

# EMS Energy Institute Strategic Plan



**2014/15 through 2018/19**

The EMS Energy Institute’s mission and vision statements have been updated in this strategic planning cycle, and a list of values has been added.

## **Mission**

The EMS Energy Institute produces advanced energy research, enables the development of novel energy technologies, engages graduate and undergraduate students in energy research, and promotes energy-related outreach by providing technical support to industries in the U.S. and abroad.

## **Values**

- To advance and disseminate fundamental knowledge
- To assist the nation and the world in meeting energy demands through research innovation
- To enrich educational experience of graduate and undergraduate students
- To promote a culture of creativity, inclusion, and collaboration

## **Vision**

To be the leading research hub for energy science and technology development.

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## Executive Summary

The EMS Energy Institute is a leading research and development organization focused on energy science and engineering. From solving challenges related to fossil fuels to exploring new technologies for alternative energy, we are involved in almost every aspect of energy research. We are committed to diversifying the nation's energy sources, improving the efficiency by which we generate and use that energy, and expanding the use of our indigenous resources while relying less on non-domestic sources of energy.

The EMS Energy Institute has developed a near- to mid-term strategic plan that builds on longstanding strengths and emerging opportunities to achieve the vision of being the leading research hub for energy science and technology development. The goals and strategies laid out in this strategic plan follow the central theme of “energy resource development and the associated challenges of water and carbon management.” To achieve this goal we will:

1. *Advance Energy Research to Tackle Contemporary Challenges in Energy Resource Development.* We are strategically positioned to expand research capabilities in the area of energy resource development and the associated challenges at the intersection of energy, water, and carbon emissions.
2. *Expand Research Capabilities through Shared Instrumentation.* Specific strategies include upgrading existing instrumentation through targeted fundraising campaigns and building networks for shared research instrumentation.
3. *Cultivate the Synergies that Promote Research Innovation.* The EMS Energy Institute is an excellent platform to further promote synergistic activities and research collaboration, to “Think Energy”.
4. *Enhance Student Educational Experience* through the creation of professional development opportunities for graduate students.
5. *Grow Global Engagement* through industrial partnerships, energy outreach, and internationalization of our faculty and research collaborations.

This document shall serve as a guide for the Institute's executive staff and administration to make budgetary and operational decisions, while remaining adaptable to institutional priorities and evolving energy technology challenges.

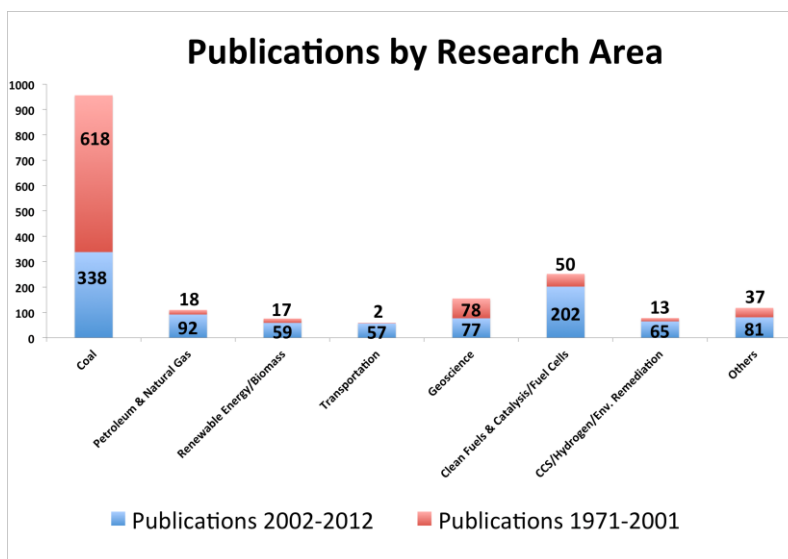
## Introduction

The EMS Energy Institute is a research-based unit within Penn State's College of Earth and Mineral Sciences (EMS) and an affiliate of the Penn State Institutes of Energy and the Environment (PSIEE). It was formally established in 1996, under Dean John Dutton, and was largely based on the former Energy and Fuels Research Center. Originally, the Institute consisted of the former carbon research center, combustion laboratory, coal utilization center, laboratory for hydrocarbon process chemistry, and organic petrology laboratory. Today, the EMS Energy Institute is a leading research and development organization with a broad energy science and engineering portfolio. The EMS Energy Institute is involved in almost every aspect of energy research, from solving challenges related to fossil fuels to exploring new technologies for alternative energy. The Institute is committed to diversifying the nation's energy sources, improving the efficiency by which the nation generates and uses that energy, and expanding the use of native energy resources.

The EMS Energy Institute houses nine research programs, including carbon materials, clean fuels and catalysis, coal science and technology, energy economics, electrochemical technologies, petroleum and natural gas, nanomaterials for energy, stationary power, and sustainable energy. The Institute is also home to several interdisciplinary centers and collaborative research initiatives such as Center for Quantitative Imaging, Center for Geomechanics, Geofluids, and Geohazards (G3), Stripper Well Consortium, the Unconventional Natural Resources Consortium, the Gas Flooding Joint Industry Project. The Institute has more than 50 research staff and affiliated faculty, 8 administrative staff members, and 50-75 graduate students at any given time.

Fossil energy is the EMS Energy Institute's core strength, and the Institute continues to be an international leader in coal-related and fuel science research. Penn State is one of the few academic centers where there are formal education opportunities in fuel science. It is also the leading U.S. institution for coal-related publications. Petroleum and natural gas research is rapidly becoming a main research focus for the EMS Energy Institute. Current research focuses on environmental concerns and explores areas such as fluid flow in porous media, gas-to-liquid conversion of fuels, and gas and liquid combustion systems. Currently, Institute researchers publish about 70 refereed journal articles a year in the most respected journals in these fields, and EMS Energy Institute publications collectively receive over 2,200 citations a year in the Science Citation Index. Since 1997, EMS Energy Institute researchers have published over 550 refereed journal articles that have been cited more than 11,000 times. The high number of citations credited to Institute faculty and students demonstrates the importance of their work within the greater national and international scientific communities. As but one example, the EMS Energy Institute researchers have published high-impact papers over the last 10 years that are among the Top 10 Most Cited Papers worldwide in fuel desulfurization, fuel processing for fuel cells, CO<sub>2</sub> capture, non-fuel uses of coal, and catalytic hydrocarbon conversion.

Although the focus of the Institute's research has long been dominated by fossil energy, technical expertise has broadened to include a wide range of topics, such as renewable energy and biofuels, combustion, catalysis, fuel processing, fuel cells, hydrogen energy, environmental issues, geoscience, and carbon dioxide capture, sequestration and utilization. The broadening of expertise at the EMS Energy Institute is illustrated in Figure 1, which shows referred and non-referred publications by research area for the periods 1971-2001 and 2002-2012. In non coal-related research areas, most of the publications (more than 75 percent) were prepared in the last ten years.



**Figure 1:** Refereed and non-refereed publications by research area (1971-2013)

The EMS Energy Institute has a major national and international presence. During the last strategic cycle, the EMS Energy Institute performed more than 400 projects of which 50 were with 22 international companies and organizations. The EMS Energy Institute continues to enhance global collaboration and industrial engagement through our many faculty-led centers and consortia. We collaborate with universities and companies in China, India, South Africa, and Germany, among others. Institute faculty hosted two major international conferences in 2013, the Twelfth International Conference on Carbon Dioxide Utilization (ICCDU) and the International Conference on Coal Science and Technology (ICCS&T). In addition, the EMS Energy Institute is home to industry-led consortia where faculty, students, and industry professionals develop engineering solutions to contemporary industry challenges. Currently, these groups include the Unconventional Natural Resources Consortium, the Gas Flooding Joint Industry Project, and the Stripper Well Consortium. At the EMS Energy Institute, currently there are 29 U.S. students and 44 international students from countries including China, India, Iran, Italy, Nigeria, South Africa, South Korea, Thailand, United Kingdom, and Venezuela. The Institute provides these students with a unique research experience within a diverse community of faculty and staff, while fostering strong relationships with various industries and government agencies – relationships critical to nurturing career opportunities. Students have the opportunity to publish papers and attend conferences to present their findings. Many of the Institute students, both undergraduates and graduates, receive recognition and awards for the work they complete at the Institute.

