuel Working Group report] by launching the Advanced Reactor Demonstration Program. This program focuses DOE and nonfederal resources on the actual construction of advanced demonstration reactors that are affordable to build and operate. The window to apply is currently open, and that window will close August 14. Ultimately, our goal is to be able to make awards by the end of this calendar year. We're also strongly supporting the National Reactor Innovation Center . . . to enable these demonstrations, and the development of the Virtual Test Reactor to ensure that we have the infrastructure necessary to support the long-term success of U.S. advanced nuclear technologies."


Holgate

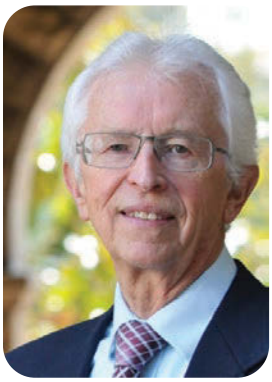
Holgate: "The first step in preventing proliferation is the preservation of the Nuclear Nonproliferation Treaty, which is currently under extreme threat. . . . The foundational commitment of the NPT—for states that do not already have weapons to refrain from acquiring them—is necessary to enable international trade in peaceful nuclear technology. The associated commitment by weapons states to refrain from transferring weapons technology is the basis for the interlocking and sometimes scrambled network of export controls and political agreements designed to prevent the illicit acquisition of nuclear weapons technology, in particular enrichment and reprocessing technology. . . . Without these guardrails, global nuclear commerce would not be tolerated on national security grounds.

"In pursuit of the safe and secure spread of nuclear energy, I believe that the U.S.

government can and should do better, once a 123 agreement has been concluded, to support private industry in pursuing nuclear deals. And there is no question that we have been losing ground in global sales. This loss of commercial reach brings a serious risk of loss of formal and informal influence in the venues where nuclear rules and nuclear deals get made: the IAEA, the Nuclear Suppliers Group, the Nuclear Energy Agency, the G7 and the G20, the U.N. climate change conferences, and others.

"[Advanced and Generation IV] reactors may break through some of the barriers to nuclear energy expansion, such as costs, safety, construction time, and grid capacity, and the innovation and creativity for which the U.S. is known has generated more than 60 firms with Gen IV ambitions—well more than any other country. But from a proliferation point of view, these are not your father's gigawatt-scale PWR Oldsmobile. Some of the designs envision high-assay low-enriched uranium, highly enriched uranium, or plutonium fuel, all of which are more susceptible to bomb building than the LEU that currently dominates fuel cycles. Some Gen IV reactors are so small, the whole reactor might be stolen and transferred to a clandestine facility where its fuel could be extracted and processed. Some designs envision sealed cores, which may be incompatible with current IAEA safeguards methods. But these new reactors also have a chance to do what Gen III reactors, whose fundamental design choices predate IAEA safeguards and the notion of terrorists seeking nuclear weapons, could not.

"Gen IV reactors can design-in modern security and safeguards elements that will make them easier to protect and inspect. If U.S. Gen IV reactors can rise to this challenge, they will rise above other countries' Gen IV reactors, which may be harder and more expensive to secure and safeguard."



Hecker

Hecker: "Because of the difficulties between countries, especially the big countries—Russia, the United States, and China—nuclear cooperation has declined dramatically. What concerns me is that even if we could get the governments to finally recognize that we must cooperate in the nuclear arena, will we have people in our national labs, in the industry, and in the universities who will continue to be interested in cooperating? That's why I think it's so great to have the ANS Young Members Group sponsor this particular session.

"I used to work a lot with the Russians, but those connections have since been cut substantially, so what I do now is work with the Russian universities on what I call a young nuclear professionals forum. I do the same thing with the Chinese. And the hope is to keep the flame alive among the younger generation in order to take up the cooperative part related to all things nuclear."

General Chair's Special Session

The final plenary session of the meeting was the General Chair's Special Session, which focused on the current and future role of advanced reactor technology. The session, titled "The Promise of Advanced Reactors During Uncertain Times: National Security, Jobs and Clean Energy," featured two panels: the Lab Directors Roundtable and the Advanced Reactor Panel. Organized by the general chair of the meeting, Mark Peters, director of Idaho National Laboratory, the panel was moderated by Corey McDaniel, of INL, the assistant general chair.

A few of the issues covered during the dual plenary session included challenges to advanced reactor deployment, public-private partnerships in research and development, nuclear nonproliferation and security, workforce issues, and market conditions and demand.

Special Report continues

Lab directors' roundtable

Peters

Peters led the Lab Directors Roundtable with a discussion about the role that U.S. leadership will play in seeing advanced reactor innovations developed, demonstrated, and deployed by 2030. Panel members included Department of Energy lab directors Thomas Zacharia, of Oak Ridge National Laboratory, Thom Mason, of Los Alamos National Laboratory, and Paul Kearns, of Argonne National Laboratory.

Peters opened by noting the importance of recognizing that the national laboratories were born out of the Manhattan Project and World War II. "It was determined that the importance of multidisciplinary science and technology at that time were vital to addressing large national and global challenges," he said. Peters added that while the labs are sometimes in competition, there is also "a tremendous amount of cooperation."

Zacharia

Zacharia noted that ORNL is not only involved in nuclear reactor research and development, but it is also making strides in computing and machine learning, as well as advanced manufacturing techniques, all of which he said can be used to support advanced reactor concepts.

"At ORNL, we are combining what we learned from CASL [Consortium for Advanced Simulation of Light Water Reactors] and some of our other work to shape a new approach to reactor design, manufacturing, licensing, and operation," he said. "Reflecting on our history, where the [X-10] Graphite Reactor was constructed and put into operation in nine months, with all of the technology advancements we have today, we ought to be able to do better than that."

Mason

Mason, speaking on the success of LANL's work on the KRUSTY (Kilowatt Reactor Using Stirling TechnologY) experiment on behalf of NASA, said, "It's worth noting that within the space of about three years, and for about $20 million dollars, [LANL and NASA] were able to design, build, and operationally test an entirely new reactor. As much as we like to talk about how difficult it is and how long it takes to do these things, it turns out that under the right conditions, you can actually move pretty quickly, which is important if you're trying to develop a technology rapidly."

Kearns

Kearns highlighted a collaborative nonproliferation effort by the DOE laboratories called the Reduced Enrichment Research and Test Reactors program, which was established in 1978. "It's been a really successful program," he said. "We have converted some seven reactors from operating with highly enriched uranium to low-enriched uranium. We've also been able to shut down 30 reactors across the nation and world to reduce the concerns of proliferation."

Kearns added, "We are excited and committed to working with U.S. industry to deploy the next generation of advanced reactor designs and technologies. We are fully engaged and looking forward to contributing significantly to maintaining U.S. leadership in nuclear technology."

Advanced reactor panel

Christine King, director of the Gateway for Accelerated Innovation in Nuclear (GAIN) at INL, moderated the session's Advanced Reactor Panel. Panel members included professionals from the DOE and private industry, including venture capitalist Ray Rothrock; Chris

King

Levesque, president and CEO of TerraPower; Kemal Pasamehmetoglu, executive director of the DOE's Versatile Test Reactor; Clay Sell, CEO of X-Energy; and Ashley Finan, director of the National Reactor Innovation Center at INL.

King, highlighting the role that GAIN plays in the development of advanced reactor technologies, began by saying, "We see GAIN not just as an initiative, but as a philosophy. We believe in meeting advanced nuclear developers where they are to understand their approach and their needs."

Rothrock

Rothrock, who serves as partner emeritus of Venrock, an early-stage tech investment partnership, said that the advanced reactor community needs to think about how it presents itself to capital markets. "I would posit the following: This advanced reactor business needs capital now more than it needs uranium," he said. Rothrock proposed the formation of a task force of capital investment experts that have a commitment to nuclear and decarbonization. "Capital is important," he said. "We have to organize ourselves and help investors take an interest in advanced nuclear and help get it going again."

Levesque

Levesque, in talking about the current state of advanced reactor technology, related the situation to the COVID-19 pandemic. "When nature acts," he said, "it can act exponentially." He added that the mathematical growth rate of the virus is something that should be easily understood to those familiar with nuclear reactor kinetics.

"But too often, decision-makers, the public, and even us engineers and scientists have difficulty in comprehending and acting upon anything other than linear change," he added. "Unfortunately, the climate is not a simple linear system. This is what has driven TerraPower's urgency in pursuing reactor designs that are ready to build."

Pasamehmetoglu

Pasamehmetoglu noted that his group, in designing the Versatile Test Reactor, used some of the existing design features of the PRISM reactor. "Basically, what we did was to take an old, reliable car with a simple design, threw away the old engine, and replaced it with a high-performance engine that meets all our requirements."

Pasamehmetoglu also addressed some of the debate going on regarding whether the United States should be building a test reactor or if it is better to invest in a demonstration advanced nuclear power reactor. "In my opinion, that is really an artificial debate," he said. "If we are serious about sustaining our leadership in advanced reactor technologies, we need both. It is not one or the other."

Sell

Sell, taking a bit of a contrarian view of the role of advanced reactors in uncertain times, said, "It is our view at X-energy that the times are not nearly as uncertain as they seem. There is a tremendous business opportunity that is before us now." That certainty about the competitiveness of advanced reactors is driven by four converging factors, Sell said, which include a growing demand for energy, a need to decarbonize energy production, the attrition of the current light-water reactor fleet, and the technological readiness of Generation IV reactors.

Special Report continues

Finan

Finan, the session's final speaker, discussed the promise of advanced reactor technology. "We are on the cusp of demonstration and commercialization and being able to apply these technologies to solving our most demanding and urgent challenges," she said, adding that getting to a demonstration reactor will require "investment, commitment, and persistence."

From global to local: Intersections of nuclear and climate policy

The Paris Agreement was written at the 2015 United Nations Climate Change Conference as a global response to the threat of climate change. While the current U.S. administration announced a plan to withdraw from the agreement in 2017, it remains a backdrop for climate change policy discussions, including "Nuclear Energy and Climate Change Policy in the United States and Abroad in a Post-Pandemic World," a panel session held during the ANS Virtual Annual Meeting. Despite their diverse backgrounds in nuclear and energy policy, six assembled panelists all agreed the United States should participate in the Paris Agreement.

Leah Parks, of the Nuclear Regulatory Commission, moderated the panel session along with Laura Hermann, of Potomac Communications Group. Parks shaped the discussion on policy approaches to achieve carbon emission–reduction targets by starting with a global perspective and then zooming in for a closer look at Arizona—one state where clean energy targets were recently put to a vote.

Valerie Faudon, director general of the French Nuclear Society and vice president for the European Nuclear Society, mentioned that a lack of consensus within the European Union on nuclear energy's role has impeded the EU's participation in Nuclear Innovation: Clean Energy (NICE) Future, a program of the Clean Energy Ministerial (CEM). NICE Future is led by the United States, Canada, and Japan.

Faudon sees a future role for nuclear in the electrification of transportation and to provide thermal energy for heating in urban areas. "We hope [small modular reactors] will be able to have the authorization, because it is a different safety paradigm, to be able to go closer to the cities and to provide heat to cities," she said.

John Kelly, a past president of ANS (2018–2019), spoke about NICE Future from personal experience. During his presidency, ANS joined dozens of nuclear societies in signing a clean energy declaration. Kelly attended a meeting of the CEM in Vancouver and laid the groundwork for ANS to become a NICE Future partner organization.

Kelly

During the panel session, Kelly asked, "What's needed now?" His answer is K–12 education. "We need to dispel the fear of radiation and nuclear," Kelly said, adding that *Navigating Nuclear*, ANS's K–12 nuclear education curriculum, is leading the way.

Bill Burchill, also a past president of ANS (2008–2009) and past chair of the International Nuclear Societies Council (2015–2016), said that tailoring energy sources to local demand conditions could yield a mosaic of many contributing energy sources: "It's not one or two or three solutions. It's all the solutions, properly applied, where they make most sense." He added that, "the only way we'll get there is to not be prescriptive on the solution itself, but to be demanding about the goal we're trying to achieve."

Burchill

Matt Crozat is senior director for strategy and policy development at the Nuclear Energy Institute, and he reinforced the need to focus on broad and pragmatic policies. "State and regional policies have been a really important step forward," he said. "There is a possibility that you can make federal policy with an eye toward appreciating what states have already done," he added, referencing the zero-emissions credits established in New York, Illinois, Connecticut, and New Jersey. Crozat advocated for a shift from arguing about specific methods and deadlines to getting on a longer-term path toward clean energy targets.

Greg Cameron works at Arizona Public Service, which spent $40 million to reach Arizona voters when Proposition 127—which would have required Arizona electricity companies to obtain 50 percent of their electricity from renewable sources (explicitly excluding nuclear)—was on the ballot. The measure was seen as a threat to APS's three-unit Palo Verde plant, and it was ultimately rejected by 69 percent of the voters in 2018. APS has its own goals of reaching 45 percent renewable energy and 65 percent clean energy by 2030.

The difficulty of getting nuclear included in the conversation was the biggest takeaway from Prop 127 for Cameron. His message? "I equate nuclear energy to vinyl records, and I think of renewables—solar and wind—like Spotify," he said. "And if I'm going to have you all over and we're going to listen to good music, we're going to use both of those options. Nuclear is a great sound, and just like a vinyl record it's cool again, it's relevant again, and people want it, and we've got to take that message out."

Martin Pasqualetti, a professor at Arizona State University who teaches and writes about energy science and policy, is supportive of the increasing role renewables are playing in the state. "I look at the largest nuclear plant in the country [Palo Verde], which is like 4 GW, with a very high capacity factor, producing electricity for decades now, and yet at ASU, the largest university in the country, there is no nuclear program to speak of," he said. "There is some disconnect there."

Near the close of an engaging discussion that brought both similarities and differences to the fore, Burchill sought some common ground.

"What is it that we're trying to achieve?" he asked rhetorically before answering his own question: "Reliable electricity, reliable energy for heating, reliable energy for transportation, and a very low carbon footprint. I guess that's the one place where we all have commonality—the very low carbon footprint." That carbon footprint, Burchill said, is at the core of the climate change issue. "If we could just see that that's the thing that binds us all together, we ought to be able to work toward a goal that makes sense," he concluded.

Registered virtual meeting attendees who may have missed the live panel session can still watch the discussion through the Meeting Portal.

More from the meeting

For more coverage of the ANS 2020 Virtual Annual Meeting, go to Newswire at ans.org/news/tag-ans+annual+meeting/.

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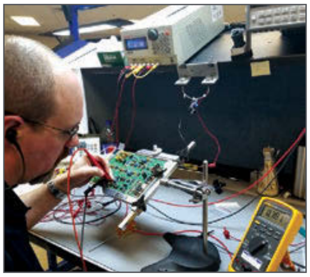

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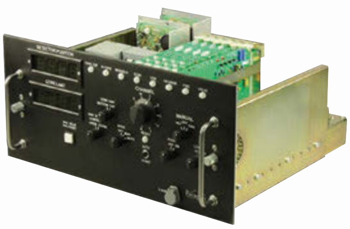

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Can flexible operations be the key to achieving low-carbon energy generation?

The increase of solar and wind power in the energy mix is impacting overall electricity generation which is good in terms of reducing carbon. However, the variable output of these renewable sources creates challenges for utilities. Implementing operational flexibility for nuclear power plants through a variety of mechanisms is a viable solution. We asked two experts, one from Framatome and one from EDF, a few questions about flexible operations.

What is flexible operations?
Flexible operations is the ability of nuclear power plants to adjust core thermal power to match electrical demand and control frequency of the electrical system. Flexible operations is typically thought of in terms of four grid operating modes: daily load maneuvers, primary and secondary frequency control, response to unexpected grid upsets and extended low power operation.

How long has EDF been using flexible operations within its French fleet?
The EDF nuclear fleet has operated in flexible mode since the early 1980s. Nuclear generates about 75 percent of French electricity and has to adapt to periods of low consumption at night or on weekends. The fleet also provides a large part of the frequency regulation required by the grid operator. Thanks to grey control rods to level the flux shape in the core of the reactor, we reduce liquid waste generation when the load varies, but load following is possible with black control rods. Every day, each reactor receives the load program for the day after, according to grid needs, consumption, renewable generation, and exports. Our reactors can make variations twice a day, going down to 20 percent of nominal power in only half an hour, and returning to full power at the same pace. Control room operators are trained to prepare and realize the load variations.

What is an example of successful flexible operations?
A successful load variation is made on schedule, in a safe manner, by monitoring core temperature, control rod positions, flux shape, chemistry, and waste generation. Some units, chosen for economic reasons, make about 100 load variations in a year, without any noticeable impact to safety and equipment reliability. Being flexible avoids using gas or coal to adjust the overall generation. It allows an electricity mix composed mainly of nuclear and renewable sources, with very low carbon emissions.

Is this a common way of operating the fleet in the U.S.?
No, but the drivers for flexible operations are changing in the U.S. Today, more and more U.S. utilities are either evaluating the transition to flexible operations or are actively pursuing implementation of flexible operations.

Why should a U.S. utility consider flexible operations?
A utility might consider implementing flexible operations for a myriad of reasons, but the most common are economics and carbon reduction efforts. In de-regulated markets where over-generation and transmission constraints can lead to negative prices, flexible operations can provide cost avoidance.
A plant might also consider flexible operations to maximize use of non-carbon emitting sources and further lower its overall carbon footprint.

What should a utility consider when exploring flexible operations?
A utility must determine how flexible each nuclear generating asset needs to be. This will depend on the inherent design limits of the plant (e.g., allowable maneuvering rates), as well as the desired grid operating modes. Higher degrees of flexibility can result in greater implementation costs. For this reason, Framatome recommends that a feasibility study be performed which should evaluate the impact of flexible operations on all plant systems, structures, components and programs from the reactor core to the grid. This will provide a holistic assessment and avoid potentially costly surprises.

A utility must consider how soon it wants to implement flexible operations. If plant modifications are required, this could require a two- to four-year implementation schedule depending on the types of modifications.

Finally, a utility must choose an implementation partner. Choosing an implementation partner that has experience in flexible operations to perform feasibility studies, engineering evaluations and plant upgrades is critical. Framatome, with the decades of operating experience of the EDF fleet, is an ideal choice.

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Holtec's principal business concentration is in the nuclear power industry. Holtec has played a preeminent role since the 1980s in expanding nuclear plants' wet spent fuel storage capacity at over 110 reactor units in the U.S. and abroad. Dry storage and transport of nuclear fuel is another area in which Holtec is recognized as the foremost innovator and industry leader with a dominant market share and an active market presence at over 115 reactor units around the globe.

Among the Company's pioneering endeavors is the world's first below-ground Consolidated Interim Storage Facility being developed in New Mexico and a 160-Megawatt walk away safe small modular reactor, SMR-160. The SMR-160 is developed to bring cost competitive carbon-free energy to all corners of the earth.

Holtec is also a major supplier of special-purpose pressure vessels and critical-service heat exchange equipment such as air-cooled condensers, steam generators, feedwater heaters and water-cooled condensers.

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Key Facts

- Holtec is a vertically integrated organization possessing in-house capabilities to design, engineer, analyze, license, fabricate, perform on-site construction and deploy the products offered by the Company.
- Holtec's three U.S. manufacturing facilities cover nearly 1.5 million square feet of manufacturing floor space.
- Holtec's Manufacturing Division (HMD) in Turtle Creek, Pennsylvania is one of the largest manufacturers of nuclear storage and ASME Code components in the U.S. HMD is also among America's largest exporters of capital equipment for the nuclear industry.
- The Company has been granted over 100 patents in the areas of equipment design, fabrication processes and materials.
- Holtec currently owns two shutdown nuclear power plants and is safely decommissioning the sites to prepare the properties for unrestricted use, pending regulatory approvals.
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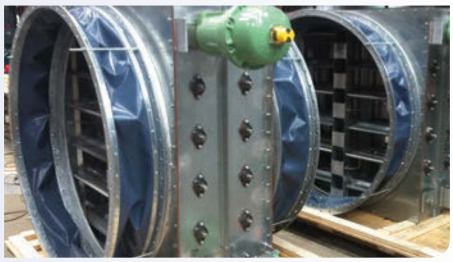

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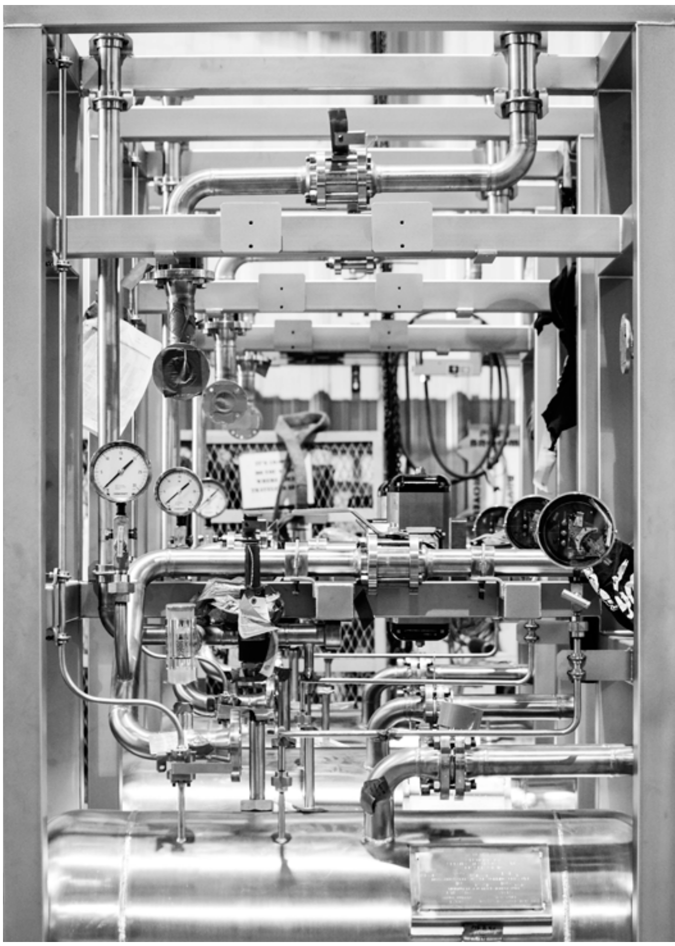

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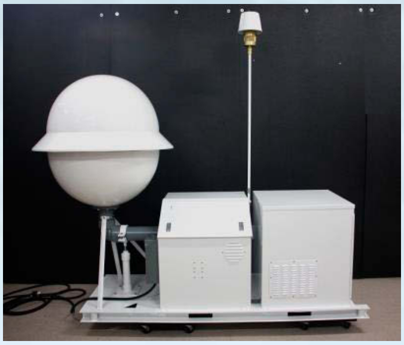

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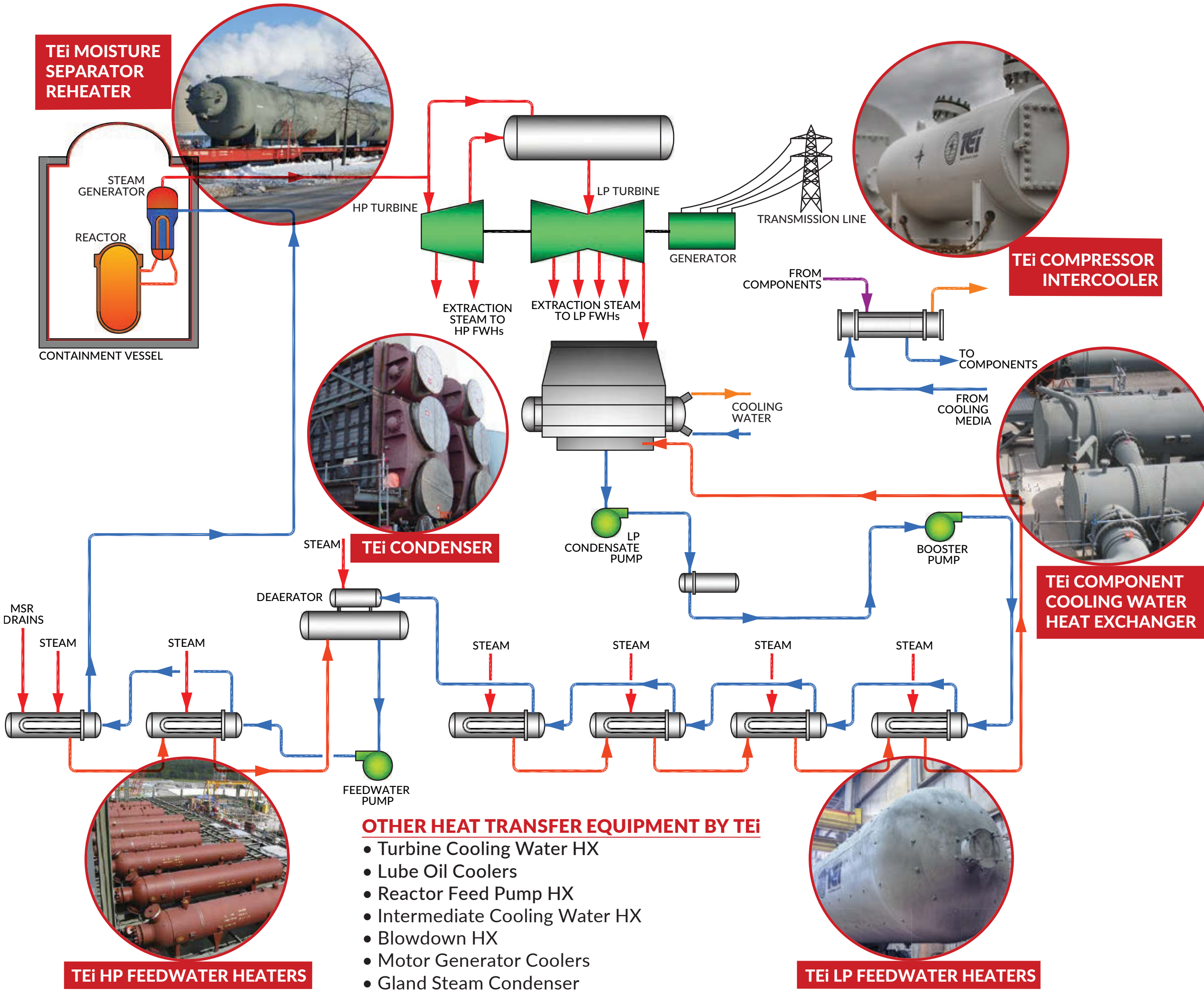

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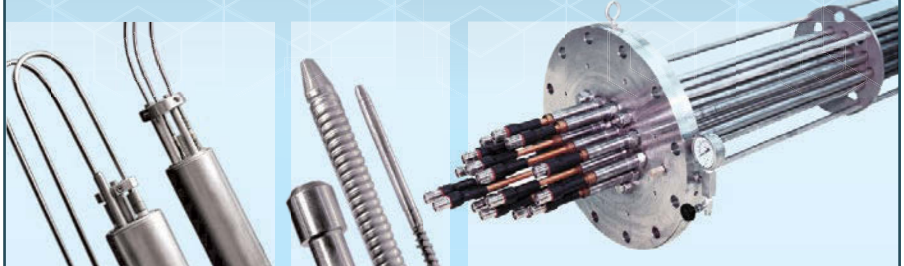

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Ludlum Measurements: Leading the way since 1962

Ludlum Measurements, Inc. has been designing and manufacturing quality radiation detection equipment for the Health Physics Industry for 58 years. Through the years the health physics industry has grown and expanded into many different industries, including the oil industry, new and recycled metal industry, university and medical research labs, as well as the traditional market, which includes local, state, and federal agencies. With this growth in the industry, the line of products Ludlum offers has grown as well.

Its primary manufacturing facility in Sweetwater, Texas is fully integrated and offers customers a full line of products and services, including custom instrument design and manufacturing. They also offer repair and calibration services for their own products, as well as many of their competitor's products.

After leaving Eberline Inc. in 1961, Don Ludlum, the company's founder, looked around West Texas for a community to start his business. Several of the communities he looked at were Odessa, Brownwood, Abilene, Cleburn, Mineral Wells, and San Angelo. He chose Sweetwater for many reasons, but most importantly for its open and welcoming attitude. It also offered many things he needed for his small company.

His first manufacturing plant was located at 1210 Broadway where the company operated until they outgrew the facility and relocated to their current location at 501 Oak Street in 1975.

From then on, the company continued to grow, leading them to now own 9 different divisions that not only cater to many different companies with an extensive number of products and services, but to cater to Ludlum competitors, as well. Most importantly, these companies assist the development of Ludlum product lines.

The acquisitions and development of all branches began in 1992 with ADIT, a company specializing in the production of photomultiplier tubes. These components are an integral element to many of Ludlum's products and, in fact, a lot of Ludlum competitors.

1996 was the year of Eljen being founded as another Ludlum division that designs and produces a specialized plastic-based scintillation. West Texas Molding, a plastic injection molding company, followed in 2000.

After the Ludlum expansion to their new and now current offices, they acquired ET Enterprises, Ltd. in 2007 leading Ludlum overseas to the United Kingdom and just another division larger.

Ludlum was approached to solve an issue found in the wind industry in 2010, which led to the development of Ludlum Wind. Shortly after that was the acquisition of Protean Instruments, a manufacturer of ultra-high performance alpha-beta sample counting systems, in 2011.

Ludlum didn't stop there. In 2012 they were on their way to obtaining their 8th division known as Plowden & Thompson / Tudor Crystal, a glass product manufacturer and in 2018 their 9th known as 2B Technologies, a designer and manufacturer of portable instruments for air monitoring, environmental and industrial applications.

With the 9 total divisions under their belt, the company prides themselves on insourcing a very large percentage of their components used in the manufacturing of their product line.

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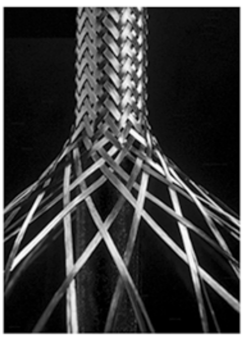

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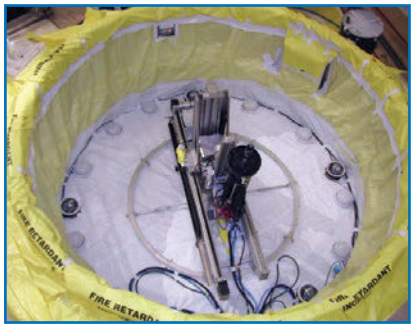

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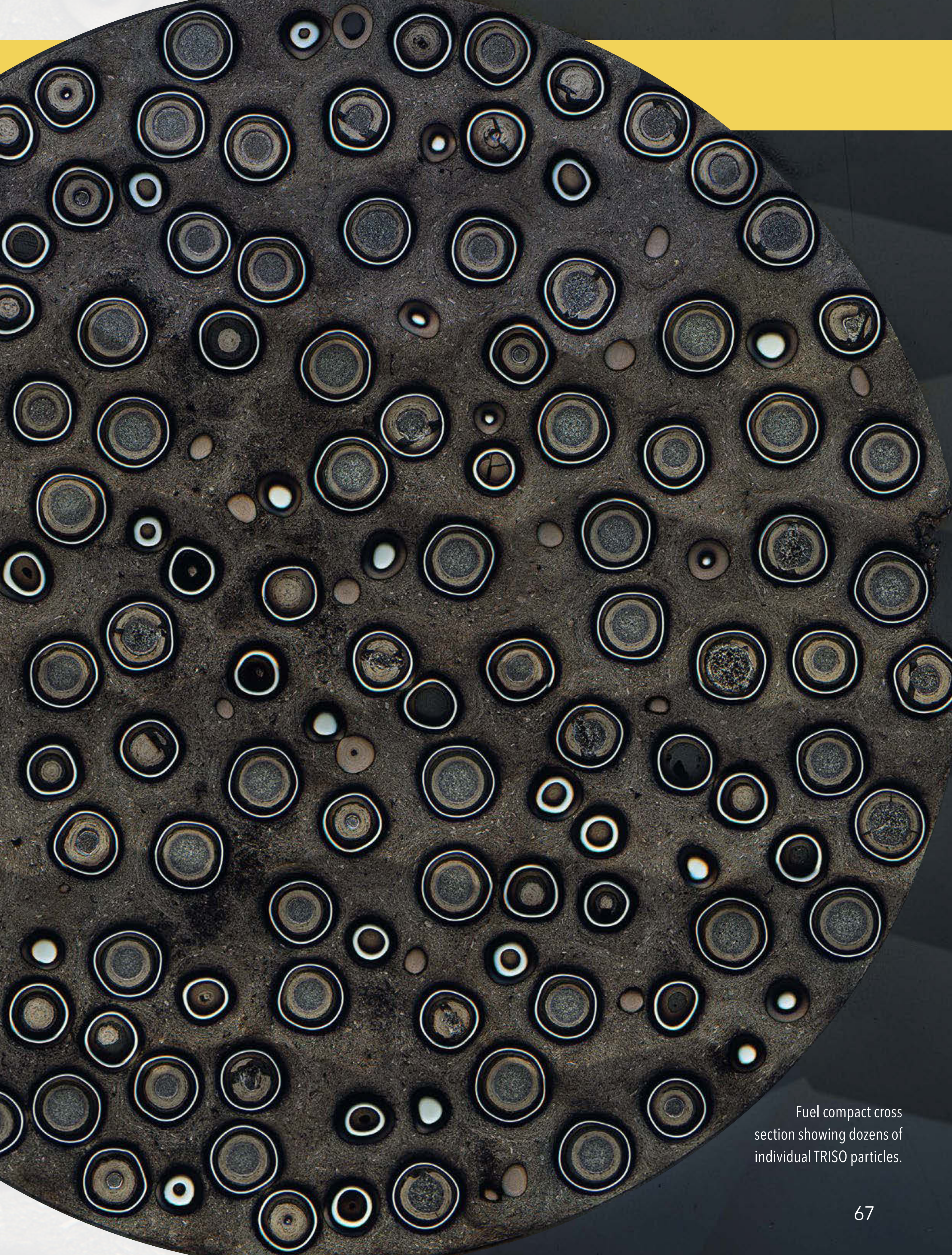
Two decades of DOE investment lays the foundation for TRISO-fueled reactors

By Paul A. Demkowicz
and John D. Hunn

Tristructural isotropic (TRISO) coated particle fuel is a robust, microencapsulated fuel form developed originally for use in high-temperature gas-cooled reactors (HTGRs). The particles consist of a spherical fissile kernel surrounded by several layers of pyrocarbon and a silicon carbide (SiC) layer. The particles are formed into cylindrical or spherical fuel forms using a resinated graphite matrix material for insertion into an HTGR. The kernel and coating layers together act to retain fission products within the particle during normal reactor operation and during postulated accidents; TRISO particles can maintain structural integrity at extremely high temperatures, reaching as high as approximately 1,600 °C in limiting HTGR accidents. This limits the fission product activity circulating in the helium coolant and the activity released to the environment during accidents. Acceptable performance of TRISO particles is therefore essential for reactor safety.

