



PennState
College of Earth
and Mineral Sciences

Earth and Mineral Sciences
Energy Institute

Overview of the EMS Energy Institute

Open House Presentation

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PRESENTATION OUTLINE

- **Historical Perspective & Current Status**
 - General discussion of the Institute
 - Institutional timeline, major development thrusts and public-private partnerships which were the foundation that built the Institute
 - Some specifics of past and current activities that defined the Institute
 - Benefits to being affiliated with the Institute
- **Future Vision**
 - Thematic Areas
 - Overarching Activities

WHERE WE'VE BEEN, WHERE WE'RE AT



EMS ENERGY INSTITUTE

- The Energy Institute is a leading research and development organization focused on energy science and engineering.
- The Institute tackles fossil fuel challenges, explores alternative energy technologies, develops materials and minerals to support energy production and storage, optimize energy systems, analyzes risks, and creates policies to facilitate the energy transition.



WHO WE ARE

- We are a research unit within the College of Earth and Mineral Sciences.
- We work with many colleges/ departments across the university. One of our main partner is the Department of Energy & Mineral Engineering. We engage with graduate and undergraduate researchers from several departments.
- We are located in four lab/office buildings, a fuel processing facility, and a couple of sample storage facilities.



WHERE WE ARE LOCATED



COMBUSTION LABORATORY INSTITUTIONAL TIMELINE



- 1949: The Combustion Laboratory was formed within the Department of Mineral Technology (until 1954)
- 1954-1966: Was within the Department of Fuel Technology
- 1966-1967: Was within the Department of Fuel Science
- 1967-1997: Was within the Department of Materials Science and Engineering, Fuel Science Program
- 1997: Energy Institute formed (1993-1997 various labs and centers consolidated)
- 2007: EMS officially added to the name



TWO MAJOR DEVELOPMENT THRUSTS (1989-2004)

- Advanced Thermally Stable Jet Fuel
 - Develop an alternate jet fuel thermally stable at 900° C
 - 1989-2004, \$40M funding
 - Sandia National Laboratory, Air Force Research Lab, Air Force Office of Scientific Research



- Series of Demonstration-Scale RD&D
 - Emissions control; hardware development and testing; fuels and emissions characterization; etc...
 - 1989 to 2004, \$23M funding
 - Projects:
 - Superclean Coal Water Slurry Combustion and Oil-Fired Boiler (1989-1996, \$6.1M – NETL)
 - Testing of an Industrial-Scale Coal-Fired Combustion System (1991-1995, \$4.3M – NETL & ABB Comb. Eng.)
 - The Development of Coal-Based Fuel Technologies for DoD Facilities (1992-2004, \$15M – NETL)
 - Multiple industrial projects (1996-2001, \$0.6M)



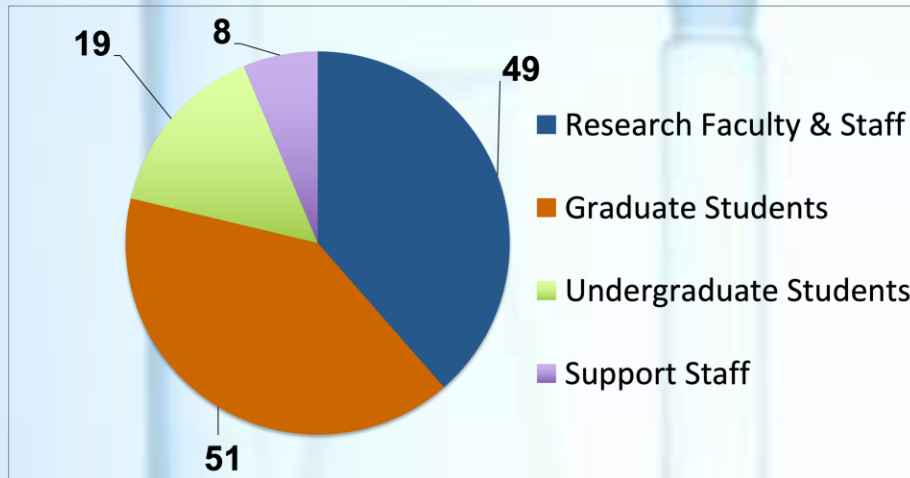
WHAT WE DO

The Energy Institute conducts fundamental and applied research in:

- Energy exploration & extraction
- Refining & conversion of fuels
- Utilization (combustion/
gasification)
- Environmental issues

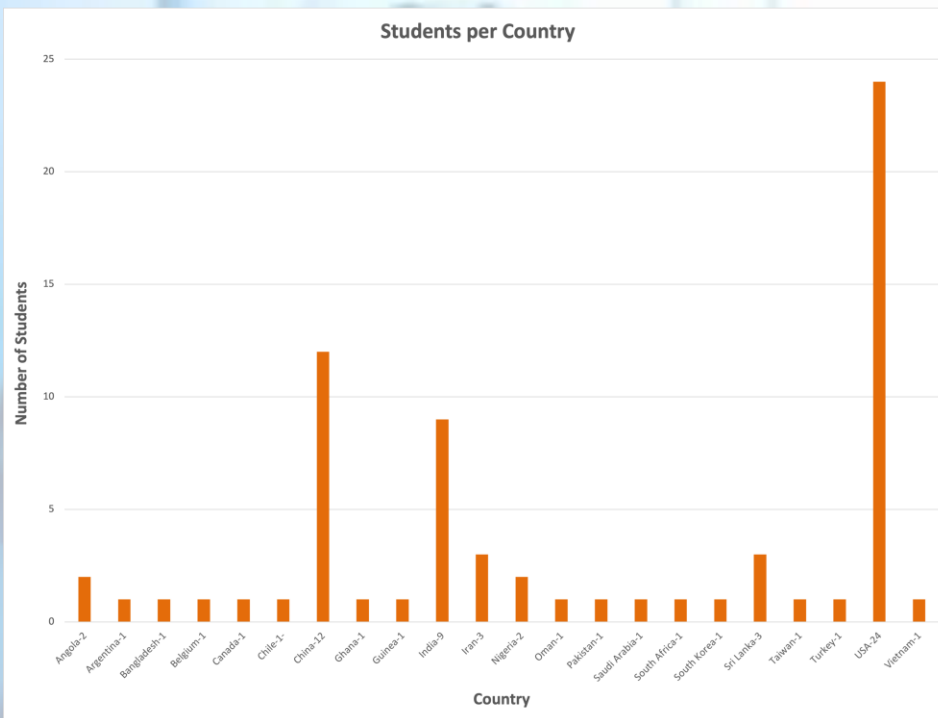


WHO WORKS HERE



Personnel (as of Summer 2023)

