ENERGY INNOVATION

Spring 2020

PennState
College of Earth
and Mineral Sciences

Earth and Mineral Sciences
Energy Institute

Letter from the Director

Welcome to the spring 2020 edition of the EMS Energy Institute (EI) Newsletter. This edition showcases faculty research in several topical areas, introduces new employees, and highlights the new EI seed grants and the honors received by our students, faculty, and staff.

The research, education, and outreach efforts of the institute continue to focus on energy and energy-related environmental effects and involve 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 associated environmental issues. While Penn State has a long history of carbon science and engineering, we saw a resurgence in this activity over the last year with several carbon materials projects being implemented. The number of publications from EI researchers in peer-reviewed journals has increased significantly, with 1,043 journal articles by the end of 2018. In 2018, 33 new external research projects were established, supported by more than $8.7 million in funding. Science citations to papers published by EI researchers continue to expand at an impressive rate, with 30,727 science citations by the end of 2018, according to the Web of Science. Those figures reflect our growth as an institute with more faculty, visiting scholars, and graduate students currently working in our labs, an increased presence at domestic and international conferences, researchers being awarded, more industry and government funded projects, and the ability to collaborate with researchers outside of Penn State through travel or online communication.

In Spring 2019, EI funded four new seed grant proposals based on a general call for proposals and a competitive peer review and selection process. Each of these new seed grant proposals involve collaborative research on novel ideas in one of three areas, energy production and upstream research; energy utilization and downstream research; and energy systems and materials. EI participated with Sarma Pisupati, Kwadwo Osseo-Asare, and Tim White in the development of the Center for Critical Minerals (C^2M) that was recently established in the College of Earth and Mineral Sciences under the leadership of Dean Kump. The institute, which hosts the center, provided C^2M with $85,000 in seed funding and equipment as well as administrative and budget support. C^2M is also supported by the Penn State Office of the Dean and the Department of Energy and Mineral Engineering. More on the EI seed grants and C^2M can be found in this newsletter.

We have also experienced a few changes in EI. We added new faculty and staff members to our ranks, but we also saw the departure of two staff members, Karlin Andersen, our communications specialist, who left to attend graduate school, and Ashley Comly, a staff assistant, who moved to another position within the University. We welcomed Jennifer Matthews and Grace Choi, who replaced Karlin and Ashley, respectively.

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, 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
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.

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Table of Contents

Featured Stories

Zuleima Karpyn appointed associate dean in College of Earth and Mineral Sciences

By Patricia Craig

Zuleima Karpyn, professor of petroleum and natural gas, has been appointed associate dean of graduate education and research in the College of Earth and Mineral Sciences. Karpyn will start in her new role effective July 1, 2020.

"Zuleima will be an excellent associate dean for our college's Office of Graduate Education and Research (ADGER)," said Lee Kump, the John Leone Dean in the College of Earth and Mineral Sciences. "She brings the breadth of experiences, and the vision, passion, and energy needed to facilitate discovery, innovation, and collaboration in our college."

Karpyn will succeed Senior Associate Dean John Hellmann, who has held the ADGER position since 2012. Hellmann will continue as associate dean through the end of June.

> "I am honored to have been selected as the next associate dean of ADGER," said Karpyn. "John has built an outstanding program and has guided the college on a path for success. I am appreciative of his leadership and my goal is to continue to build on his legacy."

Karpyn brings a wealth of leadership skills to this position. Since 2010, she has served as scientific director of the Center for Quantitative X-ray Imaging, now a core research facility of the Institutes of Energy and the Environment. She served as interim director of the EMS Energy Institute from 2013-14. Since 2017 she has served as program chair of the Petroleum and Natural Gas Engineering program in the John and Willie Leone Family Department of Energy and Mineral Engineering. She was selected the 2018-19 Administrative Fellow to the Executive Vice President and Provost Nick Jones and as a 2018-19 Big Ten Academic Alliance Academic Leadership Program Fellow. In 2019, she was appointed coordinator of STEM Faculty Development Initiatives in the Office of the Vice Provost for Faculty Affairs.

"My goals for improving graduate education and research in the college begin with ADGER being a model service unit for our research faculty, staff, and students." Karpyn said. "I see myself as a maximizer, someone who seeks to transform something good into something excellent. The college has a great intellectual capacity, access to world-class research facilities and resources, well-regarded graduate programs both nationally and internationally, and the impetus to be a place where everybody can participate, engage, and thrive."

Karpyn holds the Quentin and Louise Wood Endowed Faculty Fellowship in Petroleum and Natural Gas Engineering. Her area of research expertise is multiphase flow dynamics in porous media, image data analysis and applications of X-ray computed tomography to the study of geomaterials. She integrates laboratory experiments and numerical modeling to improve understanding, representation, and prediction of transport behavior in geologic systems, underground pollutant migration and hydrocarbon recovery processes.

In 2016-17, Karpyn was selected as a Fulbright U.S. Scholar where she traveled to Colombia to collaborate on technical challenges associated with the development of unconventional shale oil and gas reservoirs, such as La Luna shale, located in the Middle Magdalena Basin in central Colombia, and compare it with U.S. shales of similar quality. She also taught graduate and undergraduate students at the National University of Colombia at Medellín, as well as EAFIT University.

Karpyn holds a B.S. in chemical engineering from Universidad Central de Venezuela, and an M.S. and Ph.D. in petroleum and natural gas engineering from Penn State.

Song receives George A. Olah Award from the American Chemical Society

By Ashley A. Nottingham

2019 George A Olah Award recipient Chunshan Song (center) is presented his award by John Adams, Chair of the Board of Directors, American Chemical Society (right), and Bonnie A. Charpentier, ACS President (left).At ACS National Award Ceremony during ACS National Meeting in Orlando, FL, on April 2, 2019. IMAGE: ACS

Chunshan Song, Distinguished Professor of Fuel Science in the John and Willie Leone Family Department of Energy and Mineral Engineering and director of the EMS Energy Institute, received the 2019 George A. Olah Award in Hydrocarbon or Petroleum Chemistry from the American Chemical Society (ACS). He was presented with the award during the ACS national meeting, held March 31 through April 4 in Orlando, Florida.

This national award is presented to recognize, encourage, and stimulate outstanding research achievements in hydrocarbon or petroleum chemistry. Song received the award for "groundbreaking contributions to adsorptive desulfurization of hydrocarbon fuels, adsorptive carbon dioxide separation, and catalytic carbon dioxide conversion to fuels and chemicals."

"Song is an exceptional researcher, innovator, teacher, mentor, and leader in hydrocarbon and petroleum chemistry," said Anne M. Gaffney, a Distinguished Laboratory Fellow at the Idaho National Laboratory. "Specifically, Song has addressed several difficult and complex problems in hydrocarbon and petroleum chemistry. These include outstanding contributions to adsorptive and catalytic desulfurization of hydrocarbon fuels, adsorptive carbon dioxide separation, catalytic carbon dioxide conversion to fuels and chemicals, catalysis in fuel processing for fuel cells, thermal stability of jet fuels and novel catalytic routes for petrochemicals, and advanced-engineering plastics."

He serves as the founding director of the University Coalition for Fossil Energy Research, a six-year, $20 million project funded in 2016 by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory. He is also the founding co-director for the international Joint Center for Energy Research (JCER), a partnership formed in 2011 between Penn State and Dalian University of Technology, China.

Song, also a professor of chemical engineering and associate director of Penn State's Institutes of Energy and the Environment, is a world leader in clean fuels and catalysis research.

He specializes in catalytic conversion and use of energy resources, such as coal, petroleum, natural gas, biomass, and carbon dioxide as a carbon source. His current research interests include catalysis in fuel processing for ultra-clean fuels and fuel cells; adsorptive carbon dioxide capture and separation; catalytic carbon dioxide conversion and utilization; reforming of hydrocarbon and

continued on page 29

Penn State launches Center for Critical Minerals

By Patricia Craig

Edward Steidle, former dean of Penn State's College of Mineral Industries, the predecessor of the present College of Earth and Mineral Sciences, wrote these visionary words in 1952:

> "American industry will be faced not only with a lack of raw materials at home, but also with the difficulty of obtaining supplies abroad."

Those words still ring true today, and in response, Penn State has launched a new center, the Center for Critical Minerals.

Minerals are part of virtually every product manufactured in the modern global economy. New technologies from touch-screen displays to batteries to solar panels, including devices used in the medical, energy, and defense industries are increasingly reliant on specific critical minerals not widely used a few decades ago.

Many of these critical minerals are imported. They are classified as critical because they have high economic importance, high supply risk, and their absence would have significant consequences on the economic and national security of the United States.

The Center for Critical Minerals will leverage Penn State's existing faculty, facilities, and research strengths in an effort to make the University the go-to resource for critical minerals research and technical support for industry.

Initially launched by the College of Earth and Mineral Sciences and housed in the EMS Energy Institute, the center will expand to include scientists from across Penn State whose research expertise can be harnessed to address the issues posed by critical mineral exploration, characterization, separation, and production.

"We have all the major disciplines and world-class faculty expertise required for this type of work within the college," said **Sarma Pisupati**, professor of energy and mineral engineering and director of the center. "We have the skills at Penn State needed to advise industry on locating, mining, characterizing, processing, and utilizing critical minerals. We also have strengths in financial analysis."

There are thirty-five minerals or mineral material groups that are currently considered critical. The list includes the rare earth element group, a set of seventeen metals necessary for devices that people use every day like rechargeable batteries, cellphones, and magnets. The U.S. imports nearly 100 percent of its needed rare earth elements, with China producing about 85 percent of the world supply.

"Penn State has a long tradition of meeting industry and government research needs in the minerals field," said Pete Rozelle, a Penn State alumnus and a retired program manager for the U.S. Department of Energy (DOE), who is now serving as an adviser to the college on mineral resources. "From geologic exploration to mineral extraction technologies to techno-economic analyses, the University's new Center

for Critical Minerals offers a comprehensive set of capabilities to support the development of new U.S. sources for these mineral products."

The new center will build on and expand Penn State's current research examining cost-effective and environmentally friendly technologies to extract rare earth elements from clay layers associated with coal, coal waste products, and acid mine drainage.