The most common kernel types utilized in modern TRISO particles are uranium dioxide (UO_2) and a mixture of uranium oxide and uranium carbide, often colloquially referred to as uranium oxycarbide or UCO. Despite the origin and historic use of TRISO fuel in HTGRs, the conventional TRISO particle design is now being considered for other types of advanced, high-temperature reactors (HTRs) including the fluoride salt–cooled high-temperature reactor and microreactors. Particles and fuel forms with modified design—including more exotic kernel compositions and different matrix materials but retaining the fundamental TRISO coating structure—are being considered as accident-tolerant fuel for light-water reactors.



Fuel compact cross section showing dozens of individual TRISO particles.

Figure 1. TRISO fuel particle, fuel compacts, and spherical fuel pebble. Fuel pebble image provided by X-energy LLC.

TRISO fuel development program

The U.S. Department of Energy renewed efforts to develop low-enriched uranium (LEU) UCO TRISO fuel by initiating the Advanced Gas Reactor (AGR) Fuel Development and Qualification Program in 2002. The objectives were to help establish a domestic, commercial TRISO fuel fabrication capability in the United States and to generate fuel performance data that can support high-temperature reactor design and licensing efforts. To accomplish these objectives, the program set out to demonstrate high-quality TRISO fuel fabrication at the pilot scale with low coating defect levels, and perform irradiation testing and post-irradiation safety testing to provide data on fuel performance under normal reactor operating conditions and anticipated accident conditions. This work has been performed in the framework of a program compliant with ASME NQA-1 quality standards to ensure the pedigree of generated data.

The AGR program was established initially to support the DOE Next Generation Nuclear Plant (NGNP) project, which sought to deploy a modular HTGR in the United States to take advantage of enhanced safety features of this Generation IV reactor design. Although the DOE chose not to pursue NGNP design in 2011, the AGR program continues currently under the DOE Office of Advanced Reactor Technologies to support the licensing of HTR designs now being pursued by U.S. commercial reactor designers.

Fuel fabrication

The program has focused on UCO TRISO fuel in cylindrical compact form (see Figure 1), based upon previous fuel development efforts for modular prismatic HTGRs in the United States. The selection of UCO kernels over UO_2 was based on performance benefits of this fuel type at higher burnups (>10 percent fissions per initial metal atom, or FIMA), a result of a significantly lower tendency of UCO kernels to form carbon monoxide gas within the particles during irradiation. Early work was dedicated to developing fuel performance models to help evaluate past TRISO fuel performance deficiencies and establishing fuel property specifications that would result in acceptable particle performance. Initial fuel fabrication efforts concentrated on the production of high-quality fuel at the laboratory scale, using lab-scale coating and compacting equipment and processes at Oak Ridge National Laboratory (ORNL). Work then progressed in a phased approach to scale up fabrication to the pilot scale, first with TRISO coating, and finally with fuel compact fabrication by BWXT Nuclear Operations Group.

An important measure of as-fabricated TRISO fuel quality is the number of defects in the coating layers and the amount of dispersed uranium (i.e., uranium located in the fuel compact outside of the SiC layer of particles). A key defect type is called an "exposed kernel defect" because the coatings on such a particle are damaged or defective, such that fission gas is released from the particle during irradiation. The fraction of such defects was substantially less than 10^{-5} (less than one particle per 100,000) for the laboratory-scale fuel, and tended to be higher in the pilot-scale fuel used for AGR-2, with values of approximately 5×10^{-5}, highlighting one of the challenges of increasing the scale of fuel fabrication. Similarly, the dispersed uranium was extremely low in the laboratory-scale fuel (up to 4×10^{-7}) and higher by roughly a factor of 10 in the pilot-scale fuel. Information gained from this initial pilot effort can be used in follow-on efforts by commercial fuel fabricators to eliminate the causes of these observed defect fraction increases and develop more optimal large-scale processes.

Irradiation experiment overview

A series of irradiation tests have been executed to evaluate the performance of the fuel produced in each fabrication campaign. The objective was to test fuel under a broad range of service conditions, including time-average, volume-average temperature up to 1,250 °C, burnup to 20 percent FIMA, and fast neutron fluence to approximately 5×10^{25} n/m^2. In addition, a dedicated irradiation test has been performed to provide data on fission product transport in fuel and reactor core graphite materials. Essential features of all irradiations included the online monitoring of fission gas activity released from the fuel to assess the status of the particles, and computational physics and thermal modeling of the capsules to predict uranium depletion and fuel temperatures.

The irradiations have all been performed in the Advanced Test Reactor (ATR) at Idaho National Laboratory (INL); the first three are completed, and the fourth and final test will be completed in 2020. All the irradiation experiments involved multiple instrumented capsules with dedicated gas flows. In all experiments, the individual capsules were welded together into a single assembly or "test train" for insertion into the ATR; the experiments have contained between five and 12 capsules. This design approach maximized the axial length of the ATR core that could be used, providing a large test volume to irradiate fuel particles in compacts over a range of burnup and fast neutron fluence profiles while still allowing fuel temperatures in all compacts to be maintained within the desired ranges. The tests are summarized on the next page, and an accompanying table presents some of the key features of the four irradiation experiments.

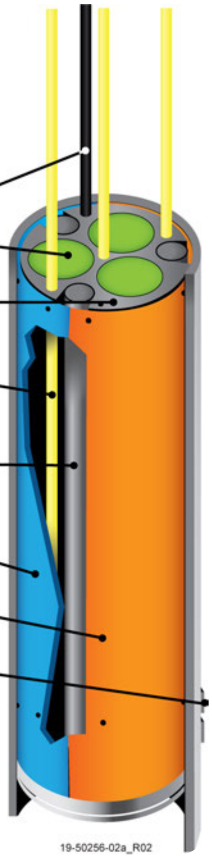


Figure 2. Cutaway drawing of an AGR-1 irradiation capsule.

■ **AGR-1:** This experiment represented a shakedown test of the multicapsule, instrumented test train design approach that would be used in all subsequent experiments and was meant to assess the performance of fuel fabricated at the laboratory scale. Kernels fabricated at BWXT were coated in a 50-mm-diameter cylindrical chamber and formed into compacts at ORNL. Several different fuel particle lots were included, involving variations in fabrication parameters for either the inner pyrolytic carbon layer or the SiC layer, to explore the impact of layer properties on fuel performance. Figure 2 shows a drawing of an AGR-1 irradiation capsule. The irradiation was performed from December 2006 to November 2009, achieving peak burnup of 19.6 percent FIMA.

■ **AGR-2:** This experiment was a performance demonstration for coated particles fabricated at BWXT in a pilot-scale process, using a 150-mm-diameter coating chamber. The test included particles fabricated from both UCO and UO_2 kernels. The UO_2 fuel was included to compare performance of the two kernel types and was driven by interest in UO_2-fueled pebble-bed reactors. Coated particles were compacted at ORNL using a laboratory-scale process similar to that used for AGR-1 fuel. The test train had a design very similar to AGR-1: three capsules contained 12 UCO compacts each, while a fourth contained 12 UO_2 compacts fabricated in the United States. The remaining two capsules contained UO_2 TRISO fuel supplied from CEA (French Alternative Energies and Atomic Energy Commission) in France and PBMR (Pebble Bed Modular Reactor, Ltd) in South Africa as part of the Generation IV collaboration. One of the U.S. UCO capsules—Capsule 2—was intentionally operated at significantly higher temperatures to test the upper temperature margin of fuel performance. Time-average peak temperature in this capsule was 1,360 °C. The irradiation was performed from June 2010 to October 2013.

■ **AGR-3/4:** This experiment was dedicated to studying fission product transport in fuel compact matrix material and reactor-grade graphite. This was accomplished by fabricating fuel compacts in which approximately 1 percent of the particles were "designed to fail" (DTF). During the irradiation, the singular, thin pyrocarbon coating on each DTF particle failed, and the particles released fission products, which migrated through the surrounding materials. The intact "driver" fuel particles were similar to the AGR-1 TRISO particles. The test train included 12 separate capsules, which allowed a large range of fuel temperatures (see table) and two different grades of graphite to be investigated. The experiment was irradiated from December 2011 to April 2014.

■ **AGR-5/6/7:** This is the final fuel qualification and performance margin irradiation experiment. It includes UCO coated particles and fuel compacts, all fabricated at BWXT in pilot-scale processes. The test train includes five separate capsules and approximately 570,000 particles. Originally planned as three separate irradiation experiments (designated AGR-5, AGR-6, and AGR-7) taking place in large B positions in the ATR, the experiments were combined into a single test designed for the much larger ATR northeast flux trap position. The central capsule (Capsule 3) comprises the AGR-7 portion of the experiment, which is a high-temperature fuel performance margin test designed to explore fuel behavior at temperatures significantly exceeding those expected during normal operation in an HTGR. The remaining capsules comprise the AGR-5/6 experiment. For this ambitious experiment, the peak burnup will be approximately 16 percent FIMA and the time-average maximum temperature target is 1,500 °C. The irradiation started in February 2018 and is expected to be completed in 2020.

	AGR-1	AGR-2	AGR-3/4	AGR-5/6/7
Description	Test of lab-scale coated particles and compacts	Performance test of pilot-scale coated particles in lab-scale compacts	Fission product transport experiment; includes 1% designed-to-fail particles to release fission products during irradiation	Fuel qualification and performance margin test (time-average peak temperatures up to 1,500 °C)
Kernel type	UCO	UCO UO_2	UCO	UCO
Average kernel diameter (μm) / enrichment (wt% ^{235}U)	350 / 19.7	427 / 14.0 508 / 9.6	357 / 19.7	426 / 15.5
Compacts/ particles	72 / 298,000	36 / 114,000 12 / 18,500	48 / 91,000	170 / 570,000
Fuel Temp (°C)[a]	1,069 – 1,197	1,080 – 1,360 1,072 – 1,105	865 – 1,418	~700 – 1,500[b]
Burnup (% FIMA)	11.3 – 19.6	7.3 – 13.2 9.0 – 10.7	4.9 – 15.3	~6 – 16[c]

a. Time-average peak fuel temperature range for all compacts
b. Targeted values; experiment temperature analysis is not complete
c. Projected end-of-life values

TRISO fuel performance

The key measure of TRISO fuel performance during irradiation is the magnitude of fission gas release. The basis of this approach is that intact TRISO layers retain fission gases extremely well, and therefore small increases in the total release can indicate TRISO failure (failure of all three dense coating layers). The fission gas release is measured by continuously monitoring the sweep gas exiting each capsule using gamma spectrometers. Fission gas release is subsequently evaluated using the release-to-birth (R/B) ratio, which compares the measured release rate for a specific isotope to the rate of generation in the fuel from fission.

The AGR-1 end-of-life ^{85m}Kr R/B values were 0.2–2 × 10^{-7} for the six capsules (note that a value of 10^{-7} indicates that one ^{85m}Kr atom is released from the fuel for every 10 million ^{85m}Kr atoms produced by fission). These low values indicated that no particles out of the approximately 300,000 in the experiment experienced TRISO failure during the irradiation. The ^{85m}Kr R/B values at the beginning of the AGR-2 irradiation were ~6 × 10^{-7} in the two capsules containing UCO at normal operating temperatures, and 10^{-6} in Capsule 2 with UCO particles operating at a higher irradiation temperature. The higher values in this experiment reflect higher uranium contamination outside of particle coatings in this fuel relative to AGR-1 fuel. Experimental issues during the AGR-2 irradiation resulted in failure of some of the gas lines and mixing of the gas streams from different capsules, which prevented determination of end-of-life R/B values from individual capsules.

Post-irradiation examination (PIE) further helps to elucidate in-pile fuel performance. PIE for the AGR-1 experiment is complete and the AGR-2 PIE is nearing completion. Two key aspects that hold the predominant focus of coated particle fuel performance evaluation are coating layer failure rates and fission product release rates, and a large volume of data on these as-

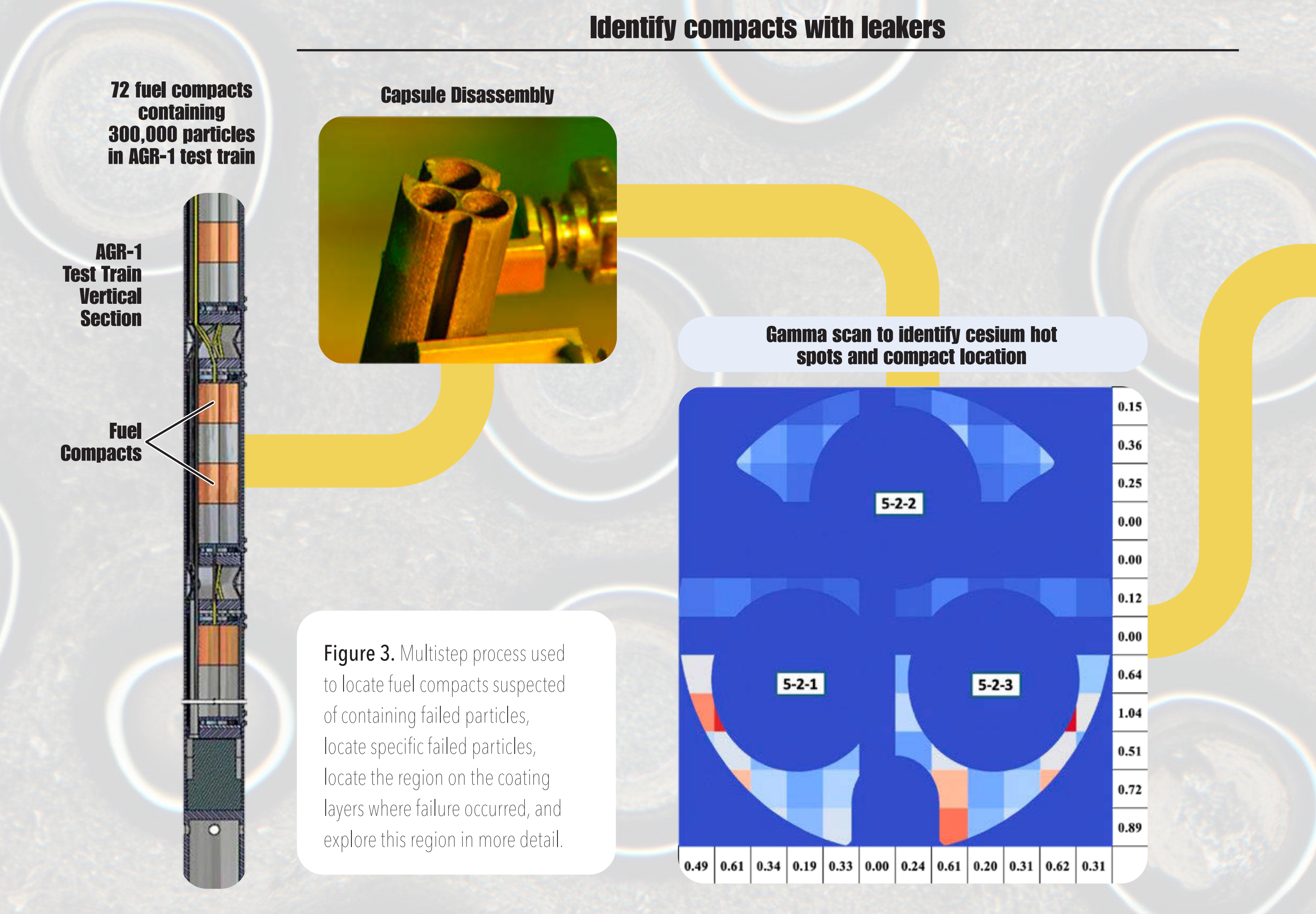


Figure 3. Multistep process used to locate fuel compacts suspected of containing failed particles, locate specific failed particles, locate the region on the coating layers where failure occurred, and explore this region in more detail.

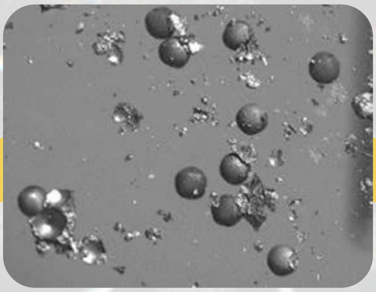
pects has been obtained from the AGR-1 and -2 irradiation and PIE campaigns. TRISO failure rates during irradiation were determined primarily by R/B data, as discussed above. Where fission gas release data during irradiation were inconclusive, additional information from PIE was used to help evaluate TRISO failure rates.

In addition to PIE, high-temperature safety tests were performed on the irradiated fuel specimens to assess fuel behavior at temperatures significantly exceeding those experienced during irradiation, and more representative of temperatures achieved during reactor accidents involving a loss of helium coolant flow. Tests were performed at temperatures of 1,500–1,800 °C for several hundred hours in pure helium while measuring the time-dependent release of fission products, including isotopes of silver, cesium, europium, strontium, and krypton. This provided critical information on the level of fission product release from the fuel as well as the impact of high temperatures on coating layer failure; elevated coating layer failure rates are to be expected because of thermally driven degradation of the coating layers at these extreme temperatures. The data obtained from these tests is an essential component of the safety evaluation of TRISO fuel.

Failure of the particle SiC layer (where at least one of the pyrocarbon layers remains intact and continues to retain fission gases) was determined by examining fission product cesium release from the fuel during PIE—an indication of SiC failure, since intact pyrocarbon alone poorly retains cesium—and studying suspect particles in detail. Advances in PIE methods in the AGR program have made this possible, and enabled researchers to find and isolate for analysis a small number of particles with failures out of hundreds of thousands of nonfailed particles

Identify particles with failed coatings

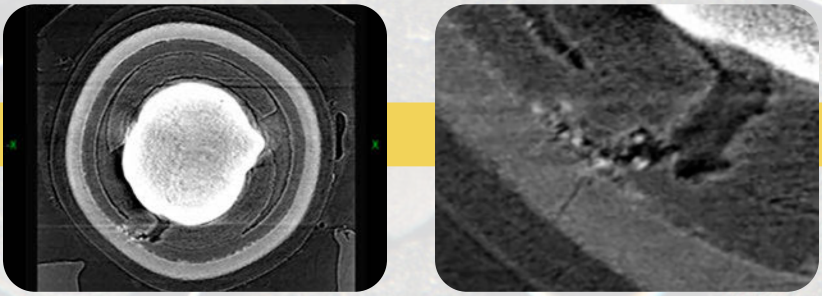
Deconsolidation to obtain ~4,000 particles from compact



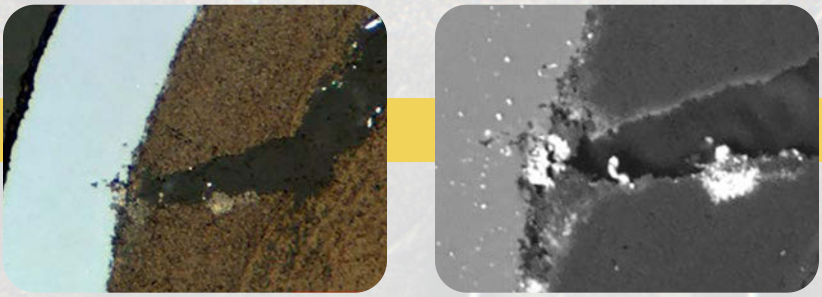
Gamma count to find particles with low cesium retention

Study particles with failed coatings

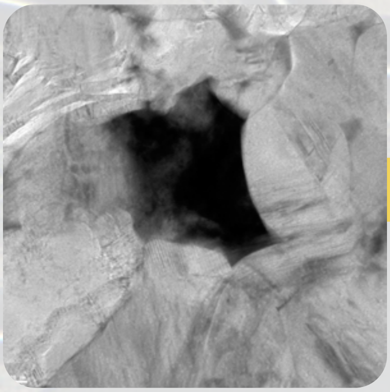
X-ray tomography to locate failures



Materialography to expose defective region for analysis



Advanced microscopy to study coating layers in detail



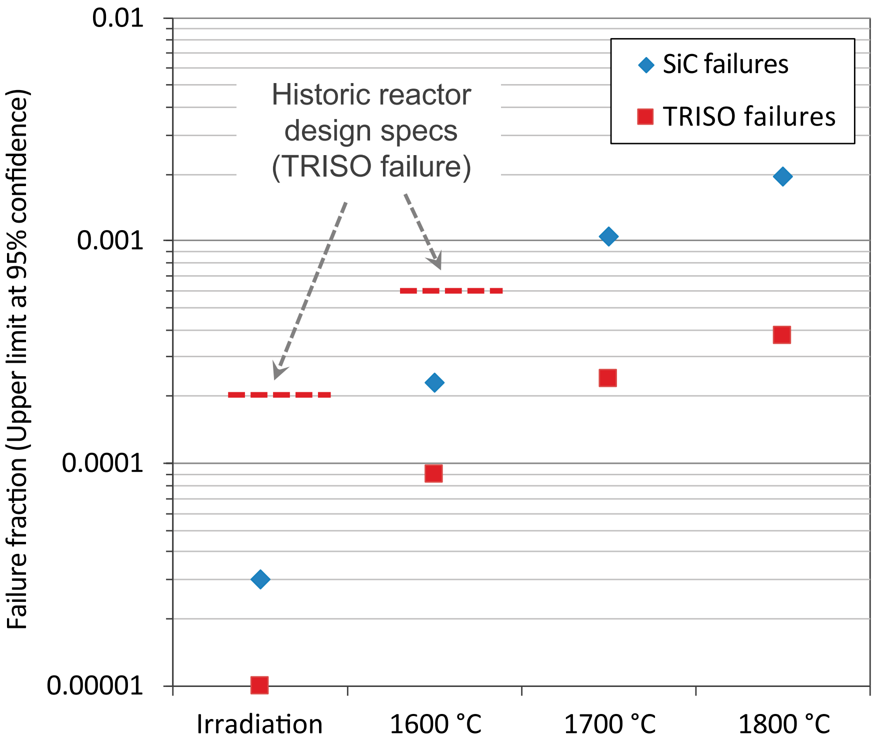
in the irradiation experiments.

The basic process for isolating and examining failed particles is outlined in Figure 3, and involves: gamma scanning the graphite components that retained the fuel compacts during irradiation to find "hot spots" of cesium that can indicate the proximity of particles with failed coatings; deconsolidating suspect compacts to obtain all the particles (up to ~4,000 particles in an AGR compact); gamma counting each particle to identify those with relatively low cesium, indicative of release; performing nondestructive examination of these particles with x-radiography to observe the morphology of the coatings; and focusing destructive microanalysis (e.g., scanning electron microscopy, transmission electron microscopy, elemental analysis) on the exact location where the coating layer(s) failed. The process is also applied following safety tests when the fission product release data indicate one or more particles experienced coating layer failures. As an example, it was determined that four particles out of approximately 300,000 in the AGR-1 irradiation experiment experienced SiC layer failure, and these particles were found and studied to better understand the failure mechanisms.

Figure 4 displays the experimentally determined coating failure rates during AGR-1 irradiation and subsequent high-temperature post-irradiation safety testing at various temperatures. This includes both TRISO failures and less-extreme SiC failures. The values on the plot are based on the combined results from the AGR-1 irradiation, PIE, and safety testing, and are the calculated upper limit on the failure rates at 95 percent confidence. Historic high-temperature gas-cooled reactor design specifications for allowable failure fractions during normal operation (2×10^{-4}) and during high-temperature accidents at temperatures up to 1,600 °C (6×10^{-4}) are shown on the plot for comparison. The results indicate significant safety margin.

Microanalysis of fuel particles following irradiation (and also after safety tests) has been performed to understand kernel and coating morphology evolution as a function of neutron irradiation and time at temperature, assess coating damage, and better understand fission product transport in the coating layers. This has included imaging of thousands of particle cross sections using optical microscopy and examining a subset of these particles with scanning electron microscopy and elemental analysis. Figure 5 shows typical particle cross sections before and after irradiation. More detailed analyses have also been performed using scanning transmission electron microscopy and related tools to understand fission product transport at the nanometer length scale. Nondestructive examination of irradiated particles using X-ray imaging and tomographic reconstruction has been an integral tool in the program to understand coating failure mechanisms and focus subsequent destructive ex-

Figure 4. Failure fractions observed in AGR-1 irradiation and safety tests.



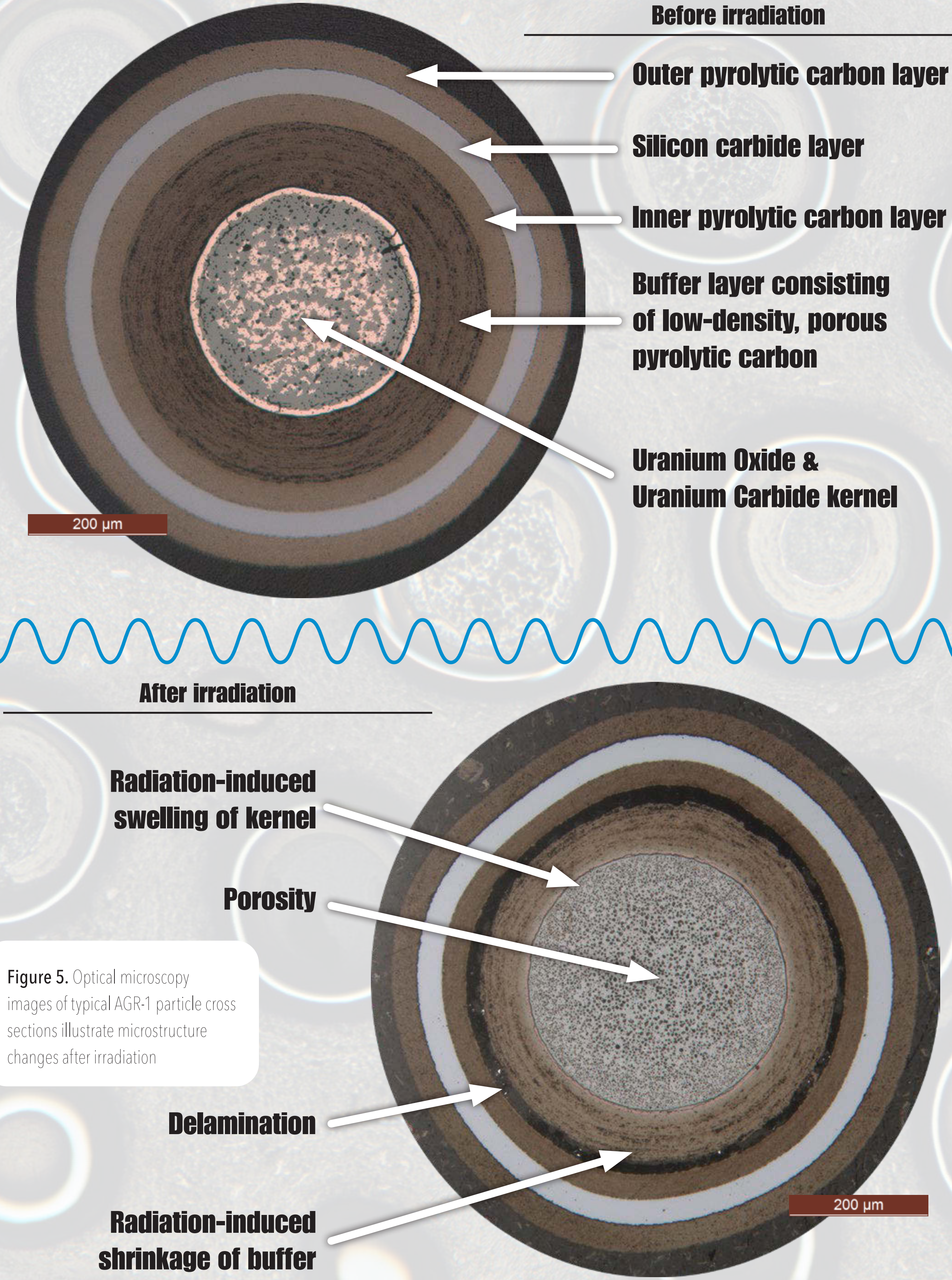


Figure 5. Optical microscopy images of typical AGR-1 particle cross sections illustrate microstructure changes after irradiation

ams to specific regions of interest.

The data from the AGR-1 and AGR-2 experiments demonstrate some broad trends in fission product release behavior of this fuel form. The particles retain fission gas exceptionally well when any of the dense coating layers remain intact and retain cesium nearly completely when the SiC layer remains intact. Hence the release of these fission products is dependent primarily on coating failure rates, which are very low, as discussed above. Europium and strontium are released in modest amounts from intact TRISO particles; the total release fraction from fuel compacts under normal HTGR operating temperatures is less than ~5×10^{-4}. As observed over decades of TRISO fuel irradiation experience, silver transports fairly readily out of intact TRISO particles at temperatures above 1,000–1,100 °C. Silver behavior in individual coated particles in these two irradiation experiments depended primarily on fuel temperature and ranged from nearly complete retention to nearly complete release.

The AGR-1 and AGR-2 fuel performance results were recently compiled and submitted to the Nuclear Regulatory Commission in a Topical Report by EPRI (see Topical Report EPRI-AR-1 [NP]), in partnership with INL and industry participants in the Nuclear Energy Institute's High-Temperature Reactor Technology Working Group ("TRISO fuel nears qualification," *Nuclear News*, September 2019). The NRC's review of the report is currently in the final stages, with a safety evaluation potentially to be issued in summer 2020. This safety evaluation will help accelerate licensing of advanced high-temperature reactor designs, by obtaining NRC review and approval of key AGR program data demonstrating TRISO fuel particle performance under high-temperature reactor conditions.

PIE of the AGR-3/4 irradiation experiment is still in progress. This focuses on examining the irradiated fuel compacts and matrix/graphite components of the capsules to measure the distribution of fission products silver, cesium, europium, and strontium within these specimens. Data on fission product migration during the irradiation will allow researchers to refine the fundamental parameters (including diffusivities) that govern the transport of these elements through the graphitic matrix and reactor core materials. This vital data will support development of fission product transport models used to predict the radiological source terms during reactor operation and accidents.

