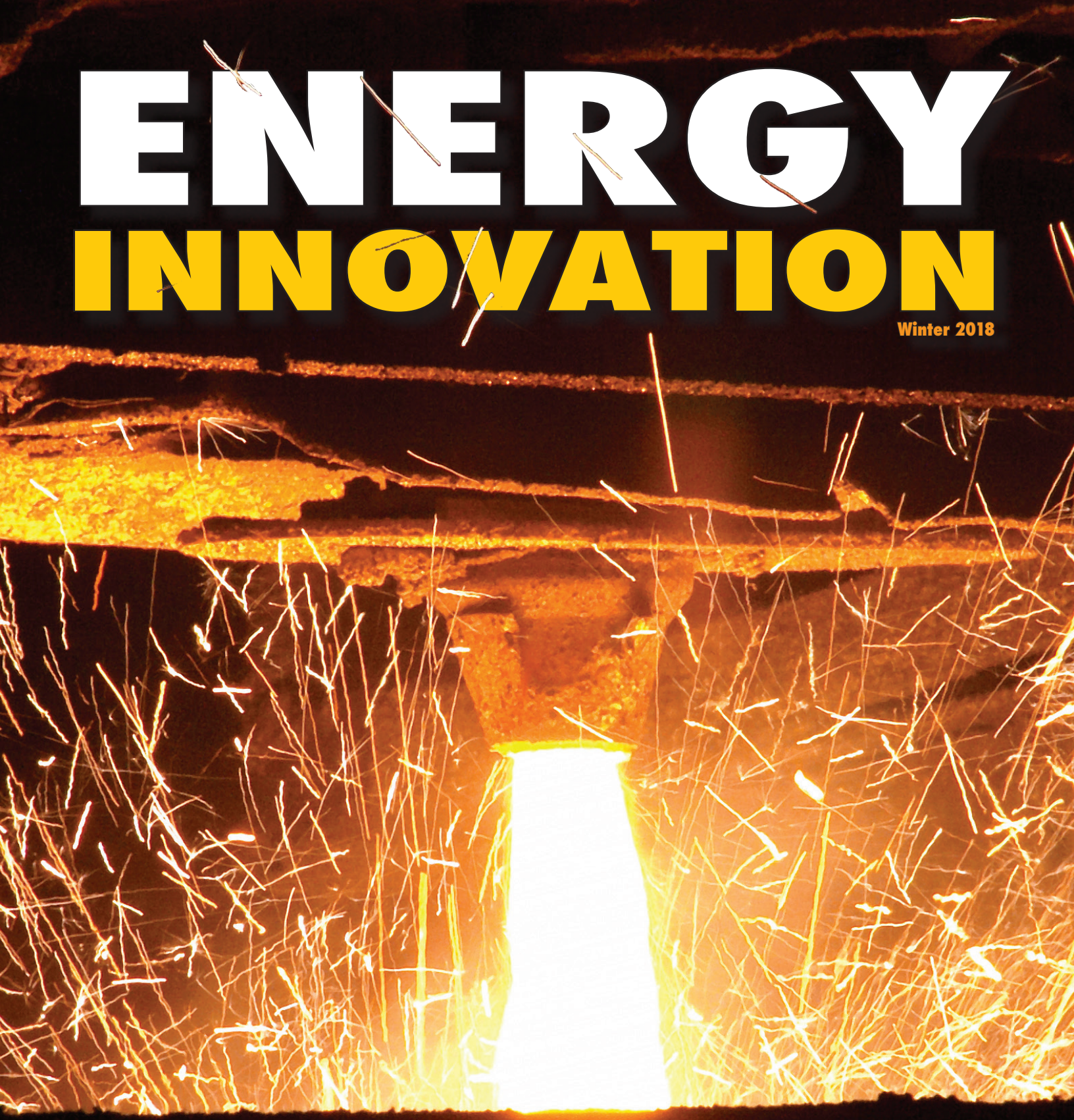
ENERGY INNOVATION

Winter 2018



PennState
College of Earth
and Mineral Sciences

Earth and Mineral Sciences
Energy Institute

Letter from the Director

Welcome to the winter 2018 edition of the EMS Energy Institute (EI) Newsletter. This edition showcases faculty research in several topical areas, introduces new employees, and highlights the honors received by our students, faculty, and staff.

The research, education, and outreach efforts of the institute continues to focus on energy and energy-related environmental effects and involves researchers in the College of Earth and Mineral Sciences and the College of Engineering along with collaborators worldwide. Current research projects cover the production and use of energy along with carbon dioxide capture, storage, and utilization. Since our last newsletter, published three years ago, 112 new external research projects have been established and supported with more than $22.5 million in funding. During the past ten years, papers published in peer-reviewed journals by EI researchers have grown from twenty-six in 2008 to ninety-eight in 2017. Citations of publications by EI researchers have also increased over the past ten years from about 600 citations in 2007 to about 4,300 in 2017, according to the Web of Science. Those figures reflect our growth as an institute with more faculty and visiting scholars working in our labs, our increased presence at domestic and international conferences, researchers being awarded more industry and government funded projects, along with the ability to collaborate with researchers outside of Penn State through travel or online communication.

The past few years we have experienced exciting changes in the EI with the addition of new faculty and staff members, who are introduced beginning on page twelve, but we also saw two staff members, Cindy Anders and Gary Mitchell, retire in 2017, and Angel Johnson move to another position at the University. Cindy worked in the front office for fifteen years supporting students, faculty, and staff members before retirement while Angel moved to the Office of the Corporate Controller in fall of 2017 after five years at the EI. Gary worked at Penn State for thirty-two years leading optical petrology research on coal and coke along with managing the Coal Sample Bank. We thank all of them for their many contributions. Since 2017, we have gained three new staff members: Christy English and Ashley Comly replaced Cindy and Angel, respectively, and Karlin Andersen serves as our new editor and writer.

I would like to take this opportunity to thank all the EI faculty members, research staff, students, and visiting scholars whose ideas and hard work have advanced energy science and engineering research, resulting in many publications as well as awards and honors. I also want to thank our staff members whose hard work supports our faculty-driven research efforts. In closing, I hope you will find the contents of this issue interesting. Please let us know if you have any suggestions or comments.

Dr. Chunshan Song
Director, EMS Energy Institute
Associate Director, IEE
Distinguished Professor of Fuel Science and Chemical Engineering

Energy Innovation is an annual publication from the EMS Energy Institute in the College of Earth and Mineral Sciences. The EMS Energy Institute is a leading research and development organization focused on energy science and engineering.

Cover Image
Electric arc steel-making furnace

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Making **coal** cleaner

Situated along the Allegheny Mountains in the west and from Hazleton to Pine Grove in the east, Pennsylvania's expansive coalfields make the Commonwealth the third-largest coal producing state. Despite its mining production capacity, the state's reliance on coal for energy production fell to 39 percent in 2013 from 60 percent in 1990 while reliance on other energy sources such as nuclear power and natural gas have increased, according to the U.S. Environmental Protection Agency (EPA).

The move away from coal-generated electricity is in part due to the Clean Power Plan, finalized in 2015, which aims to gradually reduce emissions across all states through 2030. Pennsylvania was tasked with reducing carbon dioxide emissions by about 33 percent, according to StateImpact Pennsylvania, a National Public Radio news reporting initiative focused on Pennsylvania's energy economy.

Coal is often charged for a large portion of carbon dioxide emissions in the state due to its composition of primarily carbon and its traditional majority share of energy production in Pennsylvania, according to StateImpact Pennsylvania.

"We should stop talking about getting rid of coal and start talking about what [we] really want to do which is to have available, cheap electricity with a significant reduction in the environmental footprint," said Jonathan Mathews, a professor in the College of Energy and Mineral Sciences (EMS) and co-director of the EMS Energy Institute's Coal Science and Technology (CST) program.

Mathews and Sarma Pisupati, also an EMS professor and CST co-director, understand the desire for clean energy with a reduced environmental impact, but argue that how coal is used, not the use of coal, is the problem.

"Where the disconnect is, is a lot of people are saying 'let's get rid of coal,'" Mathews said. "But, what they really want to do, what they'd like to achieve, is decarbonizing the emissions and if we can do that with coal—and there's several ways of achieving that—then coal should have the ability to meet those demands."

Making **coal** clean

Mathews' current research centers on exploring ways to capture and store carbon emissions, also known as carbon sequestration, along with examining coal behavior during use. His research has identified ways to improve carbon sequestration through the application of stress fields and creating new fractures within coal using microwave bursts.

"If carbon sequestration can be achieved commonly, then coal will continue to have a role to play and we will achieve reduced carbon dioxide emissions," Mathews said. He has published some of his result in recent issues of *Carbon*, *Fuel*, and *Fuel Processing Technology*.

The potential for carbon sequestration in a given type of coal can be predicted through x-ray imaging of a sample along with molecular-level modeling of coal's structure and interaction with atmospheric gases. Both Mathews and Pisupati are particularly focused on how carbon can be captured during coal burning and effectively stored instead of being released into the atmosphere.