- Affiliated personnel \approx 130
 - Tenure-Track Faculty
 - Research Faculty
 - Graduate and undergraduate students
 - Support staff

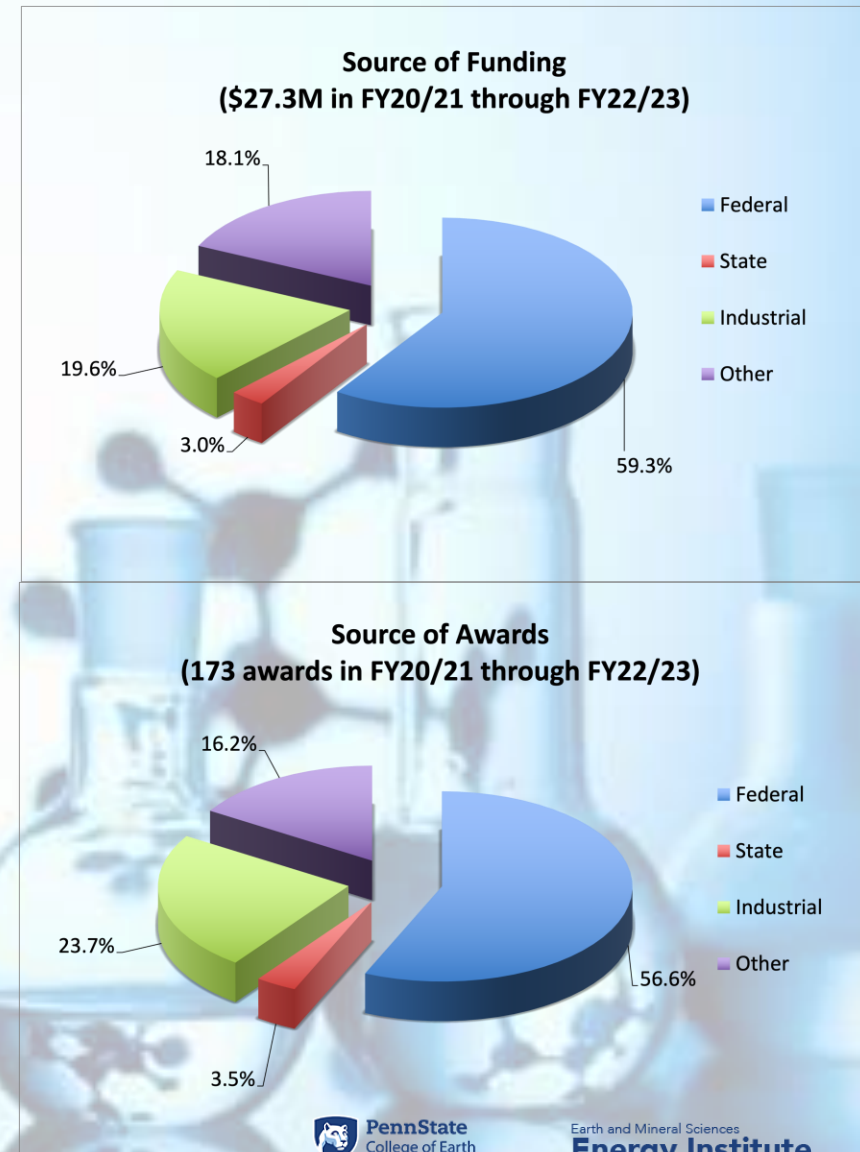


- 6 co-funded faculty

OUR RESEARCH PROFILE (FY 20/23)

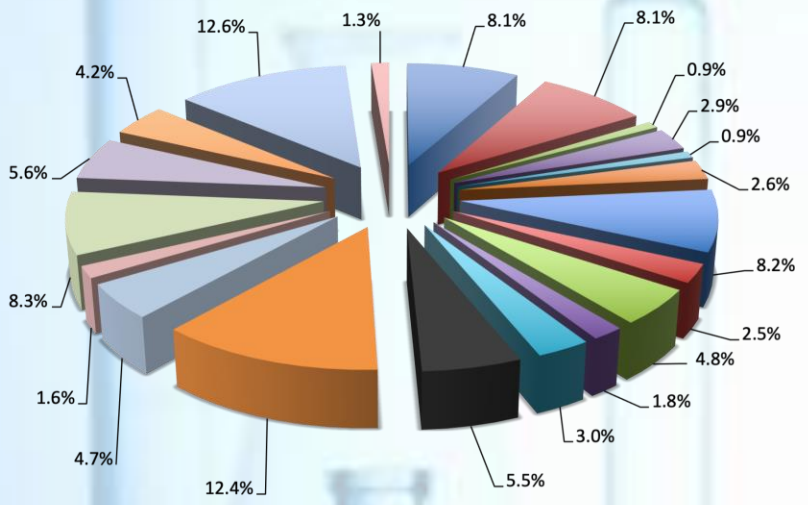
Research Profile (historically)

- Research funding ranged from \$3.5-13.4 million/year
 - Average is \approx \$7-9 million/year
- Historically 30 to 196 awards/year (**Early years included service contracts – CQI, HGI, Supelco, etc.**)
- 30 to 60 awards/year more typical
- Worked with up to as many as 150 companies/agencies per year