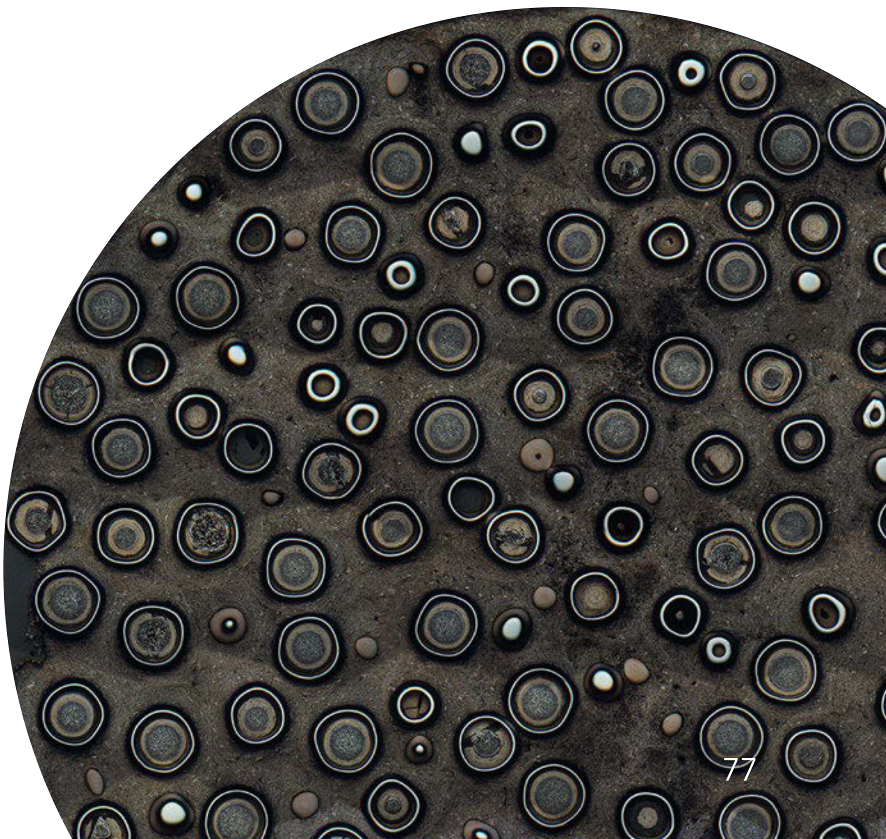
Looking ahead, the key remaining activities in the program are the completion of the AGR-5/6/7 irradiation, followed by PIE and safety testing. A critical part of this work—and a

Further reading:

- D. A. Petti et al., "The DOE Advanced Gas Reactor Fuel Development and Qualification Program," *JOM*, 62, 62 (2010); doi.org/10.1007/s11837-010-0140-5.
- P. A. Demkowicz, J. D. Hunn, D. A. Petti, and R. N. Morris, "Key Results from Irradiation and Post-Irradiation Examination of AGR-1 UCO TRISO Fuel," *Nucl. Eng. Des.*, 329, 102 (2018); doi.org/10.1016/j.nucengdes.2017.09.005.
- J. D. Hunn et al., "Post-Irradiation Examination and Safety Testing of US AGR-2 Irradiation Test Compacts," *Proc. 9th Int. Topl. Mtg. High Temperature Reactor Technology (HTR-2018)*, Warsaw, Poland, October 8–10, 2018.
- P. A. Demkowicz, B. Liu, and J. D. Hunn, "Coated Particle Fuel: Historical Perspectives and Current Progress," *J. Nucl. Mater.*, 515, 434 (2019); doi.org/10.1016/j.jnucmat.2018.09.044.
- H. D. Gougar et al., "The US Department of Energy's High Temperature Reactor Research and Development Program—Progress as of 2019," *Nucl. Eng. Des.*, 358, 110397 (2020); doi.org/10.1016/j.nucengdes.2019.110397.

component of the fuel qualification program that has not been addressed in previous experiment campaigns—is the evaluation of fuel performance at high temperatures in oxidizing environments. Work is currently underway to develop a capability for heating irradiated fuel specimens in the presence of various concentrations of oxygen or moisture while measuring the release of gaseous and condensable fission products. These tests are crucially important for assessing the behavior of the fuel in conditions that could exist in a high-temperature reactor during inadvertent ingress of oxidants (steam or air) into the core.

When complete, the data obtained from this qualification program will support advanced reactor licensing by demonstrating fuel performance under a range of operating conditions and by providing data to refine fission product transport models used in reactor design and safety analyses. In response to the widespread interest in TRISO fuel, two U.S. companies have announced that they are actively developing commercial TRISO fuel fabrication capabilities. BWXT has restarted its TRISO fuel production line in Lynchburg, Va., where it is using and expanding on capabilities applied in the pilot-scale fabrication of AGR-2 and AGR-5/6/7 fuel compacts. Also, with funding support from the DOE, X-energy LLC is pursuing development of pilot-scale fuel fabrication equipment and methods in a facility at ORNL and is working to establish and license its own TRISO fuel fabrication facility. Much of what has been developed and learned over the past two decades by the DOE AGR program, including aspects of fuel fabrication, optimization of TRISO particle design, modernization of characterization and inspection methods for quality control, instrumented irradiation testing, post-irradiation examination, and safety testing will be leveraged by these two companies and others interested in pursuing TRISO-based fuel technologies.



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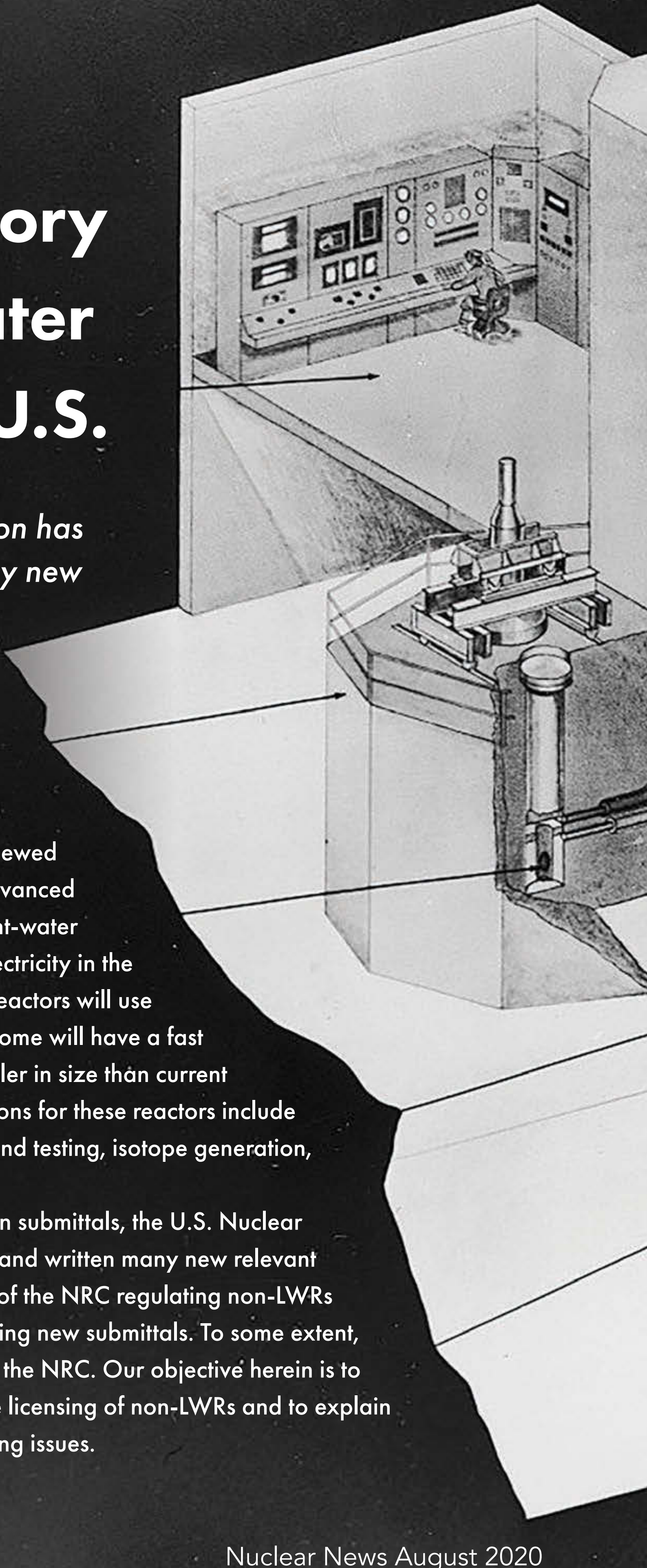
Regulatory history of non-light-water reactors in the U.S.

The Nuclear Regulatory Commission has studied issues and has written many new relevant documents to prepare for potential application submissions for non-LWRs.



Over the past several years there has been renewed interest in the development and licensing of advanced reactors that will be very different from the light-water reactors that are currently used to generate electricity in the United States. For example, some advanced reactors will use gas, liquid metal, or molten salt as a coolant, some will have a fast neutron spectrum, and some will be much smaller in size than current generation LWRs. The many possible applications for these reactors include electricity production, process heat, research and testing, isotope generation, and space applications.

To prepare for potential non-LWR application submittals, the U.S. Nuclear Regulatory Commission has studied the issues and written many new relevant documents. In addition, there is a long history of the NRC regulating non-LWRs that might be useful to study to help in addressing new submittals. To some extent, this has been chronicled in general histories of the NRC. Our objective herein is to describe the NRC's history specifically with the licensing of non-LWRs and to explain some of the most salient regulatory and licensing issues.

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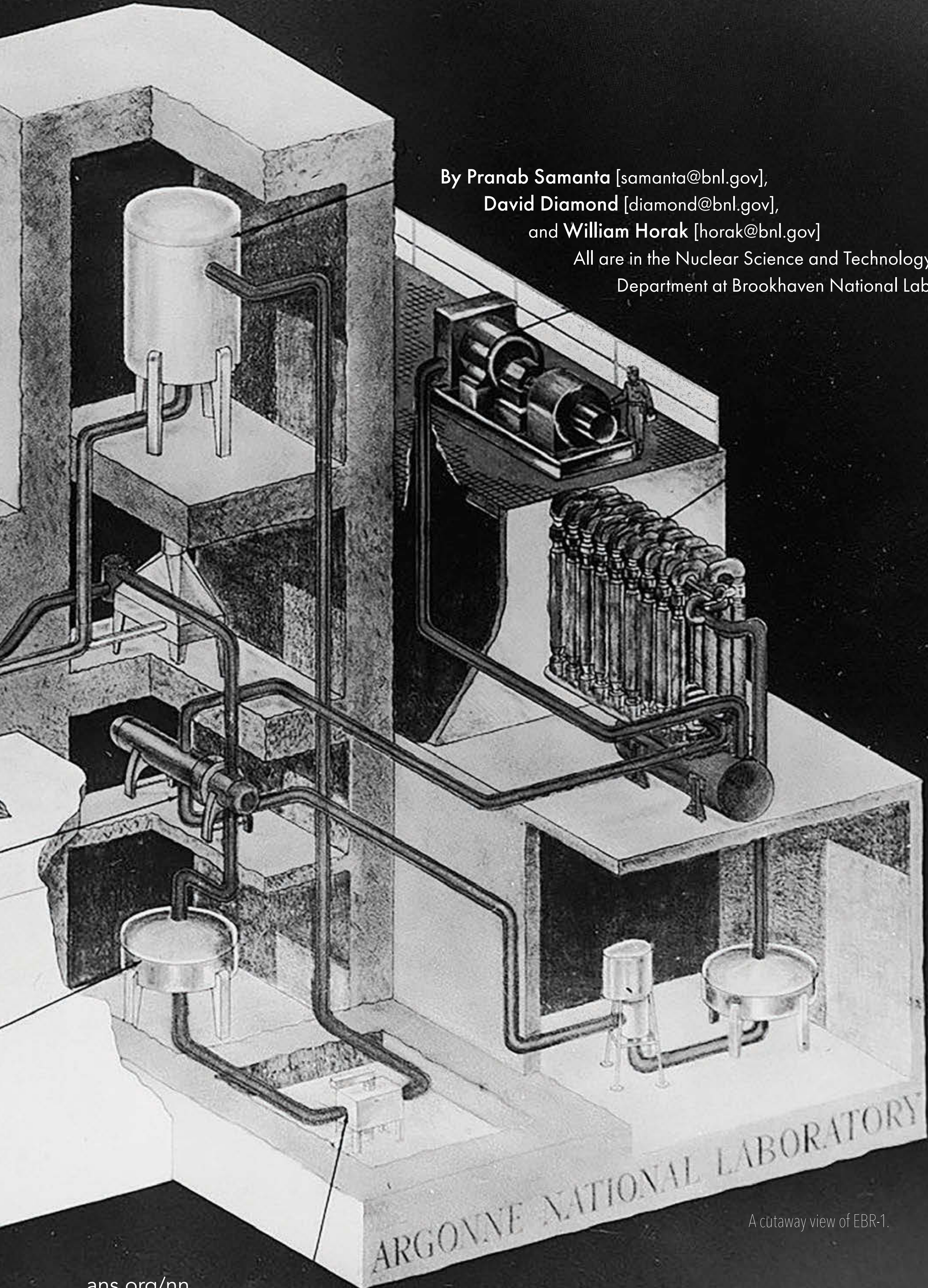


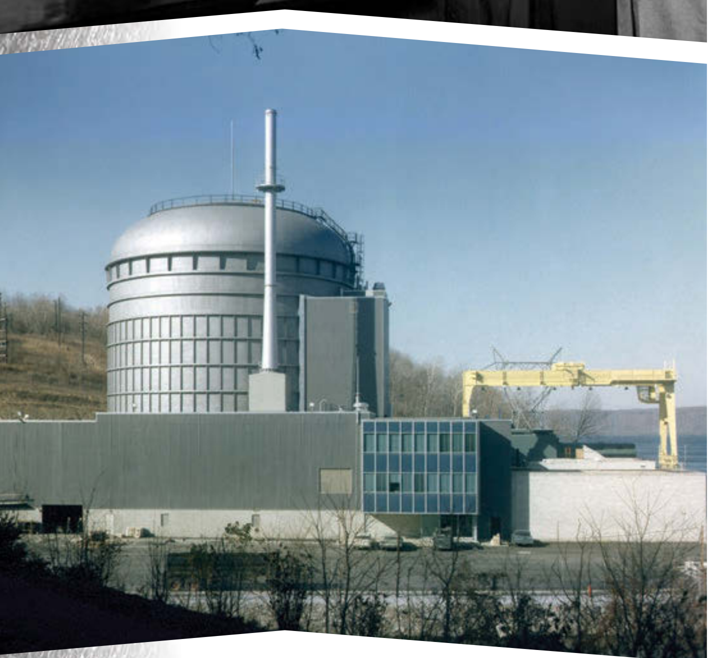
A cutaway view of EBR-1.

Early non-LWR history

The Atomic Energy Commission (AEC) was created by Congress via the Atomic Energy Act (AEA) of 1946. By the beginning of the 1950s, the AEC began to get industrial participation and initiate work at national laboratories that led to the building of many research, test, and prototype or demonstration reactors, including non-LWRs that were liquid sodium, organic liquid, heavy water, or gas-cooled.

During the 1950s, safety was regarded to be important, but the corresponding regulatory infrastructure was minimal. Safety evaluations involved writing hazards-summary reports that were evaluated by committees. Improved safety was one of the considerations in the revision of the AEA in 1954. The Advisory Committee on Reactor Safeguards (ACRS) was established as a statutory committee that was (and still is) to provide oversight on safety and report directly to the commission. The concerns over safety also led to the establishment of a separate Reactor Hazard Evaluation Staff within the AEC in 1955. Although the process was defined, the evaluation of hazards was difficult due to all the technical uncertainties. For example, there was limited experience in how properties of materials changed with irradiation and high stress levels, or how coolants would interact with metals at high temperature, or the impact of uncertainties in nuclear properties.

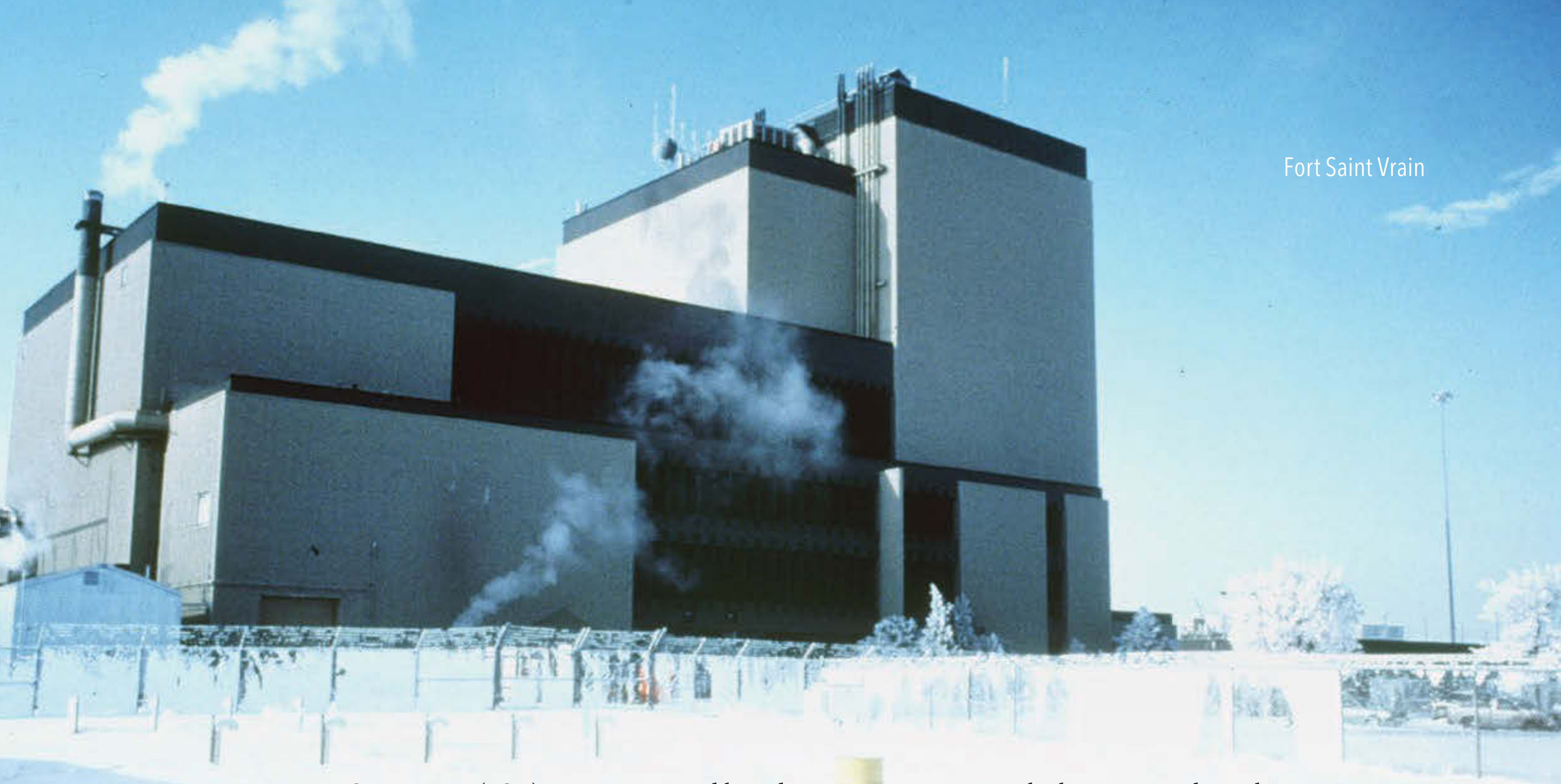
The Energy Reorganization Act (ERA) of 1974 marked the end of the AEC and the founding of the NRC to carry out the independent licensing and regulation of nuclear reactors. It was clear by the time the ERA was passed, and signed into law, that a body for regulation of nuclear safety needed to stand on its own.



Top: President Truman signs AEA
Bottom: Peach Bottom Atomic Power Station

Licensing gas-cooled reactors

Peach Bottom Atomic Power Station (PBAPS) Unit 1 was the first high-temperature gas reactor (HTGR) built in the United States. It was a 40-MWe demonstration plant, which operated at 2.4 kPa primary system pressure with a core inlet temperature of 350 °C and outlet temperature of 750 °C. The reactor went critical on March 3, 1966, and operated successfully until permanent reactor shutdown near the end of 1974, completing its demonstration mission. The goal of this plant was to demonstrate production of 538 °C steam from a reactor with good neutron economy and high fuel burnup.



Fort Saint Vrain

Fort Saint Vrain (FSV) was constructed based on the design of Peach Bottom and went into commercial operation on July 1, 1979. The reactor, with an output of 330 MWe, used high-temperature helium as the primary coolant to produce superheated and reheated steam at approximately 538 °C. The reactor fuel elements were a prismatic block design containing a mixture of carbides of uranium and thorium with tristructural isotropic (TRISO) coatings. FSV remained in commercial operation for a little more than 10 years. When the plant was shut down to repair a stuck control rod pair, numerous cracks were discovered in several steam generator main steam ring headers, and operation was terminated.

FSV was licensed under the provisions of the *Code of Federal Regulations*, Title 10—Energy, Part 50, Section 21 (10 CFR 50.21), "Class 104 Licenses; for Medical Therapy and Research and Development Facilities." FSV was considered by the AEC to be a "research and development reactor that could be shut down immediately if there were any real safety problems." It had a different oversight structure than that used at its contemporary LWRs. The Class 104(b) operating license issued for FSV and the NRC cognizant staff interpretation of the statutory basis for that license meant that FSV regulatory requirements were tailored to allow more flexibility than perhaps was afforded other contemporary plants that were licensed differently (under Section 103 of the AEA).

Reviewing the licensing and regulatory experience of PBAPS and FSV provided insights for reviewing later license applications. For example, developing clear safety analysis reports addressing principal design criteria that meet the safety functions underlying the NRC's general design criteria, and seismic and environmental qualifications for the cooling systems, among other equipment, were seen to be important. There was also concern over: the need to address industry codes and standards in a consistent manner to the new and innovative designs; defining a fire protection program and the associated mechanisms for responding to a fire to achieve hot and cold safe shutdown that is consistent with regulatory requirements; and maintaining detailed documentation of how calculations are done, how measurements are made (with all uncertainties accounted for), and how analytical and experimental results are reconciled. Some of the issues arose because FSV had a Class 104(b) license that didn't require such information.

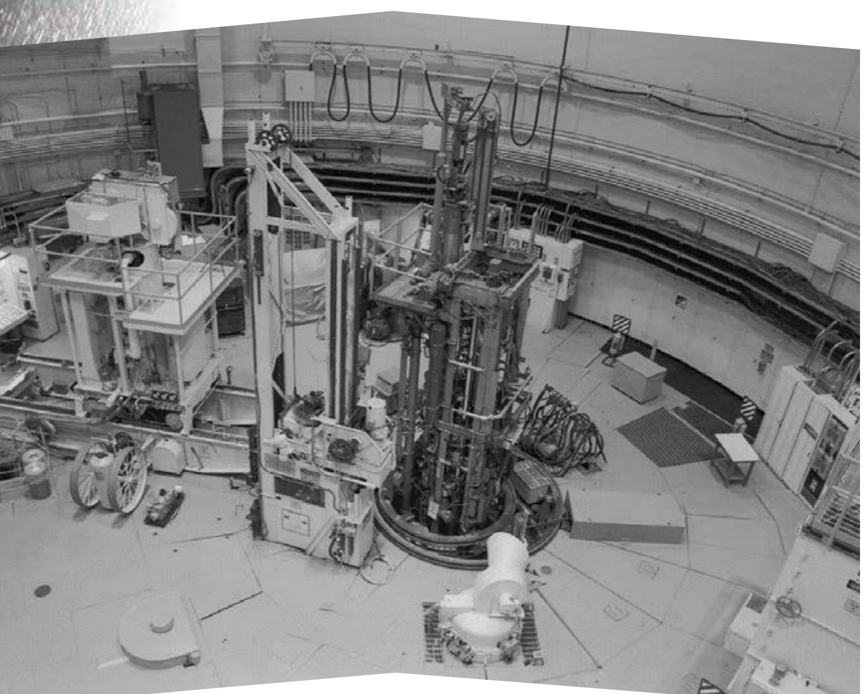
The goal of the modular high-temperature gas-cooled reactor (MHTGR) was to develop a passively safe HTGR plant that was also economically competitive. To maintain the coated-particle fuel temperatures below damage limits during passive decay heat removal, the core's physical size had to be limited; hence, the maximum reactor power was to be about 200 MWt for a solid, cylindrical core geometry. This rating, however, was projected to not be economically competitive for electric power generation. This judgment led to the development of an annular core concept to enable larger cores with increased power capacity. Licensing activities included preapplication interaction with the NRC and submittal of numerous documents, including a preliminary safety information document.

The NRC conducted and documented a preapplication safety evaluation of the MHTGR. As stated in the safety evaluation, the general safety advantages of the MHTGR, like those of other HTGRs, were its slow response to core heat-up events, because of the large heat capacity and low power density of the core, and the very high temperature that the fuel can sustain before the initiation of fission-product release (~1,600 °C). Also, like other HTGRs, its major potential vulnerabilities derive from the need to protect metal components from continued exposure at elevated temperatures to hot helium during postulated transients and to prevent uncontrolled access of air or moisture to hot graphite and fuel particles.

The preapplication safety review defined policy issues that needed commission guidance for resolution. One was the definition of four event categories (abnormal operating experience, design-basis accidents, severe accidents, and emergency planning) that must be considered in a design. Other issues were a proposed mechanistic means of source term calculation and its use in assessing the need for conventional containment structure. Lastly, the NRC staff also discussed the emergency planning requirements and stressed that the need will depend on, but may not necessarily directly follow from, the acceptance of the mechanistic source term.

The mission of the Next Generation Nuclear Plant (NGNP) project was to develop, license, build, and operate a prototype MHTGR that would generate high-temperature process heat for use in hydrogen production and other energy-intensive industries while generating electric power at the same time. The Energy Policy Act of 2005 directed the Department of Energy to develop the NGNP prototype for commercialization and provided the licensing authority to the NRC. The DOE and the NRC jointly developed a licensing strategy and carried out activities that provided useful input for the regulatory basis for non-LWRs. The DOE decided in 2011 not to proceed into the detailed design and the license application phase of the project was not pursued.

EBR-II



Licensing liquid metal–cooled reactors

EBR-I was a 1.4-MWt test reactor that began operation in 1951. A loop design, it used electromagnetic pumps in the primary loop. It was cooled by a eutectic alloy of sodium and potassium and used a metal fuel. The plant suffered a partial core meltdown in 1955 during a series of reactivity tests; the reactor was unstable under certain flow conditions. A second core was designed and installed which addressed the stability problems, and was used until the program was terminated in 1963.

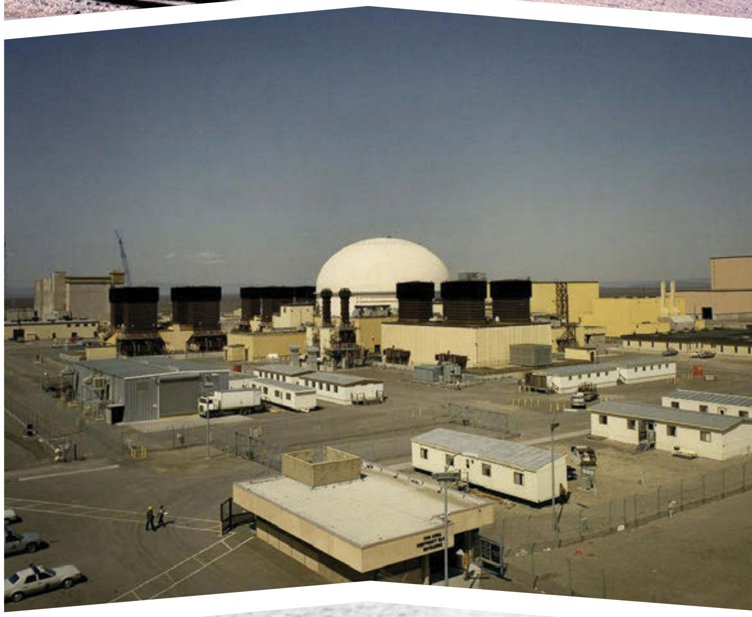
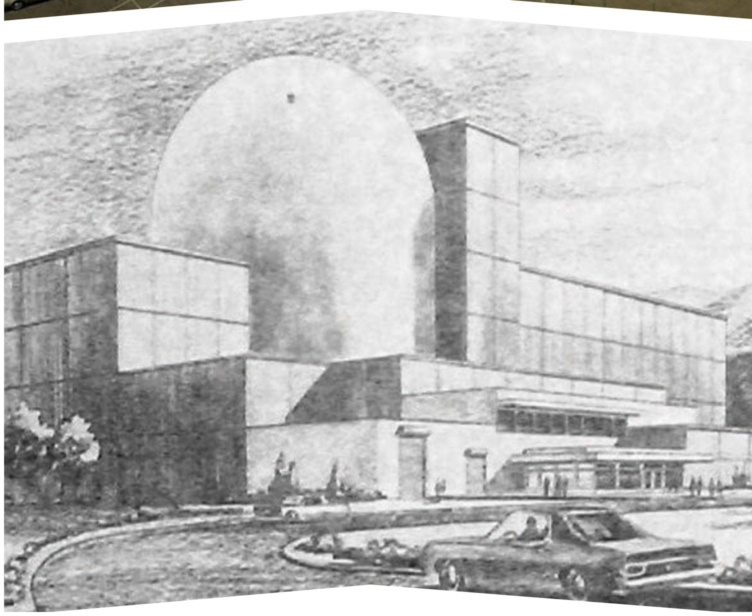
EBR-II was designed and built as a follow-on to the EBR-I project. EBR-II operated for more than 30 years, a record for a liquid metal–cooled plant in the United States. The plant was a pool design with metal fuel and used centrifugal pumps augmented by a single electromagnetic pump. Initially focused on further refining the “breeding cycle,” it also demonstrated the inherent safety of the design and at the end of its life was used to test advanced metal fuel.

Fermi-1 was a three-loop sodium-cooled fast reactor designed for a nominal power of 300 MWt (100 MWe). The fuel was a uranium-molybdenum alloy placed in 105 core (or driver) subassemblies and 531 radial blanket subassemblies. In 1966, the plant suffered a partial meltdown of two subassemblies when flow was blocked to two channels. The damage was repaired, and the plant operated until 1972.

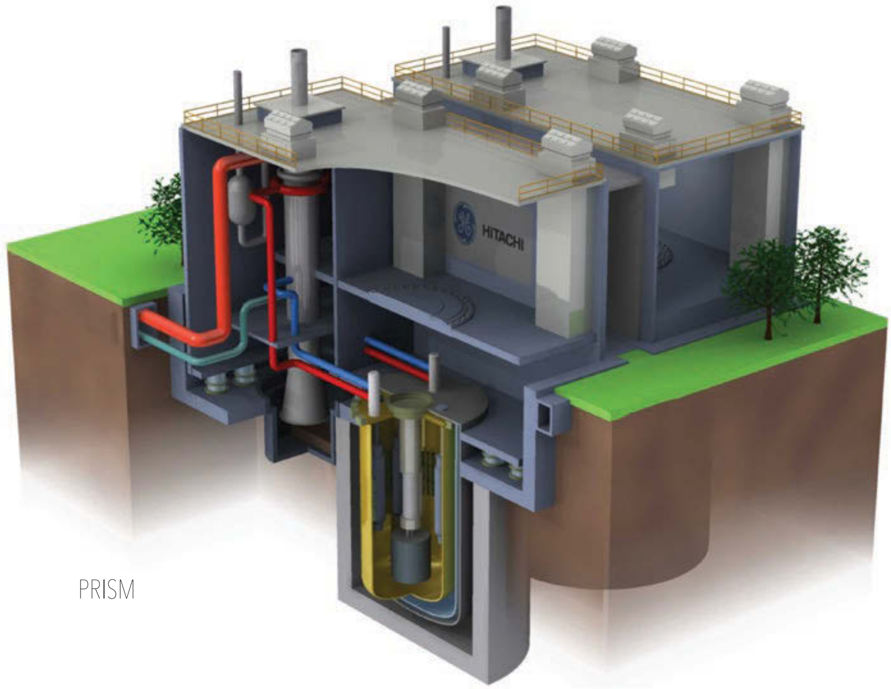
The Southwest Experimental Fast Oxide Reactor was a 20-MWt reactor fueled with mixed oxide fuel. The plant was built as a test reactor mainly to measure the Doppler reactivity coefficient that is an important contributor to the overall negative power coefficient in fast sodium-cooled reactors. The plant operated from 1969 until 1972, when the test program was completed.

The Fast Flux Test Facility was a 400-MWt loop design that operated from 1982 to 1992. Although its primary mission was irradiation of materials for advanced reactors, much data was obtained on safety tests conducted as part of the program, including natural circulation decay heat removal and transients and loss-of-primary-coolant flow without reactor trip. Although the plant was not licensed by the NRC, a review was conducted by the NRC and the ACRS and a formal safety evaluation report (SER) was written. This was the last liquid metal–cooled reactor placed into operation in the United States.