The EMS Energy Institute is committed to providing academic and technical leadership in the development and assessment of energy resources and associated technologies. The demand for these technologies is increasing, as is the need for well-educated energy professionals. This strategic plan was developed to address those demands within the scope of our mission and vision. The goals of Penn State and the College of Earth and Mineral Sciences were also an important factor in developing these strategies. This document is meant to guide the Institute’s decision-making while being flexible enough to respond to changes in global energy needs.

## Supporting Institutional Goals

The EMS Energy Institute, cognizant of the goals and strategies of the College and the University, developed its strategic goals for 2014/2015 through 2018/2019 with these in mind. The EMS Energy Institute supports the University's strategic goals including its commitment to the seven general goals outlined the University's current strategic plan, "Priorities for Excellence, The Penn State Strategic Plan 2009-10 through 2013-14", which are:

- Enhance student success
- Advance academic excellence and research prominence
- Realize Penn State's potential as a global university
- Maintain access and affordability and enhance diversity
- Serve the people of the Commonwealth and beyond
- Use technology to expand access and opportunities
- Control costs and generate additional efficiencies

### *Enhance Student Success / Advance Academic Excellence and Research Prominence*

The EMS Energy Institute supports student success by providing opportunities for graduate and undergraduate student participation in research and assisting in securing internships for students. Funded research provides active learning opportunities for graduate students, assists in and providing laboratory facilities for undergraduate research and design classes, and affords the ability to work with senior and honor thesis students on research projects for undergraduate students.

EMS Energy Institute affiliated faculty are recognized worldwide as experts in their field and for conducting research that has societal impact. This impact will continue and will be expanded upon during the next 2-3 years as the EMS Energy Institute expands its faculty base through joint appointments and additional research infrastructure for new affiliated faculty.

### *Realize Penn State's Potential as a Global University / Maintain Access and Affordability and Enhance Diversity*

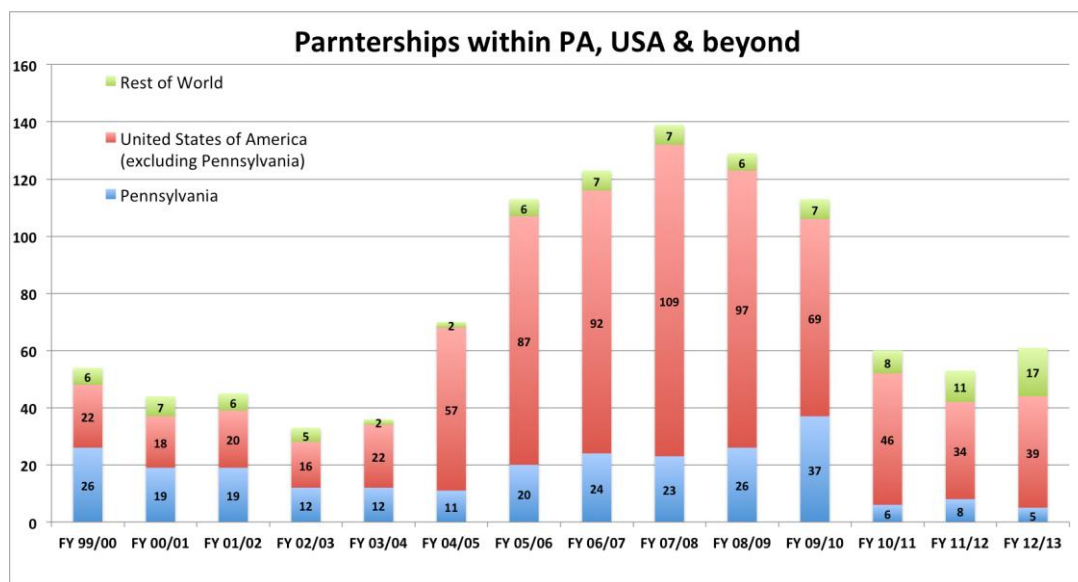
The EMS Energy Institute supports Penn State's goal of encouraging globally orientated partnerships and during the last strategic planning cycle, the EMS Energy Institute performed projects with companies from Australia, Austria, Canada, Denmark, England, Estonia, Germany, Hong Kong, India, Indonesia, Japan, Netherlands, Norway, Poland, Qatar, Saudi Arabia, South Africa, South Korea, Spain, Switzerland, Thailand, and the United Arab Emirates. In 2011 Penn State and Dalian University of Technology in China established the Joint Center for Energy Research (JCER), a research endeavor to facilitate collaborative projects and global education in energy sciences and technology. The EMS Energy Institute is leading this effort for Penn State. In addition, EMS Energy Institute researchers have established major connections to universities and companies in South Africa, India, Korea, China, Germany and Thailand, which are discussed in more detail in Goal 5. These ties will be strengthened and expanded upon over the next few years.

The EMS Energy Institute's primary diversity initiative is to increase graduate student diversity and increase student success in the completion of a doctoral degree or integration into a career. This is discussed in more detail in the diversity goal section.



### *Serve the People of the Commonwealth and Beyond*

The EMS Energy Institute is a national and international research facility and has a long history of working with companies, government agencies, and universities from across the U.S. and the world as shown in Figure 2. The number of international projects has steadily increased over the last three fiscal years and during the last strategic planning cycle, the EMS Energy Institute performed 50 projects with companies from 22 countries. The EMS Energy Institute will continue to pursue strategic interdisciplinary alliances among research institutes/centers and academic programs within and outside of Penn State. In addition, the EMS Energy Institute will retain its role in establishing and managing research consortia and centers, working closely with industry to address its needs, and maintaining a vibrant outreach component through seminars, publications, workshops, and meetings.



**Figure 2:** Projects at the EMS Energy Institute from Pennsylvania, the rest of the U.S., and other countries

### *Use Technology to Expand Access and Opportunities*

The EMS Energy Institute relies heavily on technology for all aspects of its research mission, including preparing and submitting proposals, generating, collecting, and interpreting data, preparing publications and reports, monitoring budgets, assisting in communications, data storage and retrieval, and providing outreach activities. The EMS Energy Institute works closely with College IT personnel to ensure the Institute is meeting compliance policies, using current technology, and operating efficiently.

In compliance with Penn State’s accessibility guidelines, the EMS Energy Institute is updating its technology and web presence to be inclusive for individuals with various disabilities. All web pages published or hosted by the University must be in compliance with the World Wide Web Consortium's standard: Web Content Accessibility Guidelines (WCAG) Version 2.0, AA conformance level.

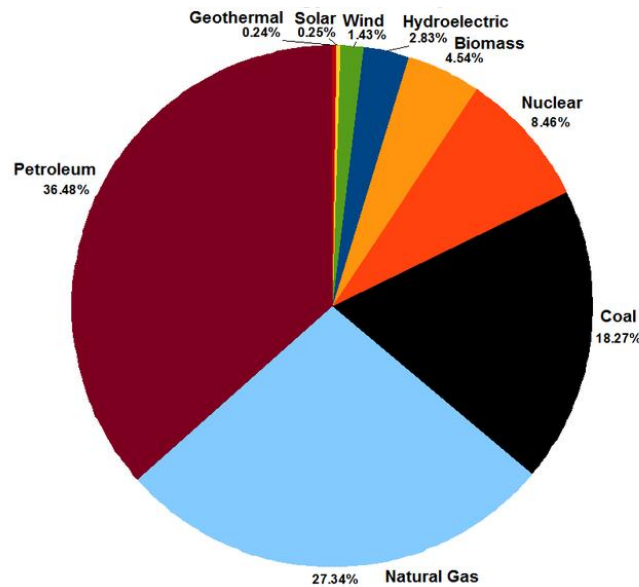
### *Control Costs and Generate Additional Efficiencies*

Penn State is strongly committed to ongoing cost containment efforts. To maintain excellence in a time of decreasing resources, Penn State will require innovative and flexible programs and policies, careful review of resources and processes, and investments in its workforce. The EMS Energy Institute will support these goals through better utilization of research and analytical facilities and coordination with other Penn State research centers. Users facilities will be established including CT scanner and FTIR user facilities. More joint faculty appointments will be established and more affiliated faculty will be recruited to fully utilize existing research facilities. Dialogue will be started with other core research facilities and departments to market/showcase existing analytical capabilities to reduce duplication of analyzers by other research groups, which will increase EMS Energy Institute instrument usage and reduce equipment costs for other research groups.