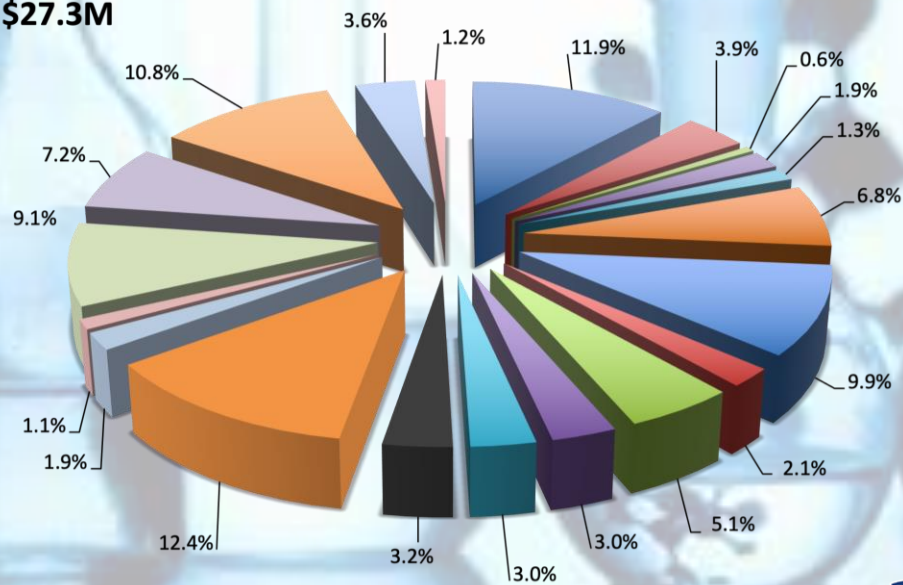


FY 20/23 FUNDING BREAKDOWN

- Carbon Dioxide Capture, Conversion & Sequestration
- Chemical Engineering
- Civil Engineering
- Coal Science & Technology
- Combustion, Gasification and Power Systems
- Computer Science
- Critical Minerals
- Electric Power Systems
- Electrochemical Technology
- Energy Economics
- Environmental Engineering
- Fuels & Catalysis Science
- Geosciences
- Geothermal
- Industrial Health & Safety
- Materials Science & Engineering
- Mining Engineering
- Petroleum & Natural Gas Engineering
- Renewable Energy
- Unconventional Oil & Gas