The Clinch River Breeder Reactor (CRBR) was a 1,000-MWt (350-MWe) reactor that was to be constructed and operated under contract initially to the AEC (and later to the DOE). An SER for the application for a construction permit for the CRBR was issued in March 1983. Because of the extremely conservative nature of the principal design criteria, the staff concluded “that core disruptive accidents can and must be excluded from the design-basis accidents for the plant.” A Memorandum of Findings, issued by the Atomic Safety Licensing Board in lieu of a construction permit in January 1984, resolved all outstanding issues regarding the construction permit, but the project was canceled.

Top to bottom: Fermi-1, Fast Flux Test Facility, Clinch River Breeder Reactor



PRISM

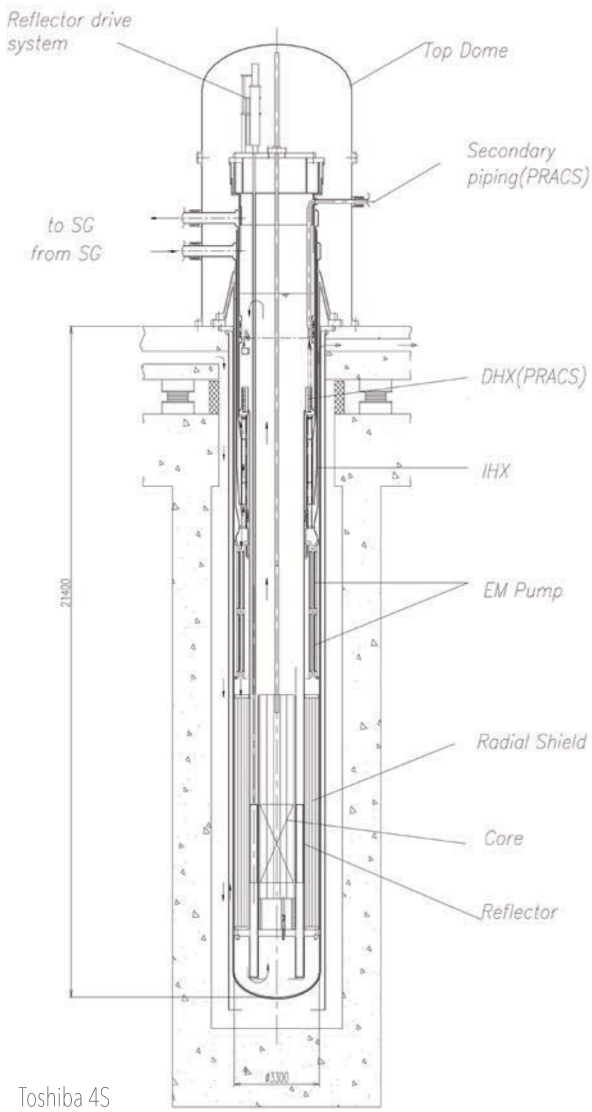
After the cancellation of the CRBR, the DOE funded the development of several liquid metal–cooled reactor designs. The most developed of these were SAFR (canceled following the development of conceptual design and partial review by the NRC) and PRISM.

The PRISM design continued to evolve over the years and eventually included a number of variations ranging in power from 425 MWt to 1,000 MWt, with the standard design being 840 MWt. The reactor was a pool design using metallic fuel, with solid oxide fuel as a backup design. The design has different arrangements of fuel, driver, and blanket elements depending on whether the core is optimized for breeding, actinide burning, plutonium burning, or long life (so-called break-even). All designs have two intermediate heat exchangers that connect to a single steam generator.

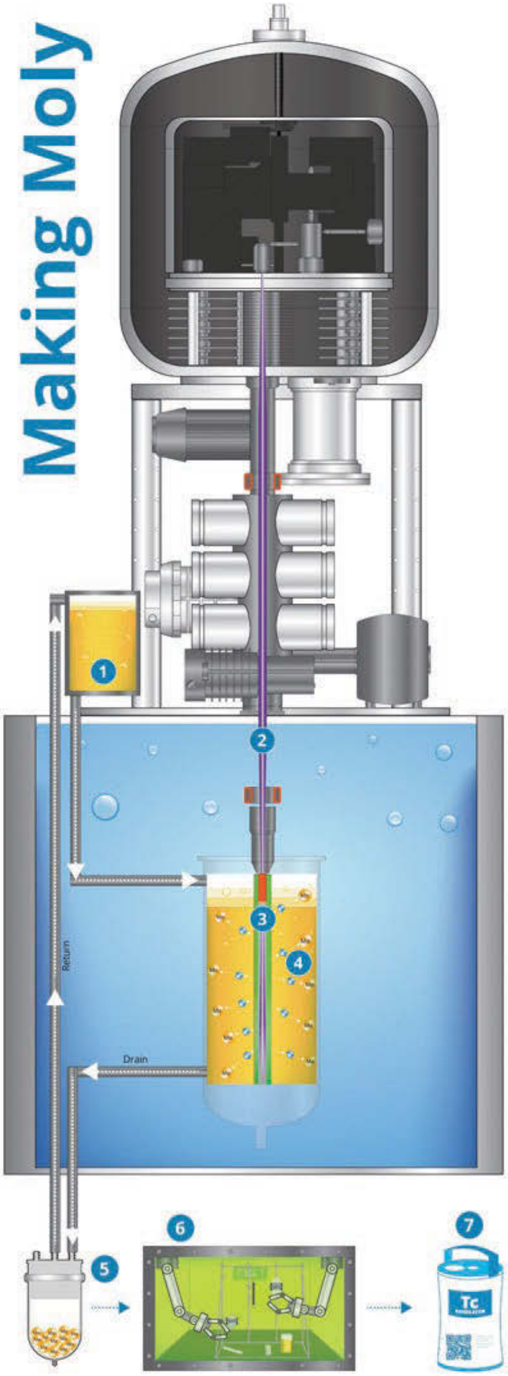
The NRC conducted a thorough review of the 475-MWt design between 1986 and 1994. The NRC staff identified eight areas where the design deviated from LWR guidance, only one of which (Control Room and Remote Shutdown Area Design) was considered not eligible for a departure from LWR regulations. After revisions to the design, the staff, with ACRS concurrence, concluded that there were "no obvious impediments to licensing the PRISM design."

The Toshiba 4S (Super-Safe, Small, and Simple) was a 30-MWt (10-MWe) pool-type reactor designed for remote locations with small grids. The reactor was designed with a long-life core (30 years with no refueling) and utilized metallic fuel. A single loop, with electromagnetic pumps, was used for steam generation to a single turbine. This would meet the current NRC definition of a microreactor. From 2007 to 2013, Toshiba submitted a series of technical reports, but the review ceased in 2013 without any review documents.

As a result of all the aforementioned experience, in 2012, Sandia National Laboratories led a Sodium Fast Reactor Safety and Licensing Research Plan that proposed "potential research priorities for the [DOE] with the intent of improving the licensability of the Sodium Fast Reactor." The report recommended that in all areas a structured knowledge management program was needed to effectively maintain and access the operational knowledge obtained during the U.S. fast reactor program prior to 1994.



Toshiba 4S



SHINE molybdenum-99 generator: 1. Target solution; 2. Accelerator; 3. Fusion Chamber; 4. Fission target; 5. Moly extraction; 6. Purification; 7. Distribution

Licensing liquid-fuel reactors

In the early days of the NRC, there were 12 liquid-fuel reactors licensed with fuel in an aqueous solution and thermal power levels of from 5 W to 50 kW. More recently, there have been two licensing activities for aqueous liquid fuel for isotope generation, and this experience might prove to be relevant to liquid-fuel molten salt reactors and to microreactors as well. One was the 220 kWt Aqueous Homogeneous Reactor (AHR), for which Babcock & Wilcox Technical Services Group submitted preapplication material in 2010. The second was the application for a construction permit in 2013 by SHINE Medical Technologies for an accelerator with an aqueous target. In both cases an aqueous solution of uranyl sulfate with low-enriched uranium was used. The objective of these projects was primarily to generate the fission product molybdenum-99, an extremely useful medical isotope, which would be separated from the fuel at the plant site.

The NRC convened a panel to produce licensing guidance taking into account the unique features of an AHR: the fuel being in solution; the fission product barriers being the vessel and attached systems; the production and release of radiolytic and fission product gases and their impact on operations and their control by a gas management system; and the movement of fuel into and out of the reactor vessel. An interim staff guidance (ISG) report for “Radioisotope Production Facilities and Aqueous Homogenous Reactors” was then written.

The ISG was applicable to the SHINE facility, which applied for its construction permit after it was written. Although the accelerator target in the facility is not a nuclear reactor, “its safety analysis must consider phenomena analogous to those of an AHR.”

The AHR never submitted a license application, and so the NRC never did a formal review of the reactor. The SHINE facility received a construction permit after the NRC staff issued an SER and after an environmental impact statement was written by the NRC.

Licensing heavy-water reactors

During the period from 1989 to 1995 the NRC reviewed documents for the CANDU-3 reactor, and during the period 2002-2005 there was a preapplication review of the ACR-700. Both reactor designs were based on the CANDU reactors that had been built, and successfully operated, in Canada and other countries.

The NRC staff documented the policy issues for the CANDU-3 along with those for several other new reactors and wrote a safety assessment report for the ACR-700.

To the present and beyond

"Regulation of Advanced Nuclear Power Plants; Statement of Policy" was published by the NRC in 1986 and revised in 2008 to include consideration of security, and it continues to provide the overall guidance of all activities relating to advanced nuclear power plants. The commission defined its expectation for advanced reactors as part of the policy statement: "Regarding advanced reactors, the Commission expects, as a minimum, at least the same degree of protection of the environment and public health and safety and the common defense and security that is required for current generation LWRs. Furthermore, the Commission expects that advanced reactors will provide enhanced margins of safety and/or use simplified, inherent, passive, or other innovative means to accomplish their safety and security functions." Details about the development and utilization of the policy statement on the regulation of advanced reactors can be found in NUREG-1226.

The NRC has initiated rulemaking to revise regulations and guidance for emergency preparedness (EP) for small modular reactors and other new technologies, such as non-LWRs and medical isotope facilities, for a consequence-based approach to establishing requirements, as necessary, for offsite EP, and is pursuing a limited scope rulemaking effort that would evaluate possible performance criteria and alternative physical security requirements for advanced reactors.

NRC staff is developing a "technology-inclusive regulatory framework" for optional use by applicants for new commercial advanced nuclear reactor licenses, as required in Section 103 of the 2019 Nuclear Energy Innovation and Modernization Act.

Regulatory Guide 1.232, "Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors," presents design criteria addressing two specific design concepts, sodium-cooled fast reactors and MHTGRs, as well as generally applicable criteria for lead-cooled fast reactors, gas-cooled fast reactors, fluoride-salt high-temperature reactors, and liquid-fuel molten salt reactors.

NRC staff prepared a number of documents (SECY) recommending positions for resolving issues related to non-LWR designs that were approved by the commission. NRC staff has developed functional performance criteria for containment and stated its belief that a mechanistic approach could be applied to non-LWR designs for accident source terms and siting subject to availability of adequate tools and analysis approaches, allowing future applicants to consider reduced distances to exclusion area boundaries.

In preparing to review and regulate a new generation of non-LWRs, the NRC developed its vision and strategy for mission readiness in assuring safe, effective, and efficient licensing of non-LWRs. The vision and strategy, when implemented, is developed to address potential inefficiencies in the current licensing process based on LWR criteria and provide for regulatory certainty for non-LWR applicants.

The NRC has also published a regulatory review roadmap for non-LWRs—"A Regulatory Review Roadmap for Non-Light Water Reactors," December 2017 (ML17312B567)—providing guidance to staff reviewers and applicants.

This article is a condensation of a more detailed report funded by the Nuclear Regulatory Commission. The report is available at nrc.gov/docs/ML1928/ML19282B504.pdf.

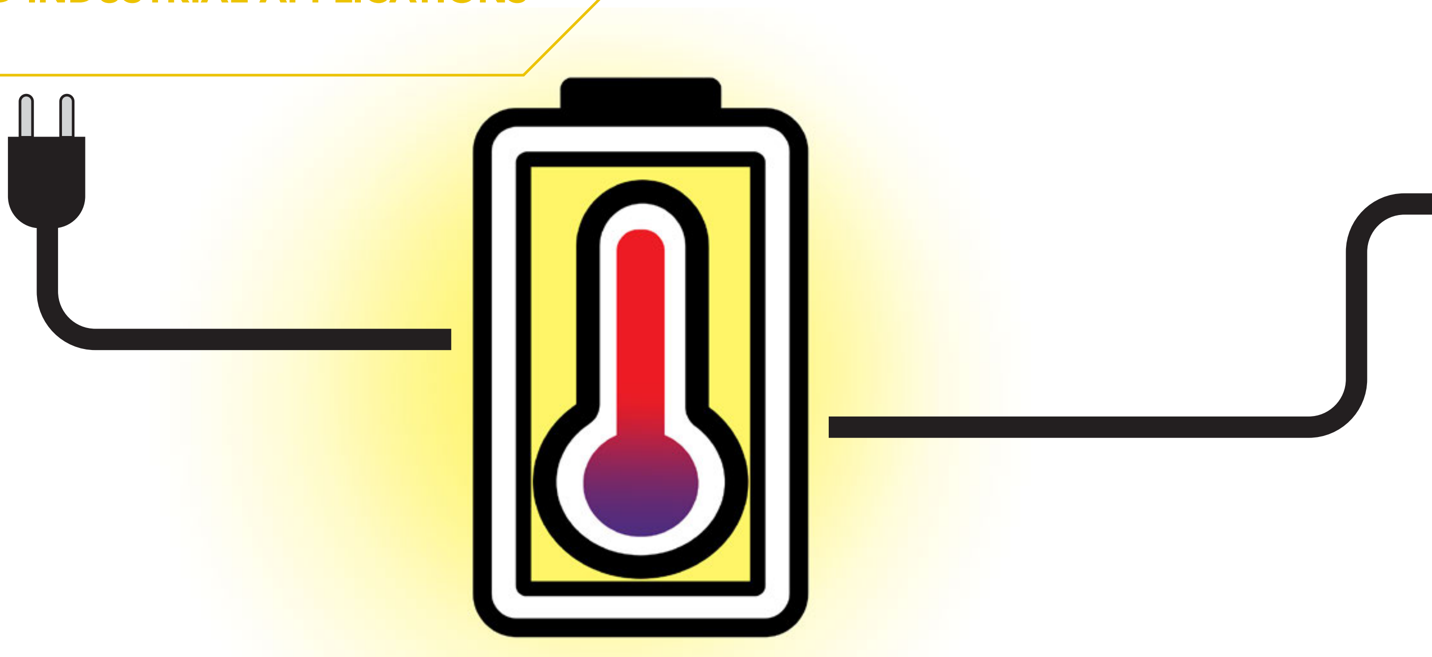
CAN CHEMICAL HEAT PUMPS FOR INTEGRATED ENERGY SYSTEMS AND INDUSTRIAL APPLICATIONS CHANGE THE WORLD?

By Vivek Utgikar, Piyush Sabharwall, and Brian Fronk

Nuclear energy is faced with a number of challenges in a changing energy landscape, driven by the need to reduce carbon emissions to mitigate climate change. Renewable energy technologies are being considered as the solution to climate change and are increasingly being deployed across the world. However, renewable energy sources, particularly solar and wind, are highly variable, and deployment of these technologies has resulted in significant perturbances in the energy market, raising questions about grid stability and the adaptability of other sources to compete in a changing marketplace that prioritizes renewables. Nuclear plants, well suited for baseload operation, have demonstrated technical capability and flexibility to respond to the fluctuating demand; however, they have also discovered that the economics of such operating mode are not necessarily optimal to their financial security. On the other hand, despite contributing to the carbon emissions, the low cost of abundantly available natural gas and resultant low-cost electricity have exacerbated the economic pressure on nuclear technologies, raising questions about their survival and role in future energy systems[1].

However, along with its challenges, the changing energy landscape has also opened up potential opportunities for nuclear energy. Energy systems of the future are anticipated and expected to be more than electricity generators, and provide alternative energy carriers, such as thermal energy or synthetic transportation fuels, in addition to electricity. Nuclear plants are well positioned to fill this niche, providing thermal energy directly for industrial processes, district heating, desalination, and, many other applications. Nuclear energy can combine synergistically with renewable energy in Integrated Energy Systems (IESs) to provide multiple energy outputs (e.g., electricity, thermal energy) while also promoting grid stability to ameliorate variable electricity production from renewable sources[2].

1. Bragg-Sitton, et al., INL/EXT-20-57708, 2020
2. Gallier, *Nuclear News*, 2020;63(2):26



INTEGRATED ENERGY SYSTEMS WITH ENERGY STORAGE

An IES with energy-storage capabilities can operate at steady state continuously, maximizing efficiency to store energy at times of low demand and cost, relying upon the stored energy to meet consumer demands at times when they exceed power generation capacity[3]. Energy storage is most commonly taken to mean the storage of electrical energy; however, direct storage of electrical energy is constrained by several difficulties, including limitations on capacity and parasitic losses. Indirect storage of electricity in electrochemical devices (secondary batteries) has garnered increasing attention; however, the modular nature of the storage limits the practical capacity, and the use of stored energy for industrial thermal applications is inefficient.

Thermal energy storage (TES) is a convenient, indirect energy storage option that avoids process complexity of the electrochemical and chemical energy storage alternatives. Nuclear heat can be stored directly in a thermal energy storage device at the time of low electricity demand, and then either be used directly in industrial processes or reconverted into electricity at the times of excess demand, enabling direct utilization of heat from baseload power generators for industrial applications. TESs are also important for utilization or reuse of the waste heat from many industrial processes. TESs function in one of the following three ways: sensible heat storage, latent heat storage, or thermochemical heat storage (TCS)[3,4].

Sensible heat storage systems employ materials such as water, steam, oil, and graphite for short term, and concrete, crushed rock, nitrate, and chloride salts for long-term storage. Thermal energy input results in an increase in the temperature of the storage medium, and the process is reversed in the energy discharge step. Latent heat storage systems feature reversible isothermal phase transitions, typically solid-liquid transformations with minimal density changes, for energy storage and discharge. Materials used for latent heat storage include paraffin waxes, fatty acids, inorganic nitrate or carbonate salts, and alloys. TCS systems feature reversible reactions, where the decomposition of a chemical and reconstitution of the separated constituents are the energy storage and discharge steps, respectively. The energy storage

3. Aydin et al., *Renewable and Sustainable Energy Reviews*, 2015;41:356

4 N'Tsoukpoe et al., *Renewable and Sustainable Energy Reviews*, 2009;13:2385, Zhang et al., *Energy Policy*, 2010;38:7884

step involves an endothermic reaction, typically the decomposition step with the resulting products physically separated and stored. These two products are brought together to reconstitute the original reactants of the decomposition step via the exothermic reaction. Systems based on thermochemical reactions have a potential to achieve much higher energy densities than those relying on sensible or latent heat storage[5].

5 Pardo et al., *Renewable and Sustainable Energy Reviews*, 2014;32:591

CHEMICAL HEAT PUMPS: THERMOCHEMICAL ENERGY STORAGE WITH TEMPERATURE AMPLIFICATION CAPABILITIES

Apart from higher energy density, the biggest advantage of TCS systems is its capability to improve the quality of thermal energy by boosting delivery temperatures. As mentioned above, TCS features an energy storage step, an endothermic reaction involving breakage of chemical bonds. Thermal energy is stored as the chemical energy of the products. The energy discharge step is the reverse of this reaction, featuring recombination of the products via an exothermic reaction. By manipulating the reaction conditions, this reverse reaction can achieve higher temperatures than that of the primary energy source driving the energy storage step—thus upgrading the quality of the thermal energy.

Chemical heat pumps can utilize heat sources directly without requiring intermediate conversion of the thermal energy to mechanical or electrical energy. As a result, CHPs are potentially more efficient than conventional vapor compression or (de)sorptions heat pump, while also offering increased versatility with respect to the range of operating temperatures[6]. Broadly speaking, CHPs can be classified into either sorption-based or reaction-based systems[7]. Sorption-based systems typically involve sorption-desorption of water, ammonia, or hydrogen, while reaction-based systems involve a hydration/dehydration, carbonation/decarbonation, hydrogenation/dehydrogenation, or redox reaction couples, such as magnesium- or calcium-hydroxide/oxide and calcium-lead-carbonate/oxide[8].

The $Ca(OH)_2/CaO$ system utilizes abundantly available inexpensive chemicals that have minimal toxicity and pose little challenge with respect to the materials of construction. Further, high reaction enthalpy translates into high energy storage density, and the product of decomposition reaction—water—can be easily managed through condensation. These characteristics make this system considerably more attractive than other systems mentioned above[9].

6 Arjmand et al., *International Journal of Energy Research*, 2013;37:1122

7 Cot-Gores et al., *Renewable and Sustainable Energy Reviews*, 2012;16:5207
8 Sabharwall et al., INL/EXT-13-30463, 2013
9 Hasatani, *Global Environment Protection Study Through Thermal Engineering*, 1992, 313–322

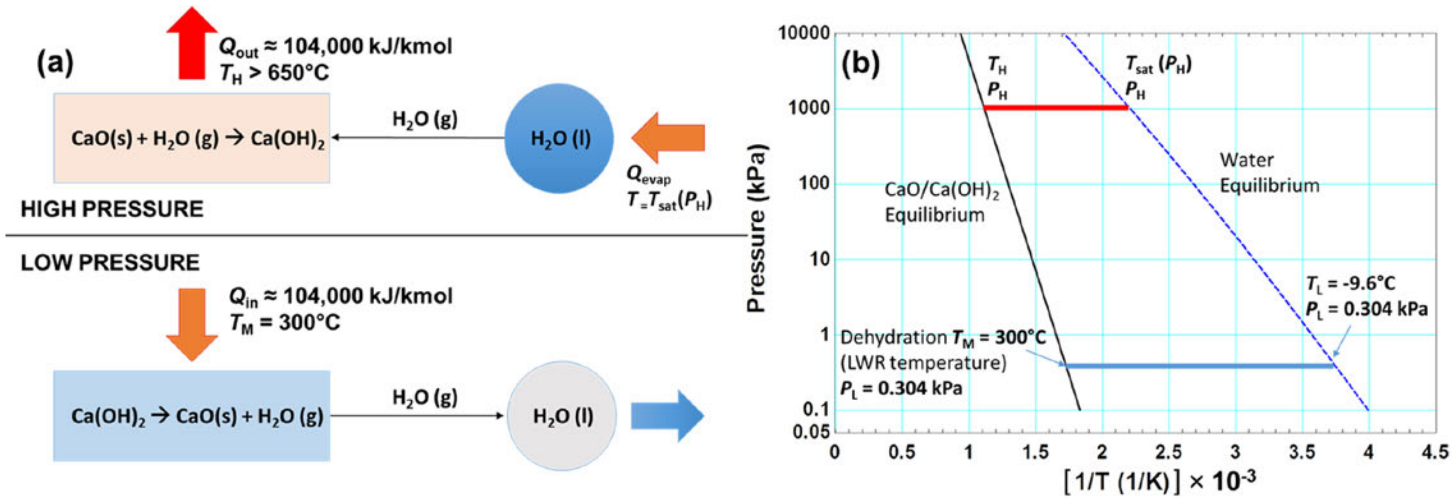


Fig. 1: Schematics of (a) components of a CHP system and (b) a heat pump cycle on the Clausius-Clapeyron diagram showing equilibrium of $CaO/Ca(OH)_2$ and $H_2O(L)/H_2O(G)$.

The reversible reactions involved in the system are:

$$Ca(OH)_2\ (s) \leftrightarrow CaO(s) + H_2O(g).$$

The forward endothermic dehydration reaction, driven by available nuclear heat, constitutes the energy storage step. The recombination of the resulting calcium oxide and water is exothermic, releasing heat that can be used for a wide variety of industrial processes. The basic principle of the process is explained by Figure 1 shown above.

The Clausius-Clapeyron diagram (Fig. 1[b]) comprises two lines, representing the equilibria for decomposition of calcium hydroxide (solid line on the left) and water vapor-liquid phase change (dashed line on the right). The energy storage step—the decomposition into calcium oxide—takes place at low pressure (hence, low temperature, represented by TM). The recombination of water vapor and calcium oxide is effected at a higher pressure PH; correspondingly, the equilibrium temperature is higher and the energy is discharged at the higher temperature TH. By manipulating the operating conditions, temperatures as high at 1,200 K are theoretically achievable [8]. As a result, light-water reactor heat can be upgraded to provide thermal energy to various industrially significant processes. Temperature requirements of some of these processes are shown in Figure 2[10].

10 Park et al., *Proceedings of National Hydrogen Association*, Columbia, South Carolina, 2009; McMillan et al, INL/EXT-16-39680, 2016; Sabharwall, et al., Proceedings of the 2018 Pacific Basin Nuclear Conference, San Francisco, CA, 2018

APPLICATIONS OF NUCLEAR REACTORS

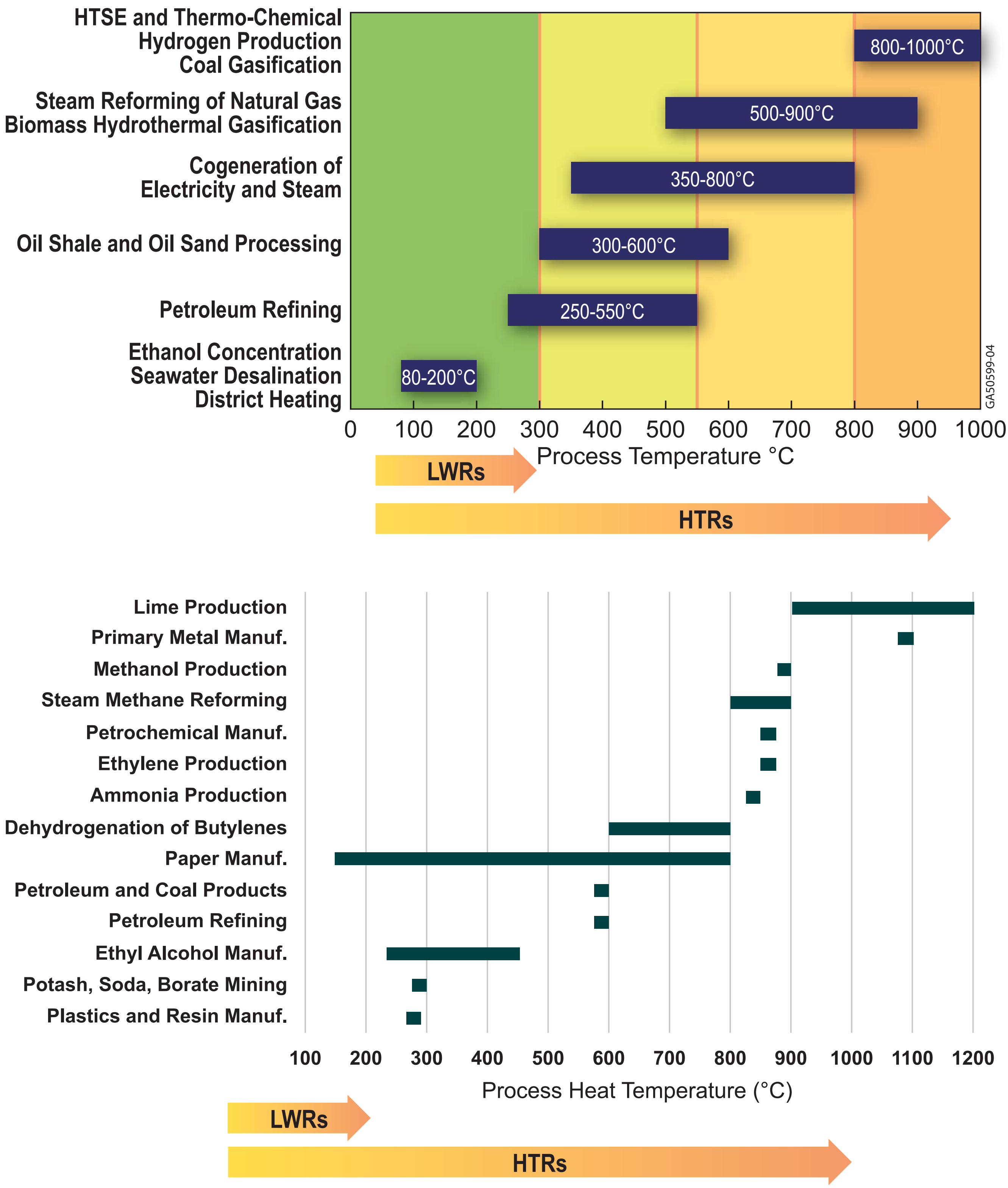


Figure 2: Potential process heat applications of CHP-enabled nuclear reactor IESs.

CHP RESEARCH AND DEVELOPMENT

Recent R&D[11] activities at the University of Idaho (UI) and Oregon State University (OSU) have focused on the $Ca(OH)_2/CaO$ CHP. Research at UI has successfully demonstrated multiple cycles of $Ca(OH)_2$ decomposition, followed by the hydration of CaO. Temperature amplification in excess of 150 °C has been observed in these cycles. The overall energy efficiency of the system is 80 percent. Component and system models are being developed at OSU. Additionally, OSU conducts experimental and modeling work on a $LiBr/H_2O$ absorption pump that is proposed to be coupled to the dehydration/hydration reactor for enhanced management of water involved in the reaction. The system enables efficient storage and delivery of large amounts of energy in a small mass.

11 Aman Gupta (UI) and Paul Armatis (OSU) are the graduate students performing the experiments to demonstrate the feasibility of the absorption and desorption process and validation, respectively.

FUTURE DIRECTIONS

Additional experiments are planned to demonstrate system robustness for a larger number of dehydration-hydration cycles. The feasibility of the absorption pump system will be demonstrated through experiments, and the data will be used to verify the models. Finally, an integrated system incorporating the reactor and absorption pump will be constructed and operated for the proof-of-concept demonstration.

AUTHORS

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ACKNOWLEDGEMENTS

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France's Fessenheim-2 closes permanently

After generating electricity for more than 40 years, Fessenheim-2 was disconnected from the grid at 11 p.m. local time on June 29, some four months after the retirement of its companion reactor, Fessenheim-1 (*NN*, Mar. 2020, p. 83). The action completed the closure of what had been France's oldest operating nuclear power facility.

Both Fessenheim units are 880-MWe pressurized water reactors; Unit 1 began commercial operation in December 1977, with Unit 2 going on line in March 1978.

The premature shuttering of Fessenheim, located in the Alsace region of northeastern France, is the result of a limitation on nuclear power output set by France's green growth law, passed in August 2015. Under that measure, nuclear generating capacity in France is capped at its current 63.2 GWe, and nuclear's share of electricity generation drops from today's 75 percent to 50 percent by 2025. Under a draft energy and climate bill presented to the Council of Ministers by Minister for an Ecological and Solidarity Transition Francois de Rugy in April 2019, however, the target date would move forward 10 years, to 2035, in order to avoid the construction of gas-fired plants and their attendant greenhouse gas emissions.

Fessenheim nuclear power plant. Photo: EDF

Électricité de France (EDF), Fessenheim's operator, announced on September 30, 2019, that it had submitted an application to the French Nuclear Safety Authority and to the energy minister requesting approval for the termination of operations and the permanent shutdown of both Fessenheim reactors. The submission followed the signing on September 27 by EDF and the state of a protocol agreement whereby France will compensate EDF for the plant's early closure.

According to the terms of the agreement, initial compensation installments to EDF will cover expenses incurred by the closure of the plant (post-operational expenditure, basic nuclear installation taxes, dismantling, and staff redeployment costs), which will be paid over a four-year period following the shutdown. The payments are expected to total nearly $440 million. Subsequent payments in compensation for any loss of earnings—such as income from future power generation based on Fessenheim's previous output figures—up until 2041 will be calculated "ex post" on the basis of nuclear output selling prices, including observed market prices.

EDF originally announced its intentions to close the plant in April 2017 (*NN*, May 2017, p. 43)—a date that was meant to coincide with the startup of the Flamanville-3 EPR. Delays to that project, however, forced EDF to continue operations at Fessenheim (*NN*, July 2018, page 41).

VOGTLE

Georgia Power resequencing new units' planned activities

Southern Company subsidiary Georgia Power, primary owner of the Vogtle nuclear power plant, near Waynesboro, Ga., announced on June 23 that it is resequencing certain planned activities at Vogtle-3 and -4, the two Westinghouse AP1000 units under construction at the site.

From Left: Vogtle-3 and -4. Photo: Georgia Power

According to the announcement, Georgia Power and Southern Nuclear, the would-be operator of the new units, have made significant adjustments to work practices at the site in order to protect the health and safety of the project workforce during the COVID-19 pandemic. These adjustments, the company said, along with continued challenges in electrical construction productivity, have required work to be performed differently, necessitating the resequencing.