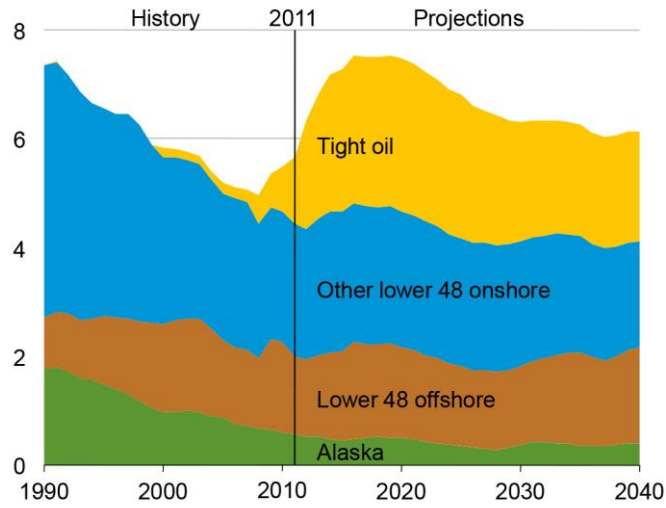
## Goals and Strategies to Achieve the Vision

The EMS Energy Institute has developed a near- to mid-term strategic plan to achieve the vision of being the leading research hub for energy science and technology development. The goals and strategies laid out in this strategic plan follow the central theme of “energy resource development and the associated challenges of water and carbon management.” Along with this thematic emphasis, the EMS Energy Institute seeks to expand research capabilities through shared instrumentation, promote synergistic activities and research collaboration, create professional development opportunities for graduate students, and grow Penn State’s global presence in energy science and technology. This document shall serve as a guide for the Institute’s executive staff and administration to make budgetary and operational decisions, without constraining the pursuit of evolving strategic opportunities.

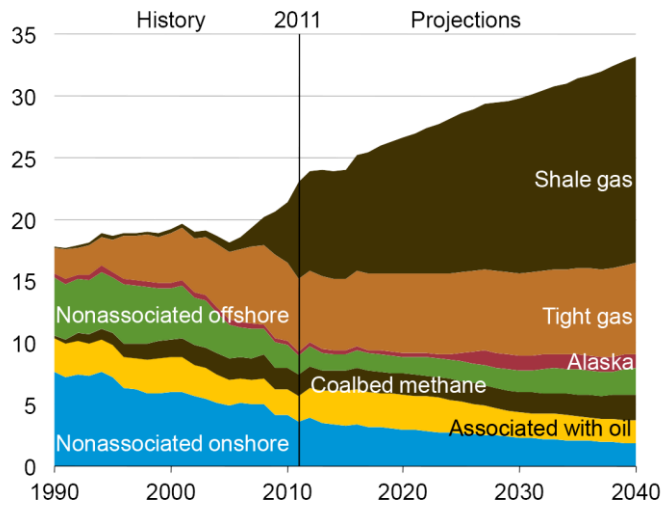
Coal, natural gas, and petroleum resources largely dominate U.S. energy consumption (Figure 3). Trends in U.S. production of petroleum and natural gas are largely geared toward increasing reliability on tight oil, gas and shale gas resources, also referred to as unconventional oil and gas resources (Figures 4 and 5). However, the development of this energy sector presents significant technological, environmental, social, and economical challenges that require a systems thinking approach to problem solving. As such, an inter-department research unit such as the EMS Energy Institute is strategically equipped to bring together the expertise required to understand, influence, and resolve contemporary challenges in energy resource development.



**Figure 3:** U.S. energy consumption by primary source in 2012. SOURCE: EIA Annual Energy Outlook 2013.

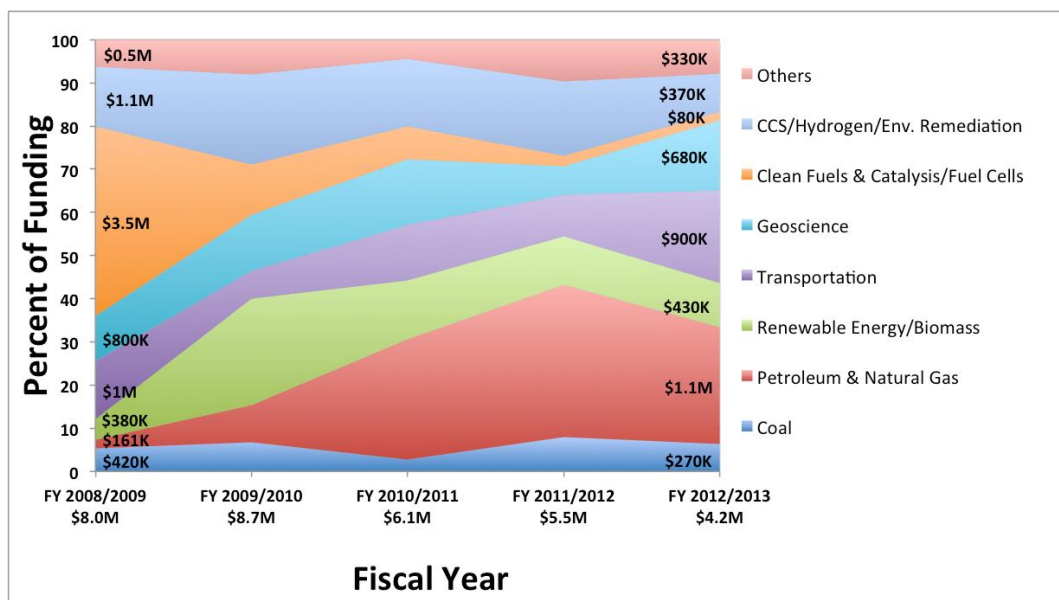


**Figure 4:** Trends in U.S. production of crude oil by source, in million barrels per day, 1990–2011 and projections to 2040. SOURCE: EIA Annual Energy Outlook 2013.



**Figure 5:** Trends in U.S. production of dry natural gas by source, in trillion cubic feet, 1990–2011 and projections to 2040. SOURCE: EIA Annual Energy Outlook 2013.

The EMS Energy Institute’s research portfolio is currently centered around nine general research areas including carbon materials, clean fuels and catalysis, coal science and technology, electrochemical technologies, energy economics, nanomaterials, petroleum and natural gas, stationary power, and sustainable energy. These general areas are used to promote the Institute’s research capabilities, but as can be seen in Figure 6 and Table 1, there is a wide range of research topics at the Institute. These research topics are aligned with the nation’s energy consumption and future energy projections. Specifically, the EMS Energy Institute is well positioned to address the future projections of major increases in the unconventional gas and oil industries.



**Figure 6:** Research Area Funding Trends (as percent of total funding for last strategic planning cycle)

Historically coal-related research was the dominant research area at the Institute (about 20-50 percent of total research funding in FY2005/2006 and FY2006/2007, when compiling these data started) but over the last 8-10 years there has been a shift to a broader research portfolio. With the exception of nuclear energy, the EMS Energy Institute’s research portfolio reflects the nation’s energy consumption, which is predominately fossil fuel and related research followed by biomass and renewable energy activities.

Research area trends for the last strategic planning cycle are shown in Figure 6 and given in Table 1. These data show that there is a significant increase in petroleum and natural gas research from 2 percent to about 30 percent of total research funding. The percent of total funding in some areas has remained relatively steady – coal (~6-8%), geosciences (~10-16%), transportation (~10-15%), the category of CCS (carbon capture and storage)/hydrogen/ environmental remediation (~14-20%), and the broad category of others (~6-10%). The area of clean fuels and catalysis/fuel cells was a major funding area but the percent of total funding has decreased over the strategic planning cycle. The percent of total funding for the renewable energy/biomass area has increased slightly from about 5 percent to 10-14 percent and has been relatively steady the last three fiscal years.