> "Extracting rare earth elements and other critical minerals from coal sequences and coal waste has the potential to bolster the state's economy and provide new employment in mining regions," said Lee Kump, John Leone Dean in the College of Earth and Mineral Sciences. "The opportunities for student engagement in the enterprise means that this initiative touches all aspects of the University's mission of research, teaching, and outreach."

Pisupati's team and DOE researchers collaborated to successfully develop an economical way to extract rare earth elements from coal byproducts using an advanced ion exchange method.

In another DOE-funded project, they partnered with Texas Mineral Resources Corp., Inventure Renewables Inc., and K-Technologies to investigate if the process would be feasible on an industrial scale. The overall goal is to find an economical way to extract rare earth elements and critical minerals, such as manganese and cobalt, from coal byproducts.

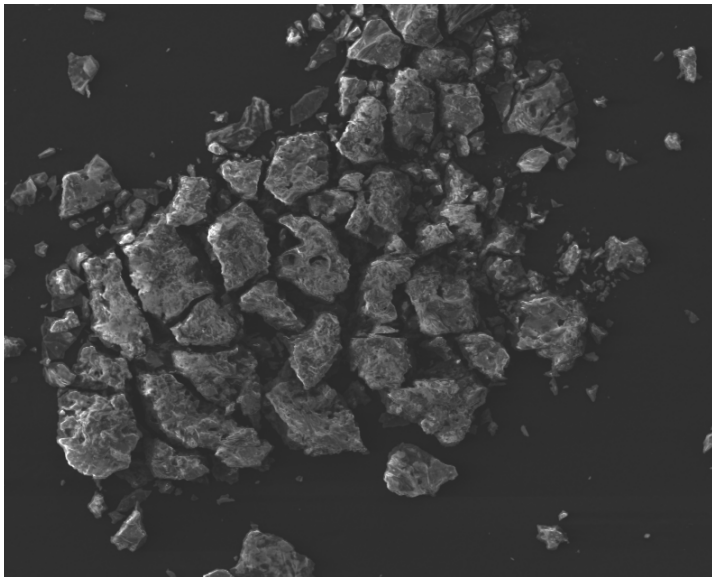
"Pennsylvania has the resources," Pisupati said. "Pennsylvania coals and coal-associated products have the highest concentrations of these rare earth elements and critical minerals in the U.S. Penn State is well positioned to play a vital role in helping industrial partners here in the state."

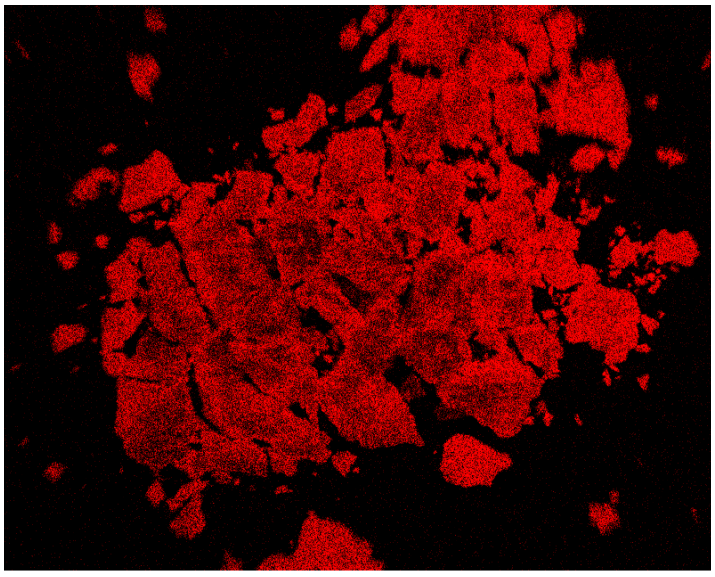
The center's focus is to:

- Gain a fundamental understanding of the presence, chemical nature, and associations of critical mineral products in geologic formations, as well as secondary sources such as coal and other mining waste streams and metallurgical waste dumps, electronic waste and sludges from the treatment of acid mine drainage, and byproduct water from the oil and gas industry.
- Develop novel processes for extraction and separation/purification while advancing the fundamentals and developing technologies for sustainable recovery of critical materials.
- Develop financial models and project values utilizing realistic models for field-scale processes for mineral recovery and detailed databases for costs and price projections.
- Analyze alternate economic and policy scenarios and develop policy guidelines for implementation of field projects.
- Provide technical support for commercial project development activities associated with bridging value chain gaps.

Extracting rare earth elements and critical minerals benefits both the economy and the environment, the researchers said.

"Coal waste, underclays, metallurgical waste, acid mine drainage and its treatment sludges, and flowback and produced water in the Marcellus basin are additional sources of critical minerals, with low production costs, that could be tied to remediation and restoration efforts," Pisupati said. "Extracting these materials is a win-win for Pennsylvania."





IMAGES: EDS images isolating rare earth elements from coals wastes

Researchers look at novel methods to enhance BATTERY PERFORMANCE

By Jennifer Matthews

Researchers at Penn State are looking at innovative ways to improve energy storage in an effort to better utilize renewable energy technologies.

"One of the primary obstacles stopping us from relying heavily on renewable energy systems is that we can't regulate when they provide us power," said **Derek Hall**, assistant research professor at the Penn State EMS Energy Institute. "Ideally, we want to find some sort of energy storage technology that can complement renewables to help us transition to a more sustainable energy infrastructure."

Renewable energy systems, such as wind and solar, are capable of producing enough electricity to power entire communities. However, they rely on natural processes to produce the electricity needed, and nature can be unpredictable. This results in ebbs and flows in renewable electricity generation. At times, wind and solar are able to produce more than the grid can handle, driving electricity prices into the negative. Alternatively, if the wind stops or there is a period of poor weather, production halts and prices skyrocket.

This phenomenon inspired Hall to start exploring more cost-effective energy storage strategies through multiple collaborative research projects at Penn State.

IMAGE: AdobeStock

Enhancing battery chemistries

Hall, along with Christopher Gorski, associate professor of environmental engineering, and **Serguei Lvov**, professor of energy and mineral engineering and materials science and engineering and director of the Electrochemical Technologies Program at the EMS Energy Institute, are using ligand chemistry to enhance the electrochemical performance of cheaper battery chemistries, thanks to an Institutes of Energy and the Environment (IEE) and Materials Research Institute grant.

"The goal is to try to find cheaper materials to make batteries with," Hall said. "The main hurdle stopping us is that most cheap materials have small energy storage densities, which leads to poor battery performance."

Ligands are ions or molecules that bind to a central metal. They are commonly used in nature and biomimetic processes to alter metal reactivity, but they have not been previously used in flow batteries. The researchers are using materials such as copper, iron, and chromium, which are cheaper than traditional materials such as lithium, cobalt, and vanadium, and pairing them with ligands in an effort to significantly reduce the capital costs associated with producing batteries.

The team will then perform experiments to identify if the metal-ligand complexes achieve high energy storage densities. They will do this in three steps: thermodynamic, kinetic, and full cell testing. In each step, different key parameters will be tested for a typical redox flow battery. The thermodynamic phase will explore how the ligands impact the electrode potential, then the kinetic phase will test how much electrical current can be harnessed. Finally, they will test all the components together to see how they work in unison.

"A lot of parts to this story are still missing, so this will be largely a fundamental research project," Hall said. "There's no real unified theory explaining how ligands impact electrochemical reactions."

The researchers hope this project, titled "New Low-Cost Flow Battery Chemistries via Ligand- Enhanced Redox Reactions," will provide preliminary results needed to pursue larger grants aimed at developing new flow battery chemistries and gain fundamental insights into why and how ligands alter the reactivities of metal complexes.

"We need to start exploring all our options for energy storage because switching over our infrastructure to renewables is a major transition that is time sensitive," Hall said. "When we built our fossil fuel infrastructure, we did that over many decades. Now we need to figure out what the best choices, or most functional choices, are and then build a whole lot of it really soon."

Converting waste heat into power

Hall is also working with Bruce Logan, professor of environmental engineering, and Matthew Rau, assistant professor of mechanical engineering, on research funded through another seed grant that looks to enhance the performance and the power output capabilities of flow batteries that are charged with waste heat rather than electricity.

"If we could find a way to redirect waste heat into electricity, even if it's a small amount on demand, this can help lessen our need for more electricity generation," Hall said.

Like with Hall's other project, this team is using a type of flow battery technology, but with a unique thermal recharging method. The project, titled "Increasing Power Densities and Cycle Efficiencies of Novel, Thermally-Charged Flow Batteries Using Advanced Flow Cell Topologies," will try to improve power density through distinctive battery flow field designs. They will do this through computational modeling using COMSOL Multiphysics software.

"The technology we're working on uses a specific chemical composition where you can recharge the chemical reaction using waste heat instead of electricity," Rau said.

In a traditional battery, a chemical reaction creates the discharge potential, generating electricity. When the process is reversed to recharge the battery, some electricity must be used to do so. For this new technology, the researchers will recharge the battery by separating two chemicals using waste heat. When those chemicals are combined back together, they will create a chemical reaction that generates electricity, therefore eliminating the need to use additional electricity to recharge the battery.

"This would be a competing technology to the traditional energy storage methods, such as lithium ion batteries, but unique in the fact that it doesn't require electricity," Rau said. "It requires heat to charge, so we're essentially opening up a new resource that could potentially power industrial processes or part of the electrical grid."

The basic idea has been around roughly five years, Rau said, but the researchers are looking to improve the performance of the basic model, so that it can become commercially viable.

"Developing this technology will not be easy," he said. "These batteries flow electrolytes through porous electrodes. The fluid flow alone is complicated enough to model without even considering the chemical reactions also occurring. We are developing the expertise to accurately model how the fluid flow in these batteries affects the different chemical reactions and ultimately how these parameters relate to the battery power output."

The researchers are hopeful that preliminary experiments done prior to starting this study have given them the tools needed for success.

"We currently have little use for waste heat in industry and in power generation," Rau said. "It just gets discarded with the cooling water or spewed into the atmosphere in an exhaust stack. If we can actually harness that the waste heat, we'll increase the energy efficiency of many different industries."

These projects illustrate the need to develop large-scale energy storage technologies that pair well with renewable energy technologies, Hall said.

"There's not going to be one solution that just wins out," he added. "It will likely be a mix. It's sort of an all hands-on-deck situation. We really don't know which one is going to work out or when it will be needed, so I think exploring multiple options is the best way forward."