As a result, for Unit 3, structural integrity testing and integrated leak rate testing have been rescheduled to occur before cold hydro testing, and the start of cold hydro testing has been moved from July to the fall of 2020. The company added that while it continues to work toward fuel loading in 2020, achieving that milestone is not required until later in 2021 to support the units' regulatory approved in-service dates of November 2021 for Vogtle-3 and November 2022 for Vogtle-4.

"Georgia Power and Southern Nuclear are continuing to employ an aggressive site work plan as part of a strategy to maintain margin to the regulatory approved in-service dates, and the resequencing of these activities reflects our efforts," said Glen Chick, executive vice president of Vogtle-3 and -4 construction. "The project team continues to accomplish major milestones despite the ongoing pandemic, while keeping safety and quality our top priority."

Power & Operations continues

A second opinion

In testimony filed in early June with the Georgia Public Service Commission (GPSC), Donald Grace, vice president of engineering for the Vogtle Monitoring Group (VMG) and a member of the GPSC's public interest advocacy staff, cast serious doubt on Southern Company's ability to complete the construction of Vogtle-3 and -4 in time to meet their regulatory approved start dates. In addition, he said he expects the total cost of the project to go up.

Grace further noted in his testimony that the COVID-19 pandemic was not part of VMG's analysis, as the analysis used data supplied by Southern Nuclear and Georgia Power through mid-March. (In April, Southern Company cut the Vogtle construction project's workforce by 20 percent in response to the pandemic.)

"With respect to the regulatory required commercial operation dates of November 2021 (Unit 3) and November 2022 (Unit 4), it is highly unlikely that they will be achieved," Grace stated, "and with respect to the total project cost, even if the regulatory approved November 2021/2022 commercial operation dates were achieved, VMG forecasts that the total project cost would be roughly $1 billion over the regulatory approved $17.1 billion."

Responding to those remarks in a June 17 email to *Nuclear News*, Georgia Power spokeswoman Adrienne Tickle reiterated her company's belief that the current in-service dates for the new units will be met. "The project is continuing its strategy of utilizing an aggressive site work plan as a tool to help us achieve the November regulatory approved dates," she said, adding that "the total project capital cost forecast remains unchanged."

FUEL

NRC accepts Centrus Energy's application for HALEU license expansion

The Nuclear Regulatory Commission has accepted for review Centrus Energy Corporation's application to produce high-assay low-enriched uranium at its facility in Piketon, Ohio, the company announced on June 23. HALEU-based fuels will be required for most of the advanced reactor designs currently under development and may also be utilized in next-generation fuels for the existing fleet of reactors in the United States and around the world.

"With support from the U.S. Department of Energy, Centrus is proud to be leading the way in the development of a domestic source of HALEU that can meet a wide range of commercial, nonproliferation, and other national security requirements," said Centrus President and Chief Executive Officer Daniel Poneman. "Providing an assured, domestic supply of HALEU will help restore U.S. nuclear leadership internationally and is a prerequisite for the United States to play a major role in building and fueling the world's nuclear reactors and setting global standards for nuclear safety and nonproliferation. We appreciate the dedicated work by the NRC on this initial step and look forward to working with them as the process moves forward from here."


Poneman

In 2019, Centrus entered into a three-year, $115-million cost-shared contract with the DOE to deploy its AC-100M centrifuge technology and to demonstrate the production of HALEU (*NN*, June 2020, p. 62). According to Centrus, the demonstration program is on schedule and on budget, with the first set of outer casings for the centrifuges having been delivered to Piketon after being manufactured in Oak Ridge, Tenn.

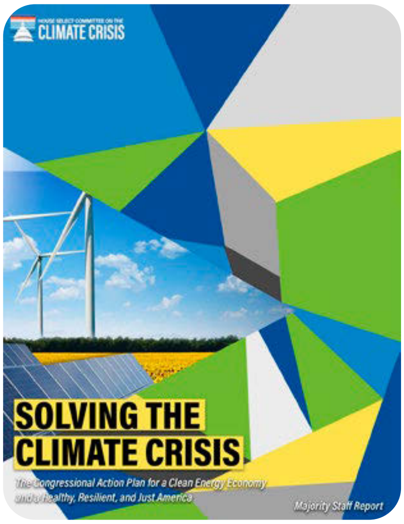
Centrus's Piketon facility is already licensed to enrich uranium to a concentration of up to 10 percent U-235, making it the only U.S. facility licensed for enrichment above 5 percent. If the NRC gives final approval of the HALEU license amendment, Centrus will be licensed to enrich uranium up to 20 percent U-235. Next-generation reactors and fuel designs will require a range of enrichment levels, but many are expected to be as high as 19.75 percent. A number of advanced reactor and fuel developers have announced plans to use HALEU-based fuel in their designs.

For more on HALEU, check out the "Looking high and low for HALEU" feature in the September 2019 issue of *Nuclear News*, page 26.

POLICY

Dems' climate action plan makes room for nuclear

House Democrats on June 30 rolled out a vision of what U.S. climate change policy might look like in the event the Democratic party holds its current House majority, retakes the Senate, and wins the White House in November. The vision was presented in the form of a sweeping, 547-page majority staff report titled *Solving the Climate Crisis: The Congressional Action Plan for a Clean Energy Economy and a Healthy, Resilient, and Just America*.



The wide-ranging report, unveiled by Speaker Nancy Pelosi (D., Calif.) and House Select Committee on the Climate Crisis Chairwoman Kathy Castor (D., Fla.) at a press conference on the Capitol steps, includes a role for nuclear energy. "Where we landed is, if we're going to get to our net-zero goal as soon as possible, then nuclear needs to remain part of the equation," Castor said.

While offering a caveat regarding "radioactive waste that lasts for thousands of years" and the lack of a permanent disposal solution for it, the report notes that nuclear is a zero-carbon source of electricity that made up about 20 percent of the nation's electricity generation in 2019 and over half of all zero-carbon electricity.

"The majority staff for the Select Committee recommends that Congress establish a federal clean energy standard that would allow electricity generated from existing nuclear power plants to qualify for credits," the report states. In addition, the report "offers recommendations to ensure the safety and continued operation of the existing nuclear fleet and invest in the next generation of nuclear energy technologies."

A pleasing plan

"When you consider that nuclear energy is America's largest carbon-free electricity source, it is encouraging the House committee proposes a technology-neutral approach to decarbonization that recognizes nuclear energy's important role in addressing our climate challenges," said John Kotek, vice president of policy development and public affairs at the Nuclear Energy Institute. "We are encouraged the plan includes support to keep our existing nuclear plants churning out reliable carbon-free power for American homes and businesses and promotes development and demonstration of advanced reactors that can decarbonize sectors beyond power generation. The recognition of nuclear in the report demonstrates the consensus that nuclear energy is viewed as an essential partner to wind, solar, and storage to achieve an affordable, reliable, decarbonized energy sector."

Power & Operations continues

CANADA

Saskatchewan to open SMR-focused office

The government of Canada's Saskatchewan province has unveiled plans to establish an office to coordinate nuclear policy and program work. The office, dubbed the Nuclear Secretariat, will have as its primary mission to develop and execute a strategic plan to deploy small modular reactors, according to a June 24 press release. The secretariat will be housed within the Climate Change and Adaptation Division of Saskatchewan's Ministry of Environment.

"The deployment of small modular reactors in Saskatchewan will require collaboration with several partners to fully encompass the benefits Saskatchewan could see in way of jobs, enhanced value chains for Saskatchewan's uranium, and our made-in-Saskatchewan climate policy," said Dustin Duncan, the province's environment minister. "Clean nuclear energy will provide Saskatchewan the tools to fight climate change. The advancement of small modular reactors in Canada brings economic and environmental benefits with new clean technology that is also safe, reliable, and competitively priced power."


Duncan

On December 1, 2019, Saskatchewan Premier Scott Moe signed a memorandum of understanding with the premiers of Ontario and New Brunswick regarding the development and deployment of SMRs across Canada. In a joint statement, the premiers said that the implementation of the new technology would "provide meaningful action in reducing our carbon emissions in electricity production, while providing affordable, baseload power to our communities and industries."

For some years now, Canada has been positioning itself as a future global leader in the development and deployment of SMR technology. For instance:

■ In April 2017, Canadian Nuclear Laboratories (CNL) published the *2016-2026 10-Year Integrated Plan Summary*, declaring the goal of demonstrating the commercial viability of SMRs by 2026.

■ In June 2017, CNL launched a request for expressions of interest (EOI) to gather input on its proposed SMR program. By October, the EOI had yielded responses from 80 organizations around the world, including 19 for siting a prototype or demonstration reactor at a CNL campus. Fifty-one responses were from Canada, 11 from the United Kingdom, and nine from the United States, with the remainder from Asian, European, and South American nations.

■ In April 2018, CNL issued an invitation to SMR project proponents that wished to participate in an evaluation process for the construction and operation of an SMR demonstration project at a CNL-managed site.

■ In June 2018, CNL announced that four SMR project proponents had submitted responses to its invitation: Global First Power, StarCore Nuclear, Terrestrial Energy, and U-Battery Canada Ltd.

■ In November 2018, the Canadian Nuclear Society and CNL partnered to host the first International Generation IV and Small Reactor Conference, which was held in Ottawa. Released at the conference was *A Call to Action: A Canadian Roadmap for Small Modular Reactors*, the result of an initiative launched earlier in the year by Canada's Department of Natural Resources. The roadmap included more than 50 recommendations, covering topics such as waste management, regulatory readiness, and international engagement.

■ In July 2019, the Canadian Nuclear Safety Commission posted to the Canadian Environmental Assessment Agency website a notice of the commencement of an environmental assessment for Global First Power's proposed 5-MWe Micro Modular Reactor (MMR), to be sited at the CNL-operated Chalk River Laboratories, in Ontario.

■ Also in July 2019, CNL launched the Canadian Nuclear Research Initiative (CNRI), a program designed to accelerate the deployment of SMRs in Canada.

■ In April 2020, CNL entered into a collaboration agreement with Moltex Energy. Funded through the CNRI, the agreement included work to support aspects of Moltex's nuclear fuel development program for its Stable Salt Reactor, a 300-MWe SMR design.

■ In June 2020, Global First Power, Ultra Safe Nuclear Corporation, and Ontario Power Generation formed a joint venture to construct, own, and operate the MMR at Chalk River. The venture, known as the Global First Power Limited Partnership, is owned equally by OPG and USNC-Power, the Canadian subsidiary of USNC.

UNITED KINGDOM

Report: More nuclear a good choice, but costs must fall

A June 18 report by Energy Systems Catapult, a U.K.-based clean energy nonprofit, concludes that adding double-digit gigawatts of new nuclear is a "low-regrets option" for the United Kingdom as it strives to achieve net-zero carbon emissions by 2050. (Legislation establishing the 2050 target date was signed in June of last year, making the United Kingdom the first of the world's major economic powers to take that step.) The report also stresses, however, that costs for new nuclear must decrease significantly for the technology to reach its potential.

In addition, the report makes the case for a U.K. small modular reactor program, with a similar emphasis on cost reduction. SMR designs that can deliver heat and power cogeneration are

Power & Operations continues

worth particular attention, the report states.

Titled *Nuclear for Net Zero: A UK Whole Energy System Appraisal*, the report provides a "techno-economic assessment" of the potential contributions that nuclear energy can make to U.K. decarbonization, including:

- 10 GWe of Hinkley Point C–type Generation III+ power generation, beyond that plant's expected contribution of some 3.2 GWe.
- Advanced Gen IV high-temperature nuclear plants coupled with hydrogen production technology, to enable the switch between power generation and hydrogen production to supply industry, heavy road transport, and marine freight.
- SMRs deployed with city-scale district heating networks, to supply cost-effective, low-carbon heat for urban homes and businesses.

"Nuclear doesn't need to be expensive if we take the right approach," said Mike Middleton, Energy Systems Catapult nuclear practice manager, in a statement on the new report. "Achieving net zero without nuclear is possible, but targeting such a system looks unnecessarily risky, to the point of being unlikely to achieve the end result, and potentially expensive. There are no easy paths to get the entire U.K. economy to net zero carbon emissions by 2050, but there is a credible path available to realize significant nuclear cost reduction, delivering potentially lower costs and risks associated with achieving U.K. net zero."

Middleton went on to outline the path: "Firstly, a commitment to a program of capacity rather than individual unconnected projects. Secondly, capitalizing on the benefits from deploying units in an uninterrupted construction sequence, with multiple units on the same site where possible. Provided that costs reduce in line with the analysis we have reported, the deployment decision regarding new large nuclear

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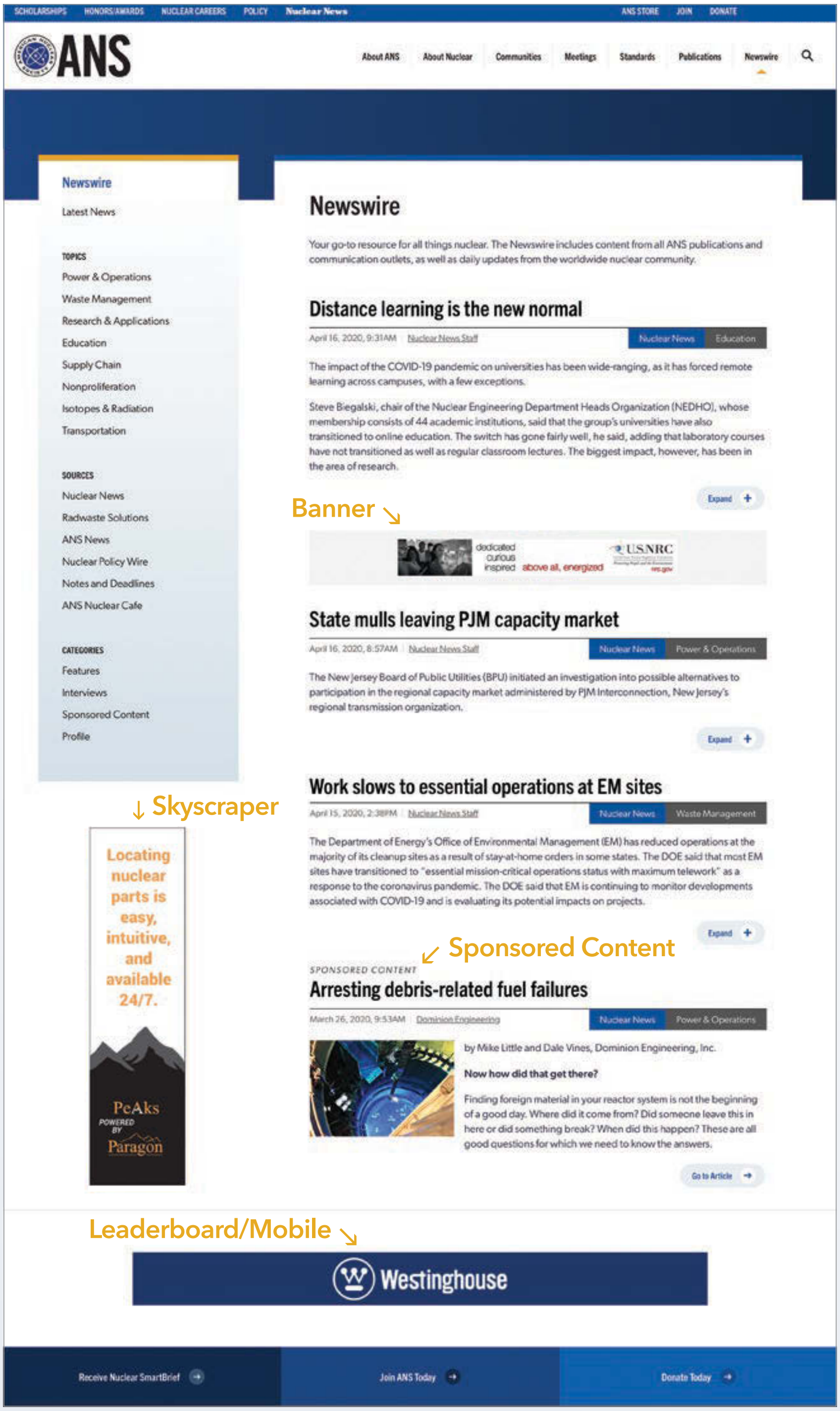

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AMERICAN NUCLEAR SOCIETY ANS

is not whether to start, but when to stop."

According to the report, if nuclear can fulfill its cost-reduction potential and contribute to the challenges of decarbonizing heat and hydrogen, approximately 50 GWe of nuclear may be needed by 2050. However, the report adds, "there is significant uncertainty about the mix within a 50-GWe nuclear portfolio, underlining the importance of stage-gated approaches for both light-water SMRs and advanced Gen IV reactors."

The 64-page analysis can be downloaded at Energy Systems Catapult's website, es.catapult.org.uk/.

Power & Operations Briefs

THE UNITED STATES AND POLAND DISCUSSED nuclear energy on June 24 at a White House meeting between President Trump, Energy Secretary Dan Brouillette, and Polish President Andrzej Duda. The talk was part of "a continuing dialogue that was furthered last summer through the signing of a Nuclear Cooperation Memorandum of Understanding," which signaled a "long-term partnership to develop Poland's civil nuclear program and jointly pursue the peaceful use of nuclear energy," according to the Department of Energy.

The previous week, on June 15, the Paris-based Nuclear Energy Agency sponsored a webchat between its director-general, William Magwood, and Michał Kurtyka, Poland's minister of climate and the president of COP24—the 2018 Conference of the Parties to the United Nations Framework Convention on Climate Change. A prominent figure in global talks on climate neutrality and energy-related emissions, Kurtyka discussed the proposed *Energy Policy of Poland until 2040*, which calls for the introduction of nuclear energy by 2033. The plan, said Kurtyka, is to begin construction of nuclear power plants in Poland by 2026 and to have six reactors in operation by 2040 "to provide baseload electricity for our zero-emission system, because right now we are in the transformation of our energy system."

THE NEA RECENTLY ISSUED four policy briefs on the role that nuclear energy might play in the post-COVID-19 recovery: "Nuclear power and the cost-effective decarbonization of electricity systems," "Creating high-value jobs in the post-COVID-19 recovery with nuclear energy projects," "Unlocking financing for nuclear energy infrastructure in the COVID-19 economic recovery," and "Building low-carbon resilient electricity infrastructures with nuclear energy in the post-COVID-19 era." The two-to-four-page documents can be found at the Nuclear Energy Agency's website, at oecd-nea.org.

NEI HOSTED A VIRTUAL EVENT on the future of nuclear on June 24. The three-segment webinar, entitled "The State of the Nuclear Energy Industry 2020," featured remarks from Nuclear Energy Institute President and Chief Executive Officer Maria Korsnick; a panel discussion with Renewable Energy Buyers Alliance CEO Miranda Ballentine and Union of Concerned Scientists President Ken Kimmell, moderated by ClearPath Executive Director Rich Powell; and an interview with Sen. Joe Manchin (D., W.Va.), conducted by Bipartisan Policy Center Founder and President Jason Grumet. The full hour-and-a-half webinar can be viewed at nei.org/news/2020/state-of-the-nuclear-energy-industry-2020.

THE WNA HAS RELEASED an expanded summary of its latest *Nuclear Fuel Report*, published last September. The summary, according to the World Nuclear Association, "will provide readers with explanations of what factors are affecting the growth of nuclear power, what new concepts were introduced in the 19th edition, and what developments the industry may require between now and 2040." A copy of the 48-page summary can be downloaded from the WNA's website, at world-nuclear.org. The full version of the report can be purchased from the WNA's online shop.

NIA adds support for nuclear in U.K. net-zero movement

Image: NIA

On the heels of the report from Energy Systems Catapult making the case for more nuclear energy to help the United Kingdom fulfill its net-zero carbon emissions by 2050 pledge (see above story) comes an assessment from the Nuclear Industry Association (NIA) to further buttress the argument. The 12-page assessment, *Forty by '50: The Nuclear Roadmap,* was published on June 24.

Prepared for and endorsed by the United Kingdom's Nuclear Industry Council, the assessment calls for a commitment to new nuclear power plants, saying that an ambitious program—based on existing and new technologies—could provide up to 40 percent of clean power by 2050 and drive deeper decarbonization through the creation of hydrogen and other clean fuels, along with district heating. The report also contends that implementation of this plan could eventually bring as many as 300,000 jobs to the United Kingdom, as well as £33 billion (about $41 billion) of added annual economic value.

"Net zero needs nuclear, and the sector is developing fast," said NIA Chief Executive Tom Greatrex. "The next large-scale projects are now deliverable much more cheaply by building on repeat and tried and tested designs, capturing learnings from our new-build program and making important changes to the way projects are financed. We're confident the price of nuclear power will fall from the £92.50 [about $115] per megawatt hour for the first plant, closer to £60 [about $74.50] per MWh for the next wave of power stations, reducing to around £40 [about $49.50] per MWh for further reactors."

Greatrex added, "Greenlighting new projects already in the pipeline would trigger a ramp-up in investment and job creation in parts of the U.K. facing the biggest economic challenges and clear the way for long-term decarbonization through the hydrogen economy, helping establish the U.K. nuclear sector as a global leader in the field. Commitment to the roll-out of smaller and advanced reactors would build on that momentum. Conversely, if we do nothing, we are effectively sitting on a winning hand for a greener future."

Forty by '50 sets out six key steps to be taken in 2020:

1. The U.K. nuclear industry must continue to drive down costs of new-build projects (30 percent by 2030) and establish delivery excellence.
2. The government should articulate a clear, long-term commitment to new nuclear power.
3. Progress must be made on an appropriate funding model or nuclear new-build to stimulate investment in new capacity and reduce the cost of capital.
4. A national policy statement and "facilitative" program, including siting and licensing proposals, should be developed for small reactors.
5. The 2030 targets of the Nuclear Sector Deal (part of the government's industrial strategy) should be maintained, including cost-reduction targets for new build and decommissioning, a 40 percent female workforce, and £2 billion (about $2.5 billion) of domestic and international contracts for the U.K. supply chain.
6. Industry and government should agree on a framework and commitments, focused on cross-sector collaboration outside traditional electricity production, including the production of medical isotopes, hydrogen, and synthetic fuels for transport, along with heat applications, including district heating and agriculture and storage technologies.

Power & Operations continues

ONR receives site license application for Sizewell C

The United Kingdom's Office for Nuclear Regulation (ONR) on June 30 received a nuclear site license application from EDF Energy subsidiary NNB Generation Company (SZC) Limited to construct and operate two reactors at the Sizewell site in the county of Suffolk, northeast of London.

Artist's rendering of the Sizewell site, with Sizewell C at right. Image: EDF Energy

The previous week, on June 24, Britain's Planning Inspectorate accepted a development consent order application for the nuclear build project. The DCO application had been received on May 27, after being deferred for two months as a result of the COVID-19 pandemic.

The proposed Sizewell C station, consisting of twin EPRs, would be built next to Sizewell B, a 1,198-MWe pressurized water reactor that began operation in 1995. (The Sizewell site also houses Sizewell A, a 290-MWe Magnox gas-cooled reactor, but that unit was permanently shuttered in 2006.) Sizewell C would be a near copy of the two-unit Hinkley Point C station, currently under construction in Somerset.

According to an ONR news release, the nuclear regulator will assess the suitability of the Suffolk site to host Sizewell C, as well as the design of the proposed development. This process includes an assessment of how the plant will withstand extreme weather and external hazards, including seismic events and coastal flood hazards, the ONR stated.

"While we are satisfied that the application is sufficiently complete to proceed to assessment stage, there is still a lot of work to do—and we do not expect to reach a decision until at least the end of 2021," said Shane Turner, the ONR's head of EPR regulation. "The assessment of a site license is a significant step, but is not itself permission to start nuclear-related construction. That requires separate regulatory permission from ONR."

Humphrey Cadoux-Hudson, Sizewell C's managing director, described the receipt of the application as "another significant step forward for Sizewell C," adding that the ONR "holds the nuclear industry to account on behalf of the public, and we welcome the robust scrutiny of our plans. We know the regulator will only award a nuclear site license once it is satisfied that the power station will be safe throughout its entire life cycle, including decommissioning, site clearance, and remediation."

If Sizewell C is approved, a financial investment decision to build the power station could be taken at the end of 2021 or early 2022, with construction commencing soon afterward, according to EDF. Expected to operate for 60 years, Sizewell C would generate enough low-carbon power for six million homes, and it would save nine million tons of CO_2 for every year of operation, EDF stated. Further, the company estimates that Sizewell C would create 25,000 job opportunities during its 10-year construction period and 900 skilled jobs once it is operational.

BULGARIA

Rosatom, Framatome, and GE partner on proposed Belene plant

Rosatom, Russia's state-owned atomic energy corporation, announced on June 18 that it has teamed up with France's Framatome and General Electric's GE Steam Power to participate in a tender to construct the Belene nuclear plant in northern Bulgaria. The Belene project would involve the construction of two AES-92 units, similar to the reactors that Rosatom supplied to India.

A memorandum of understanding regarding the partnership was signed by Kirill Komarov, first deputy director general of corporate development and international business for Rosatom; Frédéric Lelièvre, senior executive vice president in charge of sales, regional platforms, and instrumentation and control for Framatome; and Michael Keroulle, president of GE Steam Power.

According to the announcement, if Rosatom becomes a strategic investor in the project through a competitive process, GE will provide the Belene plant with an Arabelle-based turbine-generator set and turbine hall equipment, while Framatome will supply automated process control systems, electrical systems, hydrogen recombiners, and heating, ventilation, and air conditioning.

"The signed MOU underlines a continuing high level of trust between our companies," Komarov said. "I am sure that international cooperation with nuclear industry leaders will help create the best financial and technical conditions for the implementation of the Belene nuclear power plant."

Lelièvre added, "The Framatome team brings decades of global expertise in instrumentation and control systems, as well as nuclear plant design, services, and component and fuel manufacturing. It is an honor to partner with Rosatom to support the construction of the Belene nuclear power plant, an important project that will provide clean and reliable electricity."

On March 11, 2019, in an effort to find a strategic investor to help relaunch the Belene project, which had been canceled in 2012 for lack of funding, Bulgaria's National Electricity Company (NEK) issued a call for expressions of interest from potential bidders. NEK took the action to implement the decision made by Bulgaria's National Assembly and Council of Ministers in June 2018 to revive the project.

In December 2019, Rosatom, Framatome, and GE were included in the short list of five (out of an original 13) applicants for the project, along with China National Nuclear Corporation and Korea Hydro & Nuclear Power Corporation. Rosatom has previously collaborated with Framatome and GE on international projects, including the Paks-2 reactor in Hungary and the proposed Hanhikivi plant in Finland.

Researchers at Berkeley national lab create new isotope

A team of Lawrence Berkeley National Laboratory scientists has discovered a new form of the human-made element mendelevium, LBNL reported on June 23. The newly created isotope, mendelevium-244, is the 17th and lightest form of mendelevium, which is element 101 on the periodic table.

In total, the team measured the properties of 10 atoms of Md-244 for the study, which appeared on June 23 in the journal *Physical Review Letters*.

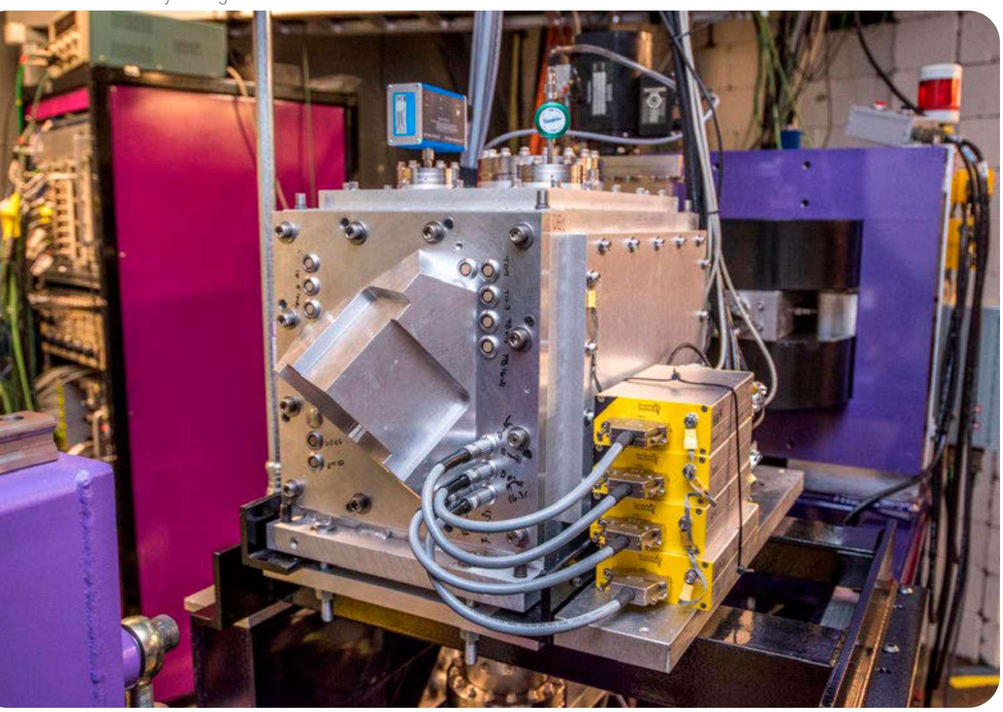
The team used LBNL's 88-inch cyclotron, which accelerates powerful beams of charged particles at targets to create atoms of heavier elements, to make the new isotope. A cyclotron is a type of particle accelerator that was invented by the lab's namesake, Ernest O. Lawrence, in 1930.

Central to the isotope's discovery was an instrument at the cyclotron called FIONA, or For the Identification Of Nuclide A. The "A" in FIONA represents an element's mass number, which for the new isotope is 244.

Mendelevium was first created by LBNL scientists in 1955 and is among a list of 16 elements that the lab's scientists discovered or helped to discover.

LBNL-led teams have now discovered 12 of the 17 mendelevium isotopes and have discovered a total of 640 isotopes—about one-fifth of all known isotopes. At the close of 2019 there were 3,308 known isotopes. The new isotope discovery is the first by an LBNL-led team since 2010.

"Each isotope represents a unique combination of protons and neutrons," said Jennifer Pore, an LBNL project scientist who led the study detailing the discovery of Md-244. "When a new isotope is discovered, that particular combination of protons and neutrons has never been observed. Studies of these extreme combinations are critical toward our understanding of all nuclear matter."



The FIONA instrument at Berkeley Lab's 88-inch cyclotron was key in confirming the discovery of mendelevium-244. Photo: Marilyn Sargent/LBNL

In addition to discovering the new isotope, the research team's work also provided the first direct evidence for a decay process involving an isotope of the element berkelium. The team included scientists from the University of California-Berkeley, Lawrence Livermore National Laboratory, San Jose State University, and Sweden's Lund University.

Researchers found evidence that Md-244 has two separate chains of decay, each leading to a different half-life: 0.4 second and 6 seconds, based on different energy configurations of particles in its nucleus.

In a separate measurement stemming from the same study, the researchers found the first evidence for the alpha decay process of berkelium-236, an isotope of the element berkelium, as it transforms into americium-232, a slightly lighter isotope. Berkelium was discovered in 1949 by an LBNL-led team.

NUCLEAR MEDICINE

IAEA teams with Japanese university on boron neutron capture therapy R&D

The International Atomic Energy Agency has signed an agreement with Japan's Okayama University that provides a three-year framework for enhanced cooperation in boron neutron capture therapy (BNCT), the IAEA announced on June 24. BNCT is a noninvasive therapeutic technique for treating invasive malignant tumors.

BNCT uses neutrons to generate energetic alpha particles that destroy cells within the tumor, but not in the surrounding tissue. Recent breakthroughs in accelerator technologies are enabling the wider use of this targeted technique.

Patients undergoing BNCT are given a boron-based reagent, often injected intravenously, that accumulates in cancer cells. When a stable boron isotope (boron-10) of the reagent is hit by a beam of neutrons in the cancer cells, it captures neutrons, causing a nuclear reaction and the creation of energetic helium (alpha particle) and lithium nuclei.

The nuclei deposit their energy within the tumor cell, causing damage and cell death. The tumor is targeted by selectively introducing the boron reagent into tumor cells, not by aiming the beam at the cells, as in other radiation therapies in which healthy tissue may be damaged. The high biological effectiveness of this procedure and the precisely targeted cell damage are

The accelerator-based BNCT system under construction at Nagoya University shows the electrostatic proton accelerator (on the left) and beam transport line toward the neutron production target (on the right). Photo: Nagoya University

Research & Applications continues

major advantages of BNCT in clinical therapy.

"BNCT is a cutting-edge cancer therapy," said Hirofumi Makino, president of Okayama University. "It is a happy marriage of the modern nuclear physics and up-to-date pharmaceutical cell biology. However, we should not forget the long history of struggle for developing this difficult medical technology. We, the researchers of Okayama University, would like to cultivate a further step of BNCT technologies together with IAEA."

