Vol. 02/ 2020 Issue 01

NETL EDGE

A Publication of the U.S. Department of Energy's National Energy Technology Laboratory

KEY LABORATORY INITIATIVES DELIVERING TECH SOLUTIONS

NATIONAL ENERGY TECHNOLOGY LABORATORY

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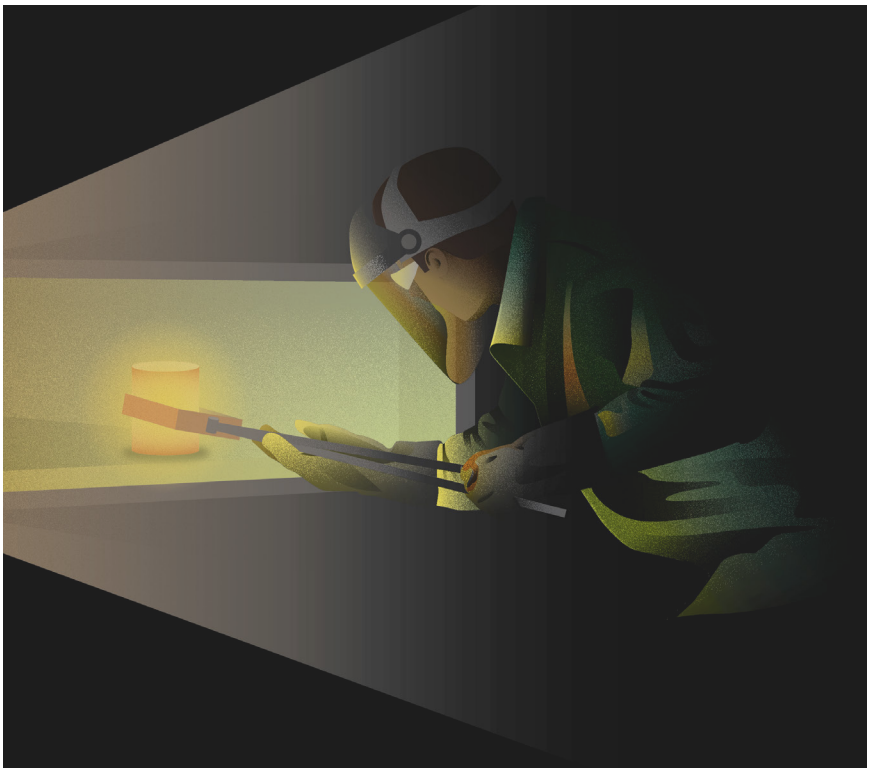
Vol. 02/ 2020 Issue 01

NATIONAL ENERGY TECHNOLOGY LABORATORY

ON THE COVER



NETL's research into high-performance materials works to characterize, produce, and certify cost-effective alloys and high-performance materials suitable for extreme environments that are found in fossil-based power-generation systems. NETL supports and catalyzes a robust domestic materials supply chain that prepares materials for advanced ultra-supercritical steam cycles (AUSC) and spinoff applications that have the potential to increase efficiencies and bolster clean coal efforts.

Read more on page 10.

DIRECTOR'S MESSAGE

NETL finds technology solutions to America's energy challenges. As DOE's only national lab devoted to fossil energy research, our Laboratory has the expertise and capabilities needed to deliver innovative solutions to complex energy challenges. We do this by nurturing and exercising scientific and technological research capabilities independently and in partnership — and we have a strong record of success.

The key word for NETL's work and mission is impact. We're impacting our nation's energy security and independence. We're impacting our nation's economic prosperity by developing technologies to provide clean, reliable energy. And, we're impacting tomorrow's energy future by finding ways to use our nation's abundant domestic energy resources in a carbon-constrained future.

Over the past year, our world-class scientists, engineers and leadership teams performed an extensive assessment of NETL's technical competencies, including our talent, facilities and equipment. We then evaluated how our unique capabilities can best serve the nation's technology development needs. From there, we initiated a strategic approach to pursuing high-profile, high-impact research through key laboratory initiatives (KLIs).

We looked at our successes, and, more importantly, we looked at the investments required to continue our record of exceptional service to our nation and provide groundbreaking solutions required for our sustainable energy future. From across our team, we identified 30 opportunities, or business case value propositions, for expansion and development, based on potential value and our ability to execute.

At the end of this process, we identified four propositions that have moved forward through individualized go-to-market plans as KLIs:

- Expand Microwave Characterization Reaction Chemistry
- Advance Alloy Development and Manufacturing
- Expand Artificial Intelligence and Machine Learning Customized for Fossil Energy Areas
- Create a Shale Gas Utilization Center of Excellence

Each of the KLIs demonstrates strength in four critical areas: alignment and value to the Office of Fossil Energy, technical impact, execution and organizational readiness, and return on the technology investment.

In this issue of NETL Edge, I'm pleased to share with our readers the results of this comprehensive assessment and insight to our efforts to add value to these critical energy technologies and, ultimately, to provide the greatest benefit to our nation and preserve our energy security.

NETL's strategic vision is to be the renowned fossil-energy science and engineering resource, delivering world-class technology solutions today and tomorrow. As we pursue the KLIs outlined in this issue of NETL Edge, we enhance our Lab's capabilities and move ever closer to realizing this vision.

I'm proud of NETL's research and the talented men and women who enable all our Lab's achievements. I look forward with great enthusiasm to what NETL will be accomplishing as we move forward with focused institutional initiative. After reading the initiatives described in the following pages, I believe you'll share my optimism.

Brian J. Anderson, Ph.D.
Director, NETL

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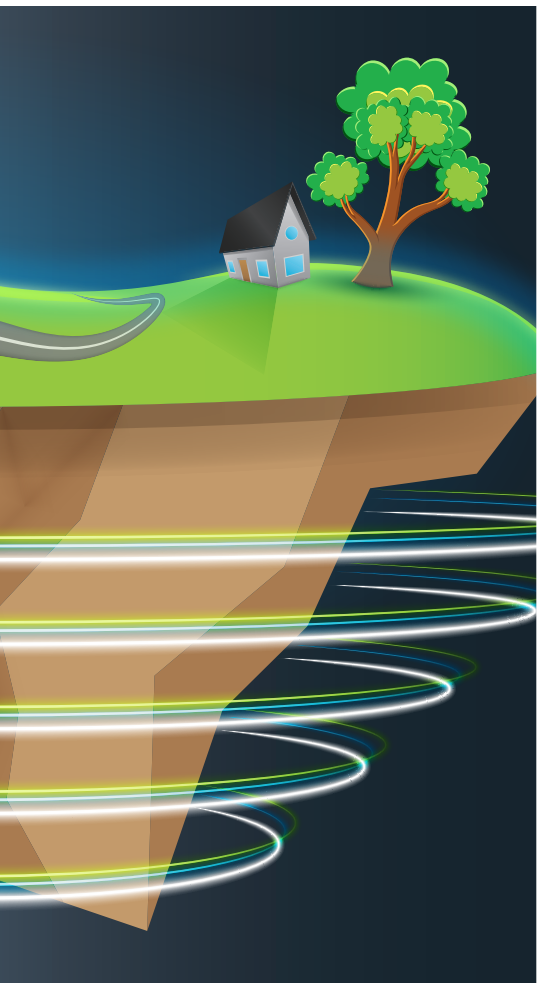
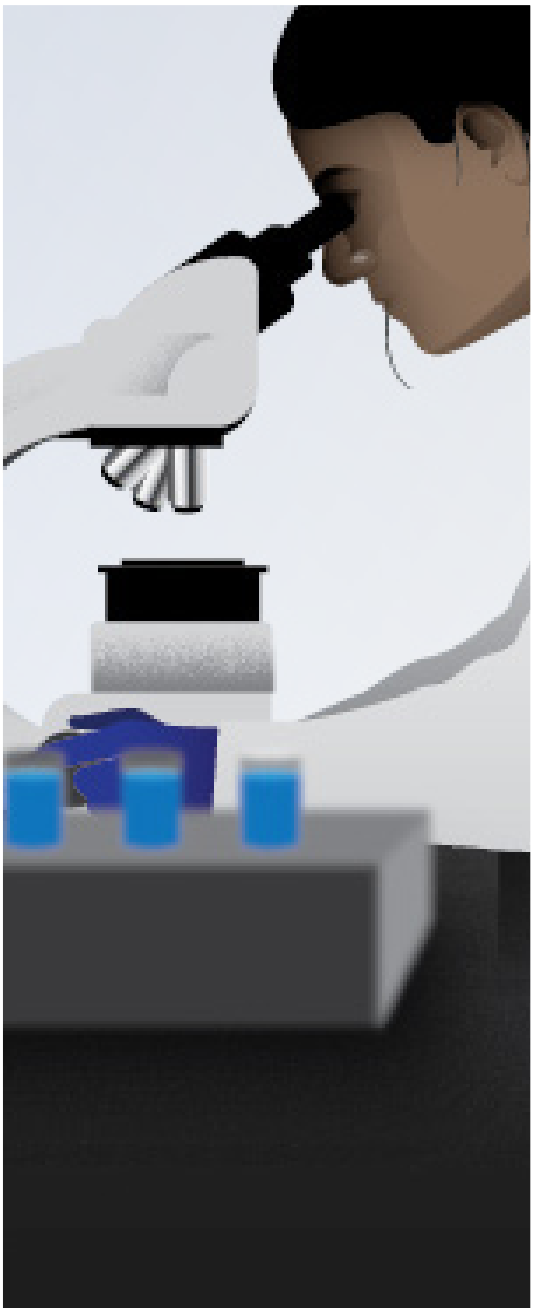
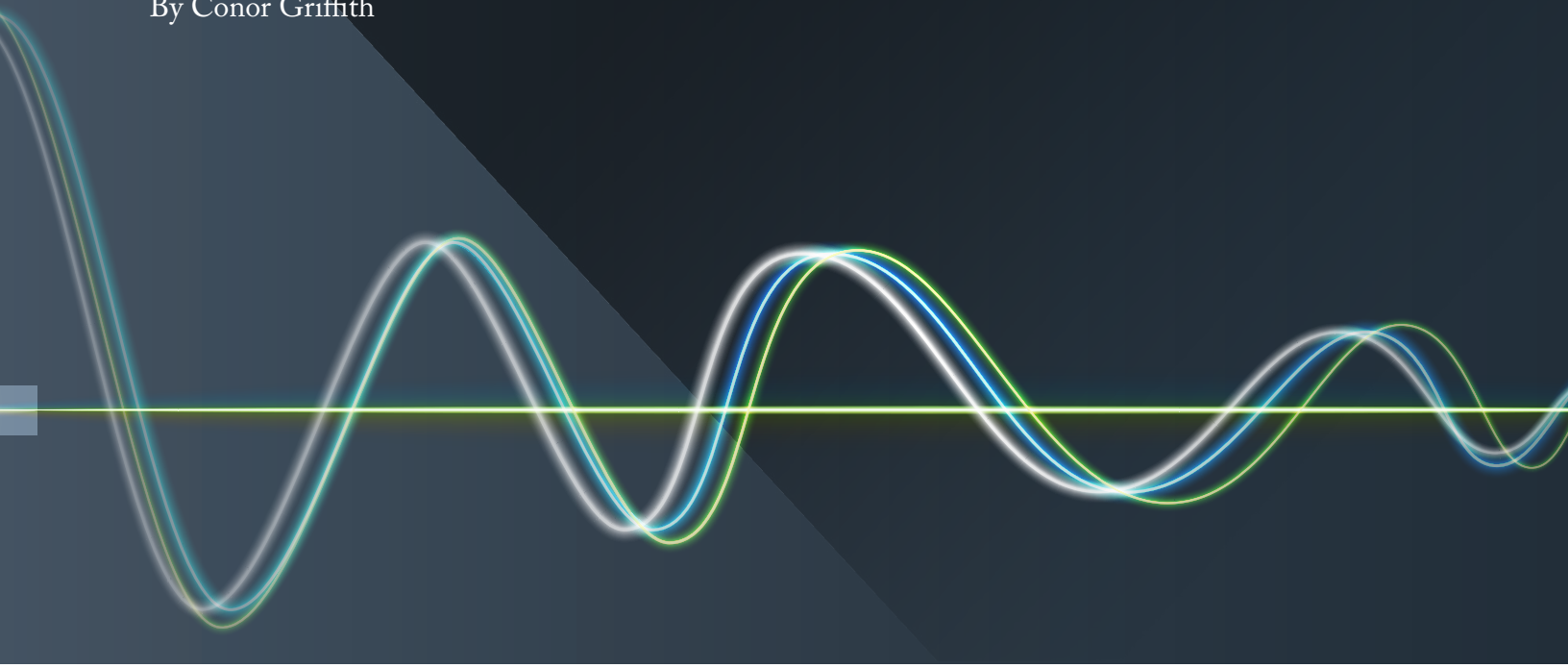