Mathematical geosciences conference focuses on food, energy, water nexus

By Karlin Andersen and Jennifer Matthews

IMAGE: Katherine Silversides

More than 175 researchers, students, and industry professionals from companies and universities around the world gathered on Penn State's University Park campus from August 10-15 for IAMG 2019, the twentieth annual conference of the International Association for Mathematical Geosciences (IAMG).

"It was indeed a privilege to have such an august assembly of scholars from all parts of the world and hear them engage in topics of profound importance to all of us, ranging from modeling of ocean margins; climate modeling; modeling complex coupled processes at the intersection of food, water, and energy; as well as modeling of complex hydrocarbon and mining resources," said **Sanjay Srinivasan**, head of the John and Willie Leone Family Department of Energy and Mineral Engineering, affiliate at the EMS Energy Institute and conference chair. "Penn State was well represented by researchers from energy and mineral engineering, geosciences, geography, meteorology, mathematics, agricultural sciences, and statistics."

The aim of the conference was to promote worldwide advancement of mathematics statistics and informatics in the geosciences. Short courses, plenary speakers, oral and poster presentations, and social events promoted discussions around geomodeling issues at the intersection of food, water, and energy. Along with attendees from thirty countries, this year's conference hosted more female researchers and Ph.D. candidates than in previous years.

Pre-conference activities included short courses on machine learning for geoscience modeling and geological applications of compositional data analysis. The courses were taught by faculty members from U.S. and international universities, including the University of Texas at El Paso, and a scientist from the U.S. Geological Survey.

Sessions comprised of both oral and poster presentations covered a range of issues from mining modeling to marine geosciences to atmospheric and earth system science.

"I was particularly impressed by the emphasis on developing early career researchers and the strong collaboration with our global sponsors—both of which will advance excellence in partnerships working across the mathematical geoscience community," said Jennifer McKinley, IAMG president and a professor at Queen's University in Belfast, UK.

A keynote address from Lee Kump, John Leone Dean in the College of Earth and Mineral Sciences, titled "Simple Models for Complex Problems" drew on his work as an Earth historian in discussing how straightforward and

complicated models can, or cannot, address relatively simple problems.

Seven other keynote speakers discussed opportunities for growth within the geoscience field including:

- "Deep-time Digital Earth (DDE) Big Science Program: Opportunity for Mathematical and Data Geosciences"—Qiuming Cheng, International Union of Geological Sciences, Canada
- "Karst Aquifer Modeling, State of the Art and Challenges"—Philippe Renard, University of Neuchatel, Switzerland
- "Object Oriented Spatial Statistics: An Approach to the Analysis of Georeferenced Complex Data"—Alessandra Menafogilo, Department of Mathematics, Politecnico di Milano, Italy
- "Geo-Information Extraction and Integration in Support of Mineral Exploration"—Wenlei Wang, Institute of Geomechanics, Chinese Academy of Geological Sciences, China
- "Driving Transformations in the Energy Industry: Convergence of Emerging Technologies with Mathematical Geoscience"—Susan M. Agar, Aramco Global Research Center, U.S.

Delegates from some of the sponsoring institutions with Jenny McKinley and Sanjay Srinivasan IMAGE: Katherine Silversides

- "Outliers and Compositional Data"—Peter Filzmoser, Institute of Statistics and Mathematical Methods in Economics, Vienna University of Technology, Austria
- "Compositional Data in Geostatistics: A Log-Ratio Based Framework to Analyze Regionalized Compositions"—Vera Pawlowsky-Glahn, University of Girona, Spain

This was only the second time the annual, international conference had been hosted in the U.S.

"The IAMG conference returned to the U.S. ten years after the meeting at Stanford," Srinivasan said. "It was an honor afforded to Penn State and a testimony to the excellent infrastructure available within the University and the breadth of research conducted across the University."

Conference partners included Aramco, Chevron, Schlumberger, and the Central Pennsylvania Convention and Visitors Bureau along with University support from the Institute for Computational and Data Sciences. The conference was organized and hosted by the College of Earth and Mineral Sciences and the EMS Energy Institute.

Matheron Lecturer Vera Pawlowsky-Glahn with Jenny McKinley and K. Gerald van den Boogaart IMAGE: Katherine Silversides

About IAMG

IAMG is a nonprofit organization promoting international cooperation in the application and use of mathematics in geological research and technology through meetings and publications. Next year's conference will be held in India. To learn more about IAMG, visit the organization's website at iamg.org.

EMS Energy Institute funded FOUR NEW SEED GRANTS in 2019

By Jennifer Matthews

In Spring 2019, the EMS Energy Institute announced a new Call for Seed Grant Proposals to encourage exploratory and collaborative research with new ideas that will likely advance energy science and technology significantly and potentially lead to new externally funded research projects. The following three areas were considered:

- Energy production and upstream research, including conventional and unconventional resources, and enhanced recovery of conventional and unconventional resources.
- Energy utilization and downstream research, including conversion and upgrading of energy involving new concepts and novel processes, renewable energy utilization, and carbon dioxide management, including carbon capture, utilization, and storage.
- Energy systems, materials, and energy techno-economics.

Nine proposals were submitted and were evaluated by a panel of senior faculty members according to the following criteria: concept and rationale; objectives, approach, and expected results; and team qualifications and collaboration. The EMS Energy Institute selected the following four proposals for seed grants in May 2019.

Energy production and upstream research

Title: Mapping Reservoir Rock Composition of Conventional and Unconventional Deposits with Intelligent Imaging

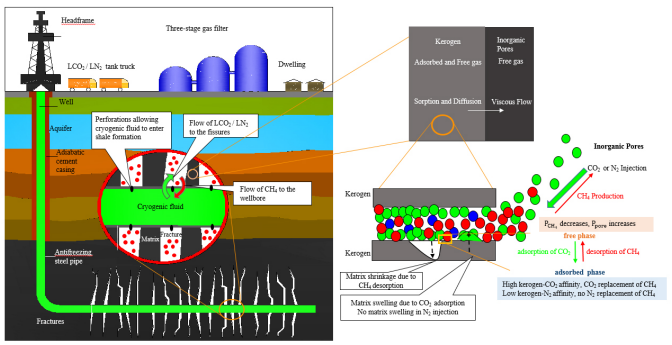
PI and Co-PI: **Zuleima Karpyn** (College of Earth and Mineral Sciences and the EMS Energy Institute) and Sharon Huang (College of Information Sciences and Technology, and Huck Institutes of the Life Sciences)

Overview: The proposed project aims to advance hydrocarbon production from conventional and unconventional reservoirs by developing novel machine learning and image analysis tools to enable automated, three-dimensional mapping of mineral constituents in reservoir rocks using high-fidelity X-ray microtomography imaging. Results from this work will support improved representation and modeling of rock-fluid interactions affecting the mobility and trapping of oil, brine, and gas in complex geologic systems. This proposal is also intended to stimulate new synergies between research groups in the College of Earth and Mineral Sciences and the College of Information Sciences and Technology and build research capacity at Penn State in the area of image data science, which can be transferrable to many fields interested in constructing material compositional maps.

Title: Exploring Nonaqueous Cryogenic Stimulation and Its Application in Gas Shale Reservoir to Maximize Gas Production and Minimize the Environmental Footprint

PI and Co-PI: **Shimin Liu** (College of Earth and Mineral Sciences and the EMS Energy Institute) and Ming Xiao (College of Engineering)

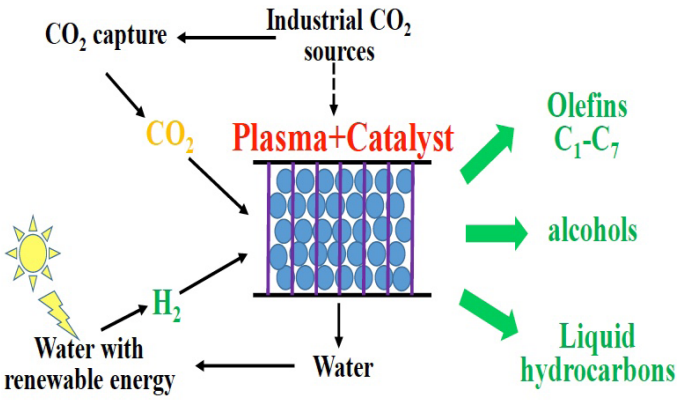
Overview: The shale gas revolution has dramatically changed the energy landscape of North America. Despite this enormous success, significant technological challenges remain. To improve the gas production from underperforming wells, the researchers will explore, investigate, and test an innovative cryogenic stimulation technology on shale and quantify its effectiveness on gas production enhancement. The fluid dynamics behaviors of gas within shale is the key for success of this early and exploratory technology. The proposed study presents an atomic-to-pore scale fluid dynamic study of shale gas reservoirs under nonaqueous cryogenic liquid nitrogen and liquid carbon dioxide treatments through a combination of experimental and numerical simulation approach. With a multiscale approach, combining experimental and numerical strategies, the fundamental mechanism of multiscale fluid-shale interactions under cryogenic treatment will be uncovered and its impact on the long-term shale gas production will be quantified.



Enhanced gas recovery using cryogenic stimulation.

Energy utilization and down-stream research

Title: Low-Temperature Plasma-Assisted Catalytic Conversion of Carbon Dioxide to Value-added Chemicals and Fuels



Schematic diagram of the proposed CO_2 capture & conversion process.

PI and Co-PI: **Xiaoxing Wang** (EMS Energy Institute) and Sean D. Knecht (College of Engineering)

Overview: To mitigate climate change, the reduction of anthropogenic carbon dioxide (CO_2) emissions is of paramount importance. Catalytic conversion of CO_2 to value-added chemicals and fuels is potentially an attractive and sustainable solution for mitigating CO_2 emissions. The researchers seek to develop a new and more efficient process for catalytic CO_2 conversion with hydrogen to chemicals and fuels with the assistance of low-temperature plasma. Through the proposed research, the team expects to gain a deep insight on the physical and chemical aspects of CO_2 and hydrogen dissociation/reactions in a dielectric barrier discharge plasma reactor; study and identify the key parameters for plasma-assisted CO_2 hydrogenation to improve the knowledge base in the plasma-catalysis scientific community; identify and clarify the synergistic effects of coupling non-thermal plasma with catalysis; and develop a catalyst working effectively for the plasma- assisted CO_2 conversion process. The proposed work will facilitate the development of new technology for catalytic CO_2 conversion in a more energy-efficient manner.