The expected areas of cooperation include the following:

- Capacity building and human resource development through the establishment of e-learning courses.
- The organization of technical events, including a forthcoming IAEA technical meeting in July to assess the current development and usage of the BNCT technique, with an emphasis on the use of compact accelerator-based neutron sources.
- The development of a global database of BNCT facilities for information exchange and the sharing of good practices among stakeholders internationally.
- The exchange of experience and best practices, with an emphasis on accelerator and target technologies, neutron instrumentation and dosimetry, preparation and evaluation of boron-containing compounds, and pharmacological aspects of BNCT.
- The preparation and release of an IAEA publication on the current status of neutron capture therapy, including updates relevant to progress made in BNCT using compact accelerator-driven neutron sources.

DEPARTMENT OF ENERGY

Research grants awarded to early career scientists

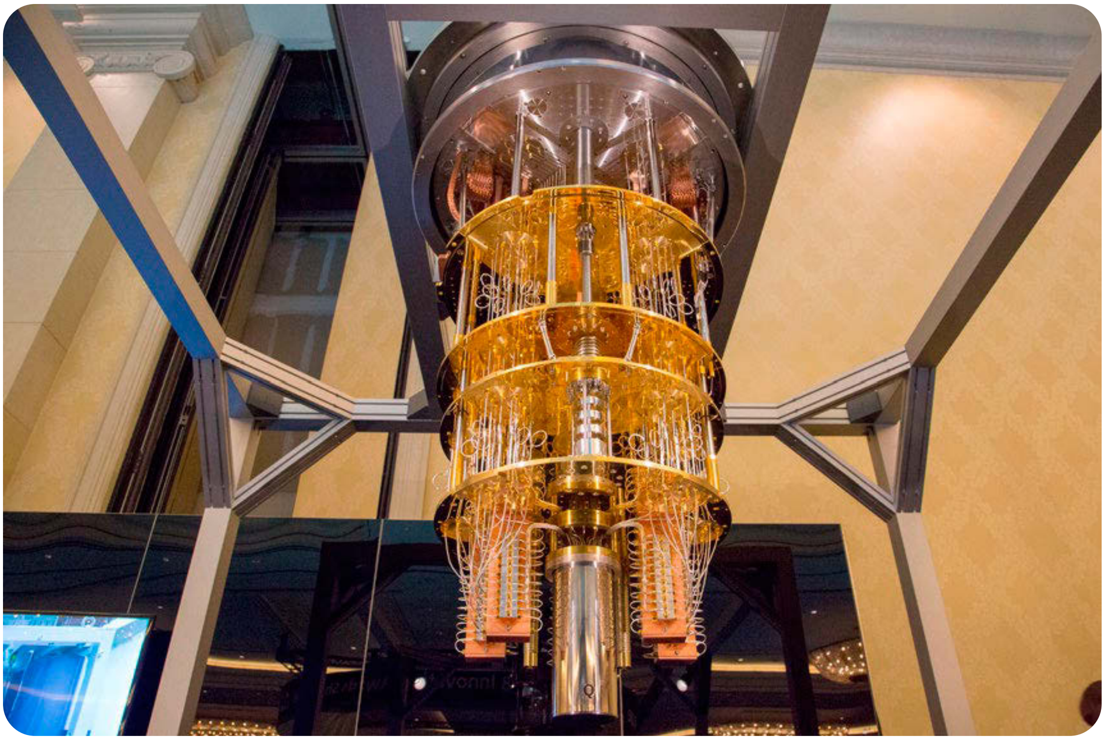
The Department of Energy on June 23 announced the selection of 76 scientists from across the United States—26 from the DOE's national laboratories and 50 from U.S. universities—to receive significant funding for research as part of the DOE Office of Science's Early Career Research Program. The effort, now in its 11th year, is designed to bolster the nation's scientific workforce by providing support to exceptional researchers during the crucial early career years, when many scientists do their most formative work.

Under the program, university-based researchers will receive grants of at least $150,000 per year, and researchers based at DOE national laboratories will receive grants of at least $500,000 per year. The research grants are planned for five years and will cover salary and research expenses.

To be eligible for the DOE award, a researcher must be an untenured, tenure-track assistant, or associate professor at a U.S. academic institution or a full-time employee at a DOE national laboratory who has received a Ph.D. within the past 10 years. The final details for each project award are subject to grant and contract negotiations between the DOE and the awardees.

"Supporting talented researchers early in their career is key to fostering scientific creativity and ingenuity within the national research community," said Undersecretary for Science Paul Dabbar. "Dedicating resources to these focused projects led by well-deserved investigators helps maintain and grow America's scientific skill set for generations to come."

The DOE announced on June 18 more than $65 million in awards for nuclear energy research, cross-cutting technology development, facility access, and infrastructure for 93 advanced nuclear technology projects in 28 states. The awards fall under the DOE's Nuclear Energy University Program, Nuclear Energy Enabling Technologies, and Nuclear Science User Facilities.



A quantum computer, such as this 50-bit version that IBM demonstrated at the International Consumer Electronics Show in 2018, is capable of solving tasks inaccessible to the most powerful "classic" supercomputer. Photo: IBM

RUSSIA

Lab for developing quantum artificial intelligence built

Rosatom, Russia's state atomic energy corporation, and the Russian Quantum Center (RQC) on July 7 announced the creation of the first laboratory in Russia to research and develop machine learning and artificial intelligence (AI) methods on quantum computers, specializing in the application of these technologies in the nuclear industry. An agreement was signed between the RQC and Tsifrum, a Rosatom subsidiary that was created in 2019 to support the implementation of Rosatom's digitalization strategy.

The laboratory was created to pair RQC's quantum information technology group and Tsifrum's AI laboratory for the development of quantum computing. Its main task is the development of quantum machine learning technologies and quantum optimization. The creation of quantum computing technologies can drastically accelerate the solution of problems of optimization, processing of large data arrays, clustering, and classification. Another promising area is the use of machine learning and neural networks to study complex (multiparticle) quantum systems.

Rosatom said that global trends in the quantum computing field led to the lab's formation as Russia seeks to ensure its competitiveness in global technology.

"The use of quantum computers in the field of artificial intelligence opens up unique opportunities due to the speed of analysis of source data and enumeration of various interdependencies in the search for patterns that is unattainable for traditional computing systems," said Boris Makevnin, chief executive officer of Tsifrum. "At the same time, it is important to consider that all quantum calculators built to date in the world are, first of all, experimental systems. In order to move to their practical use, in addition to hardware, a software component is also needed—appropriate algorithms, libraries, tools. Therefore, our laboratory will focus on R&D, which will become the basis for solving several carefully selected and substantiated tasks."

Research & Applications continues

Ruslan Yunusov, head of Rosatom's project office for creating a quantum computer, said, "We are confident that as a result of this joint work, innovative solutions to the most complex problems will be proposed, and not only in the nuclear industry."

COVID-19

X-rays size up protein structure at the "heart" of virus

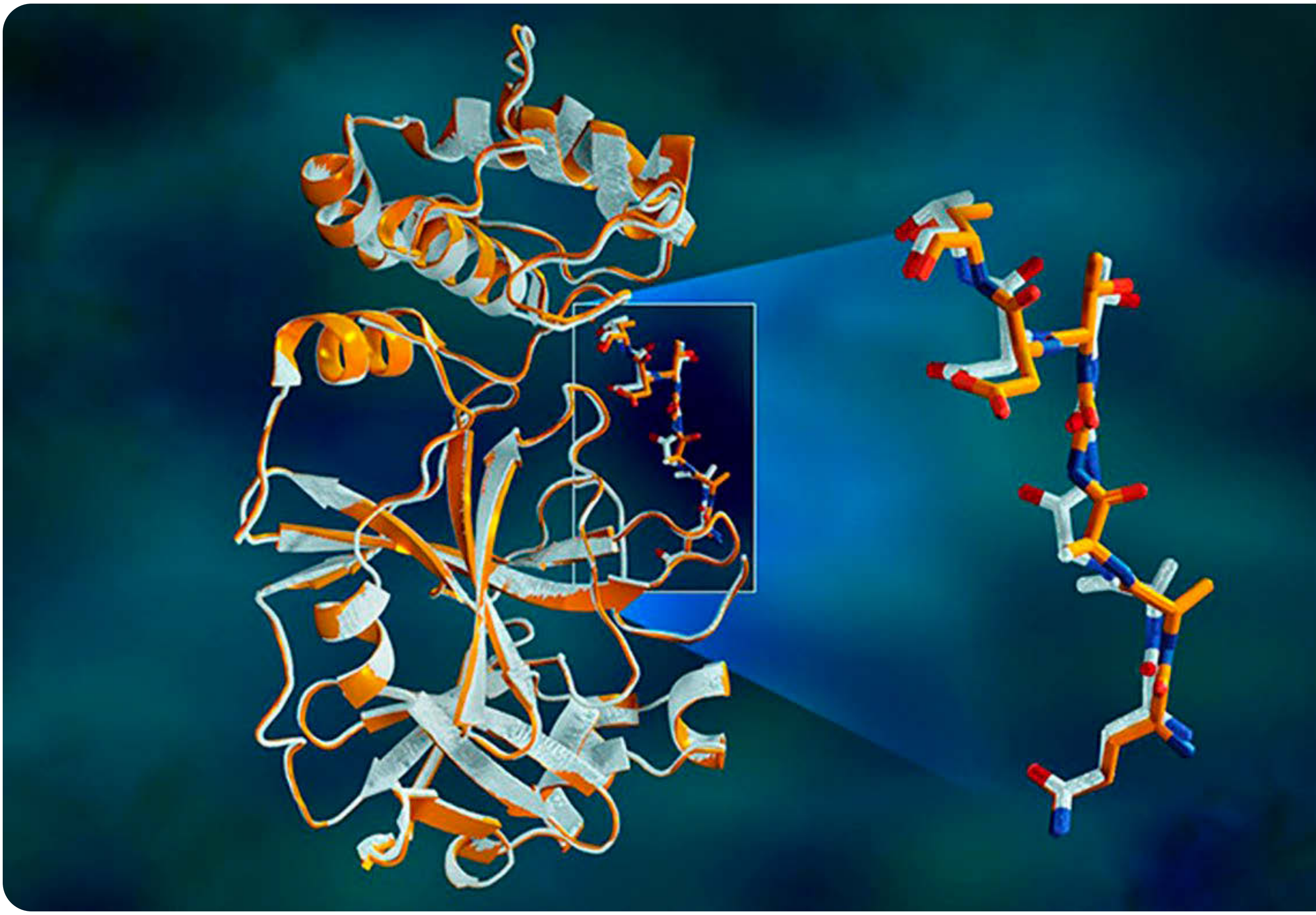
A team of researchers at the Department of Energy's Oak Ridge and Argonne national laboratories has performed the first room-temperature X-ray measurements on the SARS-CoV-2 main protease, the enzyme that enables the virus to reproduce.

The X-ray measurements mark an important first step in the researchers' ultimate goal of building a comprehensive 3D model of the enzymatic protein.

The model will be used to advance supercomputing simulations aimed at finding drug inhibitors to block the virus's replication mechanism and help end the COVID-19 pandemic. The team's research results are available and were published on June 24 in the journal *Nature Communications*.

SARS-CoV-2 is the virus that causes the disease COVID-19. The virus reproduces by expressing long chains of proteins that must be cut into smaller lengths by the protease enzyme.

"The protease is indispensable for the virus life cycle," said Oak Ridge National Laboratory's Andrey Kovalevsky, corresponding author. "The protein is shaped like a valentine's heart, but it really is the heart of the virus that allows it to replicate and



Overlapping X-ray data of the SARS-CoV-2 main protease shows structural differences between the protein at room temperature (orange) and the cryogenically frozen structure (white). Graphic: Jill Hemman/ORNL

spread. If you inhibit the protease and stop the heart, the virus cannot produce the proteins that are essential for its replication."

Building a complete model of the protein structure requires identifying each element within the structure and how they are arranged. X-rays are ideal for detecting heavy elements such as carbon, nitrogen, and oxygen atoms. Because of the intensity of the X-ray beams at most large-scale synchrotron facilities, biological samples typically must be cryogenically frozen to around 100 K, or approximately -280° F, to withstand the radiation long enough for data to be collected.

To extend the lifetime of the crystallized protein samples and measure them at room temperature, ORNL researchers grew crystals larger than required for synchrotron cryo-studies and used an in-house X-ray machine that features a less intense beam.

The researchers' next step in completing the 3D model of the SARS-CoV-2 main protease is to use neutron scattering at ORNL's High Flux Isotope Reactor and the Spallation Neutron Source. Neutrons are essential in locating the hydrogen atoms, which play a critical role in many of the catalytic functions and drug design efforts.

The protease plasmid DNA used to make the enzyme was provided by the Structural Biology Center at Argonne National Laboratory's Advanced Photon Source. Crystallization of the proteins used in the X-ray scattering experiments was performed at ORNL's Center for Structural and Molecular Biology.

State drops objections to Pilgrim's license transfer

Massachusetts Attorney General Maura Healey announced on June 17 that the state has agreed to withdraw its petitions with the Nuclear Regulatory Commission against the transfer of Pilgrim's license to Holtec International for decommissioning. The settlement agreement, signed between Massachusetts and Holtec subsidiaries Holtec Pilgrim and Holtec Decommissioning International (HDI), also resolves two lawsuits the state filed to challenge the NRC's approval of the license transfer application, as well as several administrative challenges Holtec filed to contest conditions in the January 2020 state water permit for the plant.

In return, Holtec has agreed to provide additional decommissioning trust fund obligations along with stricter radiological cleanup limits and additional site monitoring and oversight.

The Pilgrim nuclear power plant, in Plymouth, Mass.

Financially, Holtec is being required to maintain at least $193 million in Pilgrim's decommissioning trust fund throughout the cleanup process, up until the NRC approves the plant for partial site release. After that point, Holtec will need to maintain $38.4 million in funds until Pilgrim's spent nuclear fuel is removed from the site. According to the state, the $193 million will ensure funds are available to cover future cost increases and unforeseen contingencies such as project delays and newly discovered contamination, and the $38.4 million will ensure that funds are available to cover the costs to transport the spent fuel out of state and clean up Pilgrim's independent spent fuel storage installation. Holtec is also required to obtain $30 million in pollution liability insurance and secure performance bonds for certain contracts.

To satisfy cleanup requirements, the agreement calls for Holtec to work with the Massachusetts Department of Environmental Protection (Mass DEP) and Department of Public Health (DPH) in complying with the state's cleanup standards regarding radiological and nonradiological hazardous materials. Mass DEP and DPH will oversee cleanup work, and the agreement secures future funding for DPH for monitoring air and food sources outside of the plant's boundaries for any off-site radiological contamination.

The agreement also includes emergency preparedness requirements, with Holtec obligated to provide information and funding to the Massachusetts Emergency Management Agency to perform certain emergency preparedness functions in line with site risks.

"I'm pleased we were able to work with the Commonwealth of Massachusetts to find common ground that provides Holtec the certainty needed to safely complete decommissioning on the projected timeline," said Pam Cowan, chief operating officer of HDI. "Our commitment to be a good neighbor and our shared goal of protecting the health and safety of our workers, the community, and the environment were clear drivers for both parties that led to this agreement."

Attorney General Healy said, "Since the beginning of this proposed transfer, we have prioritized the health, safety, and other important interests of our residents and taken steps to ensure that the local community and environment are protected. This agreement provides critical protections, includes compliance measures stricter than federal requirements, and secures the funds necessary to safely and properly clean up this site. We are grateful for the partnership with the governor's office and our state agencies to establish this clear framework and oversight that will be needed to complete this work safely."

The NRC approved the sale and transfer of Pilgrim's license from plant owner Entergy to Holtec on August 22, 2019. A single-unit, 688-MWe boiling water reactor located in Plymouth, Mass., Pilgrim permanently ceased operations in May 2019. As part of the sale, Holtec Pilgrim assumed ownership of the site, real property, and spent nuclear fuel, while HDI is the license holder and decommissioning operator.

Massachusetts, along with the antinuclear group Pilgrim Watch, petitioned to block Pilgrim's license transfer, citing concerns with health, safety, and financial risks. NRC staff approved the license transfer while those petitions were still under consideration. Pilgrim Watch's challenges to the license transfer remain before the NRC.

DUANE ARNOLD

NextEra sets Energy Center D&D at $1 billion

NextEra Energy is estimating that it will cost just over $1 billion to decommission its Duane Arnold Energy Center over a period of 60 years, including spent fuel management and site restoration costs, according to a post-shutdown decommissioning activities report (PSDAR) and a decommissioning cost estimate the company submitted to the Nuclear Regulatory Commission in April. The NRC, with publication in the June 19 *Federal Register*, is requesting comments on the Duane Arnold PSDAR until October 19.

NextEra intends to permanently shut down the nuclear power plant, located near Palo, Iowa, on October 30. A single-unit, 622-MWe boiling water reactor, Duane Arnold began commercial operation in February 1975. Although the plant is licensed to operate until February 2034, NextEra announced in July 2018 its plans to cease operations at Duane Arnold well before then. NextEra, which shares ownership of the

Waste Management continues

Duane Arnold is to shut down in October. Photo: Wikimedia Commons/AsNuke

plant with Central Iowa Power Cooperative (20 percent) and Corn Belt Power Cooperative (10 percent), made the announcement after agreeing to end its power purchase agreement with utility Alliant Energy by 2020.

According to the PSDAR, NextEra intends to decommission Duane Arnold using the NRC's SAFSTOR method, in which the plant is maintained in a safe, stable condition for up to 60 years before decommissioning is completed. The current decommissioning schedule calls for the plant to be placed in a dormant state until 2073, followed by a seven-year dismantling and decontamination period. NextEra intends to complete the transfer of Duane Arnold's spent nuclear fuel to dry storage by August 2023.

NextEra is estimating that it will cost about $725 million to decommission Duane Arnold and terminate its NRC license. The company also estimates it will spend $259 million in spent fuel management costs and $38 million to restore the site to greenfield status and decommission the plant's independent spent fuel storage installation. According to NextEra's 2019 decommissioning funding status report to the NRC, Duane Arnold had about $472 million in its decommissioning trust fund at the end of 2018.

Comments on the PSDAR can be submitted through the federal rulemaking website, at regulations.gov, with a search for Docket ID NRC–2020–0148. Comments can also be mailed to: Office of Administration, Mail Stop: TWFN–7–A60M, ATTN: Program Management, Announcements and Editing Staff, U.S. Nuclear Regulatory Commission, Washington, DC 20555–0001.

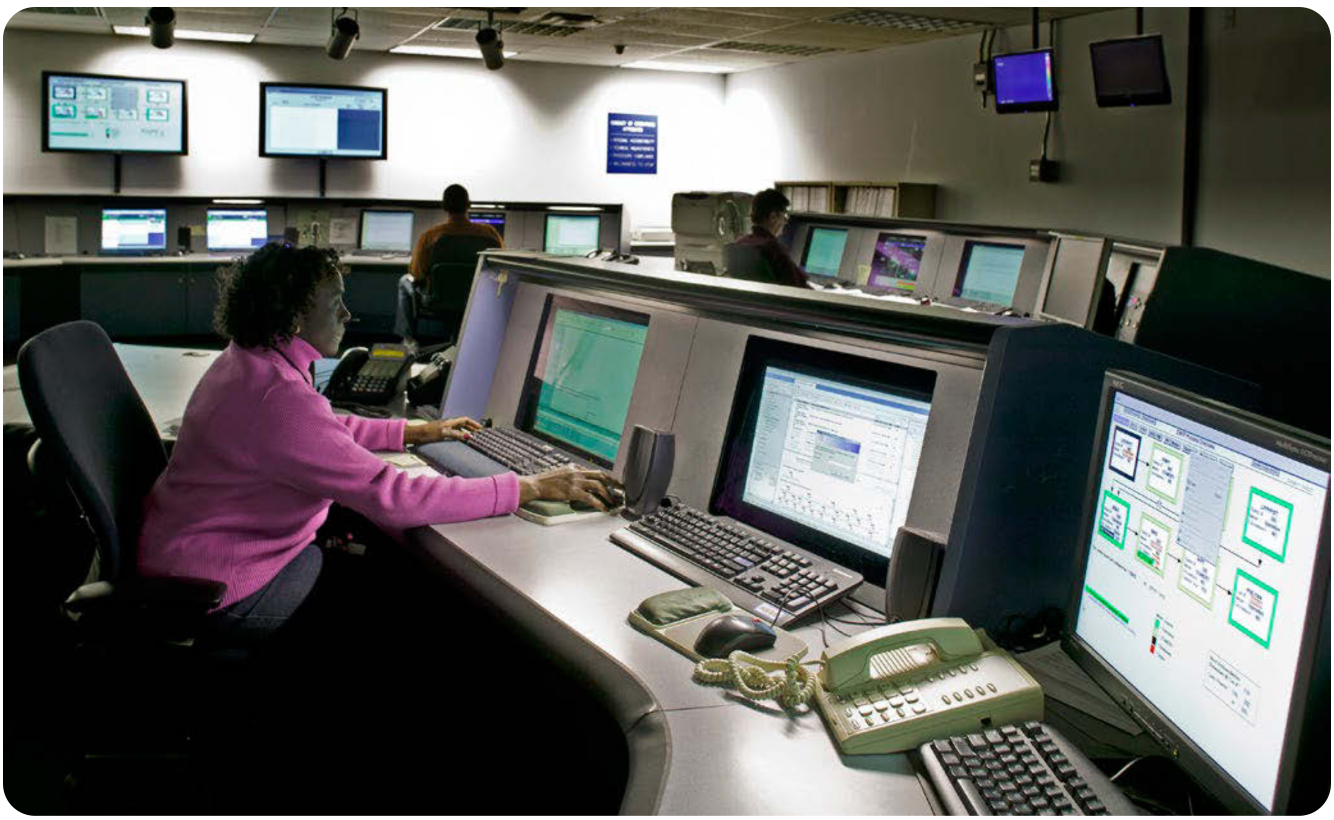
SAVANNAH RIVER SITE

Upgrade made to SRS liquid waste facilities

An upgrade to modernize computer systems across the Savannah River Site's liquid waste facilities while maintaining cybersecurity industry standards was completed recently, the site's liquid waste contractor announced on June 25. The Savannah River Site is located in Aiken, S.C.

The contractor, Savannah River Remediation (SRR), noted that over a two-and-a-half-year period the liquid waste facilities' distributed control system (DCS) was upgraded to a newer platform and the computer hardware was refreshed. The DCS was designed specifically for the site, with automated control system software and physical control elements located throughout the liquid waste facilities. The facilities—the Defense Waste Processing Facility, the Saltstone Disposal Units, and the Tank Farms—use processing equipment and instrumentation that are monitored and controlled by human operators through the DCS.

Janice Sandford, forefront, and other operators are shown in the Defense Waste Processing Facility control room. Savannah River Remediation recently upgraded its control system hardware and software.



Waste Management continues

Waste Management Briefs

A $350-MILLION CONTRACT FOR THE CLEANUP of the Nevada National Security Site was awarded to Oak Ridge, Tenn.–based Navarro Research and Engineering, the Department of Energy announced on June 17. The new 10-year environmental program services contract replaces the current NNSS cleanup contract, also held by Navarro Research and Engineering, which expired on July 31. In awarding the contract, the DOE's Office of Environmental Management (EM) used the department's new end-state contracting model, which the DOE said will reduce risk and environmental liability by giving EM the flexibility to task its contractors using a risk-based approach to better define discrete scopes of work for site closure or end states. Navarro is a small, woman-owned contractor, and the contract was awarded under a small business set-aside competition.

Cleanup services to be provided under the indefinite delivery/indefinite quantity contract will include, but are not limited to, groundwater characterization and monitoring, radioactive waste acceptance program management, soils and industrial sites close-out/post-closure monitoring, decontamination and demolition, and program management support. The services will be provided at NNSS, as well as the Nevada Test and Training Range and the Tonopah Test Range.

SAVANNAH RIVER'S HB LINE WAS PLACED in a safe shutdown status, the Department of Energy announced on June 24. The HB Line is located on top of the H Canyon chemical separations plant at the DOE's Savannah River Site (SRS) in South Carolina and is the only chemical processing facility of its kind in the DOE complex. The reversible shutdown will save about $40 million a year starting in 2021, compared to 2016, when the facility's plutonium feedstock operation was at its peak.

In February 2018, the DOE sent a letter of direction to Savannah River Nuclear Solutions, the SRS management and operations contractor, to proceed with placing the HB Line in safe shutdown status while preserving its capabilities for future use. The principal scope of the shutdown involved three tasks: de-inventorying and flushing the facility's product and cold chemical lines, which included anion exchange column resin removal; dispositioning legacy plutonium and uranium materials stored and previously used at the facility; and laying up support systems no longer needed. Other work included reducing security for the facility; revising the facility's technical safety requirements to reduce its minimum staffing requirements; and assimilating the H Canyon and HB Line organizations, aimed at reducing the future overall facility cost through the reduction in expenses related to maintenance, surveillance, and utilities.

More than 100 DCS controllers throughout the facilities were replaced to be compatible with the new software and processing requirements. The new digital upgrades for each facility connect by a communications network to interface with the facility's equipment and instrumentation.

The DCS upgrade was an effort included in SRR's strategic plans to position the site's liquid waste system to operate safely at higher throughput rates necessary to support the near-term start of operations of the Salt Waste Processing Facility. Detailed planning went into the project, including the use of offline development and test systems, and it involved personnel from various groups from SRR. The upgrade was successfully implemented with minimal impacts to the facilities' operations, according to SRR.

Nuclear material production operations at the Savannah River Site for national defense purposes resulted in the generation of liquid radioactive waste that is being stored, on an interim basis, in 49 underground waste storage tanks in the F- and H-Area Tank Farms. The Department of Energy built the Defense Waste Processing Facility to vitrify concentrated high-activity tank waste into a stable form and to store it for eventual permanent disposal. The Saltstone Disposal Units were constructed to immobilize and dispose of low-activity decontaminated salt waste. Radioactive liquid is stored in the Tank Farms in both solid and liquid forms.

INTERIM STORAGE

NRC extends comment period again for Holtec site

For the second time, the Nuclear Regulatory Commission has extended the deadline for submitting comments on a draft environmental impact statement (EIS) for Holtec International's application to construct and operate a consolidated interim storage facility for spent nuclear fuel and greater-than-Class-C waste in southeastern New Mexico. As published in the June 24 *Federal Register*, the new deadline is September 22.

The NRC said that the reason for the new extension was the recent events associated with the COVID-19 public health emergency. The draft EIS was made public on March 20 with an initial deadline for comments of May 22. That date was extended on April 27 by the NRC an additional two months due to the COVID-19 health emergency.

In the draft EIS, the NRC staff concluded that the environmental impacts of the project would not preclude granting Holtec a license for the storage facility, called the HI-STORE CISF. If approved by the NRC, Holtec would be licensed for an initial phase (Phase 1) of the project to store 8,680 metric tons of spent fuel in 500 canisters for a 40-year license period. Holtec anticipates subsequently requesting amendments to the license to store an additional 5,000 metric tons of spent fuel for each of 19 expansion phases to be completed over the course of 20 years. If granted, the HI-STORE CISF could eventually store up to 10,000 canisters of spent fuel.

Comments can be submitted through the federal rulemaking website, at regulations.gov, with a search for Docket ID NRC–2018–0052. Comments can also be mailed to: Office of Administration, Mail Stop: TWFN–7–A60M, ATTN: Program Management, Announcements and Editing Staff, U.S. Nuclear Regulatory Commission, Washington, DC 20555–0001; or by email to Holtec-CISFEIS@nrc.gov.

Waste Management continues

The Ulysse reactor before dismantling. Photo: Orano

FRANCE

Orano dismantles Ulysse research reactor

A five-year project to dismantle the Ulysse experimental nuclear reactor at the French Alternative Energies and Atomic Energy Commission's (CEA) Saclay nuclear research site near Paris has been completed, according to an Orano press release on June 22. Orano was contracted to decommission the low-power research and training reactor.

Ulysse mainly operated for teaching and continuing education purposes by the French National Institute for Nuclear Science and Technology until it was shut down in 2007. According to Orano, the completion of dismantling was in line with the schedule set in 2014 by the French Nuclear Safety Authority and now paves the way for the administrative decommissioning of the facility.

Following the selection of STMI (now Orano Dismantling and Services) by CEA in 2014, phase one of the reactor's decommissioning began in January 2015 with the dismantling of Ulysse's air and water networks, along with removal of the engineering works around the reactor core. Dismantling of the reactor's nuclear components, including the cutting of equipment and the concrete block shielding assembly in the reactor core, was completed in 2019, while the final phase of cleanup and site verification was completed this year. According to Orano, decommissioning of the reactor generated 512 metric tons of conventional waste and 226 metric tons of very low-level waste.

Built in 1961, Ulysse operated at a thermal power of 100 kW and was moderated by water and reflected by graphite. An Argonaut-type reactor designed by Argonne National Laboratory (**Argo**nne **N**uclear **A**ssembly for **U**niversity **T**raining), Ulysse was powered using uranium fuel enriched between 20 and 90 percent.

The CB-20 module being installed at Vogtle-3. Photo: Georgia Power

VOGTLE

Final major module for Unit 3 installed

A massive water tank has been placed atop the containment vessel and shield building roof at Vogtle-3, one of two AP1000 reactors currently under construction at Southern Company's nuclear expansion project near Waynesboro, Ga. The installation in May represents the final module placement for the unit and marks the latest significant milestone to be reached at the Vogtle site.

The water tank, known as CB-20, is a major part of the AP1000's advanced passive safety system, according to the Vogtle plant's primary owner, Southern subsidiary Georgia Power. Standing 35 feet tall and weighing more than 720,000 pounds, the CB-20 module will hold approximately 750,000 gallons of water, which would flow down in the event of an emergency to help cool the reactor. The water can also be directed into the used fuel pool, while the tank itself can be refilled from water stored elsewhere on-site, Georgia Power said.

ENFORCEMENT

2019 cases up from 2018, but below five-year average

The Nuclear Regulatory Commission recently issued its *Enforcement Program Annual Report* for calendar year 2019, showing that 57 escalated enforcement actions were taken against NRC licensees last year. These actions included notices of violation (NOVs) of Severity Level III or higher, NOVs associated with findings of low-to-moderate, substantial, or high safety significance (color coded as white, yellow, or red findings, respectively), civil penalties, and orders, including confirmatory orders.

Of the 57 actions in 2019, 13 (23 percent) involved civil penalties totaling $732,250, nine (16 percent) were enforcement orders without an imposed penalty, and 35 (61 percent) were escalated NOVs without a proposed penalty. "In general, the NRC considers a large percentage of NOVs without civil penalties as a positive outcome, because it demonstrates that most licensees identify and correct violations," according to the report. (A licensee will often be able to avoid a fine by identifying the violation and taking corrective actions to prevent a recurrence.)

Nuclear materials users were the major culprits in 2019, receiving 34 escalated actions (60 percent), followed by operating reactor licensees, with 18 (32 percent). The NRC also issued two escalated actions to a fuel facility (one to the facility and one to an individual associated with the facility), one to a new reactor facility (Vogtle-3 and -4), and two to decommissioning and low-level waste licensees.

The report also notes that while the 2019 total for escalated enforcement actions is higher than 2018's—57 to 45 (a 27 percent increase)—it remains well below the five-year average of 72. (The years 2015, 2016, and 2017 were particularly action-packed with escalated enforcement, with 82, 91, and 84, respectively.)

The sources of the NRC's enforcement authority are the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and the Energy Policy Act of 2005. The Energy Policy Act also expanded the definition of by-product material, placing additional by-product material under the NRC's jurisdiction, including both naturally occurring and accelerator-produced radioactive materials.

NEA

Agency issues call to action in report on nuclear cost reductions

A recent report from the Paris-based OECD Nuclear Energy Agency declares that nuclear power is needed for countries to meet their Paris Agreement decarbonization and energy security policy goals, but that governmental support for a rapid reduction in the cost of new nuclear capacity through the creation of certain policy frameworks is likely necessary.

The 134-page report, *Unlocking Reductions in the Construction Costs of Nuclear: A Practical Guide for Stakeholders*, notes that according to the International Energy Agency's Sustainable Development Scenario (SDS), new nuclear capacity will be needed in addition to ambitious lifetime extension programs for existing nuclear plants. According to the report, in 2019, nuclear power was not on track to reach the required output. In fact, the rate of annual capacity additions would need to at least double between 2020 and 2050 to meet the SDS target.

"Our analysis verifies that high costs and project schedule overruns are not an inherent characteristic of nuclear technology, but are a reflection of weak supply chains and a lack of recent nuclear construction experience in western OECD countries," said NEA Director General William Magwood during the report's online launch on July 2. The report focuses on potential cost and risk reduction opportunities for Generation III reactor designs that could be realized in the short term and that are also applicable to small modular reactors and advanced reactor concepts for deployment in the longer term.