ReACT:

Enhancing NETL's Power Potential

By Conor Griffith



NETL's newly renovated Reaction Analysis and Chemical Transformation (ReACT) facility, unveiled last summer at NETL's Morgantown, West Virginia, site aims to expand its capabilities to maximize the value of the nation's abundant fossil fuel resources while doing so with a minimal environmental footprint, in keeping with the Lab's mission.

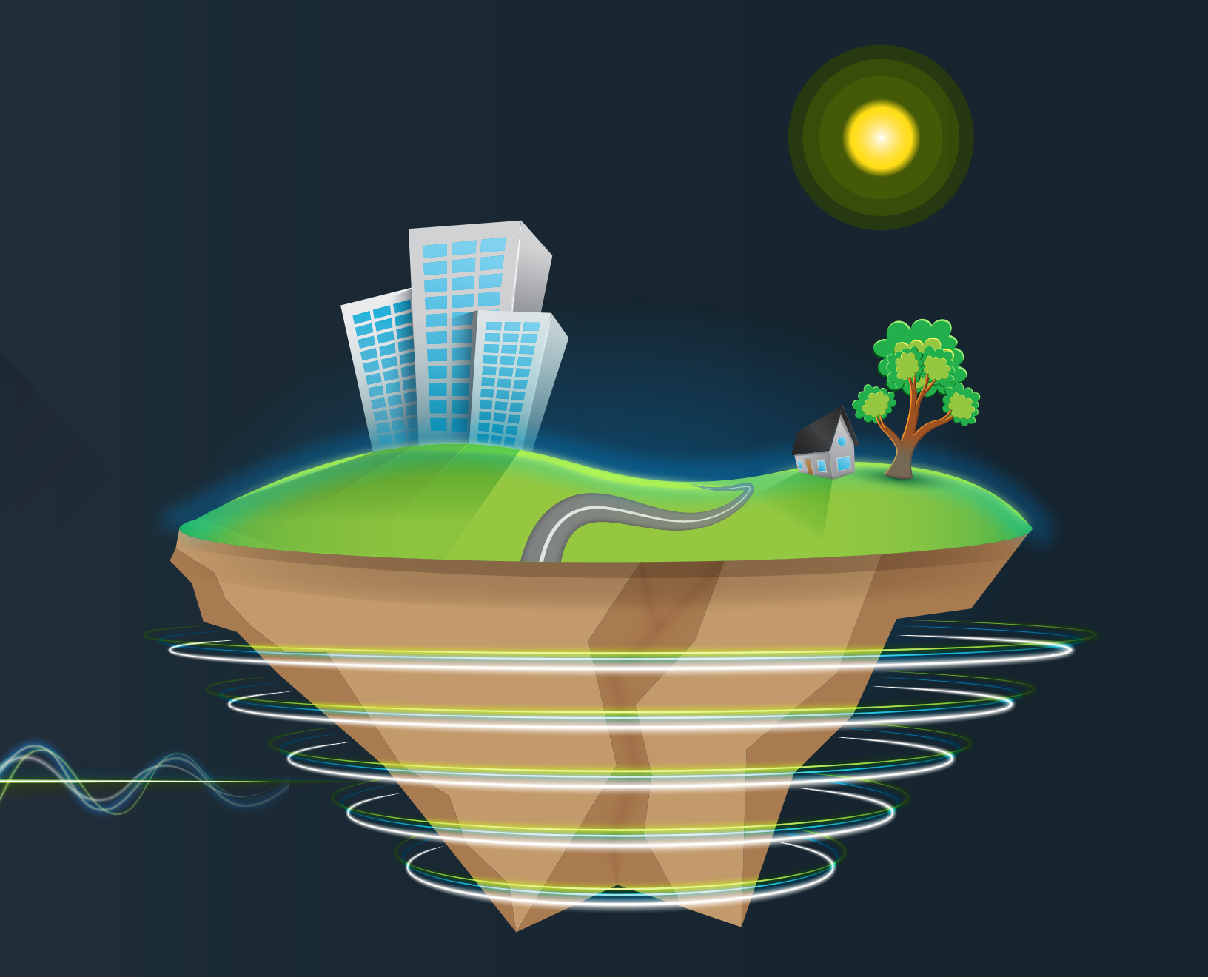
With its advanced design, host of custom-made components, versatility to use multiple fuel sources in a variety of operating conditions, highly sophisticated operating systems, and state-of-the-art microwave reactors, the ReACT facility is the only one of its kind. Currently housing six reactors, it has the infrastructure to support two more.

NETL plans to expand its current reactor facility studies to accelerate microwave chemical reaction development with the goal of establishing a state-of-the-art Electromagnetic Chemistry Center.

This center will build upon NETL's work in several fields such as advanced fossil-based power generation that could be integrated with thermal, chemical, and electrical energy storage and renewable power; the production of high-value carbon products from domestic coal; increasing the efficiency of the nation's power plant fleet; and environmentally friendly natural gas conversion to value-added products.

This expansion will create new capabilities for advanced microwave material interaction studies. Well suited for ReACT, this research is essential for developing more efficient and scalable energy processes for a wide range of fossil energy and non-fossil energy applications. Microwave-enhanced chemistry and catalysis are growing interests in the research community, and further investments in ReACT can elevate NETL's position as a leader of this frontier of science.

In view of Appalachia's abundance of coal and natural gas, such an investment plays to the region's strengths. Microwave energy sources are ideal for fossil resource conversion systems, particularly shale gas upgrading and use,



which has the potential for further economic development and employment.

Dushyant Shekhawat, Ph.D., NETL's reaction engineering team lead, said ReACT uses the fuel sources below the surface of its Appalachian home — coal and natural gas — but the facility distinguishes itself by using them in a different manner that overcomes some of the limitations of previous conversion methods.

"For example, existing fossil fuel conversion processes use conventional, thermal energy to drive their chemical reactions," Shekhawat explained. "Most of these reactions are catalyzed by materials that have been developed for decades and are able to achieve close to the maximum activity possible, leaving room only for incremental improvements."

NETL realized a different, transformational approach is needed to achieve higher efficiencies and product yields. That's why the Lab has aggressively pursued alternative energy inputs such microwaves, specifically the microwave reactors found in ReACT.

"Electromagnetic fields such as microwaves, provide the unique ability of adding energy selectively to chemical reactions by interacting specifically with targeted species like metallic sites or surface intermediates for conversion," Shekhawat said. "This selective interaction can minimize side reactions, which is beneficial because these side reactions create undesired byproducts and emissions. By using microwaves, we can reduce overall system energy requirements, saving money and leaving a lighter eco-footprint over conventional processes."

Shekhawat said ReACT was designed with adaptability in mind so NETL has the capability to meet a wide variety of DOE requirements as the department's missions change over time. As for the present, the facility has already demonstrated potential that places the Lab and its researchers at the center stage of pivotal work.