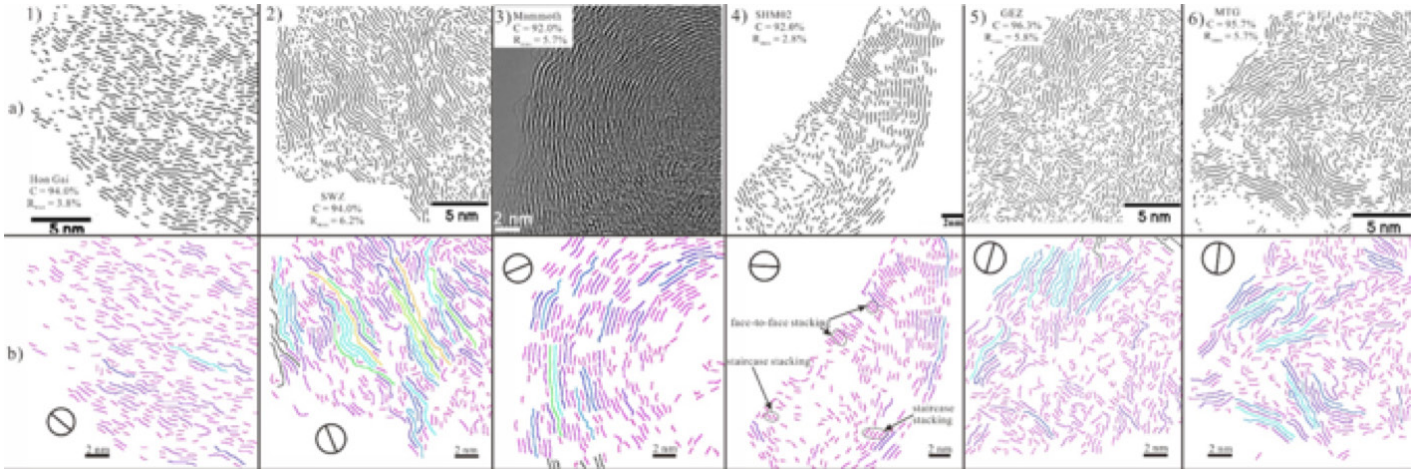
Energy Systems and Materials

Title: Graphene Production from Attrition Milling of Anthracite Coal at the Bench Scale

PI and Co-PI: **Jonathan P. Mathews** (College of Earth and Mineral Sciences and the EMS Energy Institute) and **James H. Adair** (College of Earth and Mineral Sciences and the EMS Energy Institute)

Overview: Anthracite micronization followed by a controlled hydrometallurgical processing (acid treatment and controlled attrition milling approach) is proposed to generate graphene at the bench scale using a scalable approach. Through careful selection of the anthracite and by controlling the milling process, it is expected that the graphene oxide produced can be engineered to meet graphene size needs. The abundant graphene components in anthracite also make this an inexpensive graphene source that has the potential to overcome the high cost that limits current use.

Each of the four proposals selected received $15,000 from the EMS Energy Institute.



1a) Lattice fringes and raw HRTEM micrographs of anthracites with carbon content (wt.%, daf) and mean maximum reflectance (Rmax). b) False colored HRTEM fringes (colored by fringe length) showing the mean fringe orientation (the diameter angle in the circle), Lattice fringes and raw HRTEM micrographs are reprinted with permission of copyright holder. IMAGE: Yuzhen Han

Reducing greenhouse gas emissions
using microwave plasma technology

By Jennifer Matthews

A multi-disciplinary collaborative relationship, developed between Penn State EMS Energy Institute researchers and a Pittsburgh-based start-up company, may hold the answer to reducing global greenhouse gas (GHG) emissions while also paving the way to disrupt the chemical and material industries.

Since 2015, **Randy Vander Wal**, professor of energy and mineral engineering and materials science and engineering, and affiliate at the EMS Energy Institute, has been collaborating with H Quest Vanguard on a growing number of projects that use the company's plasma technology to enable new, non-emissive uses of coal and natural gas.

> "The unique capabilities of Penn State's Material Characterization Laboratory provide invaluable insights into properties of H Quest's plasma-produced materials and are crucial to establishing a product fit for commercialization," said George Skoptsov, H Quest CEO.

The collaboration has resulted in five research projects that aim to reinvent coal and natural gas in the twenty-first century as clean, cost-effective sources of fuels and high-performance materials.

Reducing GHG emissions

While the Earth's climate has changed throughout history, the current scientific consensus is that the present global warming trend is likely the result of human activity, namely emissions of GHGs due to combustion of fossil fuels.

Switching to cleaner fuels is recognized as a key component in reducing GHG emissions. Hydrogen, in particular, is a promising energy carrier because burning it produces only water and not carbon dioxide. But hydrogen is very rare in its pure molecular form. It is abundant, however, in the form of water (11 percent hydrogen by mass) and methane, a principal component of natural gas (25 percent hydrogen by mass). In fact, according to the U.S. Department of Energy (DOE), presently 95 percent of the hydrogen for fuel in the U.S. is extracted from natural gas.

The most widely used industrial process for hydrogen production—steam-methane reforming—heats methane from natural gas using steam to produce carbon monoxide and hydrogen. Unfortunately, this process has a large GHG emission footprint and consumes large amounts of water.

Thermal methane decomposition heats natural gas to more than 2,000 degrees Fahrenheit, which cracks the hydrocarbon molecules, extracting hydrogen as gas and leaving the solid carbon behind. Introducing catalysts to this process can reduce the required temperature but introduces the problem of separating the solid carbon from the catalyst surfaces. Overall, due to constraints associated with heating, this process remains a costly, energy-intensive, and GHG-emissive process.

H Quest's microwave plasma technology catalyzes reactions in a novel way and allows very rapid (1,000 degrees Fahrenheit per second) heating of gas, which is not possible with conventional heating technologies such as boilers, furnaces, heat exchangers, or inductive heaters.

Since renewable electricity can power microwaves, and methane decomposition does not use oxygen, extracting hydrogen from natural gas using microwave plasma technology can be completely free of GHG emissions. In addition, microwave plasma technology enables modular, small-scale, low-capital deployment of chemical conversion plants, making the chemical industry more efficient, effective, flexible, and competitive.

In a recently awarded University Coalition for Basic and Applied Fossil Energy Research project, sponsored by the DOE, Vander Wal is looking to develop a deeper understanding of how process conditions within H Quest's reactor define carbon product parameters.

Vital to this effort are the capabilities of the Material Characterization Laboratory, which has a wide variety of characterization techniques in the areas of microscopy, spectroscopy, surface analysis, and thermo-physical techniques that will help shed light on why different materials show different properties and behaviors.

The project, titled "Optimization of Microwave-Driven, Plasma-Assisted Conversion of Methane to Hydrogen and Graphene," aims to identify reactor design and process conditions for hydrogen production with the capability to tune carbon product characteristics and evaluate methane conversion, product yields, and selectivity.

The goal is to develop relations between the carbon product form, characteristics, and process parameters. Such relationships will allow selective production of specific carbon forms and the ability to tailor their physical-chemical properties. The researchers hope

this will lead to next-generation hydrogen technologies that could enable using stranded domestic energy resources, such as stranded natural gas reserves, while also diversifying hydrogen feedstocks.

If successful, it could also reduce the costs associated with large-scale hydrogen energy products; create market demand, technologies, and infrastructure to enable hydrogen energy deployment; and utilize domestic natural gas for manufacturing energy and synthetic carbon products.

> "Microwave processing of natural gas represents decarbonization of a fossil fuel while paving the path toward the hydrogen economy," Vander Wal said.

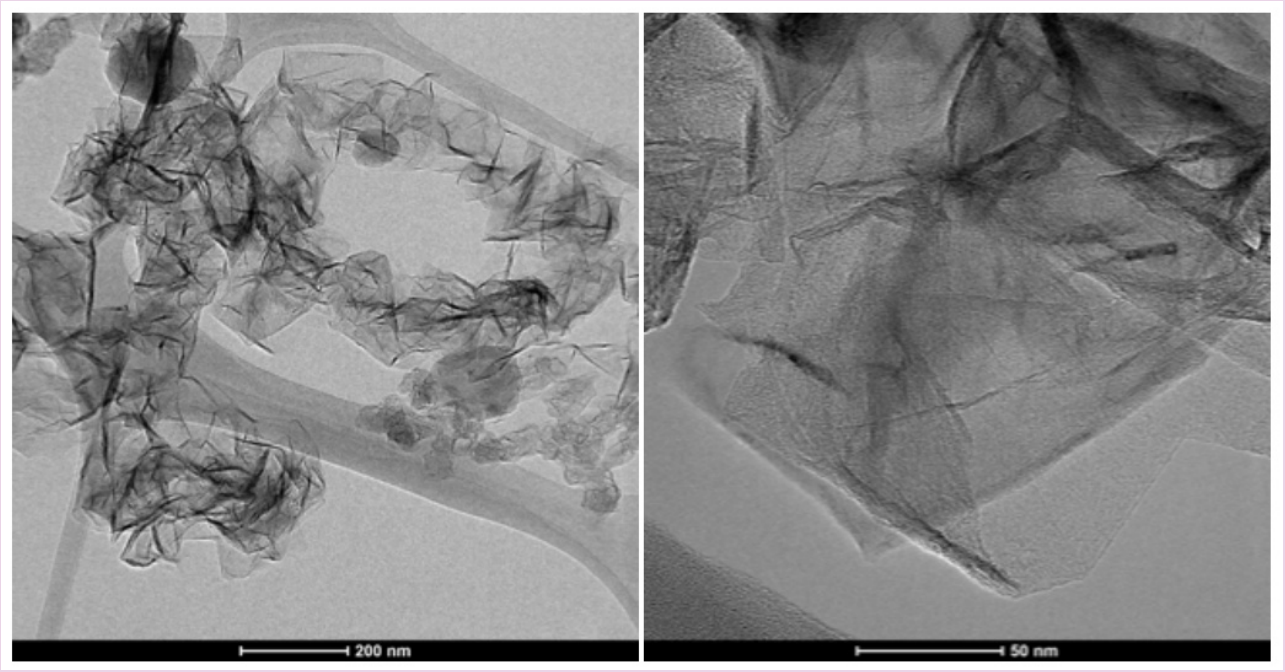
It would also create a pathway to cleaner, lower-cost carbon products. Graphene, for example, is a material that is stronger than steel and more conductive than copper.