**Table 1: Total Funding by Research Categories for the Last Strategic Planning Cycle**

Research Category	FY 08/09 %	FY 09/10 %	FY 10/11 %	FY 11/12 %	FY 12/13 %
Coal	5.27	6.70	2.67	7.91	6.45
Petroleum & Natural Gas	2.03	8.70	28.00	35.29	26.95
Renewable Energy/Biomass	4.79	24.69	13.64	11.31	10.21
Transportation	13.54	6.26	12.81	9.60	21.49
Geoscience	10.43	13.15	15.17	6.69	16.29
Clean Fuels & Catalysis/Fuel Cells	43.84	11.54	7.70	2.37	1.91
CCS/Hydrogen/Environmental Remediation	13.77	20.83	15.48	17.08	8.83
Others*	6.32	8.13	4.54	9.76	7.87

\*Others: Sensor/Materials, Materials Characterization, Industrial Safety, Nuclear, Underground Science, Economics/Policy

It is evident from these data that the EMS Energy Institute’s diversity in research activities and shift in its research portfolio allow it to be strategically equipped to tackle contemporary challenges in energy resource development. This includes all aspects of exploration, production, processing, and utilization in environmentally sound technologies. In addition, the proposed goals and strategies allow seamless integration of research, education, and outreach activities as well as increased access to facilities and research opportunities.

### *Goal 1: Advance Energy Research to Tackle Contemporary Challenges in Energy Resource Development*

The EMS Energy Institute is the ideal setting to enable advanced energy research within the College of Earth and Mineral Sciences. The Institute provides a footprint for research endeavors, including laboratories and equipment that is not available anywhere else at the University. In addition, the Institute is a node that connects faculty from various departments and units across the University. Contemporary energy challenges will be solved through interdisciplinary work and the EMS Energy Institute distinguishes itself from other University entities through its infrastructure and ability to bridge research and faculty across disciplines such as energy and mineral engineering, geosciences, materials, climate, and energy policy.

#### *Strategy 1.1: Assist oil & gas resource development with emphasis on unconventional plays and harsh environments*

Examples of research initiatives in line with this strategy are:

- Develop high-pressure, high-temperature (HPHT) technologies to recover deep oil and gas resources and model complex fluid-fluid and fluid-solid interactions under extreme HPHT conditions
- Explore new corrosion resistive materials to support deep drilling
- Create new sensors for data collection and reservoir monitoring
- Understand physicochemical and poromechanics behavior of tight reservoirs
- Understand geologic aspects of reservoir characterization
- Simulate enhanced oil recovery processes
- Analyze production and deliverability models for liquid-rich shales
- Explore advances in reservoir stimulation via hydraulic fracturing

- Develop new ionic liquid-based technology for recovering hydrocarbons from tar sands and heavy oil deposits

### Strategy 1.2: Further sustainable aspects of energy resource development and the associated challenges at the intersection of energy, water, and carbon emissions

The National Research Council released a report in 2014 that summarized the findings from a two-day public workshop on development of unconventional hydrocarbon resources in the Appalachian Basin. The workshop emphasized, among other things, the potential effects of hydrocarbon resource development on surface water and groundwater quality and quantity, and on ecosystems, air quality, and climate. The report concluded that there is a need for baseline data and ongoing monitoring of these environmental impacts. Specific needs identified were:

- Address water utilization in fuel extraction and power generation
- Address water quality issues with extraction processes such as fracking
- Develop technologies with minimal water consumption and low energy requirements, and hence lower GHG emissions (e.g., bitumen recovery from tar sands)
- Explore sustainable water use in power generation (e.g., higher efficiency systems, water re-use)
- Understand environmental aspects of maintaining air quality
- Understand interaction between water and materials to mitigate corrosion and degradation in systems generating power and chemicals
- Understand water-materials (drilling metals, casing, oil, natural gas, CO<sub>2</sub>, H<sub>2</sub>S, etc.) interactions for sustainable fuel extraction

### Strategy 1.3: Expand faculty expertise base in key research areas

The strategic emphasis on energy resource extraction and water science goes in hand with expansion of the Institute’s expertise base in the areas delineated under strategies 1.1 and 1.2. The current slate of associate tenure-line faculty members of the EMS Energy Institute is insufficient to tackle these strategic research areas. The EMS Energy Institute is strategically positioned to provide a research home for the Institute for Natural Gas Research (INGaR) faculty hires with an academic affiliation in the College of Earth and Mineral Science or with a joint affiliation in EMS and the College of Engineering and form new joint faculty appointments.

- Invest attention and resources in the creation of new joint tenure-line faculty appointments.
- Partner with (INGaR) to build bridges across academic departments in EMS, industry, and in-house and national research facilities.

### Strategy 1.4: Nourish core strengths in coal and fossil fuel research – stewarding our resources

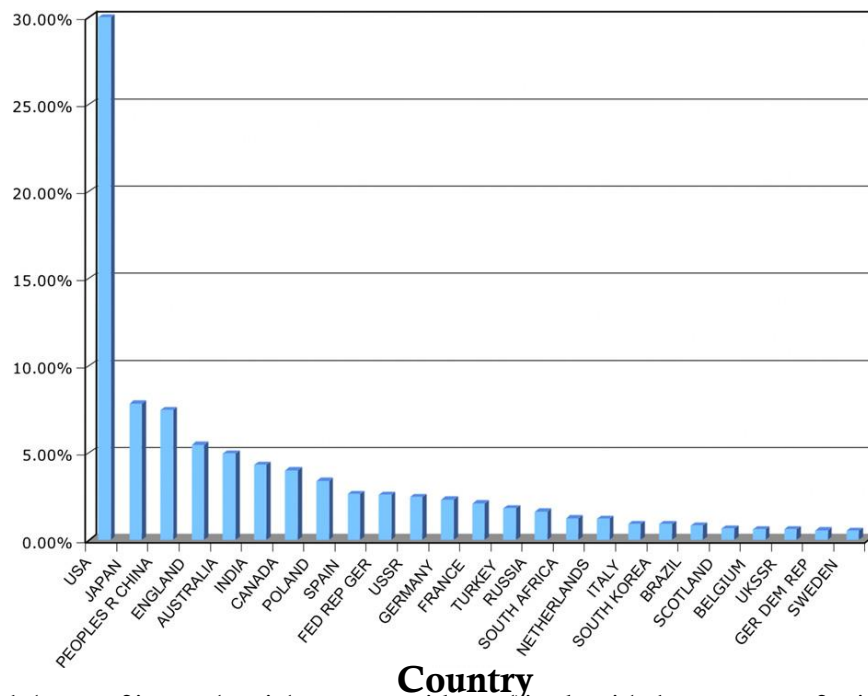
Coal related research remains a core strength of the EMS Energy Institute and Penn State is recognized internationally as one of the leading coal research entities. The Institute evolved over the years from the Coal Combustion Laboratory in 1949 to the broadly based research institute it is today. It is important that the Institute maintains coal-related research as a core strength. Table 2 provides one indication of the institutional historic productivity, which consists of the number of journal records for each institution with “coal” in the title of the journal. A search resulted in more than 22,700 journal publications. The top 100 entities were analyzed, (Penn State was the leading

university with EMS Energy Institute researchers the primary contributors) and a breakdown of the total publications by country of origin is shown in Figure 7. Publication frequency of the three leading countries with coal publications is shown in Figure 8. Between 1970 and 2010 Penn state was the leading entity in the publication of coal-in-title journal articles worldwide (318 articles). In addition, the University houses the two most active and well-regarded coal sample banks in the world. Penn State is one of the few locations where the full breadth of coal science and technology is explored and one of the few locations worldwide with academic educational opportunities. It is for these reasons that that the University has active collaborations both internationally and domestically. Since 2000, there have been publications co-authored with over 100 entities from 15 separate countries (most with collaborators from China, Australia, and South Africa), 29 domestic universities, and 3 national laboratories.