"The growing interest in applying microwaves to industrial processes and our cutting-edge research at the ReACT facility has brought NETL to the center of an ever-

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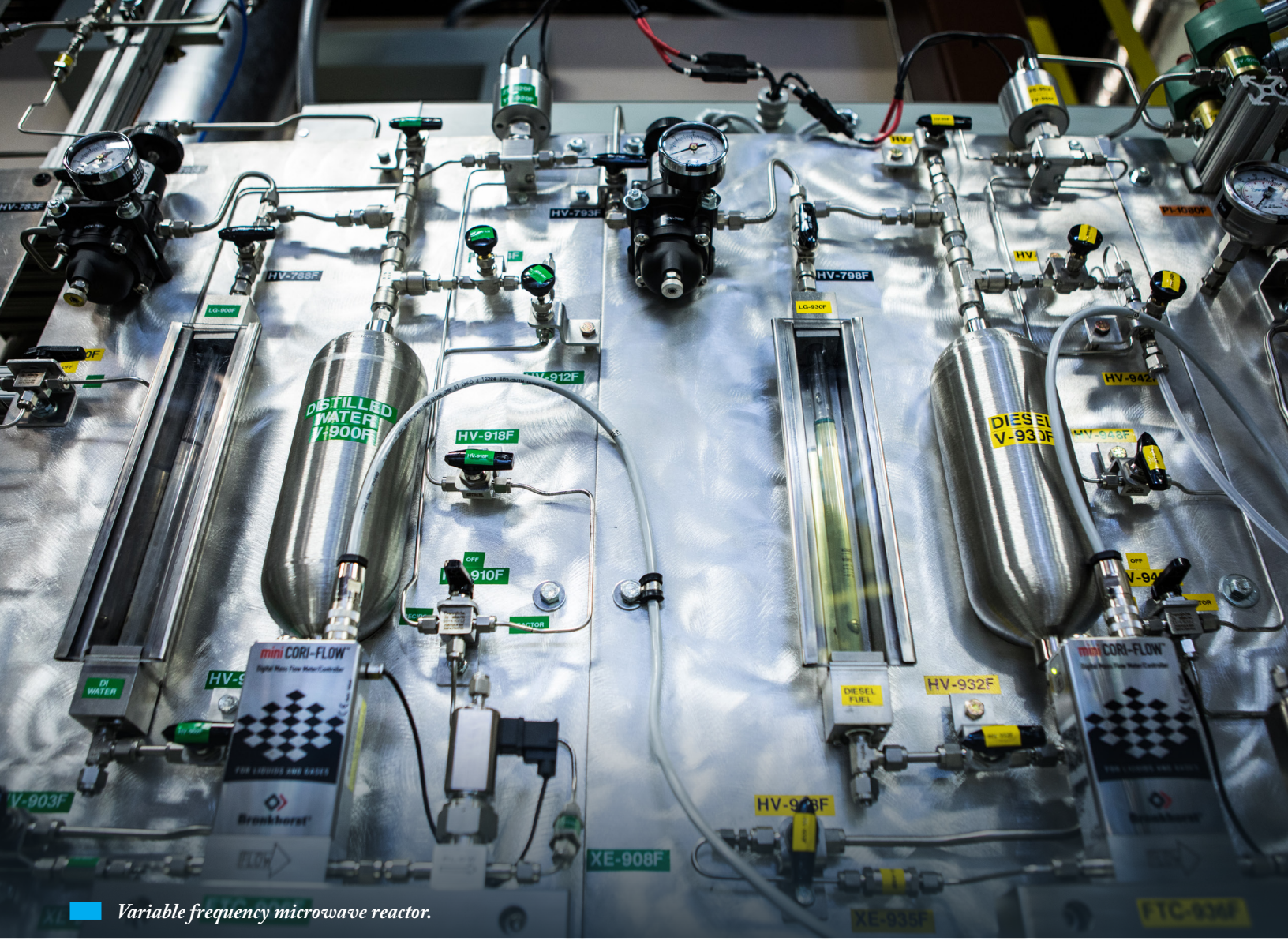
A look inside NETL's ReACT Facility in Morgantown, West Virginia

"The growing interest in applying microwaves to industrial processes and our cutting-edge research at the ReACT facility has brought NETL to the center of an ever-expanding group of researchers and companies with a potential to form an electromagnetic application center."



Variable frequency microwave reactor.

expanding group of researchers and companies with a potential to form an electromagnetic application center," Shekhawat said, adding that high-profile companies, labs and research universities already offered cooperative proposals to work with NETL.

For example, DOE/ARPA-E has just awarded NETL a project for microwave-assisted ammonia synthesis. This would be a two-year post-phase 1 project. This NETL-supported project was funded through the Renewable Energy to Fuels through Utilization of Energy-Dense Liquids (REFUEL) program by ARPA-E and includes partners from industry.

NETL is also working on microwave-assisted process intensification for natural gas conversion by the Rapid Advancement in Process Intensification Deployment (RAPID) manufacturing institute. For this, NETL and partners proposed to develop a microwave-assisted catalytic process to produce value-added chemicals from natural gas.

While the microwave technology being pioneered at ReACT shows great potential, the work is far from over. A lack of a fundamental understanding of the underlying mechanistic and kinetic phenomena leading to enhanced performance characteristics remains an ongoing challenge. This gap in knowledge hinders the advancement of this technology from the laboratory-scale to commercialization. However, closing this gap will allow greater control over reaction mechanisms and lead to enhanced performances, which could make the technology more attractive for widespread adoption by commercial partners.

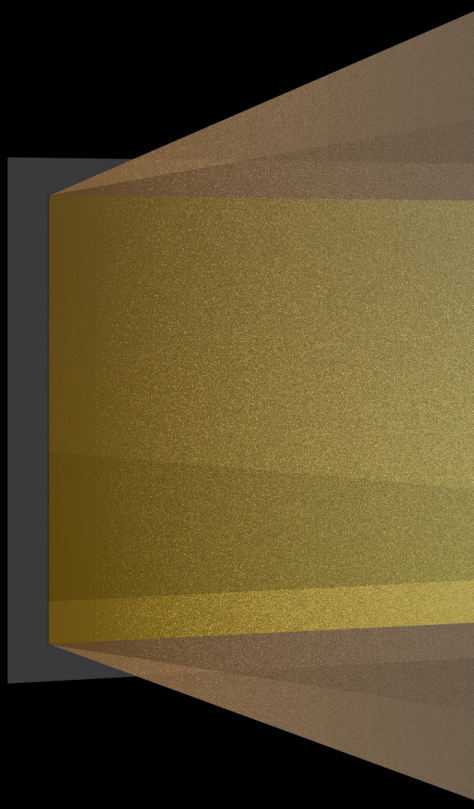
Investing in an Electromagnetic Chemistry Center to augment ReACT's already potent capabilities allows NETL to maintain its competitive advantage in this field of research. Furthermore, such an investment will deploy new and unique microwave capabilities allowing fundamental, mechanistic and kinetic studies, as well as development of scalable microwave-assisted processes. By scaling these processes, the technologies come closer to use in the field.

As other laboratories explore the possibilities of microwave reactors, a scale-up of capabilities becomes necessary for NETL to accomplish its mission of developing new tools to power the nation's energy-hungry economy in a sustainable manner. The Lab's ReACT facility has already demonstrated technological and design prowess, and with further investment to attract more collaboration with academic and industrial partners, NETL can fully realize the untapped potential of microwave reactor technology.

METALS WITH THE RIGHT METTLE

NETL Eyes Expansion to Develop the Next Generation of Advanced Alloys

By Martin Kinnunen



NETL is preparing to forge the next chapter in its proud history.

More than seven decades after developing zirconium to build the USS Nautilus, the world's first operational nuclear-powered submarine, and giving birth to the U.S. reactive metals industry, NETL is laying the early groundwork to enhance and upgrade its already-considerable alloy development capabilities and provide materials solutions needed to improve the existing fleet of fossil fuel-burning energy plants and build advanced fossil energy systems.

"We intend to reinvigorate NETL's alloy development capability in Albany, Oregon, with new equipment, research infrastructure, facilities and other improvements to manufacture the next generation of alloys that can thrive in extreme environments, including the high-temperature, high-pressure, corrosive conditions of advanced, fossil fuel-based power generation systems," said David Alman, associate director of NETL's Materials Engineering and Manufacturing directorate.

A new facility is envisioned that, if funded, will enable NETL to take full advantage of its melt processing and ingot metallurgy capabilities, which are among its unique capabilities within the DOE complex. Conceptional designs completed to date call for 40-foot-tall high-bay labs with concrete- and steel bar-reinforced walls and ceilings up to two feet thick, which are required for National Fire Protection Association compliance. This facility also would house existing and new melt processing capabilities. As part of this proposed initiative, NETL envisions upgrading and investing in other advanced manufacturing equipment.