"Some of the reasons why coal is not environmentally friendly are because what we put back in to the environment in either gaseous or solid form is not acceptable. But, if we turn those wastes in to resources, then they would be environmentally friendly," Pisupati said.

Pisupati said that rethinking how coal byproducts are handled can help coal become a more environmentally friendly resource. Currently, char, ash, liquid, and gaseous byproducts are often discarded by returning them to the earth. Discovering alternative ways to capture and discard those byproducts are challenges Pisupati views as integral to an engineer's job.

"If we don't want to touch a problem, what is there for us to solve as engineers, as designers, as scientists?" Pisupati said. "If we don't want to do research and find new things, then what is there?"

Coal ash, in particular, includes multiple high value, critical elements including vanadium and nickel that if extracted could offset the market's demand while reducing the environmental impact of coal combustion wastes, Pisupati said. Learn more about Pisupati's research into recovering rare earth materials from coal on nine.

Clean *vs.* **CLEANER**

Current electricity generation figures suggest that clean energy production is preferable to fossil fuels like coal. In 2010, almost half of Pennsylvania's net energy was produced by coal compared to natural gas' share of 15 percent. By 2017, coal's role decreased to about 25 percent and natural gas use grew to provide almost one third of the state's net energy production. During that same period between 2010 and 2016, the most recent data available, carbon dioxide emissions in Pennsylvania dropped about thirty-nine million metric tons, according to the U.S. Energy Information Administration (EIA).

Pisupati and Mathews caution consumers and policymakers from viewing increased reliance on nuclear and natural gas energy along with the decrease in carbon emissions as further evidence that coal has the largest impact on the environment.

"No energy is clean. It's hopefully cleaner," Mathews said. "Everything is going to have an environmental impact and I think it's a good conversation to have, regarding what's acceptable and how do we get down to those levels? We need to be careful that we don't make electricity so expensive that we have to choose between electricity, heat, and food. We have to keep a balance."

Mathews and Pisupati also want the public to recognize that energy from natural gas and renewables like wind and solar have shortcomings too.

"There's a reason we're not using wind, there's a reason we're not using solar historically to generate all our electricity," Mathews said. "These are more sustainable energy sources but they're currently still more expensive than coal in generating a consistent large-scale supply of electricity. "

While the technology and methods to reduce carbon dioxide emissions during coal-fired power generation are being tested and added to existing plants, carbon production from coal plants has decreased since its peak in the mid-2000s. According to the EIA, carbon emissions associated with coal plants fell by about forty-two million metric tons in Pennsylvania from 2005 to 2016.

Even after efforts to reduce emission levels, Pennsylvania remains third behind Texas and Californiain energy-related carbon dioxide emissions. However, it is important to note that the term "energy-related" refers to all energy produced in the Commonwealth including energy sold to neighboring states. Annually, Pennsylvania is the nation's second largest energy exporter. When considering per capita energy-related carbon dioxide emissions, Pennsylvania annually ranks in about the middle of all fifty states.

"We need to look at the overall environmental footprint," Mathews said.

"If we bring coal out, why is it not environmentally friendly? Because what we put back in to the environment is not acceptable either gaseous form or solids that we send back. But, if we turn them in to resources, [then they would be environmentally friendly]."

— By Sarma Pisupati

Local consumers do have the option to vote on which local utility serves their area or remodel their home to use a different energy source, but the cost and availability of energy sources are influenced by a state's legislature, utility companies, and market prices which limits a consumer from selecting an energy source over the other based on environmental impact.

However, Mathews said homeowners should not be forced to rely solely on renewable energy sources or any one type of energy because of the fluctuation in and unpredictable nature of resources. He worries about Pennsylvania's growing reliance on natural gas for heat and a push for residents to use renewable energy as their dominant power source.

"Natural gas certainly has a role to play but we need to have a mixture of energy supplies," he said.

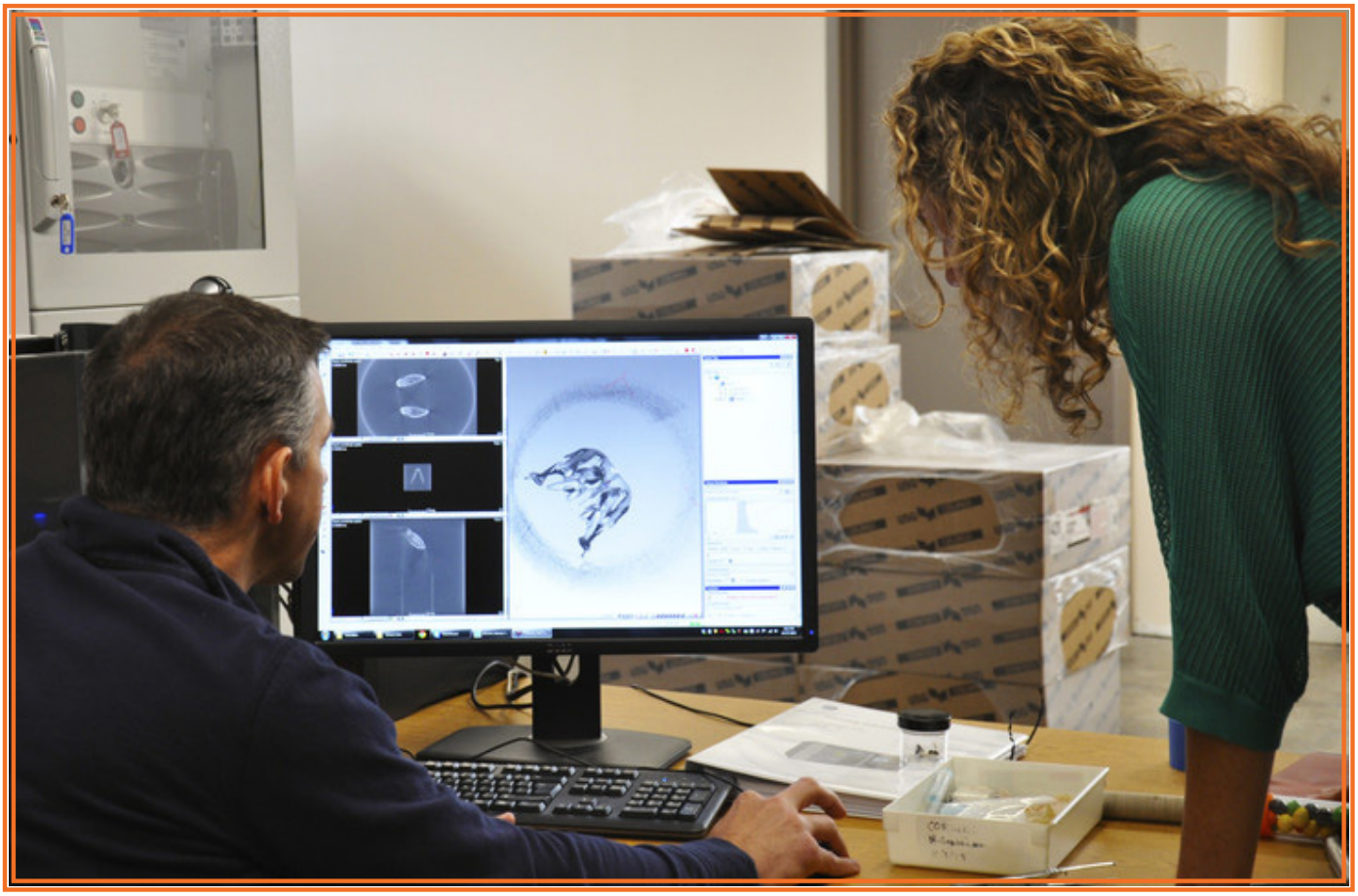
Mathews believes energy policies are in a transition period from relying on a single resource to having multiple sources available to best meet an area's needs "not just on a sunny day or a windy day, but in the darkest winter vortex."

Both researchers agree that coal fired-plants can become more sustainable by upgrading plants with new carbon capture and storage techniques along with creating better methods to reuse and dispose of coal byproducts, all challenges Pisupati says engineers are ready to solve. Despite the shift toward carbon-free energy production, coal still has a role as a "base load" energy generator Pisupati said. He said coal will continue to power residential areas and supply industries with byproducts to some extent in Pennsylvania and abroad.

"I can very clearly see that coal will not go away in the foreseeable future," Pisupati said. "Coal will play a role in our nation's energy scenario but, the question is how big of a role or what kind of role. We should be looking at coal as more than just an energy source for power generation and more as a resource to help us to a sustainable future."

Learn more about the sustainable energy research being conducted at the EMS Energy Institute in our summer edition of Energy Innovation.

Technology housed in the EMS Energy Institute provides data University-wide



Center for Quantitative X-ray Imaging co-directors Tim Ryan and Zuleima Karpyn view a 3-D image scanned on the center's new high-resolution scanner.