"Graphene, as an additive to concrete, can increase strength and durability, contributing to infrastructure improvement while sequestering at large scale carbon/graphene production," Vander Wal said.

Institute researchers and H Quest are also partnering through a National Science Foundation Small Business Technology Transfer Program award to test the company's material in these roles. They also are investigating applications of microwave plasma to convert coal into carbon products through an award from the DOE's National Energy Technology Laboratory.

The breadth of the plasma-derived products is immense, from activated carbon to 3-D-printable plastics to industrial carbon electrodes for steel and aluminum smelting, the possibilities are immeasurable, Skoptsov said.

"Coal has been foundational for modern industrial organic chemistry," he added. "So many synthetic products——from aspirin to nylon—have been produced from coal, before it became synonymous with electricity generation in the era of cheap oil in the 1950s. This research will unlock the true value of our fossil resources as the source of high-performance materials but will do so in a more sustainable and cost-effective way than has ever been possible."

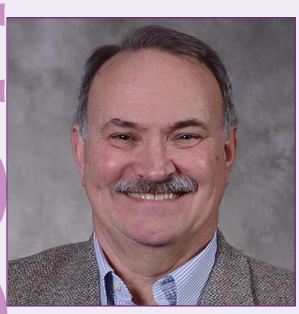


The images show the nanographene morphology as produced in the microwave plasma. The nanographene appears here in crumpled filamentary form. Higher magnification shows overlapped sheets and curled edges. IMAGE: H Quest

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**.



James Adair

Professor
Department of Materials Science and Engineering

Adair is a professor of materials science and engineering, biomedical engineering, and pharmacology. He received his B.S. in chemistry and M.S. and Ph.D. in materials science and engineering, all from the University of Florida. His research focuses on concepts and principles embedded in colloidal and interfacial chemistry with an aim toward nanomedical applications.

Grace Choi

Financial assistant
EMS Energy Institute

Choi joined the institute in August 2019 as a financial assistant. She moved from California to State College in July 2018. Prior to joining the institute, Choi worked for the Penn State Conference Services and Commons Desk Operations as a staffing assistant. Choi holds a B.S in international business.

Sharon Huang

Associate Professor
Huck Institutes of the Life Sciences

Huang is an associate professor of information sciences and technology. She received her B.Eng. in computer science from Tsinghua University and M.S. and Ph.D. in computer science from Rutgers University. Her research focuses on biomedical image data analysis, computer vision, machine learning, computer graphics and visualization, and data mining.

Athanasios Karamalidis

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

Karamalidis is an assistant professor in energy and mineral engineering. He received his B.S. in chemistry from the University of Crete and his Ph.D. in environmental engineering from the Democritus University of Thrace. His research includes energy and the environment; resource recovery; geochemistry of rare earth elements; shale gas operations geochemistry; geochemical phenomena under carbon dioxide sequestration conditions in geologic formations, groundwater, and shallow aquifers; water chemistry; fate and transport of chemicals in water, soil, and sediment; in-situ and ex-situ soil and sediment treatment; hazardous waste site remediation; and geochemical modeling of aquatic systems.

Sean Knecht

Assistant Teaching Professor
School of Engineering Design, Technology, and Professional Programs

Knecht is an assistant teaching professor in the School of Engineering Design, Technology, and Professional Programs. He is the leader of the Low-Temperature Plasma Science and Engineering research group at Penn State that focuses on the fundamental science and applications of atmospheric-pressure and in-liquid plasma sources including plasma-assisted catalysis, materials treatment, water treatment, plasma-assisted ignition and combustion, and biomedical applications. His other areas of interest and expertise include high-speed imaging, spectroscopy, and biomedical optics.

Raju Kumal

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

Kumal received his Ph.D. in physical chemistry from Louisiana State University in 2017, where he studied nanoparticle-based drug-delivery systems using non-linear laser spectroscopy. He worked as a visiting assistant professor at Georgia Southern University before joining Penn State. His current research focuses on synthesis, characterization, and applications of carbon-based nanomaterials such as graphene and conductive carbon black for potential applications in electronics, paints, and batteries. Additionally, his work focuses on the impacts of fuel chemistry on the combustion dynamics and the formation of particulate matter from aircraft engines. Kumal is advised by Randy Vander Wal, professor of energy and mineral engineering, materials science and engineering, and mechanical engineering.

Jennifer Matthews

Communications Specialist
EMS Energy Institute

Matthews joined the institute in July 2019 as a communications specialist. She is a communications professional with more than nine years of diverse writing and editing experience. She also has background in science writing, feature writing, design, photography, multimedia, website development, and marketing. Prior to the institute, she worked in Penn State's College of Engineering for five years as a communications strategist. Matthews holds a B.A. in print journalism and a B.A. in English literature.

Feifei Shi

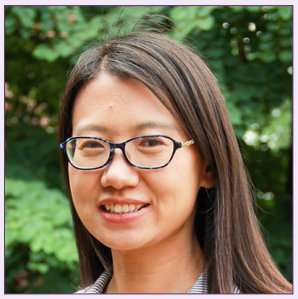
Assistant Professor
John and Willie Leone Family Department of Energy and Mineral Engineering

Shi is a Virginia S. and Philip L. Walker Jr. Faculty Fellow and an assistant professor of energy engineering. Shi's research interests lie broadly at the intersection of surface chemistry, materials science, and mechanical engineering, with an emphasis on integrated energy systems including innovation in conversion, storage, transport, and consumption systems. She holds a B.S. in chemistry from Fudan University, China and a Ph.D. in mechanical engineering from the University of California, Berkeley. Before joining Penn State in August 2019, Shi was a postdoctoral researcher in materials science and engineering at Stanford University.

Hilal Ezgi Toraman

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

Toraman is a Virginia S. and Philip L. Walker Jr. Faculty Fellow and an assistant professor of energy engineering and chemical engineering. Prior to joining Penn State, Toraman served as a postdoctoral researcher with the Delaware Energy Institute at the University of Delaware. Toraman's research is in the field of chemical reaction engineering with a focus on developing new processes, materials, and technologies for efficient and sustainable use of energy resources such as shale gas, biomass, and plastic waste. She received her B.Sc. and M.Sc. in chemical engineering from Middle East Technical University, Turkey and her Ph.D. in chemical engineering from Ghent University, Belgium.



Meng Wang

Assistant Professor
Environmental Systems Engineering

Wang is an assistant professor in environmental systems engineering. Wang received her B.S. in environmental engineering from Zhengzhou University, China, her M.S. in environmental engineering from Xi'an Jiaotong University, China, and her Ph.D. in civil engineering from the University of Massachusetts Amherst. Her research focuses on environmental biotechnology for pollution control, resource recovery, and environmental sustainability. She combines physical-chemical processes with biological processes to improve system stability and resource recovery efficiencies. Her research uses experimental work and mathematical modeling to guide the design and operation of treatment systems. She is interested in developing innovative food-energy-water systems for resource recovery, public health, and food security.

Ming Xiao

Associate Professor
Civil Engineering

Xiao is an associate professor in civil engineering. He holds a B.S. in civil engineering from Shandong University, China, an M.S. in civil engineering from Zhejiang University, China, and an M.S. in computer science, and Ph.D. in civil engineering from Kansas State University. His research interests include performances of civil infrastructures and permafrost coastal erosion and its remediation due to permafrost degradation in the Arctic and their sociodemographic impacts; performances of the built environment and infrastructure under in-service conditions and extreme events; and seepage and erosion.

Enhanced Oil Recovery

Fourteenth Annual Workshop was held on November 22

The Enhanced Oil Recovery (EOR) Industrial Affiliates Program (IAP) held its fourteenth annual workshop on Friday, November 22, at Penn State University Park, including a dinner on Thursday, November 21.

The EOR IAP focused on research topics in gas flooding, chemically-tuned water flooding, and alkali-surfactant-polymer (ASP) flooding, along with various hybrid techniques. The program currently funds research projects that use analytical, experimental, and numerical methods supervised by five Penn State faculty members.

Some notable accomplishments of the EOR IAP include developing the first multiple contact mixing cell algorithm to calculate the minimum miscibility pressure (MMP) for combined condensing/vaporizing drives; developing the first surface complexation reaction equations for wettability alteration in low salinity waterflooding; publishing the first equation-of-state for microemulsions; developing a novel coupled equation-of-state approach for relative permeability and capillary pressure that makes compositional simulation truly compositional, more robust, more accurate, and faster computationally; developing a new transport mechanism based on diffusion as the primary unifying mechanism of oil and gas production in shales; and developing generalized Riemann solutions that show how to transform MMP calculations and compositional path for gas flood displacement to tie-line space.

First Annual Short Course on

Modeling Aqueous Systems

will take place June 22–26

The First Annual Short Course on Modeling Aqueous Systems: Fundamentals and Modeling Techniques with OLI Studios will take place June 22–26, 2020 at the EMS Energy Institute on the Penn State University Park campus.

This course will cover the fundamentals of modeling aqueous solutions and corrosion processes used within OLI Studio. Lectures and hands-on OLI Studio exercises will be used to demonstrate how complex systems can be modeled. This course is appropriate for those new to OLI Studio, professionals working with this software, and those looking for a refresher course in its underlying theory. Modeling walkthroughs will be presented using OLI's Stream Analyzer, Corrosion Analyzer, and Studio ScaleChem programs.