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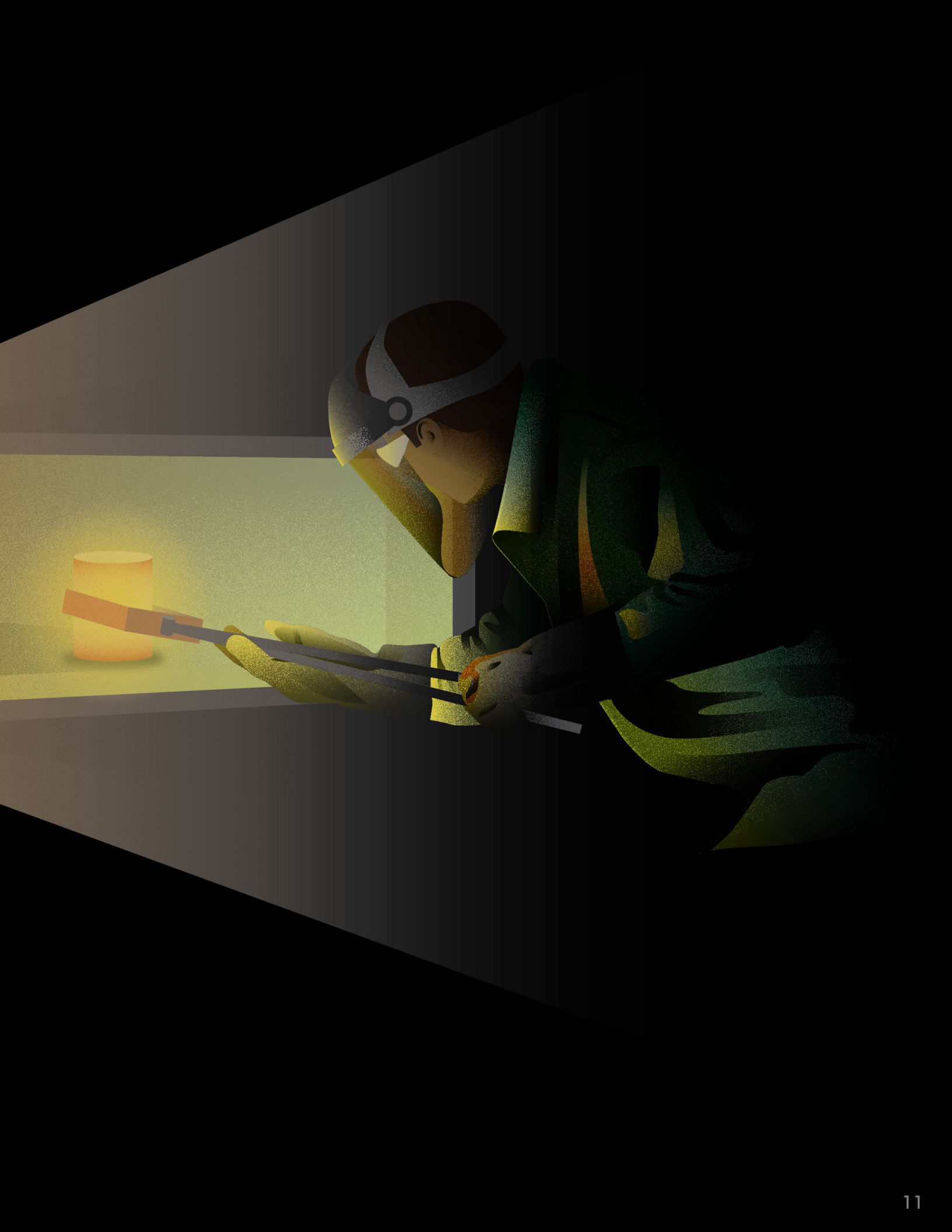


After the detailed design is funded and finished, proposals will be sought for construction, which could take 12 to 24 months, according to Alan Hartman, site manager at Albany. When completed, the expansion would triple production capabilities at the site.

Advanced alloy development and manufacturing is critical as NETL researchers work to discover technological solutions to provide Americans with clean, affordable and reliable energy.

Higher operating temperatures are necessary to make fossil energy plants more efficient and reduce emissions. However, higher temperatures degrade power plant components at faster rates, leading to corrosion, materials failures and costly maintenance issues.

Boilers, turbines and numerous components of coal-fired power plants run with greater efficiency when they are made with materials built to withstand high temperatures and pressures.

"The expansion we envision at Albany will enable NETL to more effectively develop and deploy materials for extreme environment applications and thereby improve the existing fleet of coal-fired plants and provide high-stress materials to develop new plants," Alman said.

In the 1950s, coal-fired power plants operated at a then cutting-edge steam pressure of 2,400 pounds per square inch (psi) and maximum steam temperatures of up to 538 degrees Celsius. By the end of the century, new coal-fired power plants were designed for "supercritical" steam conditions (4,300 psi and 610 °C).

The next generation of power plants will operate at advanced ultrasupercritical (AUSC) levels. AUSC steam power cycles will reach temperatures of 760 °C and higher and exceed pressures of 5,000 psi.

What's the benefit of pushing to those extremes? AUSC plants will require less coal per megawatt-hour, resulting in lower emissions of carbon dioxide, a greenhouse gas, and lower fuel costs per megawatt.

As the Albany project moves forward to attain needed congressional approvals, it will be considered a crosscutting activity because it fosters technology development across other applications. For instance, extreme offshore hydrocarbon operations require strong, durable and corrosion-resistant metallic materials for use in drill pipes, pipelines, risers, blowout preventers and other components in both the water column and subsurface systems.

NETL maintains a complete alloy development research facility at Albany, which includes an alloy fabrication laboratory, with capabilities for melting, casting, forging, rolling and heat-treating materials ranging in size from a few grams to 100 kilograms. NETL's alloy manufacturing efforts are supported by experimental capabilities to characterize the microstructure, mechanical performance and corrosion/oxidation resistance and multi-scale computational methods to predict alloy behavior in a variety of relevant environments to guide alloy design.

NETL has used these capabilities to advance the fossil energy mission. NETL's scientists used the experimental alloy manufacturing and computational materials engineering capabilities to demonstrate that thick-walled casting of precipitation-hardened, nickel-based superalloys (a critical technology for AUSC steam turbines) could be made. Currently, this capability is being used to develop cost-effective and improved Fe-9Cr alloys, austenitic stainless steels, superalloys and high entropy alloys for improving the existing fleet and enabling advanced fossil power systems. NETL's alloy development capability is also crucial to the success of DOE's Office of Fossil Energy's eXtremeMAT national laboratories collaboration.

Other government agencies, universities and the private sector use NETL's alloy development expertise and capabilities. For instance, NETL helped Boston Scientific develop revolutionary radiopaque alloys for medical coronary stents and assisted the U.S. Army in developing improved processing methods for military armor. NETL is partnering with Argonne National Laboratory on a DOE-Advanced Manufacturing Office project aimed at melt-processing alloys for advanced conductors. Industry continues to take advantage of NETL's unique alloy development capability, as NETL currently has 100% cost-reimbursable projects with several U.S. companies.

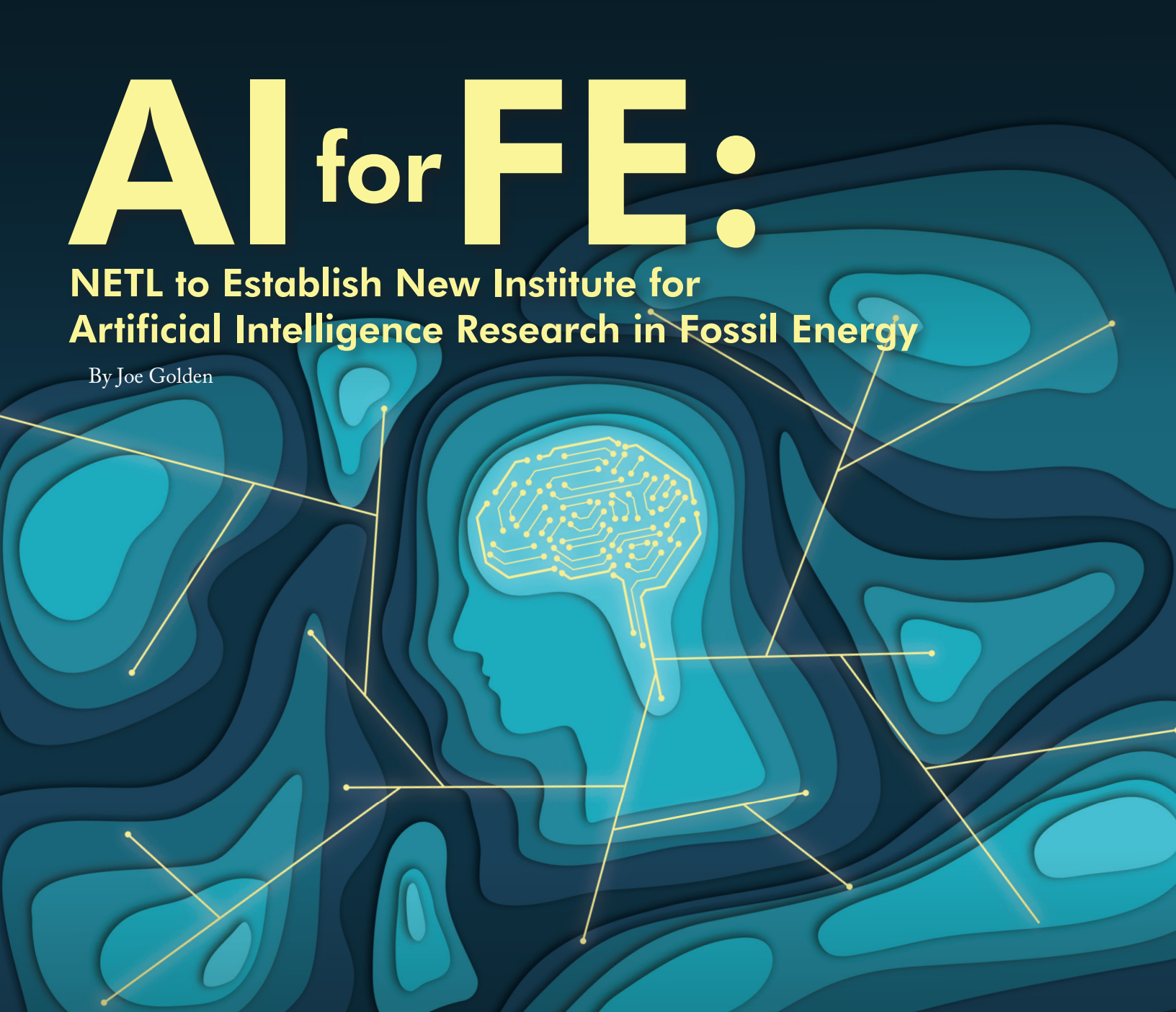
NETL's alloy development capability has a long history of providing alloy solutions that enable advanced technologies, create jobs and save lives. Completion of the expansion would position NETL to continue to serve as a vital national resource and enhance NETL's ability to contribute to the nation's energy security and economic competitiveness. "If funded, this expansion will significantly increase NETL's ability to develop new materials to enable efficient and effective power generation and resource recovery, and to assist other federal agencies, private industry and research university partners in developing materials solutions," Alman said.

Boilers and turbines are just some of the coal-fired power plant components that run with greater efficiency when built with alloys engineered to withstand high temperatures and pressures.