IMAGE: Angela Kendall

There are few places on the University Park campus where Penn State researchers examining biological samples and synthetic materials intersect and are supported by one piece of technology. A micro-computed tomography or "microCT" scanner housed in the Center for Quantitative Imaging (CQI), a section of the EMS Energy Institute, allows researchers across disciplines to examine the structure of objects the size of a femur bone to freeze-dried carrots.

"The range of projects that we get to work on is very broad," said Zuleima Karpyn, co-director of CQI and professor of petroleum and natural gas engineering. The scanner demonstrates true cross-disciplinary and cross-departmental collaboration at the University. While CQI is housed within the EMS Energy Institute, the lab is managed and operated as a core research facility of the Energy and Environmental Sustainability Laboratories within the Institutes for Energy and the Environment and the instrument is used by researchers across Penn State.

"That makes for a very nice space for interaction with different fields and research areas in different corners of the University, while having a common theme of image analysis and data science," Karpyn said.

Traditional ways of examining the internal structure of an object, especially such dense objects as bones or rocks, required the object to be cut or broken open. That technique could cause irreparable damage to an artifact or fossil thus ending the research potential for the object or restricting researchers to only examine objects deemed acceptable to lose, said Tim Ryan, co-director of CQI and associate professor of anthropology.

The introduction of x-ray technology allowed researchers to see a two-dimensional representation of the internal structure without damaging an object but offered only limited views. CT scanners removed that roadblock by taking hundreds or thousands of 2-D images of a rotating mounted object and using them to create a 3-D digital replica of the object. The

final images are viewed in a way similar to a flip book with the ability to drag the image's x- and y-axis along one another to examine the scanned object's length, width, and depth.

"That's the power of CT," Ryan said. "It's x-ray vision because it allows us to see inside objects without destroying them."

Beginning in the 1970s, CT technology was widely used in a medical context and by the early 1990s the industrial sector was using microCT imaging. With almost thirty years of advancements, microCT imaging now allows researchers to view the micro and even nanostructure of an object while avoiding any risk of damage.

"It's really a big leap because before we would have to take multiple scans, maybe use different types of instruments, and do it in multiple sections, but now we can do it in true 3-D with this contrast enhancement and improved image quality," Ryan said. The improved tool cuts down on the time and resources required to get the level of data and high-quality images the new scanner can capture.

The system is often used to analyze biological material—one project investigated evolutionary changes in the human skeleton by comparing the amount and distribution of bone in modern and fossilized humans. Differentiating between hard and soft tissues is critical to this work which the scanner provides through enhanced resolution capabilities and improved preparation techniques including the injection of contrast agents before a sample is scanned.

Despite CT technology's roots in the medical field, micro imaging is an important tool for researchers across many disciplines.

Many of Karpyn's graduate students work with the scanner by integrating imaging capability with experimentation. They rely on the system's speed and accuracy to capture time sensitive experiments analyzing the properties of gas and liquids in relation to porous solids. One student is using CT images to map how gas is transported through different shale samples to identify and quantify their storage capacity and transfer properties. Another student is attempting to improve oil production by experimenting with chemically-tuned water-flooding as a form of enhanced oil recovery.

The range of projects does not surprise Karpyn or Ryan who have seen samples ranging from mice to fossil plants to human skulls being scanned.

"At times it's not unusual where we want to scan a specimen, maybe a synthetic material for either manufacturing purposes or for construction purposes, and we apply techniques to analyze data that are similar to what you would apply in the life sciences to differentiate different textures, different materials, identify structure," Karpyn said.

The CQI lab was established in 2001 as a formal program for CT imaging at Penn State, but the University had been using the technology for years prior as one of the few universities in America to install an industrial-scale scanner. In the almost two decades since, CT scanners have become more common in North American universities.

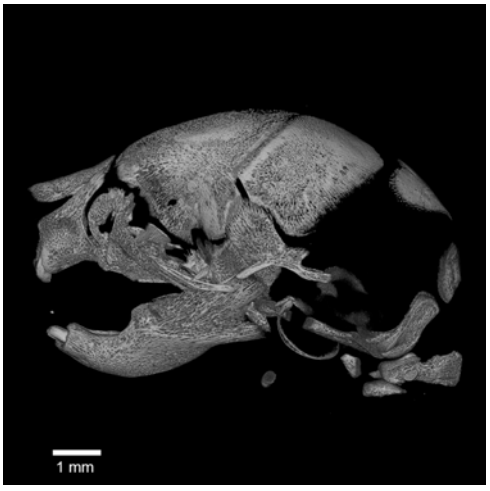
"Most major universities have some variety of a CT scanner," Ryan said. "Not all of them are like ours though—not as big or as flexible in terms of its capabilities."

The current scanner, a General Electric v|tome|x L300 multi-scale nano/microCT, brought to Penn State in 2015 after a past scanner became outdated, provides University researchers with the latest in x-ray imaging technology. A dual-tube system equipped with two powerful x-ray tubes and a high contrast digital flat panel detector allows objects of various sizes and densities to be scanned with a maximum feature detectability of 1 mm. The scanner's size and flexibility allows for high-resolution scans of hard, soft, natural, or synthetic opaque materials along with bone and tissue samples.

"It's that flexibility that our scanner has that many scanners don't have," Ryan said. "We have the facilities, the instrumentation facilities here to do really innovative work."

Cichild

Wasp



Mouse

GE v|tome|x L300 multi-scale nano/microCT system

The availability of imaging technology provides training and learning opportunities for faculty and students around the country that Ryan says may eventually benefit Penn State. The University's CQI program and its capabilities can attract young scholars or faculty who have previously been trained in the context of CT and wish to continue their research or need additional resources.

"The scanner works as a core research facility for the University," Karpyn said. "We have clients and users that are faculty or graduate students that come from different fields—from agriculture, from geosciences, from anthropology as well, from engineering."

Clients and researchers outside of Penn State have also recognized the scanner's abilities. Since its installation, Ryan said the lab has received requests from researchers across the country to visit campus and use the device. Others who cannot travel to University Park, including international researchers, have sent materials or museum artifacts to be scanned and the data then uploaded to an online repository where many researchers can examine the results. Outside companies have also used the tool to scan their products including batteries and snack foods.

While the instrument is housed within the EMS Energy Institute, the community of users and those who benefit from data obtained reaches far outside of the institute.

"I've been associated with the [EMS] Energy Institute for fifteen years, but I don't do energy research," Ryan said. "So that's a great testament to the fact that this type of instrument is so useful and [provides such diverse uses] that we can bring people together from all over campus. That's where you can have really good collaborative and transdisciplinary research projects that [are available with] these types of instruments."

To learn more about the microCT scanner, to request lab time to use the scanner, or to learn more about the CQI program, visit eesl.iee.psu.edu.

Turning waste into environmental, ECONOMIC solutions

The idea that one product, just one product, can help create high-end bicycle frames, concrete, drywall, and mechanical pencils can sound more like a late night As Seen On TV sales pitch than a potential answer to environmental and economic concerns. However, researchers including Sarma Pisupati, professor in the College of Energy and Mineral Sciences (EMS) and co-director of the EMS Energy Institute's Coal Science and Technology program, believe that extracting rare earth elements (REEs) from one waste product—coal ash—can provide an economic and environmentally solution to coal byproduct waste.

According to the Energy Information Association (EIA), in 2017 coal burning for energy generation was down five hundred thousand tons from 2012. However, many eastern and midwestern states still rely on coal as their baseload energy supplier. Pennsylvania annually mines 734.8 trillion Btu of coal which generates more than 30 million tons of coal ash to be stored or discarded by plants, according to the EIA.

"My view is that coal will lose its share for power applications, but coal is likely to become a value-added material resource," Pisupati said. Coal ash, a waste product found in mines or left after coal is burned, contains a mix of seventeen REEs that through additional refinement can become key materials for a wide range of consumer and industry products. Research by the American Chemistry Council identified that the abundant magnetic, luminescent, electrochemical, and thermal properties found in REEs can support such sectors of the American economy as electronics, health care, transportation, power generation, and petroleum refining.

"We can make a lot of products from coal that we are not able to make now because coal use has come down," Pisupati said. Removing REEs could provide solutions to the waste created by burning coal and the United States' reliance on REEs imports from other countries, including China.

Traditionally, coal preparation and combustion byproducts are disposed of by dumping the waste in landfills and retention ponds near plants or emitting gases into the atmosphere. Extracting REEs could divert some of the roughly 130 million tons of coal ash annually produced away from landfills and provide a use for coal byproducts that are removed during mine cleaning and preparation.

Along with the creation of consumer goods, collected REEs can also be used to support the renewable or alternative energy sector. Wind turbines, hydroelectric dams, and solar panels all require a mixture of concrete, semiconductor

IMAGE: Peggy Greb/ USDA

materials, and carbon fibers to construct, and coal ash waste may be used as a replacement for sand in concrete, or to make lighter, stronger pieces including turbine blades. Other elements in coal byproducts can be used to make batteries for energy storage or electric vehicles.