The NEA identifies eight cost reduction drivers that can be exploited at different stages of nuclear construction, including government support for robust and predictable market and financing frameworks, as well as policy support mechanisms for design maturity and regulatory stability. Implementing these cost-reduction drivers, the report says, should also lessen the technological, organizational, and regulatory risks associated with new nuclear plant deployment.

Patrick Snouffer named 2021 ANS Congressional Fellow

Patrick Snouffer, a senior nuclear engineer at Bechtel National who has worked on Hanford's Waste Treatment Plant and on initial design work for the Versatile Test Reactor, will take on a new type of assignment in January 2021.

Snouffer, an ANS member since 2010, was selected during the 2020 ANS Virtual Annual Meeting to serve as the 2021 ANS Glenn T. Seaborg Congressional Science and Engineering Fellow. As congressional fellow, Snouffer will have the opportunity to work in the office of a member of Congress or with a congressional committee.

"Patrick is in a unique position to provide significant technical assistance to the U.S. Congress on nuclear energy, particularly now as important discussions are shaping the future of U.S. energy policy," said Harsh Desai, chair of the ANS Congressional Fellowship Committee and a former fellow himself. "Members of Congress and their staff will greatly benefit from Patrick's depth of experience in all aspects of the nuclear fuel cycle. The fellowship will also be an opportunity for Patrick to develop his policy expertise and 'learn how the sausage is made.'"

Snouffer lives and works in D.C., but he began his professional career at Sandia National Laboratories as a reactor engineer after earning bachelor's and master's degrees in nuclear engineering from the University of Wisconsin.

Using nuclear energy to fight climate change by building new reactors that are economically competitive is important to Snouffer, and he wants to contribute to that effort as fellow. "Ideally, I would be working on energy policy," he said. "I see the fellowship as an opportunity to learn firsthand about the policy and funding process. I hope to be able to utilize this experience to continue to advance the development of new reactors, whether working on specific projects or at the policy level."

John Starkey, ANS director of government relations, emphasizes that many congressional fellows are able to do just that. "ANS has seen many of its former congressional fellows continue their work in our nation's capital even after their fellowships have ended," Starkey explained. "This aspect of the program allows ANS to continue providing technical support and background for policies that advance nuclear science and technology. I welcome Patrick to our ANS Congressional Fellowship family, and I'm excited to have him walking the hallways of Capitol Hill in 2021."

Snouffer will attend an orientation session by the American Association for the Advancement of Science this fall with congressional fellows sponsored by other engineering societies. Snouffer is looking forward to the orientation, whether it is held in person or online. "It is important to connect with other 2021 fellows and get a sense of the potential member or committee office I would work in through interviews," he said.

Snouffer anticipates heading to work on Capitol Hill in January. If he ends up working remotely, however, he is still looking forward to a successful year. "Congressional staff have found ways to be productive working from home so far and I expect that would only improve by the time I start in January," he said.

An active ANS member, Snouffer is currently on the executive committee of the Young Members Group. In 2019 he served on the program committee for the Young Professionals Congress, and he is the Young Professionals Congress co-chair for 2021. He is also a member of the working group for standard ANS-15.22.

Snouffer is thankful for ANS's support of the fellowship program. "I also would like to thank the selection committee for this opportunity and for providing their valuable insight and perspectives throughout the process," he said.

More information on the ANS Congressional Fellowship program can be found at ans.org/honors/cfellowship/.

Arndt honored with 2020 NSPE Award

ANS Board of Directors member Steven Arndt, ANS Fellow and member since 1981, finds himself in good company as a freshly minted winner of the National Society of Professional Engineers (NSPE) Award. Past honorees include a U.S. president (Herbert Hoover), the "father of inertial navigation" (Charles S. Draper), and an expert on building collapse investigations who led the structural assessments of both the Oklahoma City and World Trade Center tragedies (W. Gene Corley).

The NSPE Award is considered the top national honor given specifically to a professional engineer. First awarded in 1949, it is presented to an individual who has made outstanding contributions to the engineering profession, the public welfare, and humankind.

Arndt was honored in recognition of his lifelong sustained contributions to the advancement of the engineering profession through education, technical society participation, and community service. He received his award on August 3 during the opening day of the NSPE Virtual 2020 Professional Engineers Conference.

Young Members Group spotlight shines on Pacific Northwest National Laboratory

The ANS Young Members Group is delivering an in-depth look at the Department of Energy's national laboratories through its Spotlight on National Labs live webinar series. The fifth entry was held on July 1 and focused on Pacific Northwest National Laboratory's work in national security, energy resiliency, and environmental restoration—especially related to its nuclear research and development portfolio.

"As I am after each of these Spotlights, I was

ANS News continues

YMG's Spotlight on National Labs

The ANS Young Members Group is producing a publicly available webinar series called Spotlight on National Labs. Visit ans.org/webinars/archive to view the first webinars in the series:

April 15	Idaho National Laboratory
April 30	Argonne National Laboratory
May 6	Los Alamos National Laboratory
May 20	National Renewable Energy Laboratory
July 1	Pacific Northwest National Laboratory
July 16	Lawrence Livermore National Laboratory

thoroughly impressed with PNNL," said Catherine Prat, YMG chair and moderator for the event. "I was excited for the opportunity to moderate this webinar because of the wide variety of areas that PNNL is doing work on—from marine sciences to grid stabilization to material processes optimization."

The webinar was viewed live by 670 participants, while many more took advantage of the online archive (link below) to watch the recorded version. The event featured eight panelists, including PNNL Director Steven Ashby. The other PNNL speakers were Jud Virden, associate laboratory director of energy and environment; Daniel Stephens, manager, National Nuclear Security Administration programs; Mark Nutt, manager, nuclear energy and nuclear regulatory programs; Amanda Lines, chemist; Steven Spurgeon, materials scientist; Paul Johns, physicist; and Hellen Jiang, materials scientist.

"I appreciated how each of the speakers tied in where nuclear science, technology, and engineering play a part in what may not seem like a traditional 'nuclear' research area," Prat said.

ANS's entire library of informative webinars is archived and accessible to ANS members at ans.org/webinars/archive. Upcoming ANS webinars are listed at ans.org/webinars.

Young Members Group creates dynamic Annual Meeting sessions

That the Young Members Group has been busy this year is an understatement. The successful ANS Virtual Annual Meeting featured high-profile technical and social content organized by the YMG and saw the group receive a Presidential Citation from outgoing President Marilyn Kray in recognition of "outstanding leadership in generating digital content and creative value for the Society." Their efforts have been noticed not only during the online meeting but also through an ongoing series of well-attended webinars and virtual trivia nights.

Here's a look at some of the highlights of the YMG's contributions to the Virtual Annual Meeting.

President's Special Session

The YMG organized the President's Special Session together with the Student Sections Committee (SSC). Kelley Verner, SSC chair, and Kelsey Amundson, YMG treasurer, moderated a panel discussion on U.S. Global Leadership in Nuclear Energy and National Security. The session highlighted the role that the expansion of the nuclear fleet has in strengthening national security and featured insights from Maria Korsnick, of the Nuclear Energy Institute; Laura S. H. Holgate, of the Nuclear Threat Initiative; Siegfried Hecker, of Stanford University; and Rita Baranwal, of the Department of Energy.

Read more about the President's Special Session on page 28 of this issue and on ANS Newswire at ans.org/news.

Trivia nights

"With the ANS Annual Meeting going virtual, we wanted to be able to host an event where members could interact with each other in a more social setting," said Patrick Snouffer, a member of the YMG executive committee. The YMG worked with the SSC and the Diversity and Inclusion in ANS Committee to host two back-to-back trivia nights during the Virtual Annual Meeting, which followed a first-ever virtual nuclear trivia night in May.

"The virtual trivia nights provided a great way for conference attendees to connect, show off their creativity, and display their nuclear knowledge," Snouffer said. "It was amazing to see everyone really get into the whole experience with participants not only fully engaging with the questions but also creating team Zoom backgrounds and embracing the silly hat theme that organically developed."

Turn to page 128 to read about the YMG's latest virtual networking events.

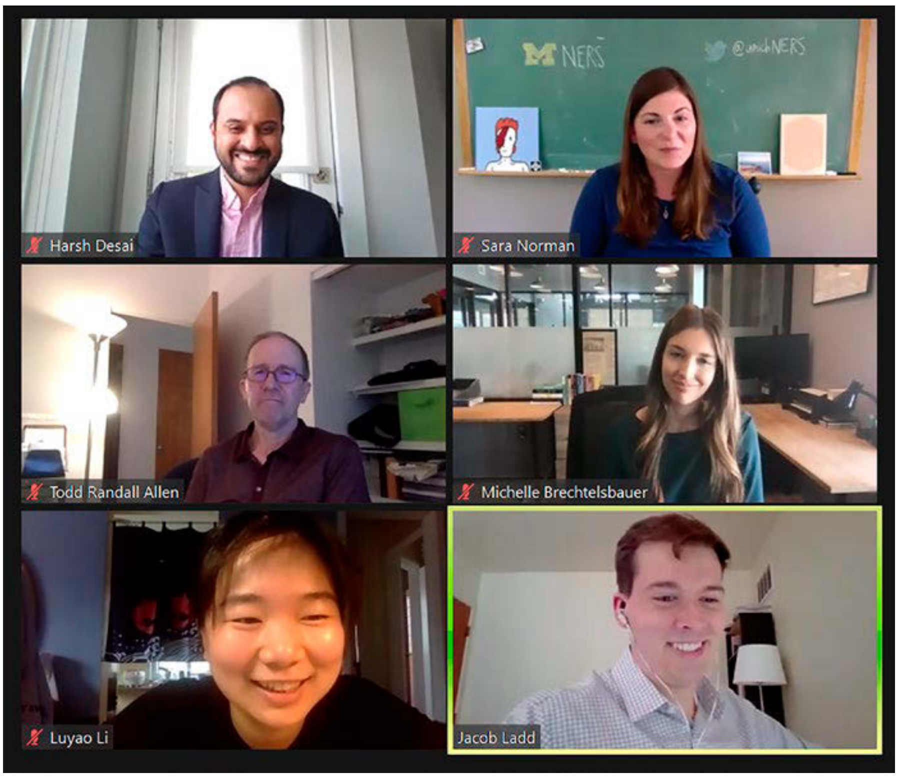
Innovating nuclear through an entrepreneurial student prize competition

Attendees at this panel session, organized and moderated by outgoing YMG Chair (and incoming ANS Board member) Harsh Desai, were treated to a lively discussion about the Nuclear Energy Grand Challenge entrepreneurial prize competition at the University of Michigan (UM) during the 2019–2020 school year. Desai welcomed sponsors and organizers of the competition from the Energy Impact Center and UM, as well as students from the winning team, to discuss the success and future applications of the competition.

The prize competition challenge—"Reimagining Nuclear Waste"—asked interdisciplinary teams of UM students to create a business plan to use spent nuclear fuel from a commercial source to create a new product or service, with $17,000 in prize money at stake.

The winning team was SustainiUM, a group of five students represented during the session by Jacob Ladd and Luyao Li. SustainiUM designed a business plan to use the heat from spent fuel in dry cask storage at nuclear plants to dry wastewater sludge that can be used as fertilizer.

Read more about SustainiUM and the entrepreneurial prize competition on Newswire, at ans.org/news.



Panelists for the entrepreneurial prize competition were (clockwise from top left): Harsh Desai (Nuclear Energy Institute), Sara Norman (University of Michigan), Michelle Brechtelsbauer (Energy Impact Center), Jacob Ladd (SustainiUM member), Luyao Li (SustainiUM member), and Todd Allen (UM).

ANS News continues

Pitch Your Job

The YMG sponsored a Pitch Your Job session cohosted by Alyse Huffman, the 2019 ANS Congressional Fellow, and Catherine Prat, the incoming YMG chair. The session was inspired by Pitch Your PhD sessions held at previous ANS meetings. Five young members competed for bragging rights by "pitching" their job in three minutes using only one slide. First place honors went to Amber McCarthy, a nuclear criticality safety engineer at the Y-12 National Security Complex, with a tie for second place between Trey Mason, a risk analysis engineer at Westinghouse, and Julianne McCallum, a research analyst in the Nuclear Energy Institute's Policy Development and Public Affairs Division.

Read more about the Pitch Your Job competition on Newswire, at ans.org/news.

And that's not all

Other sessions organized by the YMG included "Communicating Safety and Risk to the Public," "Why the STEM Community Should Run for Office and How to Do It," "Building Your Leadership Competency," and a Resume/CV Workshop. The group also cosponsored a Focus on Communications workshop presented by the Education, Training, and Workforce Development Division.

Want to catch one of these sessions? Meeting attendees can still access sessions on demand through the meeting portal at ans.org/meetings/am2020/.

Virtual events continue beyond Annual Meeting for YMG

The ANS 2020 Virtual Annual Meeting wasn't the end of digital activities sponsored by the ANS Young Members Group. Two more events took place in July, including a "happy hour" networking social on July 2 that drew around 30 participants.

On July 21, the YMG hosted another of its popular trivia nights. Members of the YMG, the Student Sections Committee, and the Diversity and Inclusion in ANS Committee planned the questions for the event—no easy task given that they also had to create batches of questions for two trivia nights during the Annual Meeting.

Luckily for them, there's no shortage of random facts to pick from.

"There are a lot of aspects to the nuclear industry, and the goal for each round of trivia is to broaden everyone's knowledge, including my own," said Kelsey Amundson, YMG treasurer and event moderator. "I've particularly enjoyed finding nuclear references in pop culture and nuclear history."

The key is to keep the questions from getting too technical, which could alienate participants who don't have that kind of background knowledge at their fingertips.

"Technical questions have been avoided because we don't want trivia to feel like a university exam. Rather, this allows people the opportunity to learn more about the nuclear industry," Amundson added.

New Members

The ANS members and student members listed below joined the Society in June 2020.

Alnaqbi, Abdelaziz Sanad, Nawah Energy Company (UAE)
Araujo, Kathleen, Boise State University
Azam, Sayed

Barrientos, David, Lucideon
Bateman, Lucas R.
Boemeke, Isabelle, Isodope

Coulter, Ted, TVA

Filippone, Claudio, HolosGen
Francisco, Barbara, University of Ottawa (Canada)
Frazar, Sarah, Pacific Northwest National Laboratory

Gilbert, William T., Nawah Energy Company (UAE)
Greaney, Allison T., Oak Ridge National Laboratory
Gulabrao, Praneel, U.S. Navy

Hancock, Monte A., U.S. Navy
Hanson, Christopher T., U.S. Nuclear Regulatory Commission
Hayne, Mathew, Los Alamos National Laboratory

Ismail, Samya Y., Federal Authority for Nuclear Regulation (UAE)

Kalas, Dan, RadQual
King, Matt, Wallowa Resources Community Solutions
Kiplinger, Jaqueline L., Los Alamos National Laboratory
Kirtley, Thomas C., University of Texas–San Antonio
Kocevski, Vancho, Los Alamos National Laboratory
Krug, David, Naval Reactors

Locke, Paul, Johns Hopkins University

Martin, Benjamin, Y-12/Consolidated Nuclear Security
McNeil, Walter J., Kansas State University

Ochoa-Ricoux, Juan P., University of California–Irvine

Partain, Katherine, General Atomics
Port, Ashley N., U.S. Navy

Samin, Adib, U.S. Air Force Institute of Technology
Sheikh, Mina R., Federal Authority for Nuclear Regulation (UAE)
Siefman, Daniel J., Lawrence Livermore National Laboratory

Tek, Sumeyra, University of Texas–San Antonio
Touchette, Adam, Southern Nuclear

Virden, Jud, Pacific Northwest National Laboratory

Wagnon, Todd, Washington River Protection Solutions
Woodward, William S., Holtec International

Yuan, Haomin, Argonne National Laboratory

STUDENT MEMBERS

Boise State University
Doyle, Cayden

Colorado School of Mines
Wilkinson, Ian

Excelsior College
Cawley, Peggy T.
Kole, Joseph E.

Harbin Engineering University (China)
Salas Tapia, Luis F.

Illinois Institute of Technology
Limestall, William R.

Kennesaw State University
Machiwalla, Alisa K.

King Abdulaziz University (Saudi Arabia)
Alhusini, Firas M.
Hazzaa, Yahya Z.

Knox College
Bharat, Saransh

North Carolina State University
Chen, Jiahao
Guo, Shujie
Xu, Yuchao

Oregon State University
Freilich, Justina

St. Mary's University
Smith, Adriana

Shanghai Jiaotong University (China)
Liu, Limin

Texas A&M University
Krezinski, Mason
Wise, Dalton T.

U.S. Navy
Boozer, David
Cheng, George Li
Kohlbrenner, Daniel P.
Williams, Tony D.

U.S. Air Force Academy
Drewes, Theodore
Eyler, Zachary J.
Gossett, Katalin I.
Hawthorne, Cameron S.
Kristensen, Cameren
Leonard, Kade J.
LoPiccolo, Vincent M.
Nyfeler, Peter
Patel, Shiv
Pelia, Manmeet K.
Quintero Hilsaca, Camila V.
Schultz, Gunnar

University of California–Irvine
Barraza-Valdez, Ernesto
Hatfield, Kaleb W.
Kim, Carlton S.

University of Florida
Coss Flores, Kervin M.

University of Idaho
Balumuru, Chaithanya
Haddon, Jayson S.

University of Michigan–Ann Arbor
O'Neil, Christopher E.
Wang, Yuhao
Yadav, Aniket

University of Pittsburgh
Lantgios, Iza G.
Spangler, Ryan M.

University of Rhode Island
Maranan, Peter

University of South Carolina
Islam, A. S. M. Fakhrul

University of Tennessee–Knoxville
Bautista, Victor
Hartman, Jonathan D.
Wells, Landry D.

University of Texas–Austin
Marcotulli, Maurizio A.
Pai, Mihir
Snarr, Patrick L.

University of Texas–San Antonio
Flowers, Jacob A.
Smith, Chrismond

University of Utah
Quist, Teancum E.

Utah State University
Pepper, Ben

Virginia Commonwealth University
Littlepage, Jake

Virginia Tech
Davis, Brenton

Institution not provided
Crittenden, Jerry A., NPPD/Cooper Nuclear Station
Heilman, Matthew, Idaho National Laboratory

BUSINESS DEVELOPMENTS

NNSA to end facility management deal with CNS

The National Nuclear Security Administration announced on June 23 that it won't extend its contract with **Consolidated Nuclear Security** (CNS) to manage the Y-12 National Security Complex in Tennessee and the Pantex Plant in Texas. The original 10-year deal, worth approximately $2 billion annually, included options for the final three years and is set to expire on September 30, 2021. An annual performance evaluation conducted by the NNSA showed that CNS failed to reach the 80 percent at-risk fee it needed to earn for fiscal 2019. The NNSA indicated that work at the two facilities will continue as the agency begins the process of replacing CNS.

■ **Lucideon**, a U.K.-based international materials technology company, has signed an agreement with the National Nuclear Laboratory's (NNL) Advanced Fuels Cycle Program (AFCP) as a research and development partner, the company announced on June 23. The AFCP, part of the U.K. government's £180-million Nuclear Innovation Program, is focused on the development of skills, knowledge, and capabilities in the areas of advanced recycle and waste management and advanced nuclear fuels. The agreement involves an initial program worth over £350,000 to Lucideon. NNL will draw on Lucideon's expertise in flash (field enhanced) sintering technology to improve the production of advanced nuclear fuels through new developments in the structure and performance of materials. Flash sintering technology uses an electric field applied to a ceramic substance at specific temperatures. In addition, Lucideon will collaborate with the University of Manchester, which will provide resources to support the program.

■ Rosatom, Russia's state atomic energy corporation, announced on June 1 that it had signed memorandums of understanding with **Framatome** and **GE Steam Power** in the framework of the strategic investor

NOTE: *Nuclear News* publishes news about nuclear industry contracts—but only about contract awards. We generally do not publish announcements that the work is under way or announcements that the work has been completed. Send your new contract award announcements to: Industry Editor, *Nuclear News*, 555 N. Kensington Ave., La Grange Park, IL 60526; fax 708/579-8204; email nucnews@ans.org.

selection procedure for the Belene nuclear plant in Bulgaria. In accordance with the MOUs, the companies will work together to participate in the tender for the construction of Belene. As part of the agreement, if Rosatom becomes a strategic investor in the project through a competitive process, General Electric will be considered as the partner of an Arabelle turbine-generator set and turbine hall equipment. Framatome will be the key partner in providing the automated process control systems, electrical systems, hydrogen recombiners, and heating, ventilation, and air conditioning for the plant.

■ Dallas-based **Jacobs** has been selected by **LLW Repository** (LLWR) to provide multidisciplinary technical services at the United Kingdom's national disposal facility for low-level radioactive waste as the sole service provider for the repository infrastructure framework. The new four-year framework, which was announced on July 1, covers a wide range of services to help LLWR manage the repository, in West Cumbria, on behalf of the U.K. government's Nuclear Decommissioning Authority. Jacobs's support includes developing strategies for appropriate storage solutions, control and electronic systems enhancement, and other technical services, all underpinned by core engineering design, construction, and program/project management capabilities.

CONTRACTS

BWXT signs deal with INL for TRISO expansion and upgrade

BWX Technologies has signed a $26-million, 20-month contract to expand and upgrade its TRISO (tristructural isotropic) fuel manufacturing line, the company announced on July 1. The contract, awarded by Idaho National Laboratory, calls for the expansion of BWXT's capacity for the manufacture of TRISO fuel compacts and the upgrading of existing systems for delivering production-scale quantities of TRISO fuel. BWXT said that it anticipates potential awards for additional contract options that would enable the fabrication and delivery of TRISO fuel in support of future missions for the Department of Defense and NASA. This project is an effort jointly funded by the DOD's Operational Energy Capabilities Improvement Fund Office and NASA, with overall program management provided by the Strategic Capabilities Office.

■ The Department of Energy's Office of Environmental Management (EM) on July 1 awarded a set of indefinite delivery/indefinite quantity contracts to provide nationwide deactivation, decommissioning, and removal (DD&R) services to help address excess facilities. The contracts will use firm fixed-price and cost reimbursement task orders to conduct DD&R of excess legacy facilities across the EM complex. This support will also be available to the National Nuclear Security Administration, the Office of Naval Reactors, and the Office of Science, as well as other DOE offices or other federal agencies that may request EM assistance in accomplishing their DD&R requirements. This multiple-award contract has a 10-year ordering period and a maximum ordering value of $3 billion.

The contracts were awarded to the following companies:

■ **Aptim Federal Services** (Alexandria, Va.)

■ **Atkins Nuclear Secured** (Oak Ridge, Tenn.)

■ **BWXT Field Services** (Lynchburg, Va.)

■ **D2R Services** (Aiken, S.C.)

■ **Fluor Federal** (Greenville, S.C.)

■ **Jacobs Technology** (Tullahoma, Tenn.)

■ **Nationwide Remediation Partners** (Newport News, Va.)

■ **Orano Federal Services** (Charlotte, N.C.)

■ **Westinghouse Government Services** (Hopkins, S.C.)

Recapping the ANS/NEI Advanced Reactor Codes and Standards Workshop

As industry steps up its efforts to design, develop, and deploy advanced reactors, codes and standards must be developed to support these technologies. Toward that end, ANS and the Nuclear Energy Institute collaborated to host a virtual workshop on June 23 for industry partners to discuss the development of advanced reactor codes and standards.


Nichol


Arndt

NEI's senior director of new reactors, Marc Nichol, welcomed more than 400 attendees to the online meeting, and ANS's director of government relations, John Starkey, outlined the meeting logistics.

Steven Arndt, immediate past chair of the ANS Standards Board, introduced the workshop's topic by providing an overview of *Setting the Right Bar: How Consensus Standards Help Advanced Reactor Development*, a special report by the ANS Special Committee on Advanced Reactor Policy (SCARP).

Shortly after the release of the ANS special report, NEI issued a report titled *Advanced Reactor Codes and Standards Needs Assessment* (NEI 19-03), which includes specific recommendations for near-term priorities for codes and standards development. Michael Tschiltz, an NEI consultant and project lead, summarized NEI 19-03 for workshop attendees.

As noted in the ANS SCARP report, "Consensus standards are a vital, albeit sometimes underappreciated, aspect of nuclear energy system design, operation, and regulation. They allow commercial suppliers and regulators to leverage the collective wisdom of the entire scientific and engineering community to ensure the appropriate margin of safety in the design and construction of nuclear systems, and they provide a technically robust basis for decision-makers. Bringing new nuclear energy systems to market requires serious commitment on the part of industry, government, and standards development organizations (SDOs)."

Dirk Cairns-Gallimore, of the Department of Energy's Office of Nuclear Energy, offered an update on the advanced reactor landscape. More than 60 companies and research institutions are working on a wide array of capabilities to meet the energy needs of the future. Standards, Cairns-Gallimore said, are recognized as the basis for efficiency, improved trade and commerce, and reduced vulnerability to a wide range of hazards.

The workshop proceeded with three panel discussions. The first, "Matching of Advanced Reactor Developer Needs and SDO Capabilities," included Lauren Latham (Southern, chair of the Molten Salt Reactor Technology Working Group), Michael Cohen (TerraPower), Jordan Hagaman (Kairos Power), Alex Harkness (Westinghouse), and Jacob DeWitte (Oklo, chair of the Fast Reactor Technology Working Group).

Advanced reactor developers are involved in standards projects that they consider urgent but recognize that consensus codes and standards take time to develop and gain approval. The panelists identified a few standards currently under development as not necessary and suggested that they not be pursued, expecting near-term, design-specific demonstrations to lay the foundation for long-term codes and standards.

Priorities identified include preapplication interaction with the Nuclear Regulatory Commission on new codes, standards, and methodologies to help identify issues as early as possible to prevent later delays; areas related to safety analysis and safety-related equipment; the potential need for changes to the supply chain for long lead items; materials not included in the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (BPVC); and the integration of risk-informed information.

Another panel, "Other Codes and Standards Organizations Perspectives," allowed SDOs to address key issues that impede progress and to discuss potential solutions. The panelists included Robert Keating (ASME BPVC, Sec. III), Rick Swayne and Thomas Roberts (ASME BPVC, Sec. XI), Rick Grantom (ASME/ANS Joint Committee on Nuclear Risk Management), Javeed Munshi (Joint American Concrete Institute/ASME Committee 359), Daryl Harmon (Institute of Electrical and Electronics Engineers, Nuclear Power Engineering Committee), and Martin White (American Society for Testing and Materials, Additive Manufacturing Programs). A number of other SDO representatives also participated in the panel discussion.

The challenges described by the panelists had many similarities. SDOs are working to continuously improve standards to meet stakeholder needs by incorporating new methods, industry data, and advancements in materials and new designs. The significant amount of time it takes to develop a standard is related to the development process, which relies on volunteer efforts. Sufficient experience with advanced reactors to achieve a consensus for standard practice is lacking, and a sufficient number of subject matter experts for standards development is also lacking. The panel identified several items considered to be part of the solution to improve standards development, including additional representatives from advanced reactor design organizations to support standards development, better collaboration between SDOs and reactor design organizations, and funding to aid the volunteer effort.

George Flanagan (ANS), Garrett Smith (DOE), Chip Lagdon (Bechtel), Kent Welter (NuScale Power), and Michael Arcaro (GE Hitachi Nuclear Energy) participated in the next panel, "Addressing the Barriers to Standards Creation." The sentiment that the process to develop codes and standards needs to be expedited was shared by all. Panelists pointed to the lack of employer-supported volunteers as the greatest factor that delays the timeline for developing codes and standards. Without company backing, standards development is not part of an expert's everyday activities. Advanced reactor developers need to understand and recognize the importance of standards over the long term and encourage their staff and the DOE to develop such standards. Other challenges include addressing the needs of a number of different advanced reactor technologies, acquiring earlier DOE work from national laboratories, attracting and retaining the next generation of engineers and scientists for standards development, continuity of knowledge among standards writers and advanced reactor developers, and lack of funding for basic research and sharing of results.

Advanced reactor developers need to understand and recognize the importance of standards over the long term and encourage their staff and the DOE to develop such standards.

Following the panel discussions, the NRC's standards executive, Louise Lund, presented "NRC Perspective and Roles in Advanced Reactor Codes and Standards." The NRC is actively par-

Standards continues

ticipating in the development and use of consensus codes and standards across multiple SDOs. The NRC recognizes that codes and standards improve the effectiveness and efficiency of regulatory oversight. Staff participation helps facilitate the NRC endorsement process, and SDOs are encouraged to notify the NRC of new and revised standards to aid in the regulatory process. In the absence of codes and standards, developers can proceed with adequate basis supporting their designs. Lund announced that the NRC will hold the next NRC Standards Forum on September 15, 2020, to continue workshop discussions on advanced reactor codes and standards.

The NRC is actively participating in the development and use of consensus codes and standards across multiple SDOs.

As the workshop drew to a close, Nichol, Arndt, and Tschiltz recapped the workshop takeaways:

- There is a need to identify and align priorities and fund those deemed to be high priority.
- Technology readiness levels could be utilized in the prioritization of codes and standards development.
- The best way to influence SDO activities is to be involved.
- Advanced reactor developers emphasized the importance of advanced reactor materials research and standards development, as opposed to the development of process standards.
- A myriad of advanced reactor designs makes standards development more challenging.
- The lack of "state of practice" experience limits interest and inhibits progress in this area.
- DOE demonstration projects that accelerate advanced reactor development and deployment need to support and fund codes and standards development activities to promote accelerated timelines.
- Trial use and pilot application standards should be considered when the state of practice has not been fully developed.
- Communication among advanced reactor developers and SDOs needs improvement.
- Consideration should be given to codes and standards development infrastructure to adapt and better support advanced reactor development.
- Conducting codes and standards development based on volunteer efforts will likely not support the accelerated development needed for advanced reactors.
- Key standards for which information is available should receive additional resources.
- Standards that require additional research (such as materials standards) should get the resources needed to gather the data.

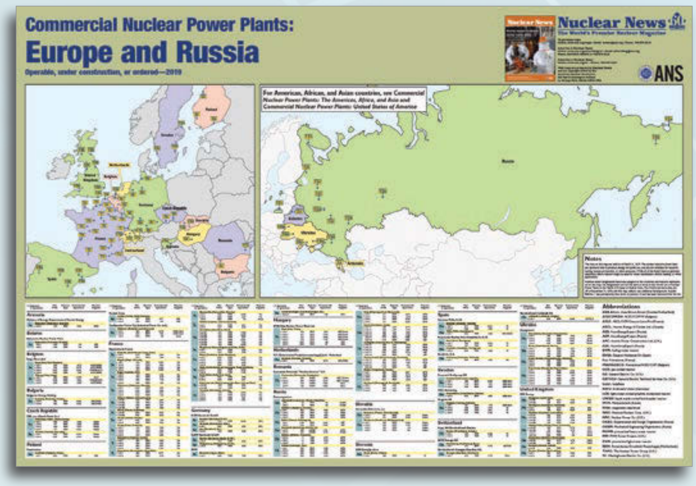
In closing, steps to achieve the goal of developing a path forward and setting priorities for the development of codes and standards were identified for industry partners. They include the following:

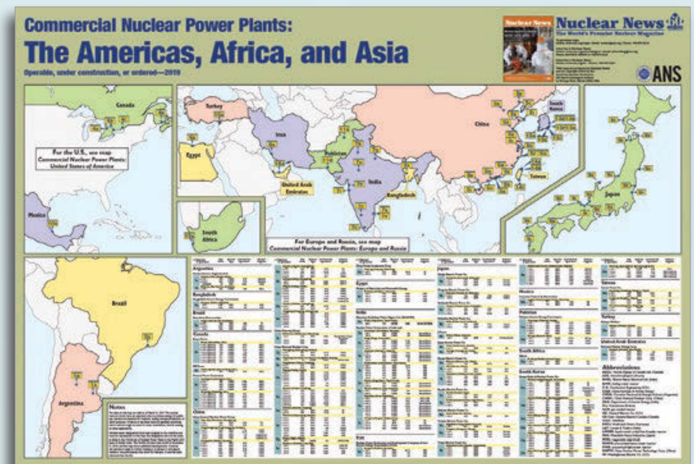
- NEI to take the role of bridging the gap between industry and SDOs.
- Advanced reactor technology working groups to develop priorities for codes and standards.
- SDOs to work with industry to understand capabilities.
- The DOE and the Gateway for Accelerated Innovation in Nuclear to clarify and establish funding opportunities.
- Advanced reactor developers and SDOs to partner on proposals for funding specific codes and standards development.
- NEI and industry partners to work on processes for accelerating the acceptance of codes and standards and on a process for licensing where no codes and standards exist.
- The NRC to participate in codes and standards development and to prepare for acceptance.