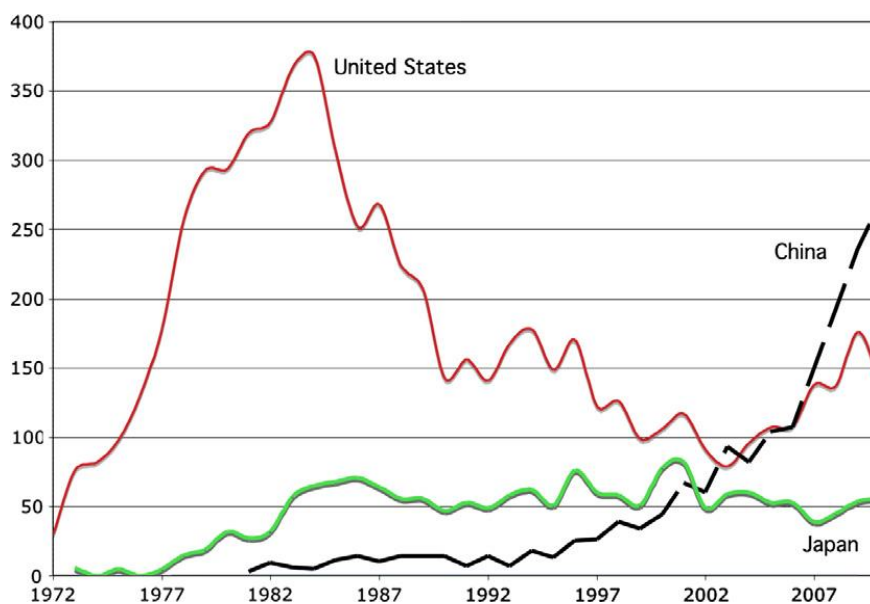


**Table 2:** Universities and institutions sorted by frequency of “Coal” in journal article titles (1970-2010)

<b>PENN STATE UNIV</b> (318)	UNIV WYOMING (78)	<b>SOUTHEAST UNIV</b> (48)
<b>CSIC</b> (307)	CENT FUEL RES INST (75)	<b>TSING HUA UNIV</b> (48)
<b>UNIV KENTUCKY</b> (302)	ELECT POWER RES INST (75)	WROCLAW TECH UNIV (48)
<b>CHINESE ACAD SCI</b> (244)	<b>CARNEGIE MELLON UNIV</b> (73)	<b>E CHINA UNIV SCI &amp; TECHNOL</b> (47)
<b>CSIRO</b> (236)	<b>OSAKA UNIV</b> (73)	SILESIAN TECH UNIV (47)
<b>RUSSIAN ACAD SCI</b> (187)	<b>UNIV NEW S WALES</b> (72)	SRI INT (47)
<b>INDIAN INST TECHNOL</b> (185)	<b>KYOTO UNIV</b> (70)	<b>BANARAS HINDU UNIV</b> (46)
<b>TOHOKU UNIV</b> (184)	<b>UNIV N DAKOTA</b> (70)	<b>UNIV GEORGIA</b> (46)
<b>W VIRGINIA UNIV</b> (179)	SANDIA NATL LABS (69)	ALBERTA RES COUNCIL (45)
<b>HOKKAIDO UNIV</b> (178)	UNIV MELBOURNE (68)	<b>TSINGHUA UNIV</b> (45)
<b>ACAD SCI USSR/RUSSIA</b> (170)	<b>BULGARIAN ACAD SCI</b> (66)	<b>UNIV OVIEDO</b> (44)
OAK RIDGE NATL LAB (160)	<b>TAIYUAN UNIV TECHNOL</b> (66)	<b>WESTERN KENTUCKY UNIV</b> (44)
<b>CHINA UNIV MIN &amp; TECHNOL</b> (154)	IOWA STATE UNIV SCI & TECHNOL (64)	<b>MIDDLE E TECH UNIV</b> (43)
<b>MONASH UNIV</b> (135)	<b>UNIV NOTTINGHAM</b> (64)	<b>UNIV BELGRADE</b> (43)
<b>UNIV LONDON IMPERIAL COLL</b> (179)	<b>DELFT UNIV TECHNOL</b> (63)	UNIV WITWATERSRAND (43)
ARGONNE NATL LAB (124)	<b>UNIV ALBERTA</b> (63)	<b>UNIV ADELAIDE</b> (42)
<b>UNIV NEWCASTLE</b> (114)	BERGBAU FORSCH GMBH (62)	<b>TOKYO UNIV AGR &amp; TECHNOL</b> (41)
<b>UNIV QUEENSLAND</b> (114)	UNIV TENNESSEE (61)	<b>INDIANA UNIV</b> (40)
MIT (113)	<b>UNIV CALIF BERKELEY</b> (60)	<b>CENT MIN INST</b> (39)
<b>SO ILLINOIS UNIV</b> (113)	UNIV PITTSBURGH (59)	FE DZERZHINSKII HEAT ENGN INST (39)
<b>UNIV LEEDS</b> (103)	UNIV TEXAS (57)	UNIV ARIZONA (39)
<b>UNIV UTAH</b> (103)	<b>ZHEJIANG UNIV</b> (57)	UNIV CALIF DAVIS (39)
<b>BRIGHAM YOUNG UNIV</b> (101)	TEXAS A&M UNIV (56)	UNIV TORONTO (39)
<b>POLISH ACAD SCI</b> (98)	<b>CSIR</b> (53)	COLORADO STATE UNIV (37)
<b>HUAZHONG UNIV SCI &amp; TECHNOL</b> (95)	PURDUE UNIV (53)	<b>DALIAN UNIV TECHNOL</b> (37)
<b>KYUSHU UNIV</b> (87)	<b>NATL INST ADV IND SCI &amp; TECHNOL</b> (52)	<b>GUNMA UNIV</b> (37)
INDIAN SCH MINES (85)	<b>ENERGY MINES &amp; RESOURCES CANADA</b> (51)	INST GAS TECHNOL (37)
UNIV ILLINOIS (85)	<b>UNIV TOKYO</b> (51)	INST OCCUPAT MED (37)
<b>OHIO STATE UNIV</b> (82)	<b>UNIV SHEFFIELD</b> (50)	LEHIGH UNIV (37)
<b>VIRGINIA POLYTECH INST &amp; STATE UNIV</b> (82)	PACIFIC NW LAB (49)	CORNELL UNIV (36)
<b>UNIV BRITISH COLUMBIA</b> (80)	<b>SHANGHAI JIAO TONG UNIV</b> (49)	GOVT IND DEV LAB (36)
AUBURN UNIV (78)	UNIV MISSOURI (49)	<b>HARBIN INST TECHNOL</b> (36)
UNIV NEWCASTLE UPON TYNE (78)	<b>CURTIN UNIV TECHNOL</b> (48)	



**Figure 7:** Breakdown of journal article source with coal in the title by country of origin between 1970 and 2010



**Figure 8:** Publication frequencies per year for the U.S., China, and Japan

### *Goal 2: Expand Research Capabilities through Shared Instrumentation*

The EMS Energy Institute is experiencing a crisis in providing instrumentation to its researchers, which is impacting the quantity, and in some cases quality, of its research. Critical capabilities are under threat. Instrumentation upgrades will increase throughput and productivity and shared instrumentation will expand access to improved facilities.

#### *Strategy 2.1: Upgrade existing instrumentation through targeted fundraising campaigns*

EMS Energy Institute instruments are aging (most instruments are between 12-15 and 20-25+ years in age), and the manufacturers no longer support many of them. Repairs are becoming increasingly more difficult and expensive to perform and, in some cases, instruments are non-operational because parts cannot be obtained. Analytical instrumentation historically has been purchased through large, multi-year research projects (e.g., Jet Fuels, DOE, Chevron); however, in recent years funding has shifted from large projects to those much smaller in size, including funding from DOE. At the same time, there are insufficient funds at the Institute to regularly replace aging equipment. Unfortunately, much of the coal-specific instrumentation is now at or beyond end-of-life and Penn State has fallen well behind our peers. Attempts to procure instrumentation through equipment funding grants are unsuccessful because funding agencies consider the types of instruments being requested as ‘standard’ and not ‘state-of-the-art.’ Approximately 50 percent of the researchers at the Institute utilize current instrumentation and their research is being impacted. Consequently upgrading instrumentation is a priority. Goals for the next strategic planning cycle include:

- Develop a fundraising plan with the College of Earth and Mineral Sciences development office
- Approach the State legislature in Harrisburg and present a layout of research capabilities and opportunities for expansion

- Focus on new capabilities/equipment for natural gas, modern coal utilization and co-utilization with renewable energy, and sustainable energy

### Strategy 2.2: Build networks for shared research instrumentation

The EMS Energy Institute is committed to enhancing Penn State energy research capabilities through shared facilities/instrumentation and supporting the development of multi-investigator research collaborations. In an effort to strengthen innovative multi-investigator research and industrial engagement, in 2014, the EMS Energy Institute kicked off a call for proposals from investigators seeking to establish new research centers, consortia, or industry membership programs.