Public pressure, concerns about the environmental impacts of coal burning, and governmental regulations have helped push much of the energy industry away from a sole reliance on coal and toward alternative and renewable energy sources, a move that would be difficult to reverse Pisupati said.

"It would be hard to make the 180-degree turn back to coal generated power because [the power] industry is now looking at coal as a resource material than putting coal back in to power," he said.

Research into alternative disposal methods and uses for coal ash began in the 1990s but experiments and studies during the past five years have shown the process is an economically viable option.

China, the current leader in commercial REEs extraction, uses ion exchange for the removal of REEs from coal byproducts. A study in 2016, completed by a team of researchers including Pisupati and published in Metallurgical and Materials Transactions E, concluded that using aqueous ammonium sulfate, an ionic liquid, as a lixiviant is also an effective method for extracting REEs from Pennsylvania coal products.

Through examining data from the United State Geological Survey (USGS), the Lower Kittanning coal bed in the northern Appalachian Basin coal region in Pennsylvania and tests in the laboratory, the team identified an additional, low-cost way to obtain a greater supply of coal ash before mining begins along with removing higher value coal. All coal contains a small amount of minerals before it is washed and scrubbed for energy production or manufacturing. The goal is to mine coal that produces the smallest amount of ash as possible to create the most marketable supply. However, this can be difficult to obtain in shallow surface mines that may have a large bench of ash. Previously seen as an expensive waste product, benches that are rich in REEs could be removed before mining to become an additional source of REEs.

The study also provided further understanding of the relationship between particle size and cost of extraction along with the effectiveness of ammonium sulfate and a deep eutectic solvent as another lixiviants.

The second process involves how to best treat coal ash for the most effective extraction method. Researchers quickly identified physically separating REEs from coal ash as an expensive and time-consuming process, but still an effective option. If that method were to be used industry-wide, the study recommended understanding the relationship between the size of coal ash particles and the cost required to extract the available REEs.

Extraction by ammonium sulfate and a eutectic solvent both proved to be more successful and less expensive than physical extraction. Those results demonstrate the ability for U.S. companies to use coal ash as an abundant resource for REEs.

However, the study was unable to identify if those methods could be economically sustainable due to the possible changes power plants would need to make to process the coal ash on site or the cost of additional facilities. Pisupati believes that despite challenges it is possible to implement those methods to existing plants.

His past projects have helped Reliance Industries Limited study their petroleum coke supply and understand how carbon in coal can be converted to a gas which reduces carbon dioxide emissions but leaves a vanadium- and nickel-rich ash that is sent to a landfill. He believes that establishing the processes to extract REEs will require changes to plants but can be completed using existing tools, a mindset Pisupati calls a cornerstone of engineering.

"As we develop [a solution,] the tools also get modified and refined. We can use these tools to solve other problems as they come up," he said. "We are problem solvers. As problems arise we should analyze the problems, break them down, and try to solve them."

Identifying cheap and abundant sources of REEs not only provides additional uses for existing coal ash but can create a buffer to protect the United States from shifts in market prices and availability. Since the late 1990s, China has produced and exported 85 to 95 percent of the world's REE supply. In 2014, the U.S. REE reserves consisted of 1.8 million tons compared a worldwide reserve of 130 million tons, according to the USGS.

That disparity creates a threat to domestic technology companies and manufacturers who rely on REEs for consumer products, a problem that Pisupati says could be solved if REE extraction becomes an industry-wide practice. Today, China continues to be the primary producer of mineral resources despite the existence of the technology and coal byproducts supply in the United States. Reliance on other nations for REEs, the USGS warns, creates "the potential for supply interruptions in the foreseeable future, or in the long-term."

An increased number of organizations, both within and outside government offices and the scientific community, have acknowledged the economic importance of developing domestic techniques for REE extraction, which has encouraged further research. Current Department of Energy (DOE)-funded projects include exploratory studies on the most efficient ways to separate REEs from coal byproducts and methods to make the process economically feasible for commercial mines and coal processing plants. West Virginia University (WVU) and the University of North Dakota are currently exploring alternative ways to recover REEs through acid mine drainage or from lignitic material, according to DOE. While a large portion of research in the field is being conducted at other universities including WVU and University of Kentucky, those universities are eager to examine

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Welcome New Faculty & Staff

The EMS Energy Institute welcomes the following new members who have joined the Institute since our last publication. Detailed profiles can be found at **energy.psu.edu**.

Karlin Andersen

Communications Specialist
EMS Energy Institute

As the communications specialist for the EMS Energy Institute, Andersen writes articles highlighting research conducted at the institute, assists with communications for meetings and conferences, and edits communications for the department. She also supports the University Coalition for Fossil Energy Research (UCFER) by editing reports, meeting documents and the UCFER newsletter. Andersen earned her B.A. from Whitworth University in Spokane, Washington and is currently working toward a master's degree in media studies in the Donald P. Bellisario College of Communications.

Sekhar Bhattacharyya

Associate Professor
John and Willie Leone Family Department of Energy and Mineral Engineering

Bhattacharyya brings twenty-three years of experience in mining and energy industries to his position as an associate professor in the John and Willie Leone Family Department of Energy and Mineral Engineering (EME). He joined EME in August of 2017, after previously teaching at the New Mexico Institute of Mining and Technology and working as a senior mining engineer in Utah. His research expertise includes mine design, mine ventilation, geostatistics, and mine safety and health.

Ashley Comly

Staff Assistant
EMS Energy Institute

Comly is a financial assistant in the EMS Energy Institute. Her duties include ordering the delivery and pickup of all gas cylinders; scheduling conference rooms, calls, meetings, and arranging catered meals for events; processing group meal reports; distributing visitor parking permits; placing orders for general office supplies as well as research equipment and supply orders; assisting with booking fleet reservations and travel. She also serves as the direct assistant for institute director, Chunshan Song, which includes managing his calendar and scheduling meetings; welcoming guests; making hotel and flight reservations; delivering and sending mail; managing and renewing memberships; and other tasks as needed.

Arash Dahi Taleghani

Associate Professor
John and Willie Leone Family Department of Energy and Mineral Engineering

Taleghani is a associate professor of petroleum engineering in the John and Willie Leone Family Department of Energy and Mineral Engineering. He earned a M.S. in civil engineering from the Sharif University of Technology and his Ph.D. in petroleum engineering from the University of Texas at Austin. Prior to joining Penn State he was a tenured faculty member at Louisiana State University and has ten years of combined experience in applied engineering, research, and consulting. He has published in peer-reviewed journals and has four patent applications in the fields of drilling and completion.

Hamid Emami-Meybodi

Assistant Professor
John and Willie Leone Family Department of Energy and Mineral Engineering

Emami-Meybodi is an assistant professor of petroleum and natural gas engineering. His research expertise is in analytical and numerical modeling of fluid flow and transport phenomena in porous media with applications to storage of carbon dioxide in geological formations, unconventional gas reservoirs, and enhanced oil recovery. He has conducted research on solutal and thermal natural convection, rate transient analysis, hydraulic fracturing, water and polymer flooding, formation steam heating, and solvent injection in heavy oil reservoirs.

Khaled Enab

Postdoctoral Scholar
John and Willie Leone Family Department of Energy and Mineral Engineering

Enab earned his master's degree and doctoral degree in petroleum and natural gas engineering from Penn State in 2012 and 2018, respectively. He is currently a postdoctoral scholar researching the applications of machine learning in the petroleum engineering field, unconventional reservoirs, and enhanced oil recovery.

Christy English

Staff Assistant
EMS Energy Institute

English is the financial coordinator for the EMS Energy Institute. Her duties include the review and approval of financial forms, budget monitoring and expenditure review, compliance with various grant requirements and restrictions, and various other tasks to assist the administrative support coordinator. Christy joined the EMS Energy Institute in July 2017.

Mohammad Ghamari

Postdoctoral Scholar
John and Willie Leone Family Department of Energy and Mineral Engineering

Ghamari is a postdoctoral fellow in the John and Willie Leone Family Department of Energy and Mineral Engineering with a focus on computer science. He joined the EMS Energy Institute in 2018.

William Groves

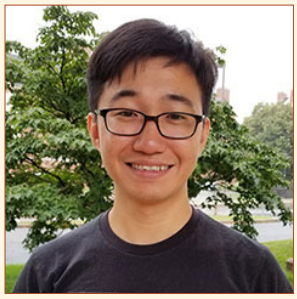
Associate Professor
John and Willie Leone Family Department of Energy and Mineral Engineering

Groves, associate professor of industrial health and safety in the John and Willie Leone Family Department of Energy and Mineral Engineering, has been with the University since 2000. His research focuses on health and safety measures related to exposure to organic vapors and the health effects of exposure. He previously held positions with Aetna Life and Casualty, Newport News Shipbuilding, and the Dow Chemical Company. He earned his Ph.D. in industrial health from the University of Michigan. Groves joined the EMS Energy Institute in 2018.