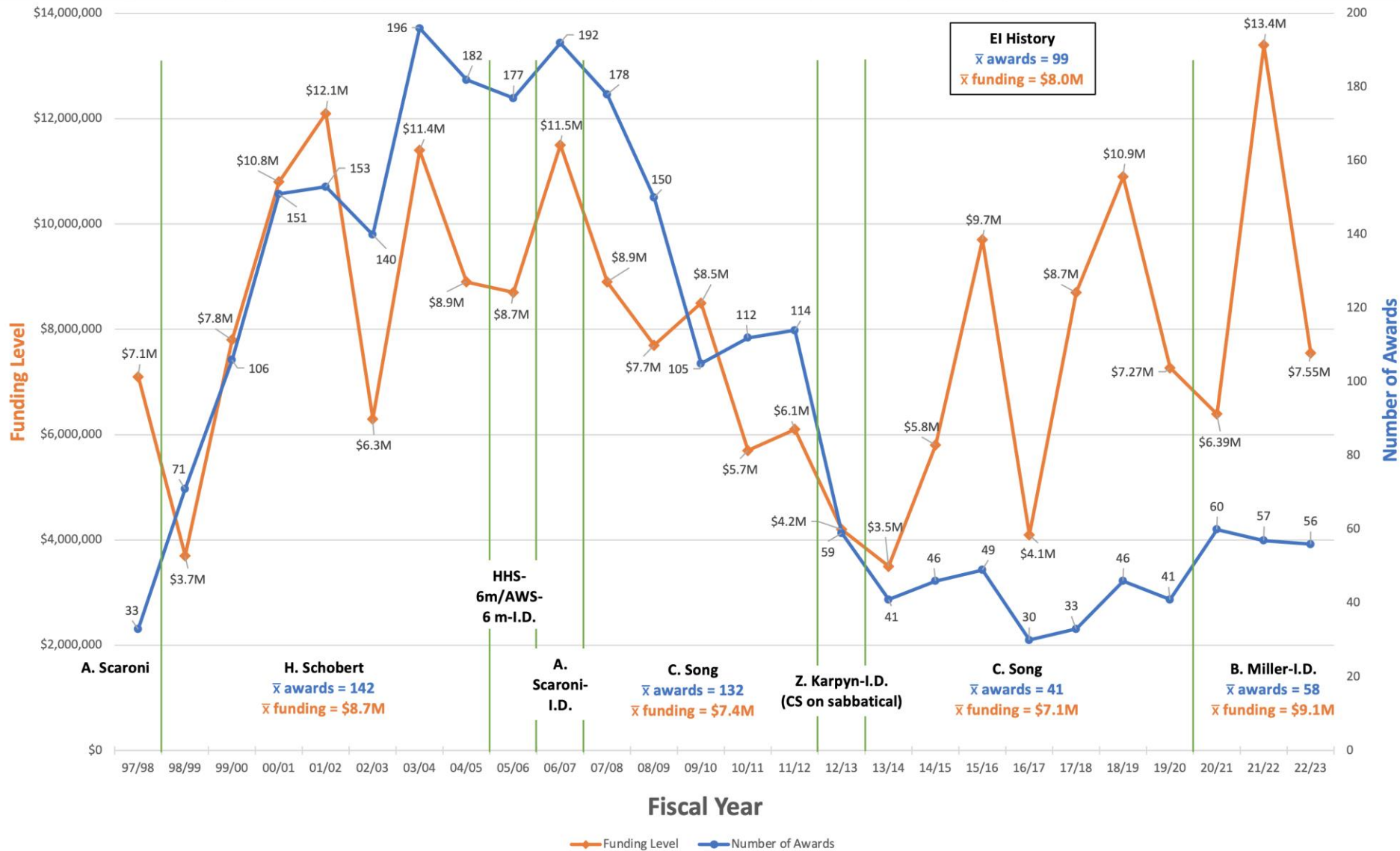


\$27.3M



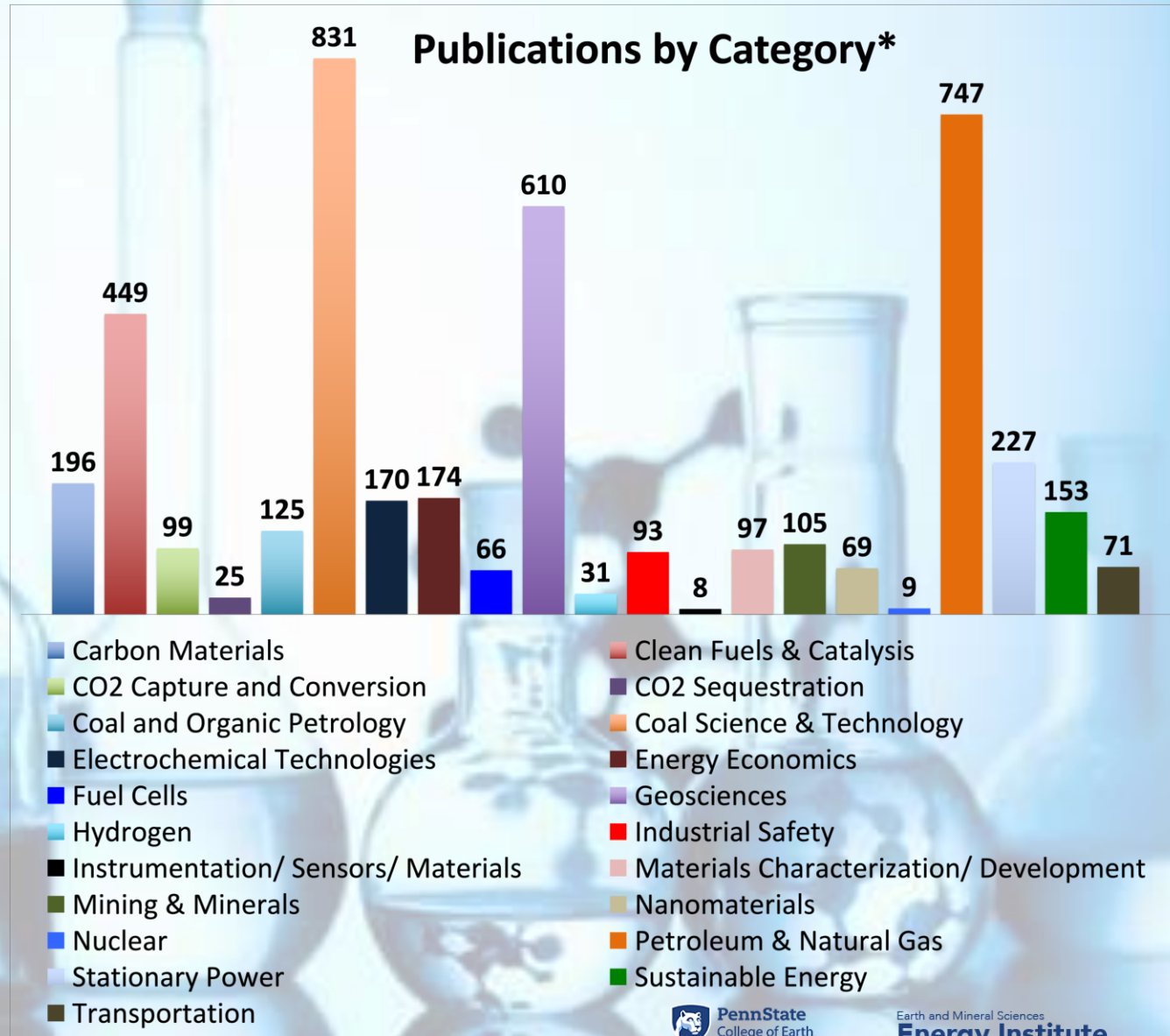
173 projects

SUMMARY OF ENERGY INSTITUTE AWARDS AND FUNDING



PUBLICATIONS (FROM 1998 TO JULY 2023)

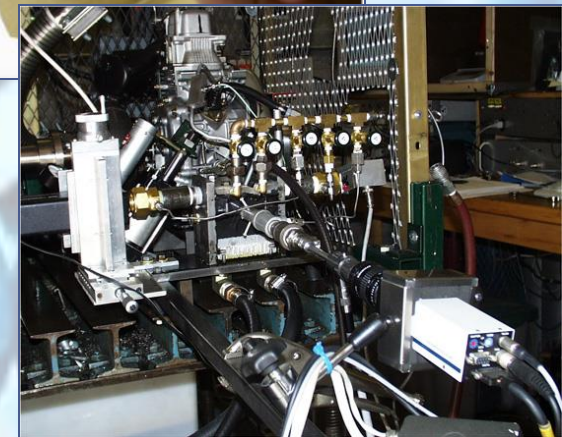
- Over 4,300 publications in our database
- Over 900 refereed journal articles (from 1998 to 2019 (being updated for external review meeting in April 2024))



INSTITUTE ORGANIZATION (Current but will be undergoing reorganization)

Most of the Institute's projects are (**were**) coordinated through nine strategic program areas:

- Carbon Materials
- Clean Fuels & Catalysis
- Coal Science & Technology
- Economics & Energy Systems
- Electrochemical Technologies
- Nanomaterials
- Petroleum & Natural Gas
- Stationary Power
- Sustainable Energy