Lecture Topics will include:

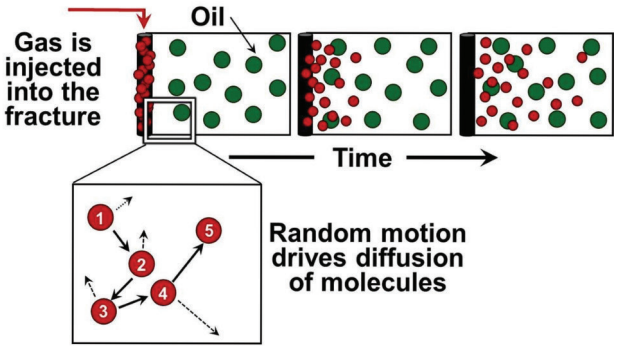
- Chemical Potential, Gibbs Energy and Standard States
- Concentration, Ionic Strength and Activity Coefficients
- Chemical Equilibria, Speciation, and pH
- Phase Equilibria and Gibbs Energy Minimization
- Redox Reactions, Redox Potentials, and the Nernst Equation
- Pourbaix (Potential-pH) Diagrams
- Overpotential and Polarization Curves
- Mixed Potential Theory
- Corrosion Rate and Types of Corrosion
- The Role of Aqueous Thermodynamics in Scaling
- The Role of Gas-Water Interactions in Scaling

The course fee is $2,500 and covers all instruction, course notes, refreshment breaks, and continental breakfasts and lunches (Monday-Friday). Registrants are responsible for all other meals and lodging.

For more information about the short course, contact Derek M. Hall at Hall@psu.edu.

Honors & Awards

Understanding **PHYSICS** could lead to big gains in **shale oil recovery**



Michael Cronin, graduate student in the John and Willie Leone Family Department of Energy and Mineral Engineering; **Russell Johns,** George E. Trimble Chair in Earth and Mineral Sciences and professor of petroleum and natural gas engineering; and **Hamid Emami-Meybodi**, assistant professor of petroleum and natural gas engineering, recently published results of their Enhanced Oil Recovery JIP in the *Society of Petroleum Engineers Journal*. Oil companies are missing out on vast sums of recoverable oil in unconventional reservoirs, according to the study. The researchers propose that companies are applying tried-and-true transport mechanisms for conventional oil extraction but are hitting recovery stumbling blocks because they are not accounting for the difference in physics found at unconventional reservoirs. The Enhanced Oil Recovery Joint Industry Project in the EMS Energy Institute funded this research.

IMAGE: Penn State

Marone awarded **Louis Nèel Medal** by European Geosciences Union

Chris Marone, professor of geosciences, was selected to receive the European Geosciences Union's 2019 Louis Néel Medal. The medal is awarded to individuals in recognition of outstanding achievements in rock magnetism, rock physics, and geomaterials. Marone was selected for his "seminal contributions to the understanding of fault mechanics and earthquake generating processes and for innovation in experimental techniques and apparatus development." He was also recognized for his role in relating laboratory research to earthquake seismology and in integrating fault mechanics into earthquake physics as a whole.

Research predicts SIZE, MAGNITUDE, TIMING of lab earthquakes

Chris Marone, professor of geosciences, along with a team of researchers from Penn State and Los Alamos National Laboratory, was able to predict the magnitude, time, and duration of earthquakes in a laboratory setting. This research improves our understanding of earthquakes and could eventually lead to prediction measures in real-life scenarios. The results were published in a recent issue of *Nature Geosciences*. The U.S. Department of Energy and the National Science Foundation supported this research.

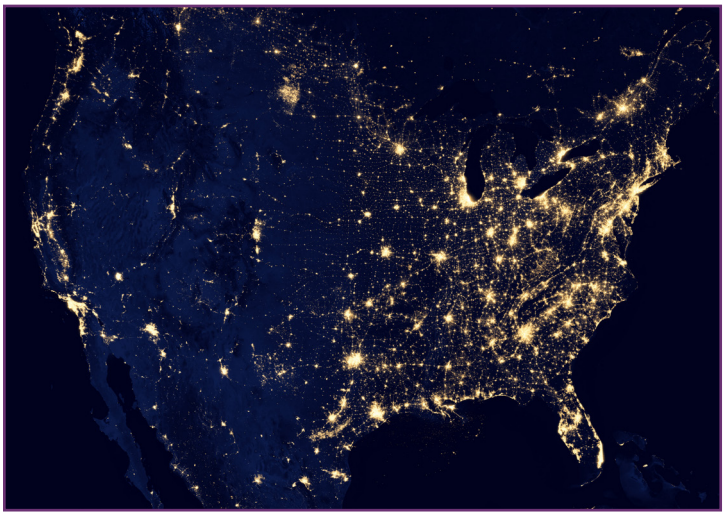
IMAGE: Penn State

Researcher to study Earth's subsurface stress during oil and gas production

Amin Mehrabian, assistant professor of petroleum and natural gas engineering, was recently awarded a $110,000 grant from the American Chemical Society's Petroleum Research Fund to study subsurface stress in hydrocarbon reservoirs. This fundamental research could potentially help better plan wells, drill less-costly wells, produce more efficiently from wells, and maintain overall well integrity during the production life of the wells.

IMAGE: Patricia Craig

Sloan Foundation grant looks at energy market structure for *wind integration*



Chiara Lo Prete, assistant professor of energy economics, was awarded a $250,000 grant for early career researchers from the Alfred P. Sloan Foundation to examine the effectiveness of energy market structures in aggregating private information on wind production forecasts to better coordinate commitment and production decisions in electric systems. **Uday V. Shanbhag,** the Gary and Sheila Bello Chair and professor of industrial engineering, and Anthony Kwasnica, professor of risk management, are also working on the project.

IMAGE: NASA

NSF grant aims to enhance resilience of U.S. electricity grids

Chiara Lo Prete, assistant professor of energy economics, was awarded a $750,000 grant from the National Science Foundation to study economic mechanisms for grid resilience against extreme events and natural gas disruptions. The three-year award is part of NSF's Critical Resilient Interdependent Infrastructure Systems and Processes program, which supports integrated research by interdisciplinary teams of engineers and social scientists to enhance resilience of critical infrastructures. As the U.S. share of electricity generated from natural gas continues to increase, power systems and gas networks are becoming increasingly intertwined. This research will quantify the need for resilience in an electrical system that heavily relies on natural gas as fuel and examine the economic mechanisms needed to incentivize efficient resilience investments.

IMAGE: © ISTOCK IMAGES / YELANTSEVV

Penn State chosen by Department of Energy to help modernize the power grid

Chiara Lo Prete, assistant professor of energy economics; **Uday V. Shanbhag**, the Gary and Sheila Bello Chair and professor of industrial engineering; and **Mort Webster**, professor of energy and mineral engineering, were one of only ten university teams chosen for the U.S. Department of Energy (DOE)'s Grid Optimization Competition. Announced by the DOE Advanced Research Projects Agency-Energy program, the competition challenges researchers from universities and national laboratories to solve the fundamental issues facing the electricity infrastructure, while addressing the concerns that widespread renewable energy sources will introduce in the future. The team also includes Hosam Fathy, the Bryant Early Career Professor of Mechanical Engineering, Nilanjan Ray Chaudhuri, assistant professor of electrical engineering and computer science; and Minghui Zhu, assistant professor of electrical engineering.

IMAGE: © ISTOCK IMAGES / METAMORWORKS

EMS Energy Institute director honored with DISTINGUISHED ALUMNI AWARD

Chunshan Song, Distinguished Professor of Fuel Science in the John and Willie Leone Family Department of Energy and Mineral Engineering and director of the EMS Energy Institute, was awarded the Distinguished Alumni of the Year Award in the category of alumni achievement on June 16, 2019 at the Seventieth Anniversary Celebration at Dalian University of Technology in Dalian, China. Song was one of ten recipients, honored for his research achievements in energy, fuels, catalysis, and carbon dioxide.

Society of Petroleum Engineers (SPE) President, Sami Alnuaim, presents Penn State researchers Michael Cronin, Hamid Emami-Meybodi and Russ Johns with Cedric K. Feguson Medals and Certificate.

Energy and mineral engineering

RESEARCHERS RECEIVE BEST PAPER AWARD FROM SPE

By Ashley Nottingham

Hamid Emami-Meybodi and **Michael Cronin** were recently awarded the 2019 Cedric K. Ferguson Medal, and **Russell Johns** was awarded the 2019 Cedric K. Ferguson Certificate from the Society of Petroleum Engineers (SPE) for the best paper published in 2018 in a SPE journal. They were presented with the international awards at the SPE Annual Technical Conference and Exhibition held Sept. 30 to Oct. 2 in Calgary, Canada.

The SPE Cedric K. Ferguson Medal honors professional achievement in petroleum engineering. Medals are awarded for the best paper to authors younger than 36 years old and certificates are awarded to co-authors older than 36.

Cronin, a graduate student in the John and Willie Leone Family Department of Energy and Mineral Engineering (EME), Emami-Meybodi, assistant professor of petroleum and natural gas engineering, and Russell Johns, professor of petroleum and natural gas engineering, were selected for their paper titled Diffusion-Dominate Proxy Model for Solvent Injection in Ultratight Oil Reservoirs.

> "Our work examines the transport of condensed fluids in shales from a new perspective, one that does not rely on conventional advective frameworks but rather on diffusion," said Emami-Meybodi. "This is important because our approach honors the true physics, with diffusion coefficients that are self-consistent and naturally entrain the influencing variables like pressure, temperature and concentration. This award represents a much welcome validation of our work and emboldens us to continue our efforts."

Cronin joined the EME department as a doctoral student in fall 2016 and hopes this research will inform reservoir decisions.

"I hope that our research guides reservoir development decisions and provides a stepping-stone towards future research. I am thrilled beyond measure and humbled to have been recognized for this award," said Cronin.

According to the researchers, including the physics of diffusion improved recovery efficiency.

"Oil and gas shale reservoirs are very important to the welfare of the United States," said Johns. "Diffusion likely explains why injection of a solvent, such as carbon dioxide, could increase recoveries significantly from the very low recoveries currently observed in oil shale reservoirs — around 5% of oil in place. Through a better understanding of physics, we may be able to improve the recovery efficiency for each well, reducing environmental impact. It's really good to have this research be recognized."

About the co-authors

Cronin earned a master's degree in geological sciences from the University of Texas at Austin and dual bachelor's degrees in petroleum and natural gas engineering and geosciences with honors from Penn State. Before starting his doctoral degree, Cronin worked as a geologist/reservoir modeler in Anadarko's reservoir technology group. He is the current deputy managing editor of The Way Ahead, an SPE publication for young professionals.