Amin Mehrabian

Assistant Professor
John and Willie Leone Family Department of Energy and Mineral Engineering

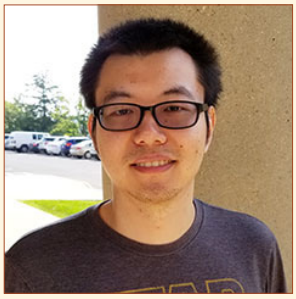
Mehrabian, associate professor in the John and Willie Leone Family Department of Energy and Mineral Engineering, earned his Ph.D. in petroleum engineering from the University of Oklahoma. He previously worked as a principal engineer for Halliburton Energy Services in Houston, Texas and holds a U.S. patent application on managed pressure drilling. Mehrabian joined the EMS Energy Institute in 2017 to research the mechanics and physics of porous media with applications in wellbore, shale, and reservoir geomechanics of drilling and completions operations.



Xiaolong Ouyang

Postdoctoral Scholar
John and Willie Leone Family Department of Energy and Mineral Engineering

Ouyang began his postdoctoral research at Penn State in 2018 with a focus on multiphase flow in porous media, heat transfer, and geothermal energy.



Cheng Peng

Postdoctoral Scholar
John and Willie Leone Family Department of Energy and Mineral Engineering

Peng is completing postdoctoral research in the John and Willie Leone Family Department of Energy and Mineral Engineering. He joined the EMS Energy Institute in 2018.

Antoine Piedfert

Postdoctoral Scholar
John and Willie Leone Family Department of Energy and Mineral Engineering

Piedfert started as a postdoctoral scholar in the EMS Energy Institute and the John and Willie Leone Family Department of Energy and Mineral Engineering in 2018 to further his research in petroleum and natural gas engineering.

Mohammad Rezaee

Assistant Professor
John and Willie Leone Family Department of Energy and Mineral Engineering

Rezaee is an assistant professor of mining engineering in the John and Willie Leone Family Department of Energy and Mineral Engineering. Prior to joining Penn State, he served as a postdoctoral research associate in Virginia Polytechnic Institute and State University's Mining and Minerals Engineering Department. He brings combined industry and research experience with his background as a mining engineer consultant and a Ph.D. from the University of Kentucky. His research interests including sustainable mining, mineral processing, and waste management. Rezaee is an active member of the Society for Mining, Metallurgy & Exploration and the Society of Mining Professors.

Parisa Shokouhi

Associate Professor
Civil and Environmental Engineering

Shokouhi is an associate professor of engineering science and mechanics. Her main research interests include stress wave propagation in fractured media, nondestructive evaluation (linear and nonlinear ultrasonic testing), structural health monitoring (acoustic emission), machine learning and data analytics, and seismic metamaterials. She received her doctoral degree in civil engineering from Rutgers University.

Xiang Zhao

Research Staff
EMS Energy Institute

Zhao received his Ph.D. in 1996 in engineering mechanics from Xi'an Jiaotong University in China. From 1999 to 2004, he conducted research on nearfield acoustical holography for noise source identification at Wayne State University. From 2004 to 2006, he conducted research on photoacoustic tomography for material characterization with laser-induced ultrasound at the Penn State. After that, he worked at Guidedwave Inc. At the EMS Energy Institute, he currently is working on a gas volume audit with special interest in acoustic well stimulation and reservoir simulation.

Tieyuan Zhu

Assistant Professor
Geosciences

Zhu has been an assistant professor of geophysics in the Department of Geosicnces since 2016. He earned a B.S. from China University of Geosciences in 2005, a M.S. from the Chinese Academy of Sciences in 2008, and a Ph.D. in geophysics from Stanford University in 2014. His main research interests are in seismic attenuation, true-amplitude seismic imaging and inversion, time-reversal theory, and carbon dioxide monitoring. He was a Jackson Distinguished Postdoctoral Fellow from 2014 to 2016 at the University of Texas at Austin.

Honors & Awards

Pisupati elected a 2018 American Chemical Society Fellow

Sarma Pisupati, professor of energy and mineral engineering, was elected a 2018 Fellow by the American Chemical Society (ACS). Pisupati was one of fifty-one scientists selected as part of the 2018 class of ACS Fellows. He was honored during the society's fall national meeting held this past August in Boston.

The ACS Fellows Program recognizes and honors members of the American Chemical Society for their outstanding achievements in and contributions to the science and the profession and for their equally exemplary service to the ACS Society. Only 1,059 of the society's more than 157,000 members from academia, industry, government labs, and small business have been distinguished with this honor.

"This is a great honor to be appreciated by professional colleagues and elected a Fellow for my work in helping to solve industrial problems through fundamental research and training the future workforce," Pisupati said. "I am very grateful for this recognition."

The ACS recognized Pisupati for "contributions impacting the availability and operation of gasifiers and fluidized bed combustors through excellence in fundamental and applied clean energy research, and outstanding energy engineering education." His contributions to the ACS community were also cited. He served in several leadership roles in the ACS Division of Fuel Chemistry and Division of Petroleum Chemistry, initiated a trust fund for student travel, revitalized technical programming, and established an outreach web portal.

IMAGE: ACS/Peter Cutts Photography

Energy Institute Director wins American Chemical Society National Award

Chunshan Song, EMS Energy Institute and University Coalition for Fossil Energy Research (UCFER) director, was selected by the American Chemical Society (ACS) to receive the George A. Olah Award in Hydrocarbon or Petroleum Chemistry. Song was recognized for his groundbreaking research in carbon dioxide capture and utilization as well as adsorption and catalysis in fuel processing. Song will be honored at a reception in April 2019 held during the 257th ACS National Meeting in Orlando, Florida. The award was originally established in 1948 as the ACS Award in Petroleum Chemistry. It was renamed in 1997 after the Nobel laureate George A. Olah to recognize, encourage, and stimulate outstanding research achievements in hydrocarbon or petroleum chemistry.

Song awarded
Honorary Professorship
at Tianjin University

Chunshan Song, distinguished professor of fuel science and director of the EMS Energy Institute, was named an honorary professor by Tianjin University in China in 2017.

"Receiving the honorary professorship is a great honor for me, my research group, and for Penn State," Song said. "Tianjin University is one of the oldest universities and one of the strongest national universities in engineering and science in China and has always been the top chemical engineering school in the nation."

Song was invited to give a plenary lecture at the 18th Chinese National Congress on Catalysis held in Tianjin in 2017, an honor he said surprised him.

"I've been honored by the American Chemical Society and North American Catalysis Society as well as with guest or visiting professorships at universities in the United Kingdom, France, and China, but this is the first time I've been given an honorary professorship," Song said. "I'm grateful for being honored for contributions to both energy and chemical engineering."

He also was selected as a Global Alumni Fellow by Osaka University in Japan. Osaka University, one of the top national universities in Japan, established the Global Alumni Fellow to promote international collaboration in education and research. It is awarded to alumni who are academically active overseas. Song earned his master's and doctoral degrees in applied chemistry from Osaka University.

Wang wins
Outstanding Young Researcher
Award at Carbon Dioxide Conference

Xiaoxing Wang, an associate research professor in the EMS Energy Institute, received the Outstanding Young Researcher Award at the 15th International Conference on Carbon Dioxide Utilization (ICCDU), held in Shanghai, China in 2017.

The annual conference is hosted by the Shanghai Advanced Research Institute at the Chinese Academy of Sciences and Shanghai Tech University. Presenters from across the globe attend the ICCDU to present research focusing on the capture, utilization, and storage of carbon dioxide in the hopes of reducing greenhouse emissions and offering carbon dioxide as a new carbon source for chemicals and fuels.

The Outstanding Young Researcher Award brings international attention to Wang's development of carbon capture techniques and recognizes Penn State as a world leader in the advancement of green energy.

"This win is a milestone in my research career," Wang said. "It encourages me to make more original and innovative contributions to my field."

The award recognizes his developmental research into carbon capture using molecular basket sorbents. These sorbents, when fully developed, will be able to capture and repurpose the excess traces carbon dioxide in the atmosphere.

Petroleum professor wins international award in reservoir engineering

"To have peers say that you are the absolute best worldwide in that field is really very amazing," said Russell Johns, George E. Trimble Chair in Earth and Mineral Sciences and professor of petroleum and natural gas engineering, after winning the 2016 Society of Petroleum Engineers (SPE) Reservoir Description and Dynamics Award.

Johns, who was presented the award at the SPE Annual Technical Conference and Exhibition held in 2016 in Dubai, United Arab Emirates, specializes in advanced oil recovery. His research on using water, carbon dioxide, and surfactants has led to more efficient recovery practices.

About two-thirds of available oil is left behind even after primary and secondary recovery methods are employed, said Johns, whose research has contributed to significant gains in extraction of oil by tertiary methods. This leaves a large target for recovery by more advanced techniques.

Improving extraction efficiency is critical to the energy security of the United States because it closes the gap between imports and exports. Johns has advanced techniques to recover more oil including injection of carbon dioxide and surfactants (soaps). Along with his students, he recently published a major paper on prediction of phase behavior and oil recovery by forming microemulsions through injection of surfactants.