TYPES OF ACTIVITIES

- Computer modeling
- Fundamental and applied research
- Bench- to demonstration-scale research and development
- Field support activities and programs
- Economic studies
- Information/technology transfer



RESEARCH PROGRAMS (up to June 30, 2023)

- **Carbon Materials**
 - Focuses research on materials such as graphite, petroleum & metallurgical coke, activated carbon, anthracite, and pitch
- **Clean Fuels and Catalysis**
 - Catalysis for clean fuels & chemicals; adsorption & desulfurization; coal conversion; advanced jet fuels; fuel processing for fuel cells; H₂ production; CO₂ capture & use
- **Coal Science and Technology**
 - Coal structure & properties; coal sample bank; coal conversion to gases (gasification), liquids (liquefaction), and chemicals & materials
- **Stationary Power**
 - Coal-fired power plants & industrial boilers; hardware development and testing; fuel preparation & characterization; coal/biomass cofiring; combustion & gasification research; emissions characterization & control; reagent/sorbent characterization & evaluation

RESEARCH PROGRAMS (CONT.)

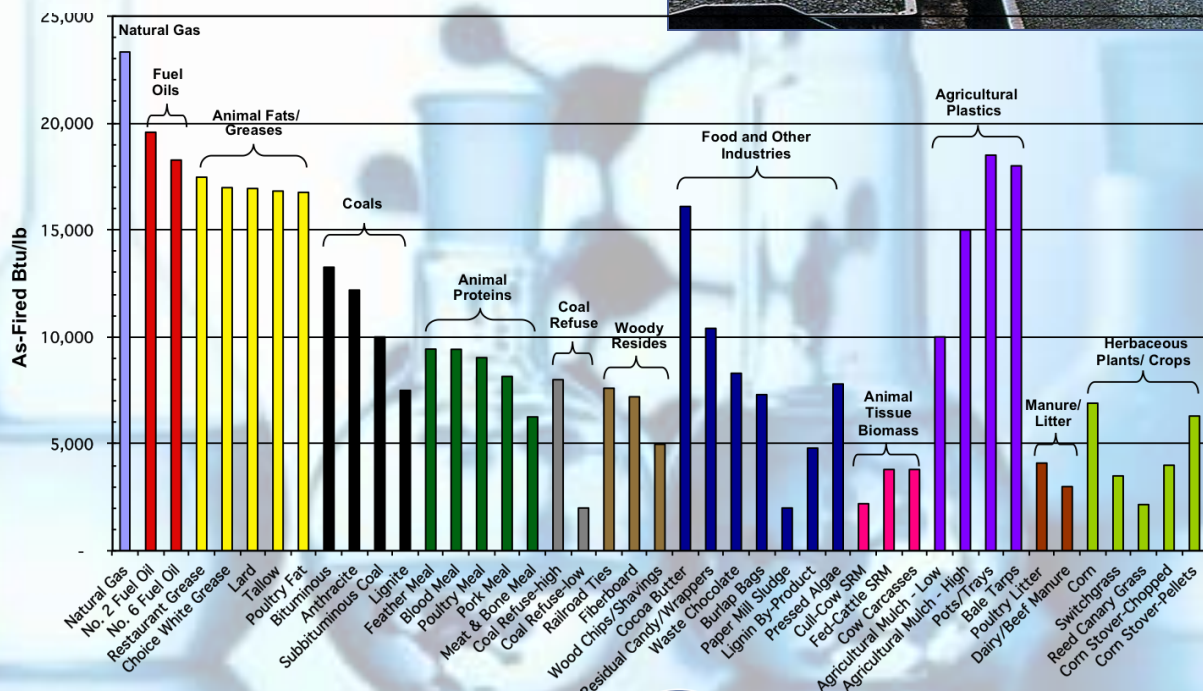
- **Electrochemical Technologies**
 - Solid oxide & PEM fuel cells; hydrogen production; high-temperature materials
- **Nanomaterials**
 - Nanomaterials development by model, design, & experiment; nanomaterials characterization; nanomaterials synthesis & evaluation
- **Petroleum and Natural Gas**
 - Advanced imaging of fluid flow in porous media; petroleum & natural gas exploration & production
- **Sustainable Energy**
 - Coordinates the West Penn Power Sustainable Energy Fund; biomass utilization & gasification
- **Economics and Energy Systems**
 - Studies the balance between supply and demand for energy and electric power. Analyzes market forces and regulations that influence availability, prices, and environmental impacts

SOME EXAMPLES OF PROJECTS/AREAS OF RESEARCH

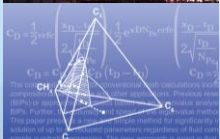
- Industrial and utility boilers
- Emissions from combustion systems
- New processes for refineries
- Catalysts for fuel processing and chemical synthesis
- Electricity markets
- Domestic petroleum and natural gas
- Fuel cells
- Biomass/ alternative fuels



Examples of feedstocks evaluated at Penn State



PUBLIC-PRIVATE RELATIONSHIPS (CONSORTIA)



- Consortium for Premium Carbon Products from Coal (CPCPC)
 - 1998-2012, \$8.6M DOE, and \$5M cost share
- Stripper Well Consortium (SWC)
 - 2000-2015, \$12M DOE, and \$3M cost share
- Gas Storage Technology Consortium (GSTC)
 - 2003-2010, \$2.8M DOE and \$0.7M cost share
- Unconventional Natural Resource Consortium (UNRC)
 - 2011-2018
- Enhanced Oil Recovery (EOR) Joint Industry Partnership (JIP)
 - 2011-2023
- University Coalition for Fossil Energy Research (UCFER)
 - 2015-2023, \$20M DOE

CENTERS/INITIATIVES

- Center for Quantitative Imaging
- Center for Geomechanics, Geofluids, & Geohazards (G3)
- Clean Power Plan Impact Initiative
- Initiative for Sustainable Electric Power Systems (ISEPS)
- Penn State – Dalian University of Technology Joint Center for Energy Research (JCER)