In addition, the Energy Institute is working in coordination with the Earth and Environmental Systems Institute of EMS (EESI) to promote the establishment of the Energy and Environmental Sustainability Laboratory (EESL) that will house shared instrumentation and will fund technical support for environmental analytical capabilities. It is envisioned that EESL will be the scaffolding that allows interdisciplinary research and education to grow. The laboratory will consist of several sub-facilities located around campus. For example, the Center for Quantitative Imaging currently housed in Energy Institute's footprint (academic activities) is programmed to upgrade its instrumentation via EESL and expand Penn State's imaging infrastructure into a world-class, imaging science center, accessible to researchers with shared interest in 3D and 4D image data acquisition and analysis.

### *Goal 3: Cultivate the Synergies that Promote Research Innovation*

As referenced earlier in this plan, the main strength of the EMS Energy Institute is its ability to bring people together through projects, centers, and other initiatives. In order to build on that strength, the Institute will create some additional opportunities for the sharing of ideas among researchers. Currently, the Institute works to bring in speakers to promote the exchange of ideas with industry, government, and academia. While the Institute will continue this initiative, small group idea-sharing sessions, trainings, and workshops will also help cultivate the connections that the Institute has worked to establish. The key to managing these synergies is strong communication and the Institute has worked to build a robust web presence, expand listservs, and explore new communication technologies.

### Strategy 3.1: Create an incubator for ideas ("Think Energy")

- Create an idea-sharing series in the style of Penn State's Research Unplugged or Materials Research Institute's Millennium cafe, in which seasoned and emerging researchers can come together to share ideas, technical challenges, and practices in search of new synergies
- Provide opportunities to forge new research initiatives and centers with an ongoing call for research initiatives, centers, consortia

### Strategy 3.2: Promote in-house research activities and services

- Increase visibility of EMS Energy Institute's research portfolio and facilities
- Hold open houses/training opportunities to showcase our shared instrumentation and capabilities

- Reorganize and update website to facilitate better navigation and information
- Increase communication with external government and industry through expanded listservs and new communication channels.

### Strategy 3.3: Expand platforms for communications and promote a technology-driven culture

- Explore social media and website mobile compatibility
- Ensure our communication and marketing efforts are inclusive as outlined in Penn State’s accessibility guidelines
- Use video and photographs more often in communication efforts
- Facilitate the use of video conferencing for faculty and students

### *Goal 4: Enhance Student Educational Experience*

The fostering and enhancement of future researchers’ skills is of paramount importance. The proposed plan to enhance student educational experience is two-fold. First, prepare current graduate students for a career as future researchers by giving them the tools necessary to be competitive in fund-seeking opportunities. Second, mentor and develop undergraduate researchers, which can have a positive impact in the quality of students being recruited by the Institute to conduct graduate level work.

### Strategy 4.1: Establish professional development opportunities

Facilitate student participation in grant writing. Most seminars provided by the Graduate School related to grant-writing have a broad nature that only characterizes the needs of a few disciplines. This strategy will take advantage of the historic experience the Institute’s faculty possess in terms of how to successfully pitch an idea to energy-related agencies during the process of grant writing. This will have a long-term benefit for the Institute, given the prevalence (in the last couple of decades) of in-house graduate students becoming faculty members at Penn State, and constituting the Energy Institute’s research core.

### Strategy 4.2: Develop research training opportunities for students in coordination with academic units

- Concentrate on recruiting opportunities for talented undergraduate students, such as summer research internships
- Host a National Science Foundation Experience for Undergraduates in Energy Science

### *Goal 5: Grow Global Engagement*

Industry-driven research has been at the core of the EMS Energy Institute research profile for over two decades. The Institute’s research facilities, its number and mix of faculty, and its supporting technical staff provide the necessary flexibility to conduct industry-sponsored research. Maintaining this strong working relationship with the clean energy industries can provide students with

employment and internships opportunities, provide faculty with research funding and access to commercial-scale facilities/field sites, and provide faculty with insight on key research needs for a particular company or energy sector. In addition to continuing strong industry ties, we will look to internationalize more of our research collaborations in the future years.

### Strategy 5.1: Develop industrial partnerships and energy outreach

During the next five years, the EMS Energy Institute will continue to strengthen its collaboration with clean energy industries. The EMS Energy Institute will engage industry through:

- Energy Exchange Seminar Series. The EMS Energy Institute will continue to take the lead role to plan, organize, and host the Energy Exchange Seminar Series. Energy Exchange brings together industry with Penn State students and faculty. The Institute will quantify the benefits of this seminar series and adjust speaker types and topics to have a broad impact within the College.
- Professional and Trade Associations. The EMS Energy Institute will increase its presence at national and regional conferences, workshops, and exhibit opportunities. The Institute will monitor and track this presence and develop a strategic follow-up plan and record any opportunities that might arise from each event.
- Clean Energy Day. The EMS Energy Institute will consider taking the lead role to organize and co-host a bi-annual clean energy day similar to MRI's Materials Day.
- Student Groups. The EMS Energy Institute should continue its support of student clean energy-related student groups and serve as a link to bring together these student groups with industry. In the past, the Institute provided space and some financial support to Penn State's Science Lions. The Institute will review its current support to such groups and work to identify additional opportunities. These activities should be coordinated through the EMS Energy Institute's Office of Student Development (OSD).
- Multimedia. The EMS Energy Institute will work with College to develop and distribute multimedia materials, such a video, to showcase the Institute's strategic priority areas. These videos will be posted to the Institute's web sites, shown at exhibits, and integrated into presentations/workshops.

### Strategy 5.2: International research collaborations

At the core of Penn State's strategy for globalization is a network of strategic partnerships with peer institutions around the world that share Penn State's commitment to solving the world's most pressing challenges through a multi-layered engagement of research, faculty, and student collaboration. The EMS Energy Institute supports this goal and during the last strategic planning cycle, the Institute performed projects with companies from 22 international companies and organizations. The EMS Energy Institute is a key participant in the Joint Center for Energy Research (JCER), a research endeavor established in 2011 between Penn State and Dalian University of Technology in Dalian, China to facilitate collaborative projects and global education in energy sciences and technology. The EMS Energy Institute will further internationalize research collaborations. POSCO in Korea has recently begun funding a research project on coking of coal for steel production. Huaneng Power (largest power producing company in China) has signed an MOU with Penn State to collaborate in six key areas of coal research. Similarly Indian Institute of Technology, Madras and Penn State are working on a joint collaborative research effort. Teams from both organizations have met and held joint workshops. In addition, many Institute researchers have established major formal and informal connections to universities and companies in other

countries. For example, Reliance Industries Limited in India is building a Petcoke gasification facility based on Conoco Phillips E-gas technology and efforts are underway to sign a joint MOU to conduct gasification research for Reliance in the new High Pressure Entrained Flow Reactor built at the EMS Energy Institute. The University of Freiberg in Germany is a leading coal research organization and Penn State, through Global Programs, has established a faculty team to implement a strategic partnership with the University of Freiburg. The team has a three-part mission: to promote a broad range of research, education, and outreach programs in collaboration with the University of Freiburg. The EMS Energy Institute will promote research collaboration in the area of coal gasification. Also, faculty are currently collaborating with peers in South Africa (e.g., Sasol, University of Witwatersand, and North West University) on several research projects including graduate student education. During the next strategic planning cycle, these ties will be strengthened and expanded upon. This will be done by:

- Formalizing partnerships with universities and companies overseas
- Developing more research projects with international companies
- Attracting international students and scholars to the Institute for joint collaborations

## Diversity and Inclusion Planning

The EMS Energy Institute supports the University's commitment to creating an inclusive environment of equal access and participation for all individuals irrespective of culture, ethnicity, race, gender, or sexual orientation and valuing that diversity. The Institute also recognizes that "diversity" extends to individuals with disabilities, veterans, first-generation and low-income students, adult learners, and those with dependent-care responsibilities. The EMS Energy Institute supports the University's seven diversity challenges outlined in the "Framework to Foster Diversity at Penn State 2010-15." Those challenges are:

- Challenge 1: Developing a shared and inclusive understanding of diversity
- Challenge 2: Creating a welcoming campus climate
- Challenges 3 and 4: Recruiting and retaining a diverse student body and workforce
- Challenge 5: Developing a curriculum (programs) that fosters intercultural and international competencies
- Challenge 6: Diversifying university leadership and management
- Challenge 7: Coordinating organizational change to support our diversity goals

### *Current Strategies that Support Challenges*

The EMS Energy Institute integrates programs that convey a clear and consistent description of Penn State's diversity objectives for creating an inclusive environment. This past year the Institute hosted a workshop for students, staff, and faculty titled "Climate control: Promoting mutual respect in the workplace" and presented by the Penn State Affirmative Action Office. In addition, all students and staff undergo an orientation that includes information on diversity and the marks of an inclusive environment and then meet on an annual basis to review diversity and work place environment policies. All students, faculty and staff are made aware of the level of respect and value that each individual plays in the success of the Institute.