Emami-Meybodi joined EME in 2015 following ten years in academia at the University of Calgary, Canada, and the Petroleum University of Technology, Iran. His research has been centered on the study of fluid flow and transport phenomena in porous media, spanning both applied and fundamental aspects. Emami-Meybodi has authored and co-authored more than 30 technical publications. He is the current faculty adviser for the SPE Student Chapter at Penn State. He is also the recipient of 2018 SPE Regional Reservoir Description and Dynamics Award.

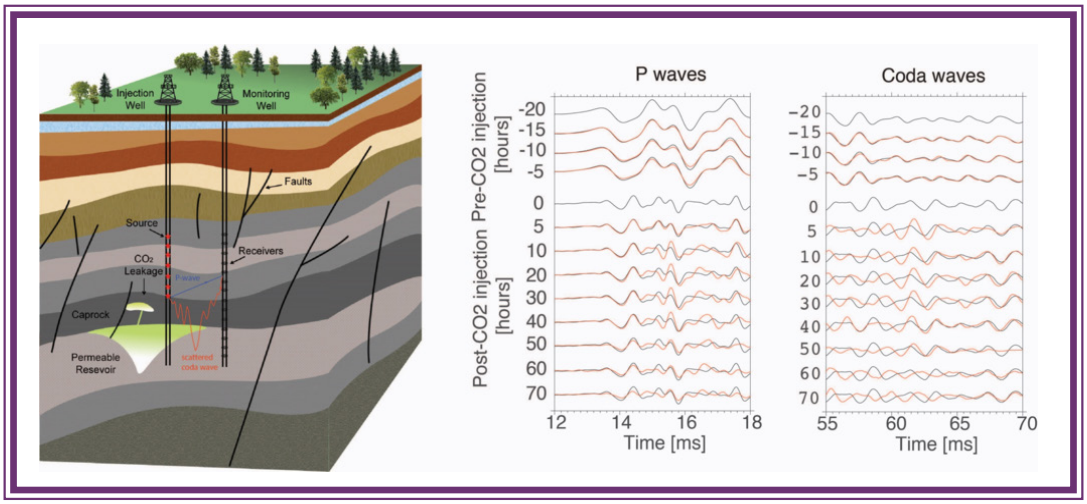
Johns is a former recipient of the Cedric K. Ferguson medal in 1994. He is also a recipient of 2016 Reservoir Description and Dynamics Award from SPE International. Johns is the current George E. Trimble Chair in Energy and Mineral Sciences and the Energi Simulation Chair in Fluid Behavior and Rock Interactions. He is also the director of the Enhanced Oil Recovery Join Industry Project (EOR-JIP).

IMAGE: Society of Petroleum Engineers (SPE)

CODA WAVES

reveal carbon dioxide storage plume

Tieyuan Zhu, professor of geophysics, and **Chris Marone**, professor of geosciences, as well as researchers from Lawrence Berkley National Laboratory, are using previously ignored seismic waves to pinpoint and track carbon dioxide gas clouds in an effort to better keep track of the plume when pumping it into the ground to remove it from the atmosphere. The DOE's National Energy Technology Laboratory supported this work.



2019 End of Year Awards

Wilson Banquet and Awards Presentation

The College of Earth and Mineral Sciences held its 2019 Wilson Banquet and Awards Presentation on April 28 to recognize student achievement, faculty mentoring, faculty commitments to service, and excellence in research and teaching.

George H. Deike, Jr. Research Grant

The George H. Deike, Jr. Research Grant is awarded in support of an innovative research project.

Randy Vander Wal, professor of energy and mineral engineering and materials science and engineering, was selected for his proposal "Transitioning to the H_2 Economy Using Shale Gas."

John T. Ryan, Jr. Faculty Fellowship

This award was created to provide supplementary funds to an outstanding faculty member in the college to further their contributions in teaching, research, and public service.

Mort Webster, professor of energy engineering, was chosen for this fellowship.

Wilson Research Initiation Grant

The Wilson Research Initiation Grant was established to provide an extra spark to the research career of a junior faculty member.

Hamid Emami-Meybodi, assistant professor of petroleum and natural gas engineering, was selected for his proposal "A Diffusion Perspective on Solvent Injection in Ultratight Oil Reservoirs."

Gladys Snyder Junior Faculty Grants

The Gladys Snyder Junior Faculty Grants are awarded to junior faculty for the development of new courses or the improvement of current offerings; for travel to professional meetings; to broaden the studies of junior faculty members; or to recognize significant contributions in research efforts.

Joel Landry, assistant professor of environmental and energy economics, was selected for his proposal "The Unintended Congestion Cost and Greenhouse Gas Emissions Impacts of Solar Policies in California."

E. Willard and Ruby S. Miller Faculty Fellowship

The E. Willard and Ruby S. Miller Faculty Fellowship was created to support faculty of exceptional creativity who propose highly innovative approaches to major contemporary challenges in the earth, energy, and material sciences.

Meng Wang, assistant professor of environmental systems engineering, was selected for her proposal "Dynamics of Reactive Nitrogen Released into Environment in Biological Nutrient Removal Processes."

2019 Department of Energy and Mineral Engineering student awards

The John and Willie Leone Family Department of Energy and Mineral Engineering had its 2019 Awards Banquet on April 15. 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

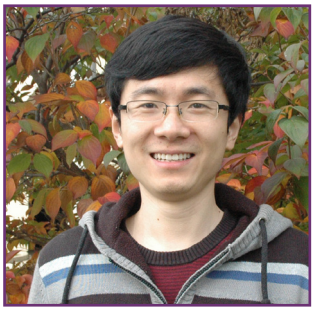
Madhu Singh, Ph.D. student

Outstanding Graduate Teaching Assistants

Behzad Vaziri Hassas, Ph.D. student

Lihe Xiu, Ph.D. student

Graduate Teaching Assistant



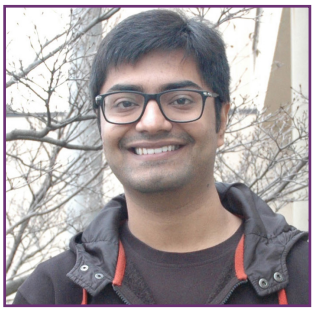
Jiehao Wang, Ph.D. student

Student Merit Awards

Ian W. Wasserman, ENENG undergraduate senior student

Mpila Nkiawete, ENENG undergraduate senior student

EME-PNGE Graduate Merit Award

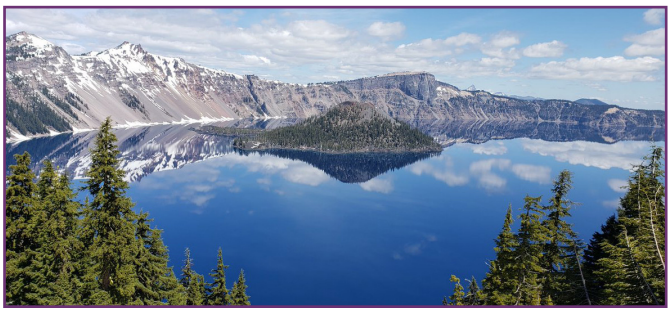


Prakash Purswani, Ph.D. student

ME Graduate Merit Award

Timothy Duffy, Ph.D. student

EME 2019 Photo Contest Winner



Taylor Young, undergraduate junior student
Third place winner – "Crater Lake"

2019 Staff Awards

5-Year

Christy English, staff assistant

5-Year

Jennifer Matthews, communications specialist

2019 Institutes of Energy and the Environment Seed Grants

The following EMS Energy Institute researchers were 2018–19 Institutes of Energy and the Environment (IEE) seed grant recipients:

Future Energy Supply

"Increasing Power Densities and Cycle Efficiencies of Novel, Thermally-Charged Flow Batteries Using Advanced Flow Cell Topologies"—Matthew Rau, College of Engineering; **Serguei Lvov**, (left) College of Earth and Mineral Sciences; **Derek Hall**, (right) College of Earth and Mineral Sciences; and Bruce Logan, College of Engineering

Human Health and the Environment

"The Role of Olfactory Neuron Death in Particulate Matter-Induced Neurodegeneration" — Patrick Drew, College of Engineering, and **Randy Vander Wal**, College of Earth and Mineral Sciences

Energy and Environmental Resilience

"Lighting Up the Subsurface for Tomorrow's City: Initiating a Penn State DAS Array for Monitoring Geo/Environmental Hazards"—**Tieyuan Zhu**, College of Earth and Mineral Sciences; Patrick Fox, College of Engineering; Andrew Nyblade, College of Earth and Mineral Sciences; and Eileen Martin, College of Science, Virginia Tech

Food-Energy-Water Systems

"Rare Earth Element Enrichment from Mining Wastewater Streams"—Xueyi Zhang, College of Engineering; **Mohammad Rezaee**, College of Earth and Mineral Sciences; and Michael Hickner, College of Earth and Mineral Sciences

High-Performance Building Systems

"Uncertainty-Aware Transactive Building Controls"—Gregory Pavlak, College of Engineering; **Uday Shanbhag**, (left) College of Engineering; and **Mort Webster**, (right) College of Earth and Mineral Sciences

Other Awards

Meng Wang, assistant professor of environmental systems engineering, received funding provided by the University's Wastewater Management Committee for her project, titled "Towards Energy Neutral Wastewater Treatment Plant by Enhanced Organic Carbon Capture and Mainstream Deammonification"

Chris Marone, professor of geosciences, was awarded a 2019 Penn State Multidisciplinary Seed Grant for his collaborative research with Jing Yang, assistant professor of electrical engineering, on "Machine Learning Approaches for Safe Geothermal Exploration."

Hilal Ezgi Toraman, Penn State assistant professor of energy engineering and chemical engineering, has been named the Virginia S. and Philip L. Walker Jr. Faculty Fellow in Materials Science and Engineering and Fuel Science Program. The fellowship was awarded to Toraman for her contributions to teaching, research and service in the John and Willie Leone Family Department of Energy and Mineral Engineering.

Song receives George A. Olah Award from the American Chemical Society cont.

alcohol fuels for syngas and hydrogen production; shape-selective catalysis for synthesis of organic chemicals; catalysis and reaction chemistry for energy conversion; and synthesis and applications of nano-porous catalytic and adsorbent materials.