ENHANCED OIL RECOVERY

$$C_D = \frac{1}{2} \operatorname{erfc} \left(\frac{x_D - t_D}{2\sqrt{t_D}} \right) = \frac{1}{2} e^{x_D N_{Pe}} \operatorname{erfc} \left(\frac{x_D - t_D}{2\sqrt{t_D}} \right)$$

$$C_D = C_{D1} + C_{D2} + C_{D3} + \dots + C_{Dn}$$

$$C_D = \frac{1}{2} \operatorname{erfc} \left(\frac{x_D - t_D}{2\sqrt{t_D}} \right)$$

The computational time for conventional flash calculations increases significantly with the number of components, making it impractical for use in many fine-grid compositional simulation and other applications. Previous research to increase flash-calculation speed has been limited to those with zero binary interaction parameters (BIPs) or approximate methods based on an eigenvalue analysis of the binary interaction matrix. Practical flash calculations, however, nearly always have some nonzero BIPs. Further, the accuracy and speed of the eigenvalue methods varies depending on the choice and number of the dominant eigenvalues. This paper presents a new and simple method for significantly increasing the speed of flash calculations for any number of nonzero BIPs. The approach requires the solution of up to 3 reduced parameters regardless of fluid complexity or the number of components and is based on decomposing the BIPs into two parameters using a simple quadratic regression. The new approach is exact in that the equilibrium phase compositions for the same BIPs are identical to those with the conventional flash calculation; no eigenvalue analysis is required. Further, the new approach eliminates the Rachford-Rice procedure and is more robust than the conventional flash-calculation

CENTERS/INITIATIVES (CONT.)

- Penn State Initiative for Geostatistics and Geomodeling Applications (PSIGGMA)
- Center on Critical Materials (C^2M)
- Silicon Carbide Innovation Alliance (SCIA)

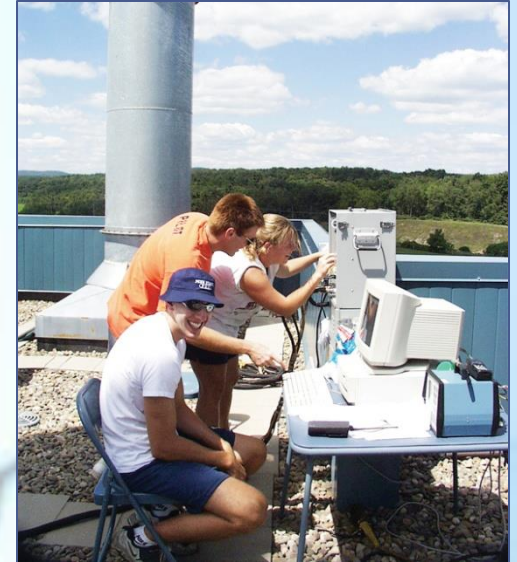


Rare-earth oxides, clockwise from top center: praseodymium, cerium, lanthanum, neodymium, samarium, and gadolinium.

EDUCATION/OUTREACH

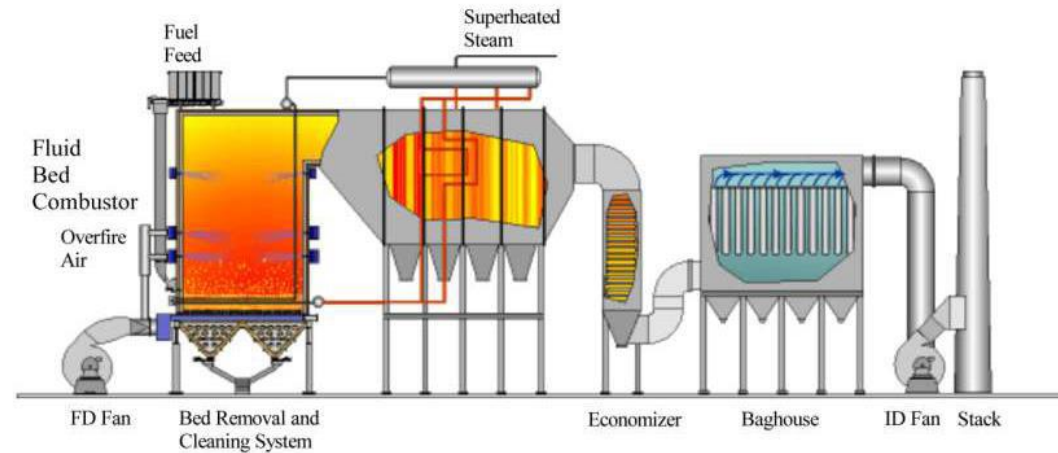
(Some activities were discontinued several years ago)

- Institute provides opportunities for graduate and undergraduate students
 - Participation in research projects
 - Individualized senior undergraduate and honor students' projects
 - Internships with industry
- Institute actively supports honors and minority programs and programs for elementary to high-school students

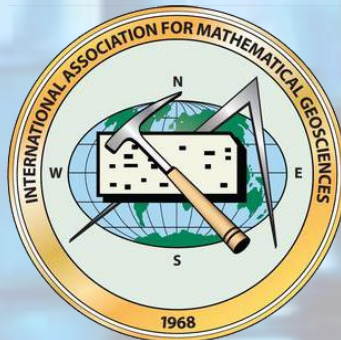


EDUCATION/OUTREACH (CONT.)

- Institute faculty and staff, with a diverse range of expertise, provide assistance/education to the general public
- Institute assists with holding workshops, seminars, and conferences including international conferences (e.g., 20th Annual Conference of the International Association for Mathematical Geosciences (IAMG))



Cargill used results from feasibility testing at Penn State and implemented them into a full-scale combined heat and power plant in Alberta, Canada that replaced coal and natural gas with compostable materials, deadstock, facility waste, etc.