For more information, visit ans.org/standards or view the workshop presentations at ans.org/file/1716/NEI-ANS+Advanced+Reactor+Codes+%26+Standards+Workshop+Presentations.pdf.

WALL MAPS

Commercial Nuclear Power Plants





Nuclear News has produced three wall maps that together show the location of every commercial power reactor in the United States and around the world that is operable, under construction, or ordered. Each map includes a table that lists the generating capacity, design type, date of commercial operation (actual or expected), and reactor supplier of the reactors on that map.

The U.S. map contains information never before shown on the *Nuclear News* maps: The current license expiration date for every operating U.S. reactor. The U.S. map also features an updated, easy-to-read table on the status of the 10 reactor projects that have had an application for a combined construction and operating license docketed by the Nuclear Regulatory Commission.

All three maps—**United States of America, Europe and Russia, and The Americas, Africa, and Asia** (which includes Canada, Mexico, South America, Africa, and Asia) are available for purchase now. Order single maps, or save by ordering a two- or three-map combo.

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  Europe and Russia map & The Americas,* Africa, and Asia map

All maps are rolled (unfolded) and delivered in shipping tubes. Shipping and handling charges apply and are based upon quantity. See website for additional information.

Actual map dimensions: 39.25" X 26.75". Map data valid as of 3/31/19. Note that U.S. nuclear power plants are shown on the U.S. map only, not on either of the worldwide maps.

*The Americas include Canada, Mexico, and South America, but not the United States.

AMERICAN NUCLEAR SOCIETY ANS

Why are we so afraid of nuclear?

By James Conca and Judith Wright

There is little doubt that the words "nuclear" and "radiation" engender fear and anxiety in many humans. What is less certain is why.

Although we tend to interpret reality through the lens of our present knowledge and awareness, the roots of common societal sentiments are not as obvious as images of mushroom clouds. They are the result of how humans interpret and project fundamental symbols of good and evil, and how they incorporate new ideas and new capabilities into their existing lore.

Fusing the work of Spencer Weart, Daniel Dennett, and Richard Dawkins, understanding this fear requires understanding how knowledge arises and is passed between generations in the complex system of a society of aware beings, an understanding that is in its infancy and that has given rise to the concept of a meme (the real concept, not the one of kitty pictures on Facebook).

Dawkins originated the idea of memes as the sentient version of the biological gene—sentient traits that can compete and be passed along to subsequent generations as vigorously as physical traits are expressed through biological genes. But much faster.

Subsequently, Dennett used memes in the conceptual framework of the evolution of human society, e.g., belief systems, political structures, taboos, and mythologies.

It is not coincidental that powerful ideas spread and develop over time, confer advantage to groups exploiting these benefits, and compete and then replace lesser ideas, in ways eerily similar to physical traits. That memes can also adapt to changing times and embody efficiencies as well make them even more powerful and useful to humans whose most successful trait is sentience.

Something as fundamental as energy to society is perfectly suited to incorporation into memes. Whether it was harnessing fire more than 100,000 years ago, the explosion in biochemical energy provided by the advent of agriculture 20,000 years ago, or the development of coal 150 years ago with its ability to produce abundant steel and heat, energy is incorporated into every culture in history through a spiderweb of images and mythologies.

With the advent of coal, and then hydro, nuclear, and gas, the meme of owning or exploiting large numbers of humans to provide sufficient energy to the privileged few collapsed as the inevitable condition of the masses. Suddenly energy was available to all. Even the choking, coal-dust reality of Dickensian London was preferable to the hardships and poverty of rural life. Visions of global equality among people became a common theme in the late 1800s, all powered by the new scientific sources of energy.

Like genes, memes change in a punctuated manner as external conditions suddenly alter, and like genes, they build upon what is already present. Ideas formerly held in the minds of a society or culture morph to describe new concepts. Old images take on the new properties but hold the same relationships of good and evil, past and future, savior and destroyer.

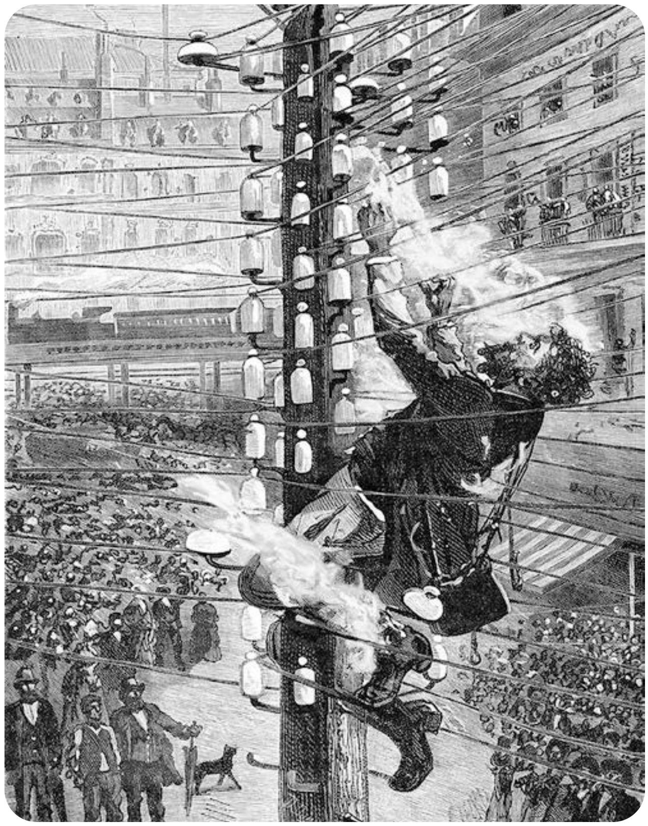
Various incarnations of the Garden of Eden appear in so many cultures, both pre-dating and post-dating Judeo-Christian beliefs, that it seems a fundamental construct of human sentience. The benefits and detriments of energy and technology fit beautifully into these memes and even forced them to evolve into more modern versions of themselves.

The power was greater. The stakes were greater. The images were greater.

Although Weart does not describe it as a meme, fear of radiation is an obvious candidate. Weart traces how the fear of nuclear is much more complicated and much older than nuclear weapons or nuclear energy, starting from the beginning of technology and modern science itself in the late 1800s. While we presently think of radiation as a byproduct of nuclear, it was the concept of radiation that came first.

The discovery of radiation occurred at about the same time as electricity began to significantly impact society. Electricity, itself, completely changed society almost overnight. It was also invisible and could hurt or kill you easily, as it did often at its beginning.

These developments were so new and so utterly profound that they challenged the foundations of belief, becoming intertwined in the classic good-evil myths as either protagonists or antagonists, depending upon each person's vision of the future. Futurists saw technology as engendering brotherhood and wisdom across the globe. Traditionalists saw it as destroying the fabric of society and all that was held sacred.



The death of Western Union Lineman John Feeks led to laws finally being passed to move AC lines underground in New York City, 1891. D. Dumon

As seen in silent movies from that era (and talkies ever since), scientists became a symbol of the struggle between good and evil, and technology the apple in the Garden of Eden. Would technology save mankind or destroy it?

At that time, scientists were more commonly called technologists, as the things they created were more important to people of that time than the basic science behind them.

But fear of power in any form, and those who wield it, is quite deep in the human psyche. The idea of individuals meddling with dangerous powers that could destroy the world was not new. Wizards, witches, shamans—those with magical powers might release demons, pestilence, or any number of evils, not the least being heretical thought, like science, that would turn the world as they knew it upside down.

Atomic weapons, and then nuclear energy, came much later and fell smoothly into this

Opinion continues

British troops blinded by poison gas during the Battle of Estaires, 1918. Thomas Keith Aitken (Second Lieutenant)

social evolution, coming to epitomize this basic struggle as it epitomizes our ability to create energy and power. The old images of alchemy came to the fore, correctly so, as nuclear became the intentional transmutation sought after for so many centuries.

By the time atomic energy emerged as a possibility, adults that had grown up reading by candlelight and riding horses were now reading by electric lights and riding in electric trolleys. Atomic power came to be the ultimate association with this new world and its infinite possibilities.

Then there were the wars. WWI and WWII emblazoned in the global psyche what the evil side of this new technological world could do. Death from the air and clouds of poison gas were the greatest fears long before atomic weapons, and the notion of a preemptive first strike was developed with these chemical weapons, not with nuclear. Even the concept of deterrent, détente, and mutually assured destruction came well before nuclear because the mustard gas and weapons of WWI were considered so horrific that no one thought anyone could possibly use them.

Later, with the dropping of the first atomic bomb on Japan, nuclear came to be associated with the ultimate end of the dark side of technology.

That the many fire-bombing campaigns during WWII released more than 10 times more energy than Hiroshima and Nagasaki combined and killed 10 times more people is not relevant to this meme. The idea that so small an amount of mass could release so large an amount of energy captivated the mind and enshrined nuclear as the ultimate power, and thus the ultimate seduction in these mythologies to those who would wield it.

In the end, what humans do with power, any power, has little to do with the specific source, but everything to do with the way we control ourselves and our interactions. The memes that structure our society will determine our future, and energy and technology will be incorporated into these sets of memes as will any other aspect of humanity.

Nuclear is no different. It will no more easily destroy the world than will coal, drug-resistant bacteria, or terminator-GMO seeds.

The fear of nuclear, however, has significant negative consequences that appear worse than the effects of radiation itself. The health risks of radiation are real but uncommon. Within 10 kilometers of the Hiroshima and Nagasaki detonations, there were 86,600 survivors who received significant radiation exposures, and they have been followed and compared ever since with 20,000 non-exposed Japanese.

Only 563 of these atomic-bomb survivors have died prematurely of cancer caused by radiation, an increased mortality of less than 1 percent. Victims of Chernobyl and Fukushima received far less dose than these Japanese, and had even fewer health effects. But the fear caused by Chernobyl cost tens of thousands of lives through depression, alcoholism, and forced evacuation.

Fukushima has had no deaths at all from radiation, but more than 1,600 deaths were caused by the forced evacuation. The only health effects suffered by those from Fukushima continue to be from stress, depression, and fear.

Then there's politics—the memes that govern interactions among large groups of humans. The Founding Fathers of the United States understood how the previous 500 years of religious wars tore Europe apart and was something to be avoided at all costs. Although not using the concept of memes, they understood that religions represented incompatible memes, and that those wars constituted a competition of ideas that was so destructive that something new needed to take its place.

So they wrote the Constitution of the United States, giving a structure to the meme of democracy. A meme that could adapt and evolve faster and better than competing memes without needing to destroy opposing thought and opposing people. A meme that might, if spread across the globe, be sufficient to contain the power soon to grow in the global society.

In the opinion of these authors, it is certainly the best meme humanity has yet developed. It remains to be seen whether it will adapt fast enough to contain the energy we will continue to release as a species on this planet. Renewables, new-generation nuclear, low-carbon sources, efficiency, and environmental protection, all need to be incorporated into a new meme—a sustainable clean-energy future.

James Conca is a scientist in the field of the earth and environmental sciences, specializing in geologic disposal of nuclear waste, energy-related research, planetary surface processes, radiobiology and shielding for space colonies, and subsurface transport and environmental cleanup of heavy metals.

Judith Wright is a geologist, earth-systems scientist, entrepreneur, and eco-philosopher. She became a staff scientist at the Pacific Northwest National Laboratory before becoming president of UFA Ventures Inc., an environmental remediation and characterization company.

People

Georgia Power recently announced several executive leadership moves and organization realignments.

Lackey

Meredith Lackey has been named executive vice president of external affairs and nuclear development. She previously served as senior vice president, general counsel, corporate secretary, and chief compliance officer.

Spainhour

Succeeding Lackey is **Sterling Spainhour**, who will oversee corporate compliance, risk management, security, and legal services functions. He currently serves as senior vice president and general counsel for Southern Company Services (SCS) and will maintain his responsibilities for the corporate, energy regulation, and technology functions for SCS.

In addition, Georgia Power's Customer Service and Operations organization will be restructured into two organizations: Power Delivery, and Corporate and Customer Services. **Glen Grizzle**, senior vice president of power delivery, will continue as leader of the Power Delivery organization. **Nicole Faulk**, formerly vice president of corporate services, now leads the Corporate and Customer Services organization as senior vice president.

Grizzle

Faulk

Southern Company announced that it has combined the leadership of three of its businesses—Southern Power, PowerSecure, and Southern Holdings—under one chief executive officer. **Chris Cummiskey** has been named to the new position of group CEO for Southern Energy Resources and executive vice president of Southern Company Services Commercial Development.

Cummiskey

Cummiskey was previously executive vice president of external affairs and nuclear development for Georgia Power, also a Southern Company subsidiary. Southern Power, PowerSecure, and Southern Holdings will maintain their brands as individual companies, and **Mark Lantrip**, president and CEO of Southern Company Services, will continue as the companies' chairman.

Pardee

Charles "Chip" Pardee has been elected to Xcel Energy's board of directors, filling the vacancy created by the retirement of **Patricia Simpson**. Pardee currently serves as president of Terrestrial Energy USA. He is also the chair and director of the Committee on Nuclear Power for the Emirates Nuclear Energy Corporation in the United Arab Emirates and sits on the nuclear safety advisory board for Tokyo Electric Power Company. Pardee was previously chief operating officer of the Tennessee Valley Authority.

Ansaldo Nucleare, a subsidiary of the Italian company Ansaldo Energia, has appointed **Luca Manuelli** as its new chief executive officer. Manuelli joined Ansaldo Energia in 2012 and most recently served as chief digital officer.

Manuelli

The Tennessee Valley Authority has appointed **Beth Jenkins** as plant manager at the Watts Bar nuclear plant near Spring City, Tenn. Jenkins, who served as the site's director of engineering for the past three years, is the first woman to serve as a plant manager for TVA Nuclear. Prior to joining Watts Bar in 2016, she worked at Bechtel, where she supported projects for the U.S. Navy's nuclear fleet.

Jenkins

The CANDU Owners Group (COG) has appointed **Stephanie Smith** president and chief executive officer, following the retirement of **Fred Dermarkar**. Smith previously served

Smith

as deputy senior vice president of Ontario Power Generation's (OPG) Darlington plant. She is the first woman to serve as president and CEO of COG, following a 30-year career at OPG.

Australia-based Lotus Resources Limited has appointed **Eduard Smirnov** as its managing director, following the departure of **Simon Andrew**, the company's former chief executive officer. Smirnov was previously the CEO of Uranium One, based in Toronto, Ontario, Canada.


Smirnov

The Nuclear Regulatory Commission announced on June 23 the selection of **Chris Roettgen** as the new senior resident inspector at the Columbia nuclear power plant in Richland, Wash., and **Jennifer England** as the new resident inspector at the FitzPatrick plant in Scriba, N.Y. Roettgen joined the NRC in 2014 as a project engineer in the agency's Region I Office in King of Prussia, Pa., and subsequently served as a resident inspector at the Calvert Cliffs nuclear power plant in Lusby, Md. England rejoined the NRC in 2019 as a reactor engineer in the Division of Reactor Projects in the NRC's Region I Office. She had previously worked for the NRC as a resident inspector at the Indian Point nuclear power plant.


Roettgen


England

Standard Uranium, a Canadian uranium exploration company, has added **Galen McNamara** and **Sean Hillacre** to its technical team. Hillacre was appointed project manager for the upcoming Davidson River drill program. He previously worked at NexGen Energy as an exploration geologist. McNamara, chief executive officer and director of Summa Silver Corporation, will serve as a technical advisor.

Lucideon, a materials technology company based in the United Kingdom, has named **David Barrientos** as its new technical sales consultant for nuclear. Barrientos' primary focus will be to support Lucideon's growth, as well as to find new opportunities in the U.S. nuclear industry. Prior to joining Lucideon, he was employed by Duke Engineering in the spent fuel management group.


Barrientos

Kudos

Bryan Erler, ANS member since 1989, began his term as the 139th president of the American Society of Mechanical Engineers during its virtual annual meeting in June. A 45-year nuclear industry veteran, Erler held significant leadership roles in the designing of electric power plants as an owner and senior vice president of Sargent & Lundy. He is the recently retired president of Erler Engineering, where he served as a consultant to the power industry.


Erler

Obituaries

Peter J. Davis, 96, ANS member since 1957; held a bachelor's degree in mechanical engineering from the Massachusetts Institute of Technology; early in his career, worked at Kellex Corporation, Babcock & Wilcox Company, and Nuclear Development Associates; participated in the design and construction of nuclear fuel reprocessing plants at the Hanford Site, near Richland, Wash.; led the design group for reactor components and test facilities for the Belgian Engineering Test Reactor, the test facility for the European Community's nuclear power development program; was employed by the Department of Energy and its predecessor agencies from 1960 until his retirement in 1986; worked on the licensing of the Fermi-1 reactor in Michigan and the Hallam reactor in Nebraska; was the project manager for the design, construction, and safety review of the Advanced Test Reactor in Idaho; later work included the safety review and operating authorization of the Fast Flux Test Facility at Hanford; died in April.


Davis

Index to Advertisers

Since the magazine accepted its first advertisement in 1960, *Nuclear News* has proudly partnered with hundreds of vendors and organizations to help keep the worldwide nuclear field informed about the latest products and services, conferences and events, employment opportunities, and academic/training courses. If you are performing or seeking nuclear-related work, make sure advertising in our magazine is part of your business development strategy and annual budget.

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Calendar

● First time listed, or significant change made.
■ ANS event.
■ Non-ANS event cosponsored by ANS.

September

Sept. 8–9—**2020 RadWaste Summit**, Henderson, Nev. www.radwastesummit.com

Sept. 9–11—**World Nuclear Association Symposium 2020**, London, England. www.wna-symposium.org

Sept. 10–11—**Decommissioning Strategy Forum**, Henderson, Nev. www.decommissioningstrategy.com

Sept. 14–15—**New Advanced Clean Energy Summit (ACES 2020)**, Denver, Colo. event.asme.org/ACES

Sept. 16–18—**National Cleanup Workshop**, Alexandria, Va. www.cleanupworkshop.com

Sept. 18–23—**31st Symposium on Fusion Technology (SOFT2020),** Virtual meeting**.** soft2020.eu

October

Oct. 4–8—**Women in Nuclear Global Conference**, Niagara Falls, Ontario, Canada. www.win-global.org/activities/annual

Oct. 7–8—**9th EU Nuclear Power Plant Simulation Forum**, Brussels, Belgium. nrg-events.com/enppstech/

Oct. 13–15—**ETEBA Business Opportunities and Technologies Conference (BOTC)**, Knoxville, Tenn. www.eteba.org

Oct. 19–20—**20th Nuclear Security Information Exchange Meeting**, Vienna, Austria. www.iaea.org/events/evt1903488

Oct. 19–23—**International Conference on the Management of Naturally Occurring Radioactive Materials (NORM) in Industry**, Vienna, Austria. www.iaea.org/events

Oct. 26–30—**NuMat 2020: The Nuclear Materials Conference**, Ghent, Belgium. www.elsevier.com/events/conferences/the-nuclear-materials-conference

Oct. 31–Nov. 7—**2020 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)**, Boston, Mass. conferences.ieee.org/conferences_events/conferences/conferencedetails/42677

November

Nov. 9–13—**International Conference on Radiation Safety: Improving Radiation Protection in Practice**, Vienna, Austria. www.iaea.org/events/international-conference-on-radiation-safety-2020

■ Nov. 15–19—**2020 ANS Winter Meeting and Nuclear Technology Expo**, Chicago Ill. answinter.org

Nov. 24–26—**9th International Conference on Nuclear Decommissioning (ICOND 2020)**, Aachen, Germany. www.icond.de/welcome.html

Nov. 30–Dec. 2—**12th Annual European Power Strategy & Systems Summit**, Prague, Czech Republic. www.europeanpowergeneration.eu

December

Dec. 7–10—**OECD/NEA Specialist Workshop on Advanced Measurement Method and Instrumentation for Enhancing Severe Accident Management in an NPP Addressing Emergency, Stabilization and Long-term Recovery Phases (SAMMI-2020)**, Fukushima, Japan. www.sammi-2020.org

Dec. 8–10—**PowerGen International**, Orlando, Fla. www.powergen.com/welcome

Dec. 8–10—**World Nuclear Exhibition (WNE 2020)**, Villepinte, France. www.world-nuclear-exhibition.com

January

Jan. 18–22—**15th International Congress of the International Radiation Protection Association (IRPA15)**, Seoul, South Korea. www.irpa2020.org/

Jan. 28–29—**ICNETH 2021: 15. International Conference on Nuclear Engineering and Thermal Hydraulics**, New York City, N.Y. waset.org/nuclear-engineering-and-thermal-hydraulics-conference-in-january-2021-in-new-york

Jan. 28–30—**11th International Conference on Future Environment and Energy (ICFEE 2021)**, Tokyo, Japan. icfee.org/

Jan. 28–30—**SNMMI 2021 Mid-Winter Meeting**, San Francisco, Calif. www.snmmi.org/MeetingsEvents/Content.aspx?ItemNumber=33340

February

- Feb. 8–11—**Conference on Nuclear Training and Education: A Biennial International Forum (CONTE 2021)**, Amelia Island, Fla., ans.org/meetings/view-331/
- Feb. 24–26—**International Power Summit 2021**, Virtual meeting, www.arena-international.com/ips

Nuclear-Related Meetings Affected by COVID-19

As of July 7, 2020, the following meetings have been rescheduled, postponed, or canceled because of COVID-19 concerns.

Rescheduled

Utility Working Conference
Original date: August 9–12
New Date: August 11 (Virtual)
uwc.ans.org

Technical Meeting on Nuclear Power Plant Personnel Training
Original date: August 18–21
New Date: November 3–6, 2020
www.iaea.org/events/EVT1804444

31st Symposium on Fusion Technology (SOFT2020)
Original date: Sept. 20–25
New date: Sept. 18–23 (Virtual)
soft2020.eu

28th IAEA Fusion Energy Conference (FEC 2020)
Original Date: Oct. 12–17
New date: May 10–15, 2021
www.iaea.org/events/fec-2020

Postponed

Advances in Thermal Hydraulics (ATH 2020)
Original date: Oct. 20–23
www.sfen-ath2020.org

Technical Meeting on Nuclear Power Plant Personnel Training
Original Date: Nov. 3–6
www.iaea.org/events/EVT1804444

International Conference on Generation IV and Small Reactors (G4SR-2)
Original Date: Nov. 9–12
www.g4sr.org

Canceled

POWER 2020
Original date: August 2–6
event.asme.org/POWER

28th International Conference on Nuclear Engineering (ICONE 28)
Original date: August 2–6
event.asme.org/ICONE

Regulatory Affairs Forum,
Original date: August 11–13
www.nei.org/conferences/regulatory-affairs-forum

13th International Topical Meeting on Nuclear Reactor Thermal-Hydraulics, Operation and Safety (NUTHOS-13)
Original date: August 23–26
www.cns-snc.ca/events/nuthos-13

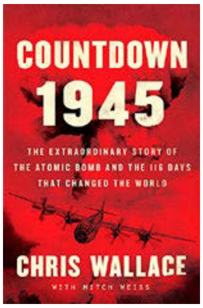
ICRS 14/RPSD 2020
Original Date: Sept. 13–17
icrs14.ans.org

International Conference on Nuclear Plant Chemistry (NPC 2020)
Original date: Sept. 28–Oct. 1
Web www.sfen-npc2020.org

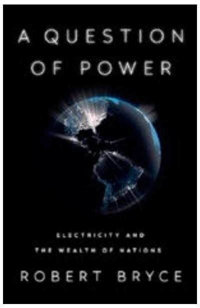
Nuclear Energy: Challenges and Prospects
Original Date: Sept. 30–Oct. 3
nsconf2020.ru/en

Publications

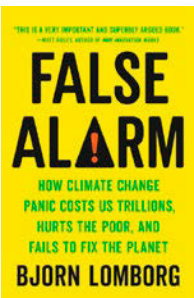
Recently Published



Countdown 1945: The Extraordinary Story of the Atomic Bomb and the 116 Days That Changed the World, by Chris Wallace, with Mitch Weiss. On April 12, 1945, after years of bloody conflict in Europe and the Pacific, America is stunned by news of President Franklin D. Roosevelt's death. In an instant, Vice President Harry Truman, who has been kept out of war planning and knows nothing of the top-secret Manhattan Project to develop the world's first atomic bomb, must assume command of a nation at war on multiple continents—and confront one of the most consequential decisions in history. *Countdown 1945* tells the gripping true story of the turbulent days, weeks, and months to follow, leading up to August 6, 1945, when Truman gives the order to drop the bomb on Hiroshima. *Countdown 1945,* from veteran journalist Chris Wallace, is the story of an untested new president confronting a decision that he knows will change the world forever. Truman's journey during these 116 days is a story of high drama, from the shock of learning of the bomb's existence, to the conflicting advice he receives from generals such as Dwight D. Eisenhower and George Marshall, to wrestling with the devastating carnage that will result if he gives the order to use America's first weapon of mass destruction. (320 pp., HB, $30, ISBN 978-1-982143-34-3. Order from Simon & Schuster: simonandschuster.com.)



A Question of Power: Electricity and the Wealth of Nations, by Robert Bryce. Global demand for power is doubling every two decades, but electricity remains one of the most difficult forms of energy to supply and do so reliably. Today, some 3 billion people live in places where per capita electricity use is less than that used by an average American refrigerator. In *A Question of Power*, journalist Bryce tells the human story of electricity, the world's most important form of energy. He highlights the factors needed for successful electrification and explains why so many people are still stuck in the dark. He also debunks the notion that our energy needs can be met solely with renewables and demonstrates why—if we are serious about addressing climate change—nuclear energy must play a much bigger role. Electricity has fueled a new epoch in the history of civilization. *A Question of Power* explains how that happened and what it means for our future. (352 pp., HB, $28, ISBN 978-1-61039-749-0. Order through PublicAffairs Books, an imprint of Perseus Books: publicaffairsbooks.)



False Alarm: How Climate Change Panic Costs Us Trillions, Hurts the Poor, and Fails to Fix the Planet, by Bjorn Lomborg. The *New York Times* bestselling "skeptical environmentalist" argues that panic over climate change is causing more harm than good. Politicians, activists, and the media espouse a common message: Climate change is destroying the planet, and we must take drastic action immediately to stop it. Children panic about their future, and adults wonder if it is even ethical to bring new life into the world. Enough, argues Lomborg. Climate change is real, he says, but it's not the apocalyptic threat that we've been told it is. Projections of Earth's imminent demise are based on bad science and even worse economics. In a panic, world leaders have committed to wildly expensive but largely ineffective policies that hamper growth and crowd out more pressing investments in human capital, from immunization to education. Published by Basic Books, an imprint of Perseus Books. (320 pp., HB, $30, ISBN 978-1-5416-4746-6. Available from Amazon, Barnes & Noble, and other online booksellers.)

ANS Technical Journals

FUSION SCIENCE AND TECHNOLOGY • AUGUST 2020

Calorimetry: An NDA Method for Tritium Measurement and Accountancy *F. Bachelet et al.*

Research Facilities of IAE NNC RK (Kurchatov) for Investigations of Tritium Interaction with Structural Materials of Fusion Reactors *Yu. Gordienko et al.*

Evaluation of the Effect of Protons and Alpha Particles Irradiation on Fusion Structural Materials *S. I. Radwan et al.*

Edge Toroidal Rotation Analysis by CXRS Diagnostic on EAST *D. Jiang et al.*

Expected Environmental Effects of Long-Term Tritium Supply—Lessons Learned *A. V. Golubev, V. N. Golubeva*

Numerical Comparison of Dehydriding Behaviors of Full-Scale Depleted Uranium Beds Equipped with Copper Foam or Copper Fins *J.-Y. Choi et al.*

Machine Learning Algorithms for Automated NIF Capsule Mandrel Selection *K. J. Boehm et al.*

MHD Simulation of Hemispherical Plasma Focus Using Snowplow Model *M. E. Abdel-Kader, M. A. Abd Al-Halim*

Preliminary Safety Analysis of Tritium Source Term for the CFETR Tritium Plant *S. Wei et al.*

A Review of Pellet-Injector Technology: Brief History and Recent Key Developments *S. K. Verma*

NUCLEAR SCIENCE AND ENGINEERING • AUGUST–SEPTEMBER 2020

Selected papers from the 18th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-18)
This special issue features 17 papers selected from the NURETH-18 meeting.

NUCLEAR TECHNOLOGY • AUGUST 2020

Selected papers from the 2019 Nuclear and Emerging Technologies for Space Topical Meeting (NETS 2019)

Nuclear Security Considerations for Space Nuclear Power: A Review of Past Programs with Recommendations for Future Criteria *S. S. Voss*

Emergence of a Commercial Space Nuclear Enterprise *J. W. Locke, B. Lal*

Comparing the Effectiveness of Polymer and Composite Materials to Aluminum for Extended Deep Space Travel *D. K. Bond et al.*

LEU NTP Engine System Trades and Mission Options *C. R. Joyner II et al.*

Numerical Investigation and Parametric Study on Thermal-Hydraulic Characteristics of Particle Bed Reactors for Nuclear Thermal Propulsion *Y. Ji et al.*

Monte Carlo–Informed Decay Heat Model for Cermet LEU-NTP Systems *A. Denig, M. Eades*

Design Studies for the Optimization of ^{238}Pu Production in NpO_2 Targets Irradiated at the High Flux Isotope Reactor *C. R. Daily, J. L. McDuffee*

Impact Temperature Determination for GPHS Safety Testing *J. G. Teague, R. N. Mulford*

Study on the Development of a Small ETG for the Korean Launch Vehicle's Low Orbit Test *J. Hong et al.*

Temperature and Power Specific Mass Scaling for Commercial Closed-Cycle Brayton Systems in Space Surface Power and Nuclear Electric Propulsion Applications *C. G. Morrison*

An Exploration of Mission Concepts That Could Utilize Small RPS *Y. H. Lee et al.*

NuclearNews *Asks*

What is your ANS resume?

Donald Lorentz

Donald Lorentz is a principal engineer at the Naval Nuclear Laboratory at Bettis Laboratory in West Mifflin, Pa.

I've created a listing of my involvement with ANS in order to keep track of what I've done over the years. I thought it would be fun. Here it is:

1973-1974	Student Member
1975-1982	Treasurer, ANS Pittsburgh Local Section
1976	Treasurer, International Conference on Liquid Metal Technology in Energy Production
1982-1983	Vice-Chair, ANS Pittsburgh Local Section
1983-1984	Chairman, ANS Pittsburgh Local Section
1986	Chairman, First Regional Conference—Pittsburgh
1987-1998	Member, ANS National Program Committee (NPC)
1991-1998	Elected Member, ANS Power Division Executive Committee
1994-1998	Chairman, NPC Policy and Procedures Subcommittee (My committee introduced "embedded topical" policies for use in ANS national meetings)
1997-2000	Member, ANS Planning Committee
2003-2008	Member, ANS Bylaws & Rules Committee
2008-2011	Chairman, ANS Bylaws & Rules Committee (My committee instituted student member voting privileges)
2003-Present	Member, ANS Publications Steering Committee
2011- 2015	Vice-Chairman, ANS Publications Steering Committee
2016-2017	Ex-officio, ANS Planning Committee
2016-2017	Member, Special Committee on ANS Restructuring
2016-Present	Chairman, ANS Publications Steering Committee
2016-Present	Member, ANS Bylaws & Rules Committee

As undergraduates in chemical engineering at Ohio State University, we were "required" to join AIChE [the American Institute of Chemical Engineers] if we ever wanted to graduate. So when my graduate school advisor in 1973 encouraged me to join the American Nuclear Society, it seemed like the logical thing to do.

Upon starting my career at Westinghouse in 1974, I quickly sought out the ANS Pittsburgh Section as a way to meet other new engineers and to advance my career interests. After being elected chair of the section, I started attending ANS national meetings and became involved with the National Program Committee as it formulated plans to hold embedded topical meetings during the Annual and Winter meetings.

The rest of my ANS "career" seemed to go quickly, from one committee to the next, and I've always enjoyed the camaraderie and close professional ties that I have made over the years. What also has been a joy is seeing the young engineers who I have mentored attend our national meetings and become ANS leaders.

With my involvement in the Publications Steering Committee over the past 17 years, I have seen the quality of our meetings and their technical content steadily improve and evolve. I've also witnessed quality improvements firsthand in our three outstanding technical journals, ANS books, and proceedings. During that time, the headquarters staff has made all of this content available for download from the ANS website, including archived copies of our publications. Along with an update to the ANS website, our flagship commercial publication, *Nuclear News*, has recently been reimagined, and much of its content is now online daily on the ANS Newswire.

I've always enjoyed my involvement in ANS, and I strongly recommend that our members build their own ANS resumes.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