The Office of Student Development (OSD), a "signature" program unique to the Institute, plays an important role in creating an inclusive environment for students. The director of OSD acts as an advocate and mediator for students on workplace issues and personal concerns. The OSD is also a resource to connect students to College and University services.

The Institute supports the College's mission to retain a diverse student body through providing unique research experiences that build upon classroom academics as well as build confidence. Examples include participation in research experiences in Upward Bound Programs (i.e., SEEMS), the Summer Research Opportunities Program (SROP), and the EMS Open House. These programs are often geared toward first generation students and other underrepresented groups in the sciences. Students are encouraged to continue research over multiple semesters, and attend conferences and sponsored research meetings, which have significant impact on student retention when implemented early in the student's educational career. In addition, all students are supported by faculty, research staff, and technical and administrative staff to ensure that they have access to the necessary facilities, training, and advising to ensure success.

With respect to staff and faculty, the Institute conforms to the non-discriminatory hiring policies of the College. The Institute provides a workplace environment that values employee contributions and encourages professional development while respecting employees' diverse needs and perspectives. Faculty, and staff, and students are encouraged to participate in strategic planning, to

serve on College and University committees whose mission is to address diversity issues effecting students and employees, and pursue training and professional development leading to leadership roles. Faculty and staff of the Institute serve as representatives on numerous committees that reflect their commitment to diversity, including Diversity Council, Commission for Women, search committees related to staff hires, Fixed Term Promotion Committee, and Fixed Term Teaching and Research Advisory Committee. These committees provide a voice and representation for specific populations in the University on important issues.

The Institute's success in meeting these seven challenges has not been quantitatively measured, but can be seen in a positive and productive work environment where students and staff feel free to seek help if needed and have their concerns addressed with respect and action if necessary. The Institute will work to improve assessment techniques through the following strategies:

- Survey students and staff prior to and after workshops on diversity to assess improvement in an understanding of diversity issues
- Gather activity sheets from Institute staff and research faculty to document service to the University and College with respect to diversity.
- Document assistance to students on issues related to workplace climate
- Expand existing undergraduate database to track graduate student population, including activity, ethnicity/race, gender, major, college, sexual orientation, disabilities, veteran status, first-generation and low-income students, adult learners, and those with dependent-care responsibilities (Note that all of the data is submitted voluntarily)
- Design an exit survey for students to gather feedback regarding their research experience and work climate
- Track students upon graduation to assess the impact their research experience at the Institute has had on their job or educational career

### *Diversity Goal for 2014/15 - 2018/19 Strategic Planning Cycle*

For the current strategic plan cycle, the Institute's primary diversity initiative is to increase graduate student diversity and increase student success in the completion of a doctoral degree or integration into a career, which is consistent with the Institute's mission as a research facility within the College of Earth and Mineral Sciences. To facilitate this initiative, the Institute will support pipeline programs that produce undergraduates well prepared for graduate study. Programs include Research Experiences for Undergraduates (REU), SROP, Women in Science and Engineering Research (WISER), and Minority Undergraduate Research Experience (MURE). The Institute will continue to actively engage undergraduate students in research as wage payroll employees or volunteers as well as through course-related research or Honor's College research. This approach has significant impact on student interests in graduate education when implemented early in the student's educational career. Three initiatives focusing on graduate student diversity are proposed.

- Identify potential graduate students interested in energy research by collaborating with the faculty and Office of Educational Equity. Host or co-host these students for the Fall Open House and participate in one-on-one meetings with Institute faculty, tours, and advising.
- Develop an enhanced mentoring program in which senior graduate students are paired with incoming graduate students and high performing upperclassmen.



- Collaborate with the College to form a professional development series for incoming graduate students focused on technical and grant writing, verbal and presentation skills, critical thinking, and organizational skills to better ensure success.

## Performance Indicators

The EMS Energy Institute recognizes the importance of metrics for evaluating performance. The Institute proposes to use metrics to assess research productivity, dissemination of research results through scholarly publications and outreach, and student participation and accomplishments at the EMS Energy Institute.

### Research Productivity

The EMS Energy Institute is facing increasing challenges in securing research funding due to changes in government funding areas of energy research, which calls for thematic adaptability, smart infrastructure (i.e., shared instrumentation), and collaboration among other research faculty both from within and outside of Penn State.

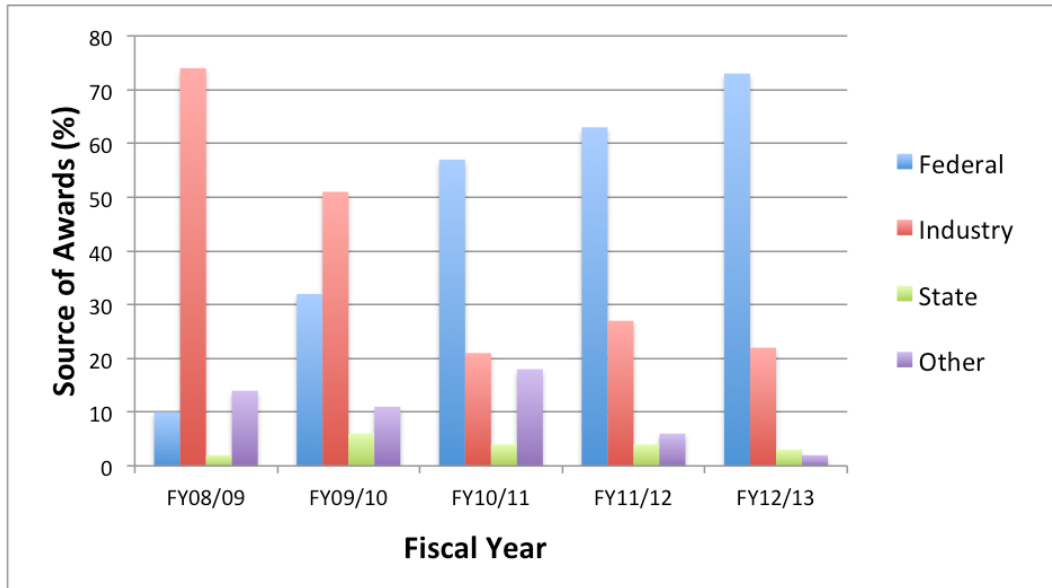
Research funding has decreased from a consistent \$8-12M per year for the period FY1999/2000 to FY2009/2010 after which time research funding has decreased each fiscal year to ≈\$4M in FY2012/2013, as shown previously in Figure 6. The EMS Energy Institute needs to broaden its research portfolio as historically strong research areas such as coal are facing challenges in securing funding. More diversity in research areas is needed.

The number of proposals prepared each year ranges from about 105 to 175, which are prepared by 20-24 PIs. During the last strategic planning cycle, the number of proposals prepared during 2 of the 5 years was on the low end. This is an area for improvement during the next strategic planning cycle. The success ratio in proposals being awarded was good and was around 60%, as shown in Table 3. More proposals need to be written. More joint appointments are needed. More affiliated faculty need to be recruited to the Institute.