AI for FE:

NETL to Establish New Institute for Artificial Intelligence Research in Fossil Energy

By Joe Golden



Leveraging powerful artificial intelligence (AI) and machine learning (ML) techniques, NETL has vastly improved the way researchers innovate fossil energy technologies by developing processes that lower costs, improve safety, reduce environmental risks and strengthen cybersecurity. However, as more robust computational resources come online, the full potential of these transformative tools is only just emerging. Boundless discoveries still await NETL researchers working to solve the toughest energy challenges facing the nation.

To flourish in this era of accelerated technology development for cleaner and more efficient energy production, NETL plans to capitalize on its vast collection of data and powerful computational resources to establish a joint institute for AI and ML, headquartered and led by NETL, called the Science-Based AI and Machine Learning Institute (SAMI). The Lab has already established computational infrastructure required for SAMI, including the Joule 2.0 supercomputer and the Energy Data eXchange, while additional high-performance computation facilities are in the planning stages.

For example, NETL is investing in new infrastructure to support SAMI, including the Center for AI and Machine Learning (CAML) at the Lab's Pittsburgh site and a Computational Science and Engineering (CSE) Center at its Morgantown site. CAML will allow researchers to explore problems using AI, ML, data mining and data analytics techniques and will feature a petascale machine designed to house, transport and process up to 37 petabytes of data using cutting-edge algorithms developed in-house and with external collaborators. Partners for this initiative include Carnegie Mellon University, West Virginia University, Battelle, Leidos, industry and other national labs.

Design of the CAML project is anticipated to be completed this summer, and construction is expected to be underway in fiscal year (FY) 2021. The CSE Center, which will be a 10-12,000 square foot facility featuring NETL's powerful supercomputer, received congressional funding for FY20.

SAMI will address key priorities of DOE and the Office of Fossil Energy, such as modernizing the existing coal fleet; optimizing the recovery of oil and gas; expanding the use of big data; estimating emerging oil and gas resources; and providing materials for carbon capture, utilization and storage. The institute will enable NETL to become a clearinghouse for the fossil energy data needed for training ML algorithms and build the foundation for sustained long-term research in AI to drive discovery and insight.

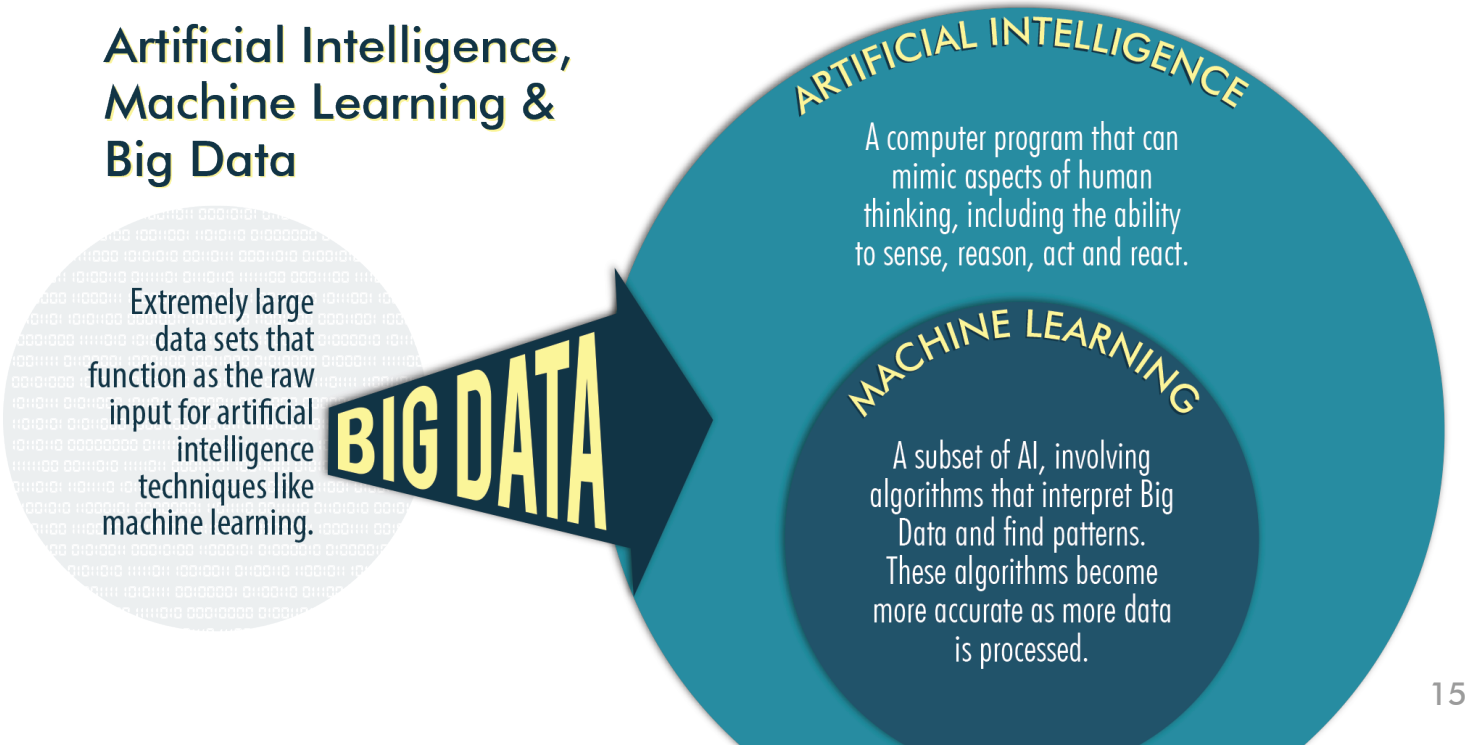
The new AI institute will also support and enhance efforts already underway as part of DOE's newly formed Artificial Intelligence and Technology Office, which was created in September 2019 to serve as the coordinating hub for the work being done across the DOE enterprise in AI.

NETL has proven itself as a key player through past ML project successes across the energy spectrum. For example, NETL researchers used the Lab's cutting-edge computational tools combined with ML to model more than 45,000 simulated microstructures of solid oxide fuel cells (SOFC), which help boost the performance and longevity of these energy-efficient, near-zero-emission technologies. Prior to the incorporation of ML learning approaches, researchers could only model around 10 SOFC microstructures per year.

The Lab has developed high-throughput materials screening techniques using data analytics and machine learning. A significant advancement in this area involved an ambitious computational modeling project that identified materials called mixed matrix membranes (MMMs), which are capable of making carbon capture more affordable for coal-fired power plants. NETL experts collaborated with researchers from the University of Pittsburgh to screen more than 1 million possible MMMs and identify several that significantly reduce the cost of carbon capture to less than $50 per ton of carbon dioxide removed. This is a significant cost reduction over existing carbon-capture membrane technologies.

One final example among NETL's many recent AI-enabled successes involves the successful application of ML approaches in accelerating the Lab's world-renowned computational fluid dynamic code MFiX. With the latest release of NETL's carbonaceous chemistry for computational modeling, or C3M, software, researchers leveraged ML approaches to overcome one of the biggest drains to computational resources when modeling advanced energy systems: solving the chemical reaction equations. Version 19.1 of C3M introduced the Machine Learning Accelerated Stabilized Explicit Variable Load software, which solves complex chemical reaction equations much faster than previous versions of C3M. This update drastically shortens design time and significantly reduces research and development costs.

Enormous amounts of energy-related data exist, spanning all sectors of the energy landscape. As part of the new AI institute, NETL will combine this data and use ML to capture behaviors of complex energy systems, which will significantly improve the scientific community's understanding and work toward the ultimate goal of accelerating decision making and more efficient designs. In this way, NETL's efforts in improving AI and ML with DOE will lead to securing more affordable and reliable energy for the nation.



COMPLETING THE PUZZLE TO POWER THE FUTURE:

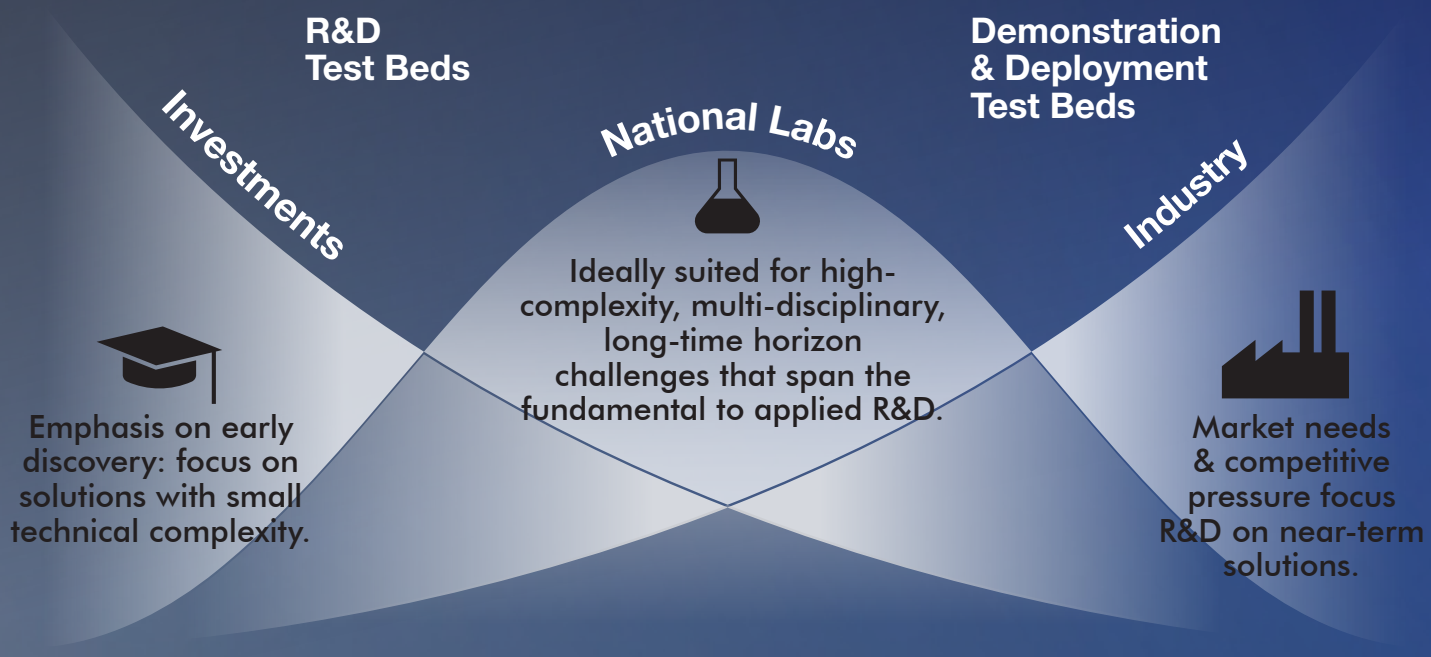
NETL Center of Excellence for Shale Gas Utilization

By Connor Griffith

To better fulfill its mission to power the vast and fuel-hungry modern economy, and do so in an environmentally sustainable manner, NETL is taking steps to foster the development of new products using the country's immense energy resources to enhance our nation's energy dominance and economic prosperity.