For making clean liquid fuels, Song and his research team have developed sulfur-selective adsorbents for removing sulfur from liquid fuels at ambient temperature and pressure, which enabled liquid fuel use in fuel cells and changed the way of thinking in the field. Many prototype fuel processing systems have been fabricated by an industrial partner and applied for liquid fuel-based polymer electrolyte and solid oxide fuel cells. Song and his team have developed novel solid molecular basket sorbents (MBS) with high capacity for selective carbon dioxide capture and separation from gas mixtures, such as flue gas from coal-fired power plants. Penn State researchers have scaled up the MBS technology from laboratory experiments to use in a plant that was conducting a pilot demonstration supported by DOE.

Song and the Penn State team, along with collaborators at JCER, have developed a series of novel catalysts for selective carbon dioxide conversion to chemicals and fuels. They not only have developed new bimetallic catalysts with high selectivity for carbon dioxide conversion to lower olefins, liquid hydrocarbons, and methanol, but also have delineated the elemental reaction pathways on the surfaces of the new bimetallic catalysts.

Song has written or co-written 360 refereed journal papers and thirty book chapters, edited eleven books and eleven special issues of research journals, delivered sixty plenary or keynote lectures at national and international conferences, and given more than 290 invited lectures worldwide. He also holds eight patents.

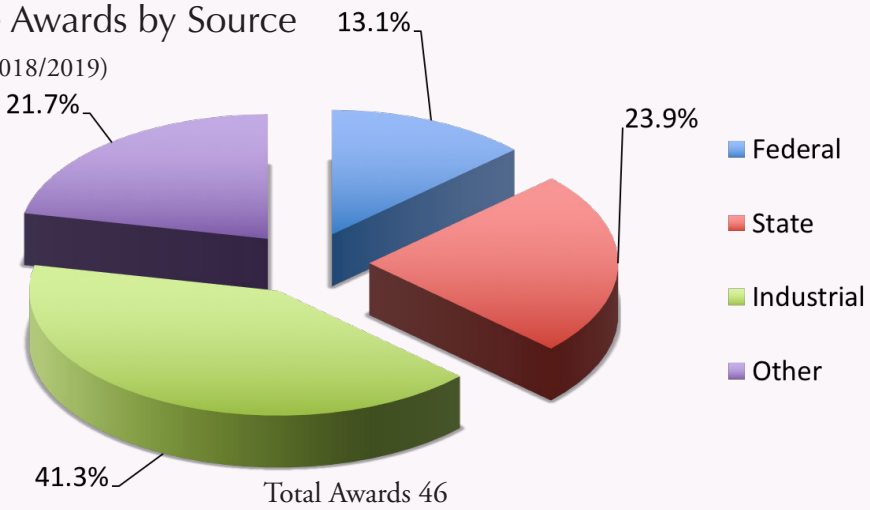
Song is an ACS Fellow and has received many awards, including Penn State's Faculty Scholar Medal. For additional information, visit https://www.eme.psu.edu/directory/chunshan-song.

The George A. Olah Award in Hydrocarbon or Petroleum Chemistry was established in 1948 as the American Chemical Society Award in Petroleum Chemistry. It was renamed in 1997 after the Nobel laureate George A. Olah. The award has been supported under the current title since 1997 through a fund initially created by donations from the Morris S. Smith Foundation and the Dow Chemical Company.

Summary of projects & FUNDING

EMS Energy Institute Awards by Source

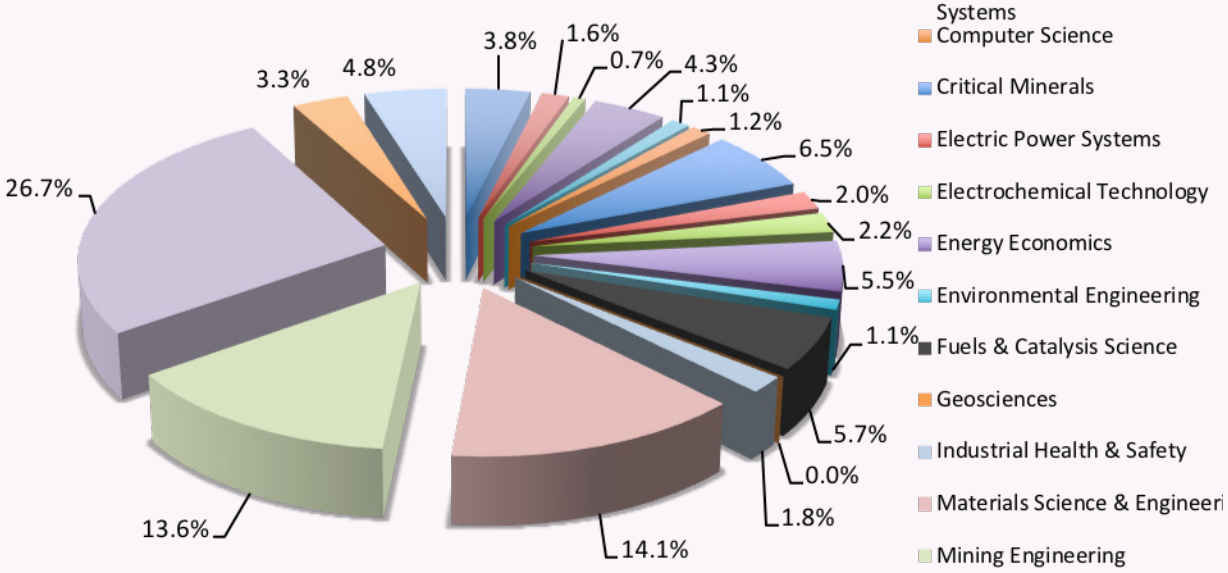
(Fiscal Year 2018/2019)



Total Awards 46

EMS Energy Institute Projects by Program Area

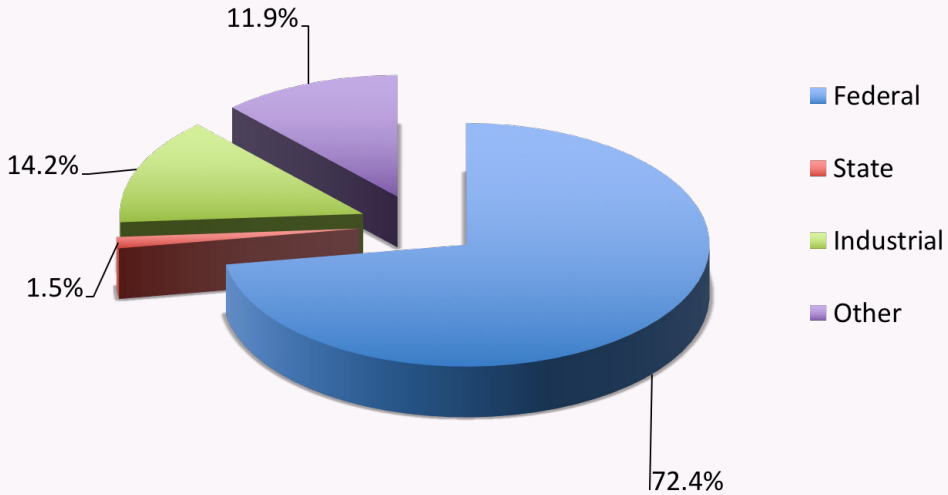
(Fiscal Year 2018/2019)



46 projects

EMS Energy Institute Funding by Source

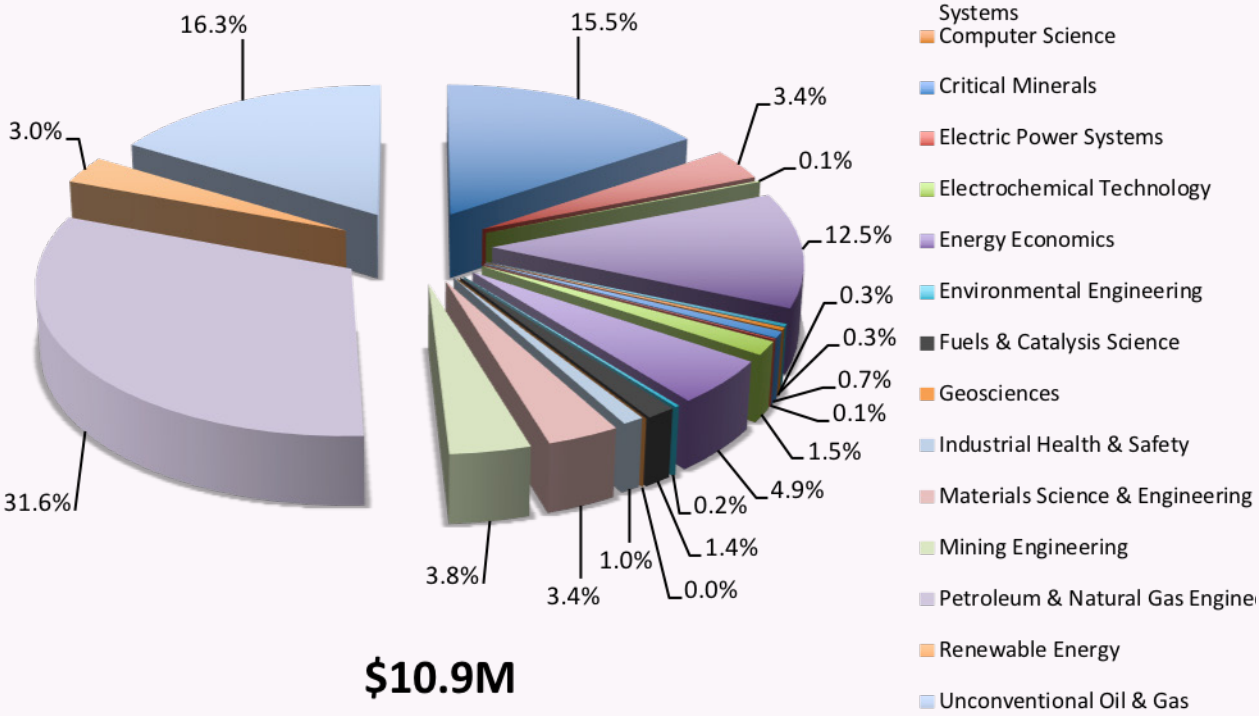
(Fiscal Year 2018/2019)



Total Funding $10.9million

EMS Energy Institute Funding by Program Area

(Fiscal Year 2018/2019)



$10.9M

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