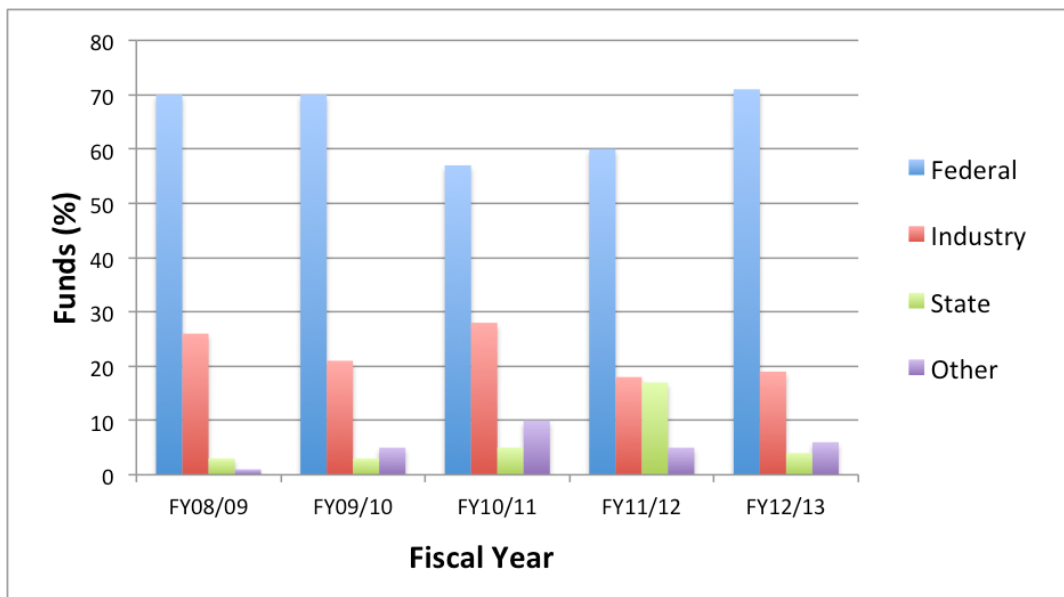
Funding profiles have also changed over the last several years. There are fewer large dollar amount projects (mainly from the U.S. Department of Energy) being awarded. Now the Institute researchers are obtaining more DOE projects but they are much smaller in award size. In addition, the Institute is noting fewer industrial projects being awarded. This can be seen in Figures 9 and 10.

**Table 3:** Summary of Proposal Preparation and Success Ratio during the Last Strategic Plan Funding Cycle

Fiscal Year	Pending		Rejected		Awarded		Success Rate (%)
	No. of Awards	Amount Requested	No. of Awards	Amount Requested	No. of Awards	Amount Requested	
2008/2009	3	\$464k	39	\$12.6M	66	\$8.0M	61
2009/2010	0	\$0	76	\$56.6M	76	\$8.7M	50
2010/2011	1	\$126k	65	\$147.3M	107	\$6.1M	62
2011/2012	4	\$3.4M	52	\$18.4M	116	\$5.5M	67
2012/2013	4	\$846k	36	\$12.1M	65	\$4.2M	62



**Figure 9:** Source of awards during the last strategic planning cycle



**Figure 10:** Source of research funds during the last strategic planning cycle

During the next strategic planning cycle, the Institute will monitor and work towards improving research productivity at the Institute. Metrics will include:

- Total funding
- Average award size
- Number of PIs
- Interdisciplinary make-up of projects/PIs
- Number of graduate students supported per research funding
- Funding sources
- Proposal success rate

### *Dissemination of Research Results*

The EMS Energy Institute recognizes the importance of disseminating research results to the scientific community, as it is an indicator of academic excellence and research prominence. This will be done through preparing referred and non-referred publications, organizing various outreach activities including clean energy seminars, participating in and hosting workshops, conferences, and industrial consortia meetings, maintaining an outreach web presence, and preparing various electronic and print newsletters and news stories.

Publications by EMS Energy Institute personnel remain strong even though overall funding has decreased the last few years. Publications have increased from about 70 in 2002 to a steady 100-130 per year. The number of citations of Institute publications is very high as well.

During the next strategic planning cycle, the Institute will monitor and work towards improving the dissemination of research results at the Institute. Metrics will include:

- Number of referred and non-referred publications
- Number of citations of EMS Energy Institute publications
- Publications per research funding
- Number of outreach activities
- Success/feedback from outreach activities including seminars, workshops, and newsletters/news stories
- Website activity statistics

### *Student Participation*

A database was established in 2006 when the Office for Student Development (OSD) was formed to track student participation in research activities at the EMS Energy Institute. Each year the OSD presents an annual report documenting participation by gender, race/ethnicity, country-of-origin, department, college, and nature of research activity. Students are identified for research at the Institute through affiliated faculty, the Office of Educational Equity, Department of Energy and Mineral Engineering courses, and open house events sponsored by the OSD. Note that the level of student participation varies and is a function of external research funding and faculty participation as mentors.

During the next strategic planning cycle, the Institute will continue to monitor student participation at the Institute. Other indicators that may be used include:

- Individuals with disabilities, veterans, first-generation and low-income students, adult learners and those with dependent-care responsibilities
- Number of students, graduate and undergraduate, supported through research funds
- Ratio of research and general funds to full-time equivalents (FTEs) and students
- Collaboration and participation with academic departments
- Student reviews of out-of-classroom experiences (e.g., research, field trips, writing opportunities)
- Exit surveys by students regarding the work environment and diversity issues
- Demographics of students as compared to the Department of EME as this is the source of most students who participate in activity at the Institute

## Practices that Promote Integrity and Ethical Behavior

The EMS Energy Institute promotes integrity and ethical behavior. The Institute accomplishes this by ensuring all Institute personnel adhere to high ethical standards. Specifically, the Institute:

- Ensures that all personnel abide to Penn State regulations and compliance
- Ensures a friendly working environment at the Institute
- Provides resources to educate personnel on sexual harassment, bullying, intimidation, unwanted physical contact (e.g., pushing or hitting; this includes non-physical forms of harassment such as teasing). These resources include distributing information from Affirmative Action's office, hosting workshops, and putting resources on the Institute website.

## Framework for Sustainability

Penn State's vision is to embed sustainability as a fundamental value at the University through the development of sustainability literacy, solutions, and leadership. This comprehensive integration of sustainability into the University's research, teaching, outreach, and operations will prepare students, faculty, and staff to be sustainability leaders. This integration is especially important today as we face the challenge of sustainability by protecting a threatened environment while ensuring energy security. It is important to implement sustainability practices while at the same time accessing energy sources and ensuring economic progress under stringent environmental constraints. The EMS Energy Institute supports the University's sustainability goals, which are:

- Realize, advocate, and contribute to sustainability literacy
- Actively engage the science, practice, and art of sustainability
- Lead higher education in transformational innovations in policy, practice, and knowledge that address critical, complex, and systems-level sustainability challenges

Examples of the EMS Energy Institute's multi-level sustainable mentality to meet the University's goals are:

- Implement procedures to eliminate once-through water cooling of experiments or test equipment (e.g., using chillers or effluent stream from nuclear reactor for cooling)
- Support Penn State's efforts towards establishing a sustainable work environment (e.g., turning off lights to reduce electricity consumption, embracing Penn State's new recycling efforts in all buildings)
- Perform research to enhance efficiency of systems to reduce carbon emissions
- Perform research to reduce water usage or increase water recycling

## Conclusion

The EMS Energy Institute is well positioned to solve contemporary energy challenges through interdisciplinary work. As a leading energy research facility, the Institute must balance its historical strength in coal science with the exploration of new energy technologies. This strategic plan formalizes our goals to focus efforts on natural gas and unconventional resource development, and issues such as water use and quality and carbon emissions. The EMS Energy Institute distinguishes itself from other University entities through its infrastructure and ability to bridge research and faculty across disciplines and we will continue to nurture this strength through increased workshops, trainings, seminars, and other collaborative efforts. Over the last five years, Institute faculty and

students have published a large body of work and their research has continued to thrive despite aging equipment and reduced funding. Our first priority for the upcoming strategic cycle is to build our infrastructure and our connections to realize increased funding, so that we can better serve the students and the greater energy community.