Mathews named a 2016 Fellow of the American Chemical Society

Jonathan Mathews, associate professor of energy and mineral engineering, was named a 2016 Fellow by the American Chemical Society (ACS). The ACS Fellows Program recognizes members for their outstanding contributions to science and the profession, and service to the ACS community. He was honored during the 2016 ACS National Meeting and Exposition.

"I'm incredibly honored," Mathews said. "To be one of only fifty-seven inductees in a society of nearly 157,000 members speaks to the work that my colleagues and I have performed for our fields and the society."

Mathews served as the inaugural co-chair of the ACS Energy and Fuels Technical Division, which was formed after the merger of two divisions, Fuel Chemistry and Petroleum. He also assisted the division with strategic planning and now serves as the membership chair.

In addition, Mathews served as chair for the 2013 International Conference on Coal Science and Technology. He also serves on the advisory board of the journal Energy and Fuels, as Penn State's representative for the Coal Users Research Council, and as a reviewer and author of nearly seventy coal-related journal articles.

EMS professors, couple to research Colombian shale through Fulbright Awards

What are the odds that two spouses and Penn State professors both receive Fulbright awards for consecutive semesters in the same country?

For Luis Ayala and Zuleima Karpyn, luck seemed to be on their side.

Ayala, the William A. Fustos Family Professor in Energy and Mineral Engineering and associate department head for graduate education, and Karpyn, the Quentin E. and Louise L. Wood Faculty Fellow in Petroleum and Natural Gas Engineering, both applied for the Fulbright-Colciencias Innovation and Technology Award from the Fulbright Program with the hopes of one of them landing the opportunity to conduct research in Colombia for a semester.

Karpyn and Ayala, both Energi Simulation Co-Chairs in Fluid Behavior and Rock Interactions, participated in the Fulbright program in the fall 2016 and spring 2017 semesters, respectively.

The U.S. Fulbright Program offers competitive, merit-based grants for students, scholars, teachers, and professionals, and aims to create mutual understanding among the many cultures of the world. The Fulbright-Colciencias Innovation and Technology Award is designed specifically for fundamental and applied research in Colombia.

"We wanted to use the Fulbright award to make a difference professionally as teachers and researchers," Karpyn said, who is also a 2018 Penn State Administrative Fellow mentored by Nick Jones, executive vice president and provost.

Graduate student receives FAA student award

— shared from U.S. Department of Transportation

As a Penn State energy and mineral engineering doctoral candidate, Joseph Abrahamson '17 was selected to receive the Federal Aviation Administration's (FAA) Centers of Excellence Student of the Year Award. Abrahamson was chosen for his research with developing data-based tools to predict emission indices for alternative fuels. His faculty adviser was Randy Vander Wal, professor of energy and mineral engineering, and materials science and engineering.

Abrahamson's research focused on nonvolatile particulate matter (nvPM) emissions from conventional and alternative fuels. He worked on developing predictive tools based on data compiled across a comprehensive set of NASA-coordinated field campaigns to separate nvPM fuel dependence from engine combustor conditions in order to develop predictive tools for nvPM emission indices for alternative fuels, in partnership with GE Aviation.

"These predictive tools will be useful for testing future fuels and developing future FAA regulations, and they should enable future fuels to be evaluated without requiring expensive rigs or full-scale combustor testing," Abrahamson said.

Ayala named **Fustos Family Professor** in Energy and Mineral Engineering

Luis Ayala, professor of petroleum and natural gas engineering, was named the inaugural William A. Fustos Family Professor in Energy and Mineral Engineering in 2016. The endowed professorship was established with a $1 million gift from William and Lindsey Fustos, both Penn State graduates.

"I'm honored to have been selected as the first William A. Fustos Family Professor in Energy and Mineral Engineering," Ayala said. "This financial support will help my research group further our natural gas production and engineering research and help elevate Penn State as a leader in this area."

Ayala's research focuses on natural gas engineering, gas well performance, hydrocarbon phase behavior, and advanced numerical modeling. His work addresses novel methods to understand the behavior of natural gas reservoirs in unconventional formations, and how those behaviors change as gas is produced. His team also investigates methods to optimize the production of natural gas, from extraction to storage, to transportation. He has authored or co-authored more than eighty publications in peer-reviewed scientific journals and proceedings.

"Luis is very deserving of this professorship. He has made numerous advances in different facets of natural gas engineering research, and this professorship will allow him to continue his excellence," said Turgay Ertekin, former head of the John and Willie Leone Family Department of Energy and Mineral Engineering. "Mr. Fustos is a distinguished alumnus who has been a leader within the industry. His vision—that Penn State should be a pioneer in advancing the petroleum and natural gas engineering—is one we share here."

Turning waste into environmental, economic solutions cont.

Pennsylvania's REE rich Appalachian region and collaborate with Penn State.

Pisupati's current research provides a greater understanding about which types of minerals are more susceptible for extraction of REEs by ion exchange and other separation techniques. He sees the possibility for REEs, with certain types of mineral associations, being removed from coal byproducts becoming an industry-wide practice with the right technology that researchers at Penn State are currently developing and are near patenting.

"As engineers we can solve this problem in both an environmentally friendly way and an economically viable way. If it is expensive, no one can afford the technology," Pisupati said. "Rather than blame what it is, we need to start changing it."

Penn State to host conference focused on geomodeling food, energy, water nexus

For the first time in ten years, the Annual Conference of the International Association for Mathematical Geosciences (IAMG) will be hosted in the United States. Penn State, a tier-one research university, will host the twentieth annual conference August 10-16, 2019 on the University Park campus in State College, Pennsylvania. The conference will include such topics as geomathematics, geostatistics, geoinformatics, and geomodeling, with a special focus on geomodeling issues at the intersection of food, water, and energy.

The conference's theme will be examined through oral and poster presentations, plenary presentations, and short courses along with select articles to be published in a special edition journal.

Interested researchers can submit a short abstract through the conference website by January 8, 2019. Any contributions to the development and application of mathematics and information theory focused on geoscientific problems are welcome. The conference committee will select authors to present their research through either an oral presentation or a poster. Authors can also choose to submit a manuscript which will be considered for publication in a special edition of a peer-reviewed journal. A complete timeline for abstract submission, review and notification is available on the IAMG 2019 website.

Hosting the conference will be a joint effort between IAMG, the College of Earth and Mineral Sciences (EMS) and the EMS Energy Institute.

"EMS is a world leader in generating the fundamental knowledge needed to develop novel solutions for the issues pertaining to the conference theme," said Sanjay Srinivasan, IAMG 2019 conference chair. "The conference speakers will share their insights into how water, climate, and ecosystems will change in the face of the energy and food needs of a growing human population."

Situated in the Appalachian Mountains, the University Park campus is near major, unconventional shale gas production areas and coal and mineral mining areas. Several local optional tours and activities will be offered to help attendees learn more about energy resources in the area and the regional culture.

To learn more about IAMG 2019 visit iamgconferences.org/iamg2019. Register by April 30, 2019 for a discounted registration fee.

EME professor appointed Missouri S&T associate dean of research

Angela Lueking, professor of energy and mineral engineering and chemical engineering, joined Missouri University of Science and Technology (S&T) as associate dean of research in the College of Engineering and Computing on August 1, 2018. Lueking was a Penn State faculty member since 2003. She taught graduate and undergraduate courses in the both the Department of Chemical Engineering and the John and Willie Leone Family Department of Energy and Mineral Engineering. While at Penn State her research focused on improving absorption, catalysis, and environmental separations of hydrogen and carbon. In 2012 she was selected for a Marie Curie International Incoming Fellowship allowing her to broaden her research as a visiting scholar at the University of Crete in Greece. Immediately prior to joining S&T, she served a two-year appointment as a program director for the National Science Foundation.

End of Year Awards

2018

Wilson Banquet and Awards Presentation

The College of Earth and Mineral Sciences held its 2018 Wilson Banquet and Awards Presentation on April 15 to recognize student achievement, faculty mentoring, faculty commitments to service, and excellence in research and teaching.

Promotions

Angela Lueking, professor of energy and mineral engineering

Jonathan Mathews, professor of energy and mineral engineering

Faculty Advising Award

Luis Ayala, William A. Fustos Family Professor of Energy and Mineral Engineering and associate head for graduate education, EME

G. Montgomery and Marion Mitchell Award for Innovative Teaching

Mort Webster, associate professor of energy engineering

Wilson Award for Excellence in Research

Russell Johns, professor of petroleum and natural gas engineering

Wilson Research Initiation Grant

Mohammad Rezaee, assistant professor of mining engineering — "Feasibility Study of Recovering Rare Earth Elements from Coal Waste Streams Through an Integrated Bio-Extraction Process"

Tieyuan Zhu, assistant professor of geosciences — "Quantifying Subsurface CO_2 Leakage Hazards Using Seismic Coda Waves"

Earth and Mineral Sciences Academy for Global Experience Laureate

Gregory S. Kojadinovich, Petroleum and Natural Gas Engineering '18

2018 Department of Energy and Mineral Engineering student awards

The John and Willie Leone Family Department of Energy and Mineral Engineering had its 2018 Awards Banquet on April 13. This banquet recognizes students and faculty in the department. The banquet is held in conjunction with the G. Albert Shoemaker Lecture. EMS Energy Institute Students who received awards are listed below.