20th Annual Conference
IAMG2019
State College, Pennsylvania, USA



SERVICES

- Penn State Coal Sample Bank
 - 60 years in existence; 38 well-preserved DOE samples; 500 historical samples
- Argonne Premium Coal Sample Bank
 - 8 well-protected (never exposed to O_2) coals sealed in glass ampoules or 5-gallon carboys
- Hardgrove Grindability Index Standard Reference Samples
 - Penn State is the world's sole provider of primary HGI SRSs; each set contains nominally 40, 60, 80, & 100 HGI coals

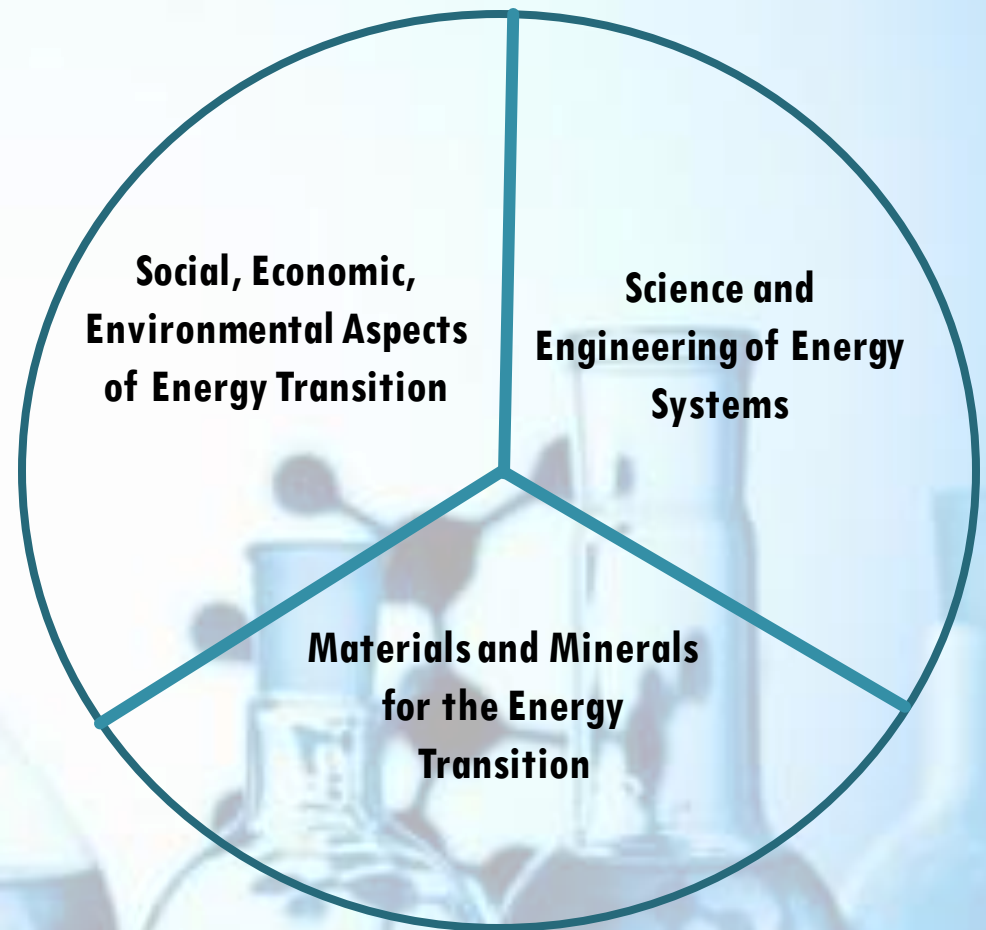


WHAT DOES THE ENERGY INSTITUTE OFFER TO POTENTIAL AFFILIATES

- Pre- and post-award assistance
- Cost share for proposals
- Funding for analyzers and equipment
- Laboratory staff assistance
- Website development and maintenance
- Assistance in hosting conferences and major meetings
- Assistance to consortia and centers
- Poster design and printing
- Research marketing through news articles, fact sheets, and brochures