NETL-enabled technological advancements during the past decade, such as improved metal coatings, advances in energy efficiency and contributions to hydraulic fracturing, helped unleash America's energy producing potential. Due to the growth of the shale gas industries since these advances, the United States is endowed with some of the lowest-cost natural gas resources in the world. In the U.S., this gas is used primarily for heating, transportation and power generation. However, if used to produce high-value products, shale gas and its liquid components would position the nation to regain global leadership in hydrocarbon manufacturing.

In a 2011 Statement to Congress, George Blitz, a vice president in Dow Chemical Company, stated that the use of "natural gas to make petrochemicals results in eight times the value over simply combusting it."



Bridging the "Valley of Death"

Industry faces a formidable challenge of bringing economic processes to market that can convert these low-cost raw materials into high-value goods consumed domestically. To accomplish this, focus and coordination on technology development associated with the conversion of natural gas and natural gas liquids (NGLs) to high-value commodities is required at the regional and national level.

To see this endeavor through, NETL seeks to establish a Center of Excellence for Shale Gas Utilization that brings together multi-disciplinary teams in partnership with industry to focus on the discovery and deployment of innovative technologies that will transform the sector for decades to come.

Such a center could play several critical roles that further NETL as both a developer of new technologies and an entity that takes an active role in pushing those developments beyond the lab space and into the hands of commercial users, where they'll make the most impact.

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The proposed Center of Excellence would be designed to bridge the technology development Valley of Death — the gap between the initial discoveries and full-scale commercialization by industry during which funding or support for a new technology often falls through. NETL's Center of Excellence for Shale Gas Utilization would bridge this valley by uniting multi-disciplinary research teams and stakeholders from industry.

"Our own researchers, as well as our collaborators in academia, have explored and tested some very promising concepts," NETL Director Brian Anderson said. "However, a consistent challenge remains: seeing widespread adoption of these tools and technologies by industry. With a new Center of Excellence for Shale Gas Utilization, we could explore the means by which these tools can be refined and made affordable to incentivize large-scale commercialization. The center can be a vital piece to completing the puzzle."

NETL's ultimate vision for the center is to serve as a catalyst for developing new products and supply chain opportunities as the nation's abundant energy resources allow for the emergence and growth of new markets. Fostering the growth of markets for newer uses of natural gas — such as structured nanocarbons, which show promise as platforms for developing novel catalytic composites — becomes even more important in view of the economic challenges that accompany an oversupply of gas and low floor prices.

Without a balance between demand and natural gas supply ensuring attractive prices, producers scale back their operations and investments, resulting in job losses and idled projects. If energy producers scale back, so do their respective supporting industries.

The envisioned goal of the NETL Center for Excellence is to avert the effects of the natural gas industry's boom-and-bust cycle by spurring innovations that can lead to increased demand for gas products. Consistent demand can keep gas prices at a level conducive for attracting investments in new products and additional production. This, in turn, is anticipated to increase economic activities associated with natural gas such as transportation, facility maintenance, construction and manufacturing, which employ thousands of people across the nation.

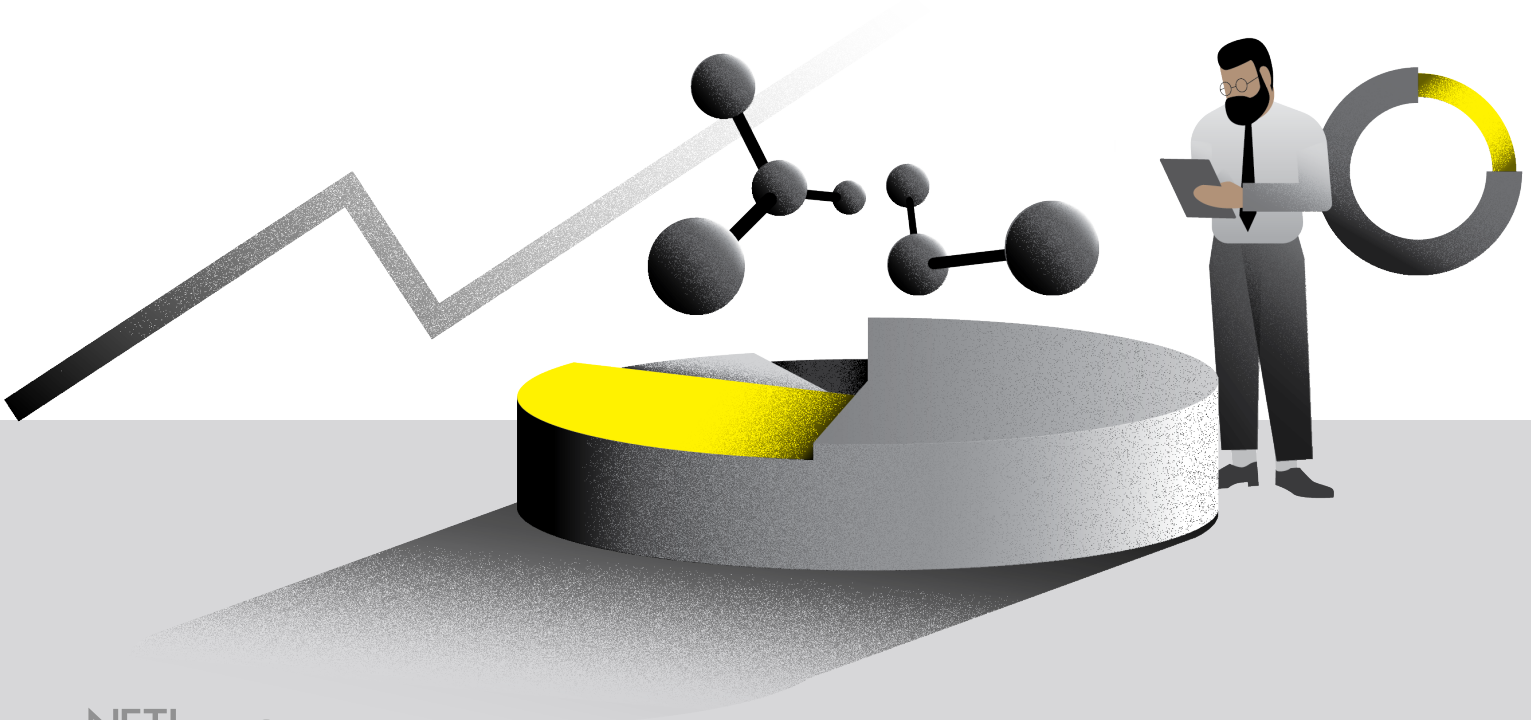
Multi–Pronged Strategy for Success

If funded, the Center of Excellence would bring together the brightest minds from across NETL and collaborating universities in partnership with industry.

The center is intended as a self-sustaining entity, which is anticipated to generate more than $100 million of new revenue through a three-pronged approach of business development, technology development, and marketing and communications.

The center would pursue a strategy of business development to forge the partnerships with entities that either directly contribute to revenue generation via paying for research products, or indirectly contribute by advocating for prospective partners. It is anticipated that early work would consist of identifying strategic partnerships and strategies to maximize funding from several sources from within the federal government as well as the private sector.

The center's business development efforts would be supported in concert with technology development to acquire the



technical knowledge, lab materials and other equipment vital to fulfilling the research projects demanded by partner organizations.

Throughout these processes, a marketing and communications component is planned to increase brand awareness associated with the center, NETL capacities and people, research portfolio and its success stories. The development of a new website to showcase these facets is also envisioned to play a role.

By tackling the issue of development and awareness on multiple fronts, the center would work to fulfill its goals in a self-perpetuating manner after initial investments and set-up is completed. This approach would allow the center to concentrate on its three primary focus areas: petrochemical building blocks, novel carbon materials and synthetic military fuels, which is a crucial strategic component to ensuring national security.

Best of NETL

As an organization, the Lab has several attributes that make it ideal to fulfill the Center of Excellence's objectives.

NETL is the only federal laboratory that's government-owned and -operated with both the mission to develop fossil energy technology and a long history of successful technology deployments. Its techno-economic capabilities are a trusted source of information in several offices within DOE, which would serve to inform the center of opportunities for technological deployment.

Furthermore, the Lab's considerable pool of talent and expertise has gained a reputation for excellence as seen by its numerous R&D 100 Award recipients. Dubbed as the "Oscars of Invention," the R&D 100 Award Celebrates the top game-changing technologies developed each year. In 2019, 32 of these awards stemmed from work at DOE laboratories. Among NETL's works to be recognized last year include the Carbon Capture Simulation Initiative Toolset, the only suite of computational tools and models specifically tailored to help maximize learning and reduce risk during the scale-up process for carbon-capture technologies, along with the Lab's NETL's Computationally Optimized Homogenization Heat Treatment Process, which provides an easy method to optimize heat treatment to achieve the desired degree of homogenization in metal alloys with a minimum of furnace time.

By using the Lab's impressive roster of engineers and scientists, the envisioned Center of Excellence will be well equipped to see its intended purpose to fruition.