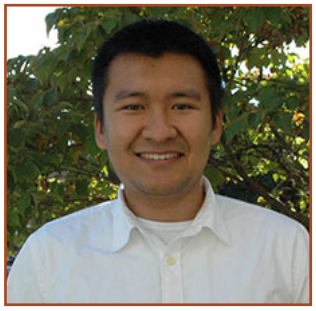
C. C. Wright Award

Joseph P. Abrahamson, Ph.D. student

Outstanding Graduate Teaching Assistant

Gregory S. Kojadinovich, M.S. student

Graduate Teaching Assistant



Daulet Magzymov, Ph.D. student

Student Merit Awards

Ian W. Wasserman, ENENG undergraduate junior student

Lihe Xiu, ENENG undergraduate senior student

Staff Awards

2018

30-Year

Kelly Rhoades, administrative assistant

25-Year

Brad Maben, research technologist

20-Year

Barbara Robuck, writer/ editor & public relations

5-Year

Heather Harpster, staff assistant

2017

25-Year

Ronald Wasco, research assistant

20-Year

Elizabeth Wood, multimedia specialist

10-Year

Steven Swavely, research technologist

Retirement

Cindy Anders, administrative assistant

2017 April 23, 2017 Wilson Banquet and Awards Presentation

Retirements

Sharon Falcone Miller, senior research associate, EMS Energy Institute, assistant professor of energy and mineral engineering, and director of Office of Student Development

Gareth Mitchell, research associate, EMS Energy Institute

Gladys Snyder Junior Faculty Grant

Chiara Lo Prete, assistant professor of energy economics—"Understanding the Impacts of Water Scarcity on the Evolution of the U.S. Electric Power System"

Promotion

Zuleima Karpyn, professor of petroleum and natural gas engineering

April 7, 2017 Department of Energy and Mineral Engineering student awards

Outstanding Graduate Teaching Assistants

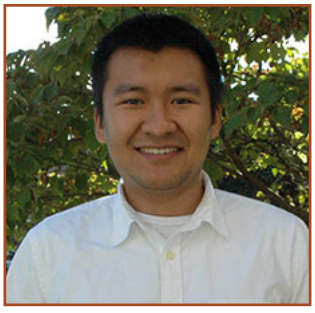
Vijayaragavan Krishnamoorthy

Miral Tawfik

Student Merit Awards

Khalifa Adel K. M. Aljaberi, undergraduate in energy engineering

Joseph P. Abrahamson, Ph.D. student



Daulet Magzymov, PNGE Graduate

April 17, 2016 Wilson Banquet and Awards Presentation

2016

Promotions

Luis Ayala, professor of petroleum and natural gas engineering

Zhen Lei, associate professor of energy and environmental economics

Li Li, associate professor of petroleum and natural gas engineering

John Yilin Wang, associate professor of petroleum and natural gas engineering

E. Willard and Ruby S. Miller Faculty Fellow

Chiara Lo Prete, assistant professor of energy economics — "Complementarity-based Equilibrium Models for the Analysis of Market Power in Electric Distribution Networks"

25-Year Service Award

Sarma Pisupati, professor of energy and mineral engineering and co-director of Coal Science and Technology program, EMS Energy Institute

Gladys Snyder Junior Faculty Grants

Hamid Emami-Meybodi, assistant professor of petroleum and natural gas engineering — "Unconventional Gas Reservoirs: Production Data Analysis"

Joel Landry, assistant professor of environmental and energy economics — "What are the Economic and Emissions Impacts of New Climate Regulations on Big Trucks?"

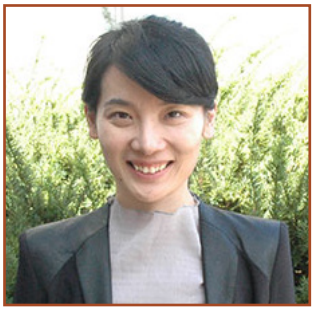
April 8, 2016 Department of Energy and Mineral Engineering student awards

Outstanding Graduate Teaching Assistants

Joseph P. Abrahamson, Ph.D. student

Devesh Kumar, Ph.D. student

Student Merit Award

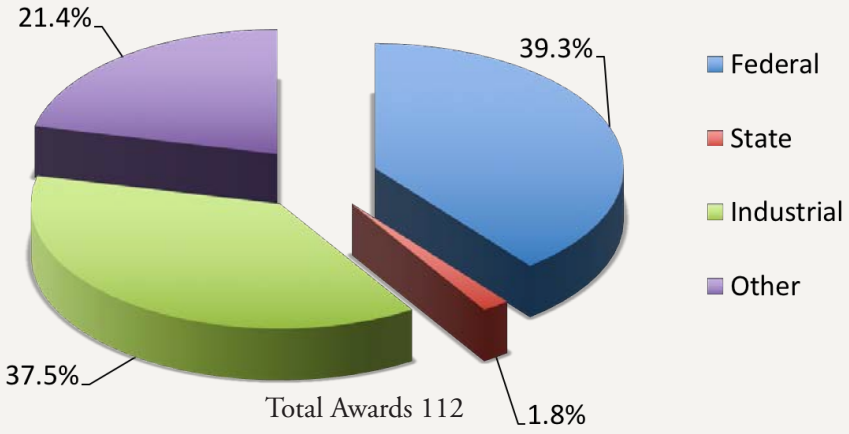


Miao Zhang, Ph.D. student

Summary of projects & FUNDING

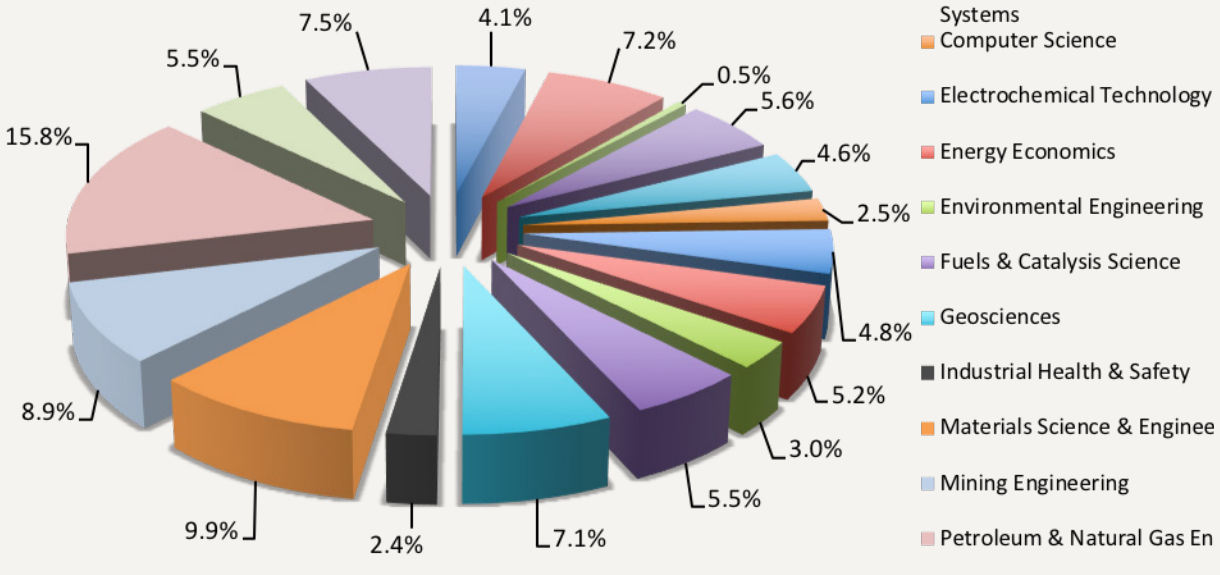
EMS Energy Institute Awards by Source

(Fiscal Year 2015/2016 through 2017/2018)



EMS Energy Institute Projects by Program Area

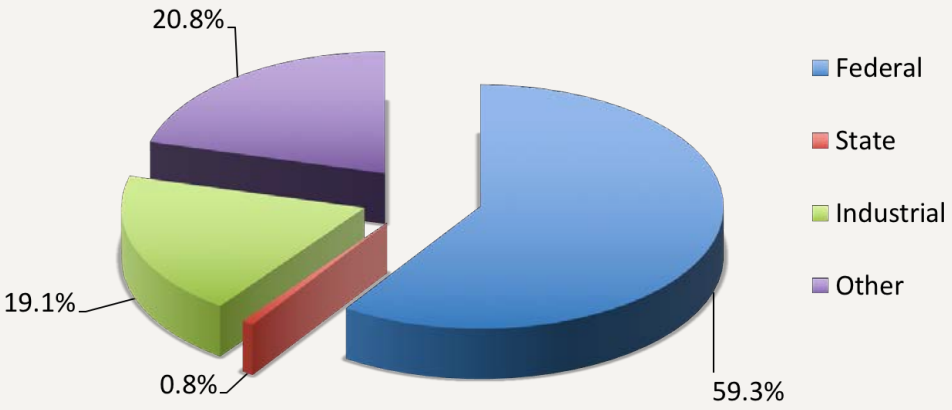
(Fiscal Year 2015/2016 through Fiscal Year 2017/2018)