WHERE WE ARE GOING FROM HERE

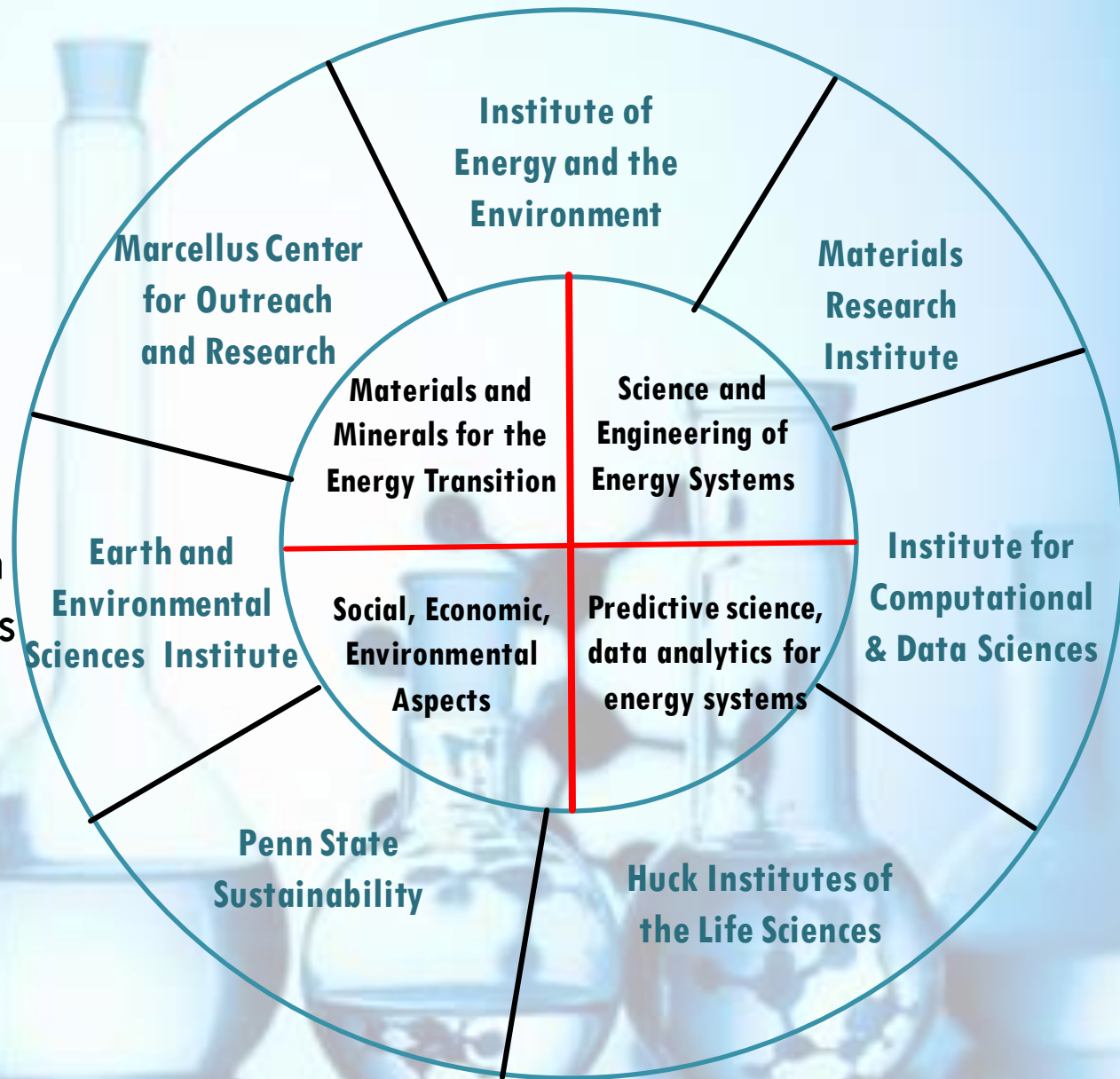
- Recognize our legacy, but foster and promote new areas for growth
- Maintain a healthy portfolio of projects across all “technology” readiness levels
- Build a strong connection to industry, national labs, other research centers both domestic and abroad, funding agencies
- Promote a diverse and vibrant community of researchers – faculty, post-docs, students
- Invest effort in the professional development of students
- Foster an active outreach program that promotes exchange of ideas and research to/from communities



EI ORGANIZATION

- Organize into 4 broad thematic areas:
 - Minerals and Materials for sustainable energy systems
 - Scientific and Engineering aspects of sustainable energy systems
 - Social, economic and environmental aspects of sustainable energy systems
 - Predictive science, data analytics for sustainable energy systems
- Promote EI activities within these thematic areas:
 - Meetings of interest groups
 - Suggestions for EI seminar series speakers
 - Visiting scholar activity
 - Student cost share allocations
 - Investment in EI infrastructure – lab space allocation, deployment of shared equipment, marketing and communication activities, seed funds
- Expand the number of co-funded faculty. Identify key researchers from across the college and university

- Collaborate with organizations across the university to foster a culture of research excellence
- Identify and support niche areas that complement research in other organizations
- Leverage resources to support researchers working in energy related areas



INVEST IN RESEARCH

We invest in research infrastructure. Some examples within last 5 years:

- New TGA
- New ICP-MS
- New XRF analyzer and benchtop plasma furnace
- CHNSO analyzer and microwave digester
- VWR drying ovens; 2 Thermo Scientific vacuum drying ovens; muffle furnace
- Zeiss Camera for petrology work
- Various equipment/analyzer repairs
- Laptop computers

Be on the lookout for opportunities to enhance research infrastructure – infrastructure grants, industry support, donor support

RESEARCH INFRASTRUCTURE

- Shared facilities
- Facilities for sample storage
- Detailed inventory of equipment in labs and also within the storage facilities.
- Space for sample preparation, water bath, centrifuge, ovens etc.
- Computational facility to support research computation, database access etc.
- Collaborative spaces. Space for hoteling, meeting etc.

SOME OVERARCHING ACTIVITIES

- Work on building a vibrant student community
- Promote professional development activities for students
- Facilitate collaborations through students. Assign student shared offices.
- Make students skilled at presenting their research, writing – make provisions for faculty to teach professional dev. topics – expose students to real world issues through seminars
- Provide trainings for example on proper use of Swagelok fittings, Labview etc.

SOME OVERARCHING ACTIVITIES

- Build a strong infrastructure to facilitate collaborations with industry, national labs and other research organizations
 - Form affiliates programs within each of the thematic areas
 - Support current and planned programs:
 - Power and Minerals Stakeholders Group
 - Silicon Carbide Innovation Alliance
 - NSF-IUCRC on subsurface CO₂ sequestration
 - Initiative for Repurposing Current Energy Infrastructure for the Energy Transition

SOME OVERARCHING ACTIVITIES

- Have a vibrant visiting scholar program
 - Invite world class researchers – provide infrastructure to facilitate their stay and collaborations
 - Promote the institute as a destination of choice for faculty sabbaticals
 - Invite a limited number of student scholars who high caliber recruits for departments in the college
- Establish a strong outreach effort
 - MCOR re-envisioned

SOME PLANNED ACTIVITIES

- Constitute an Advisory Board for the institute
- Organize research symposia/showcase – invite national lab researchers, industry experts, funding managers
- Coordinate strategic planning activities
- Establish a student engagement program – professional development, topical seminar series, research training, career placement
- Form Research Initiatives/Affiliates program in each thematic area
- Invest effort in developing alumni supporters to serve on various development activities for the institute



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**THE EMS ENERGY INSTITUTE NEEDS
YOUR ENERGY TO PROPEL ITSELF
INTO A CENTER OF EXCELLENCE!!!!**