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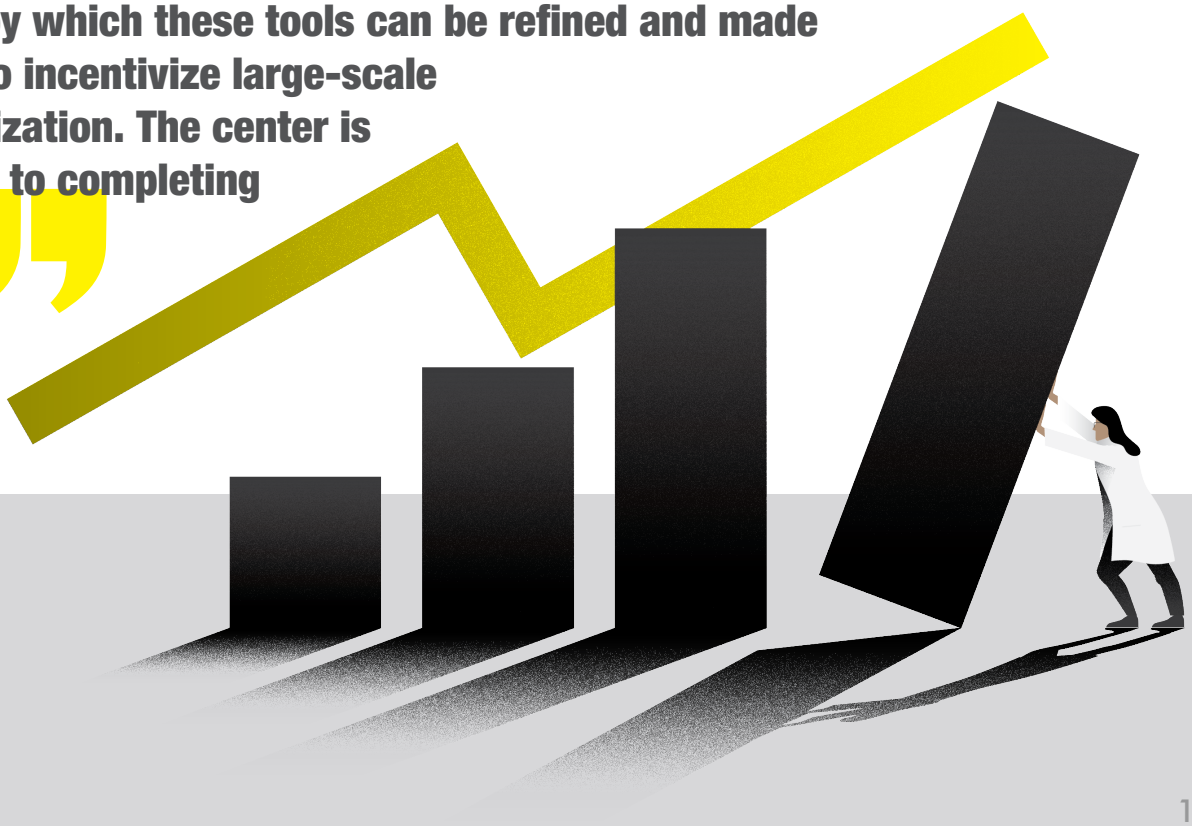
"A consistent challenge remains: seeing widespread adoption of these tools and technologies by industry. With the new Center of Excellence for Shale Gas Utilization, we can explore the means by which these tools can be refined and made affordable to incentivize large-scale commercialization. The center is a vital piece to completing the puzzle."



Leveraging Storage Hub Potential

According to data from the U.S. Energy Information Administration, dry natural gas production in the U.S. is anticipated to grow from more than 20 trillion cubic feet in 2020 to more than 35 trillion by 2050, with the Appalachia region seeing the largest share of the growth. Prior to the region's shale gas boom starting around 2008, America's dry natural gas production was less than 5 trillion cubic feet, demonstrating the importance of these resources.

Capitalizing on them is beneficial because it can alleviate geographic concentration of petrochemical infrastructure and supply along the Gulf Coast, which may pose a strategic risk due to its vulnerability to hurricanes.

As the Marcellus and Utica shales continue to see expanded use, NETL's Center of Excellence could partake in this journey by supporting facets of the Appalachian Storage and Trading Hub (ASTH) Initiative, the proposed underground storage facility for highly valuable NGLs.

Intended to provide an alternate supply base for the country's energy needs away from the hurricane-prone Gulf Coast, the proposed ASTH would be a built-for-purpose storage facility that offers tremendous benefits for both business and society. Partners with the ASTH include The Center for Innovation in Gas Research and Utilization at West Virginia University, Shell, Pacific Northwest National Laboratory, Mid-Atlantic Research and Innovation Center, Chemical Alliance Zone, Florida State University, Marshall University, and University of Pittsburgh.

"The Appalachian Storage and Trading Hub represents the opportunity of a lifetime, one that can see the prospects of U.S. energy dominance to fruition," said Justin Adder, NETL's senior economist. "The possibilities are almost endless, but so are the demands. As the world's population continues to grow and more countries continue to industrialize, the need for cheap and reliable energy to ensure a better quality of life is going to be at the forefront. The Center of Excellence will play a critical role in this process by uniting all the key players."

The ASTH also shows promise for continued economic development as labs such as NETL work to develop the tools and techniques that allow expanded uses of natural gas and NGLs. The abundant gas resources of the Marcellus and Utica shales go far beyond power generation. With the construction of polyethylene cracker plants on the Ohio River, the NGLs act as a valuable feedstock for processing the gas into solid pellets. These can then be manufactured into plastics and resins. Among dentures, parachutes, cell phone frames, arterial limbs, tires, vehicle upholstery, agricultural fertilizer, and many other petrochemical products, a wide variety of consumer products are derived from natural gas.

Bringing the ASTH online can bring robust employment opportunities throughout the Appalachian region by feeding the demands of manufacturers while attracting new ones to set up shop close to its supply.

Geography also plays in the ASTH's favor. The Appalachian region is an ideal location for petrochemical manufacturing because it is near the abundant NGL resources from the Marcellus and Utica shale plays, as well as East Coast and Midwest manufacturing bases that use petrochemicals as feedstocks. The American Chemistry Council estimates that an Appalachian petrochemical industry could attract over $30 billion in capital investment, create more than 100,000 permanent jobs, increase annual business revenue by $30 billion annually, and generate approximately $3 billion in annual tax revenues. Additionally, it would geographically diversify the U.S. petrochemical manufacturing base, which is positive for U.S. manufacturing and energy security.

Products Produced from Petrochemical Plastics

Feedstocks

Dentures

Prosthetics

Parachutes

At the same time, the ASTH may help the Gulf Coast region by freeing up more of its feedstock to be used more locally or exported overseas.

In the end, NETL's proposed Center of Excellence would aim to make the most efficient use of the Lab's talented staff in concert with robust planning to make the most of its funding resources. With these assets, the center would be well-positioned to assist in developing and supporting industries for decades to come as the ASTH takes shape and new industry partners step forward to take advantage of the latest innovations that will ensure economic prosperity and national security. Appalachia finds itself amid a petrochemical renaissance and through this envisioned new center, NETL can position itself to be front and center to ensure a constant supply of energy and manufacturing feedstock immune from any price spikes stemming from severe weather along the Gulf Coast or other regional disruptions throughout the nation.

Petrochemical plastics are also used to make many of the automotive interior finishes that make the ride safe and comfortable.

FORGING THE FUTURE: AN INSIDE LOOK WITH SENIOR METALLURGIST

Paul Jablonski

By Abby Humphreys

Paul Jablonski, Ph.D., and member of NETL's Structural Materials Team, has offered his expertise at the Lab's Albany site for nearly 20 years. He currently serves as a senior metallurgist, where he works in alloy fabrication to test their sustainability in a variety of fossil energy applications.

Jablonski has worked as a metallurgist his entire career, from process and product development to manufacturing, research and failure analysis. He received his undergraduate degree from Michigan Technological University and Ph.D. from the University of Wisconsin-Madison, both in metallurgical engineering. He has more than 35 years of experience in metals and alloy design.

Jablonski is an author or co-author of more than 80 publications and holds eight patents. Additionally, he has received four R&D 100 awards, the Secretary of Energy Achievement award and several other honors for his groundbreaking work in metallurgy.

NETL Edge spoke with Jablonski about his long and accomplished career at the Lab, as well as his successes and his predictions for the field of metallurgy in the coming years.

Edge: What are some of your accomplishments over your tenure at NETL?

Jablonski: The development of the high-radiopacity stent is certainly at the top of the list. NETL developed this series of stents jointly with Boston Scientific Corporation in 2010, and it has become the leading stent platform in the world since then. The coronary stents have a higher visibility on X-rays, which means they can be placed more easily and precisely inside a patient's blood vessel.

In addition, the greater yield strength of the alloy allows the material to be thinner and more flexible, which grants easier threading through a patient's artery without doing damage along the way. Because of these properties, this stent is able to be deployed in much smaller vessels in and around the heart, which saves more lives each year.

We are currently working on a biodegradable alloy for a number of applications in the medical industry. This new alloy was developed through computational thermodynamic simulations and laboratory experiments. While implants can be helpful and even lifesaving, in many cases they need to be removed once a patient has healed sufficiently. The follow-up surgeries to remove the implant further expose patients to additional risks such as infections and other complications. Therefore, having an implant that degrades in the body and can be expelled naturally is advantageous to the health of the patient.

The computational homogenization approach is also something that is very impactful, as it is used on every alloy we make. We use modeling software to design ways to optimize heat-treatments for — or homogenize — alloys, which helps improve an alloy's performance and minimizes the chance of degradation during processing. Modeling the process beforehand allows us to homogenize the casting chemistries of alloys to levels that are appropriate for specific uses in industry. This allows for the creation of sturdier alloys for every application.

Edge: Where do you see the future of metallurgy heading?

Jablonski: Thirty years ago, they said steel research was dead. However, we see new steels being deployed in transportation and power industries every day.