112 projects

EMS Energy Institute Funding by Source

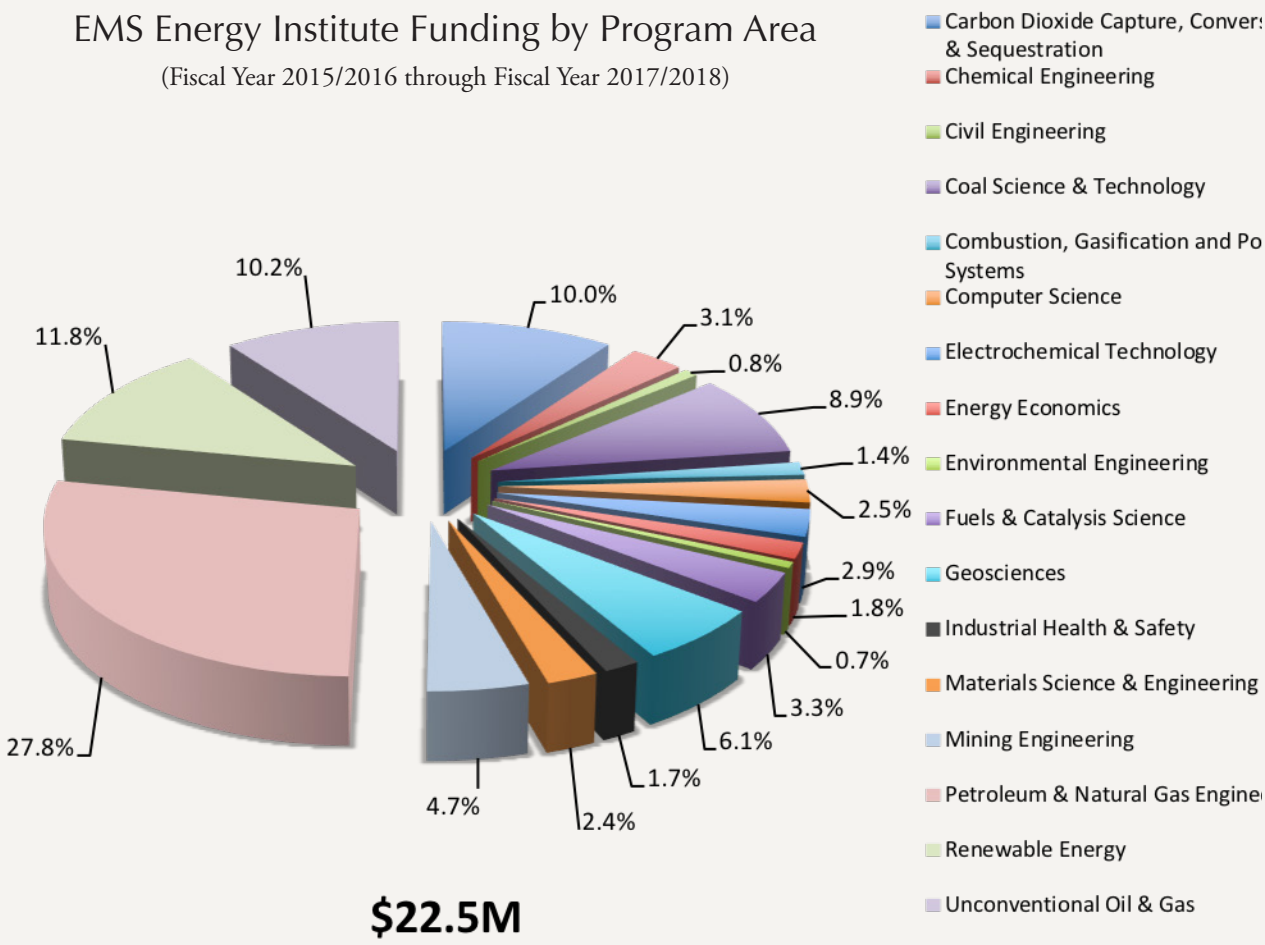
(Fiscal Year 2015/2016 through 2017/2018)



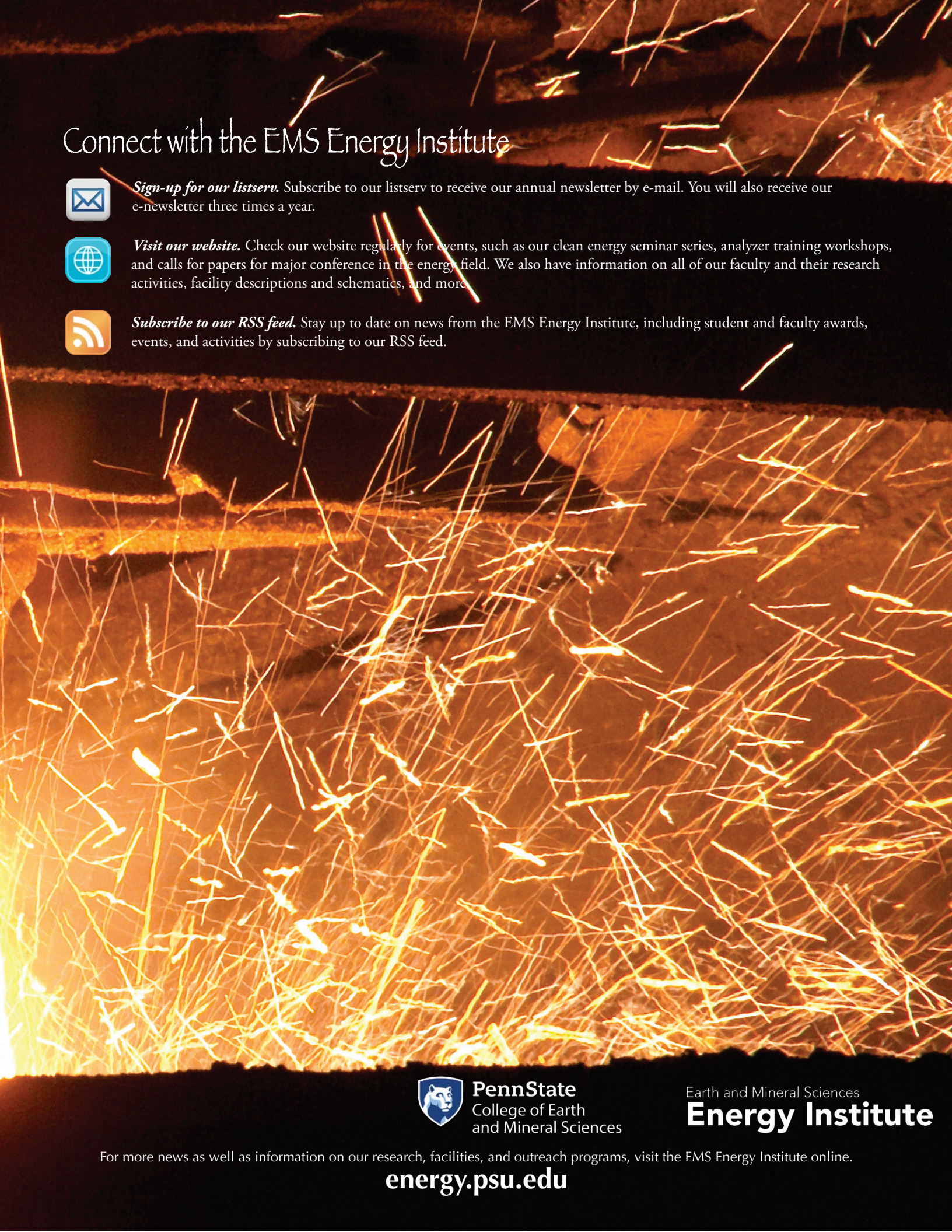
Total Funding $22.5 million

EMS Energy Institute Funding by Program Area

(Fiscal Year 2015/2016 through Fiscal Year 2017/2018)



$22.5M



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Sign-up for our listserv. Subscribe to our listserv to receive our annual newsletter by e-mail. You will also receive our e-newsletter three times a year.

Visit our website. Check our website regularly for events, such as our clean energy seminar series, analyzer training workshops, and calls for papers for major conference in the energy field. We also have information on all of our faculty and their research activities, facility descriptions and schematics, and more.

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PennState
College of Earth
and Mineral Sciences

Earth and Mineral Sciences
Energy Institute

For more news as well as information on our research, facilities, and outreach programs, visit the EMS Energy Institute online.

energy.psu.edu