For example, NETL developed a ferritic/martensitic steel that has a use temperature roughly 50°F degrees higher than the best previous alloy, which expands its use in the energy industry. This increase use temperature can displace higher cost stainless steels, which greatly reduces the construction and operating costs of new power plants. Given what improvements have taken place in this short amount of time, I see a steady improvement in the years ahead.

Edge: Is there something possible today that wasn't possible several years ago in your field?

Jablonski: Our computational homogenization process replaces an Edisonian approach to homogenization. A trial-and-error approach was previously used, or "heat and look," which allowed us to only test one alloy at a time.

Today, we use computational modeling to test many alloys at once to determine which would be the most suitable for a specific use. This digital approach helps optimize the process, which minimizes time in the furnace and conserves resources while producing the best outcome possible — even before the actual alloy has been made.

Edge: What would you like people to know about NETL's capabilities?

Jablonski: NETL probably has the best melting and fabrication laboratories within the government laboratory system. The Lab maintains a complete alloy development research facility at its Albany site, which includes an alloy fabrication laboratory for prototyping alloy manufacturing — something unique among the national laboratories. Additionally, we have the capabilities for melting, casting, forging, rolling and heat-treating materials ranging in size from a few grams to 100 kilograms.

NETL-Albany is internationally recognized for its leadership in designing, developing and deploying advanced materials for use in energy applications and extreme service environments. Our facilities deliver high-performance, affordable materials that enable diverse energy technologies.

DATA DEFENSE:

DOE's CyberForce Competition Inspires Next Generation of Cybersecurity Professionals

By Abby Humphreys

NETL joined other DOE national labs in supporting the development of the next generation of cybersecurity professionals by hosting this year's CyberForce Competition — a one-of-a-kind competition that uses real-world challenges to increase participants' knowledge and understanding of cyber-physical threats.

Coordinated by Argonne National Laboratory and held Nov. 15-16, 2019, the fifth-annual CyberForce Competition consisted of small teams ranging from undergraduate to Ph.D.-level students responding to a mock cyberattack. NETL staff added an extra bonus to the Lab's competition by sharing their expertise and technical backgrounds in information technology to illustrate to participants what it takes to ensure robust cybersecurity measures in real-world scenarios.

Cybersecurity is a uniquely complex field due to the ever-changing nature of threats and vulnerabilities. According to Digital Guardian, the average cost of a data breach spanned anywhere from $1.25 to $8.19 million in 2019, which is part of a 12% increase in data breach costs since 2014. Additionally, one study estimated that 3.5 million unfilled cybersecurity jobs will exist globally by 2021.

As technology's role in society continues to grow, potential damage from security breaches will only increase in coming years. The CyberForce Competition seeks to foster a new cohort of cybersecurity professionals to keep our personal information protected and our nation's networks safe from attack.

Protecting the Network

The competition divided participants and volunteers into several teams. Students made up several groups inside the Blue Team and competed against each other while defending their network against the Red Team, which consisted of volunteers from NETL attempting to hack the Blue Team's systems. Members of the Green Team, also from NETL, tested the usability and availability of the Blue Team's networks by playing the role of a typical customer and sending requests to the Blue Team. Other teams judged each Blue Team group on their innovative cyber defense approaches and ensured all technology worked properly.

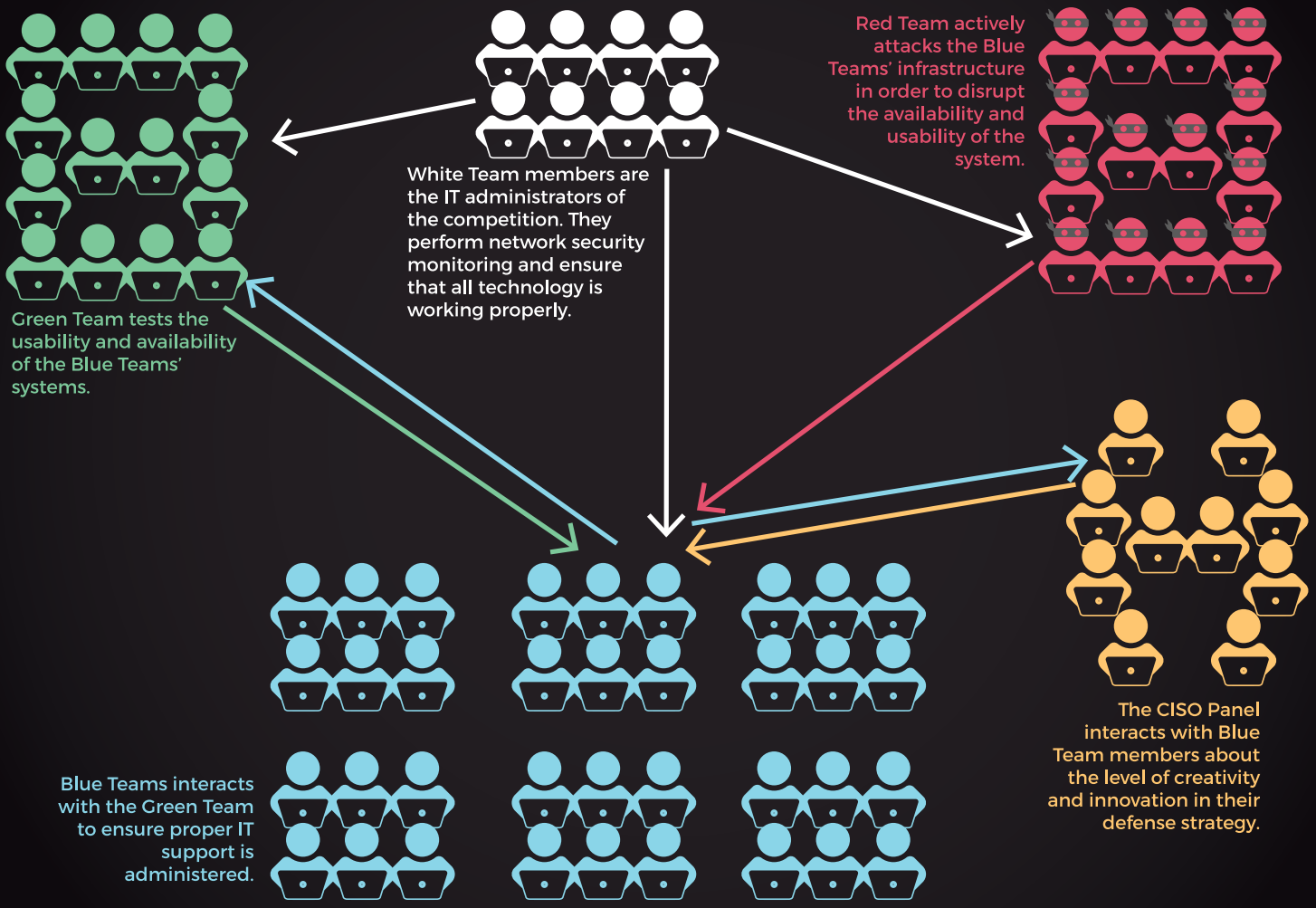
The score of each Blue Team group was determined in part by how well it could ensure continued usability of the system. "The competition is unique because it prompts competitors to respond to attacks as they occur in real-world settings. For example, final scores rely on each Blue Team group's ability to protect against outside threats while simultaneously ensuring normal work operations can continue for the Green Team," NETL's Energy Delivery & Security Associate Director Eddie Christy said.

The competition seeks to help participants understand what goes into the protection of a network, which includes preventing attacks, identifying vulnerabilities and understanding consequences. It also encourages teams to seek creative and innovative solutions to challenges by adapting to constraints that would be present in real-world attack scenarios, such as having little to no budget for cyber defense measures.

By working around restrictions, participants are encouraged to try new approaches to solving problems as they arise. As threats continue to evolve, "out-of-the-box" solutions will become increasingly important in enhancing the cybersecurity infrastructure of critical organizations such as hospitals, government offices and others.

Continued on page 26

How the CyberForce Competition Works:



Cybersecurity in Energy

The CyberForce Competition works to increase hands-on cyber education and awareness to better inform the next generation of cybersecurity specialists. Giving students the chance to participate in a hypothetical cyberattack offers a valuable chance to understand the daily career demands of a cybersecurity professional firsthand. Additionally, its focus on maintaining energy-specific system components offer a realistic view into the challenges a cybersecurity professional with DOE may encounter on the job.

Ensuring robust cybersecurity measures goes hand in hand with important energy research already taking place at NETL. Research areas like NETL's Crosscutting Sensors & Controls program pursue projects that address fossil energy's cybersecurity needs. As more capable sensors and controls, high-performance computing and predictive maintenance strategies are used to make energy production more reliable, they can create gaps in cybersecurity infrastructure and generate new categories of risk. To combat this, NETL assists other DOE offices by researching machine learning, automated situational awareness technologies, data integration tools and more to prevent future cyberattacks.

The competition also complements NETL's other Education & Outreach endeavors that promote science, technology, engineering and math (STEM) and provide opportunities to students interested in a science career. The Lab's K-12 STEM Education and Outreach Team conducts classroom visits and hosts workshops for teachers that promote implementing STEM lessons in the classroom, and the Lab offers graduate and post-graduate education programs that provide unique research and training opportunities to ensure that young professionals are prepared to meet the demands of the modern workplace.

The benefits of strong cybersecurity ultimately impact more than just DOE. Other fields such as financial services, communications, information technology, health care and public health, the military and more all benefit from protection against information breaches. The CyberForce Competition encourages the next generation of cybersecurity professionals to rise to the challenge of securing our nation's networks to defend against ever-evolving threats, which works toward building a safer cyber environment for every user.

PARTICIPATING SCHOOLS:

Baldwin Wallace University (Berea, OH)
Pennsylvania State University (State College, PA)
Rochester Institute of Technology (Rochester, NY)
University of Maryland Global Campus (Adelphi, MD)
Virginia Tech (Blacksburg, VA)
West Virginia University (Morgantown, WV)

NATIONAL FIRST-PLACE WINNER:

University of Maryland, Baltimore County

REGIONAL FIRST-PLACE WINNER:

Baldwin Wallace University

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