

**Self-Study Report for  
External Review of the EMS Energy Institute**

**Prepared**

**By**

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## **1. Introduction**

The EMS Energy Institute is a college research unit that involves 130 people and occupies four buildings in the College of Earth and Mineral Sciences at Penn State University Park. The mission of the EMS Energy Institute is to conduct advanced energy research, which 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. The focus of our research is to develop clean energy solutions to meet the U.S. and global energy challenges through more environmentally friendly and more efficient production and utilization of energy while eliminating pollutants and minimizing the greenhouse gas emissions through carbon capture, utilization, and storage.

The faculty members affiliated with the EMS Energy Institute bring diverse expertise from the Departments of Energy and Mineral Engineering, Geosciences, Materials Science and Engineering, Chemical Engineering, Meteorology and Atmospheric Sciences, and Mechanical Engineering. The institute supports seven co-funded faculty members, and several other researchers have their research administered by the EMS Energy Institute. We also partner with academic departments in the research training of graduate and undergraduate students. The research efforts started with down-stream focused projects when the EMS Energy Institute was first established in 1997 and later expanded to include the upstream, middle stream, and downstream areas of research, as well as energy materials, energy systems, and energy economics. The ongoing research projects involve the production, conversion, and utilization of carbon-based energy (coal, petroleum, natural gas, and shale gas) and of renewable energy (solar, biomass, and biogas) and several other associated technologies such as carbon dioxide (CO<sub>2</sub>) capture, utilization, and storage, exploration and production of energy materials (nanomaterials, carbon materials, critical minerals, and catalytic materials), and energy systems (fuel cells and power plants). Researchers affiliated with the institute also have expertise in energy policy, economics, optimization of energy systems, and the coupled analysis of energy systems and climate change.

The research projects at the institute are supported by government agencies, industrial partners, and foundations with average research expenditures of about \$8 million/year that have resulted in nearly 1,500 refereed journal publications and over 63,000 science citations. In addition to supporting numerous research projects involving faculty and students, we have organized and managed multiple government-funded coalitions and industry-funded consortia consisting of many organizational members in the U.S. and across the world. These coalitions and consortia have resulted in additional funding of nearly \$50 million. Examples include the recently completed U.S. Department of Energy-National Energy Technology Laboratory (NETL) funded University Coalition for Fossil Energy Research (2015-2023), Premium Carbon Products from Coal Consortium, Stripper Well Consortium, and Gas Storage Consortium. In the following sections, additional details about the institute and its activities are provided to facilitate the external review process.

## **2. Historical Development of the Institute**

The EMS Energy Institute was officially established in 1997 in the College of Earth and Mineral Sciences (EMS) at Penn State by integrating multiple energy-related research laboratories including the Combustion Laboratory, Energy and Fuels Research Center, Laboratory for Hydrocarbon Process Chemistry, and the Penn State Coal Sample Bank.

The historical development of the EMS Energy Institute can be traced back seventy-five years to 1949 when The Combustion Laboratory was formed within the College of Earth and

Mineral Sciences with support from the Central Pennsylvania Coal Producers Association and the Western Pennsylvania Coal Operators Association, in cooperation with the Pennsylvania Department of Mines. Some years later, the Coal Research Program was established in 1957. This led to the development, in 1967 and continuing today, of the Coal Sample Bank and Database with funding initially from the U.S. Department of Energy and later several state agencies and companies, to preserve samples collected using Penn State prescribed procedures. In 1988 the Coal Research Program expanded into the Energy and Fuels Research Center. During the period from 1993 to 1997, and under the college's direction, various laboratories and centers were consolidated into the EMS Energy Institute. The DOE NETL, in 2002, requested the EMS Energy Institute take over production and sale of Hardgrove Grindability Index (HGI) standard reference standards. The institute is the sole provider of primary coal grindability standards worldwide.

The acronym "EMS" was formally added to the name of the EMS Energy Institute when the university-wide Penn State Institutes of Energy and the Environment was established in 2007 following a university-wide Energy Task Force recommendation. In the same year, the EMS Energy Institute became one of the Institutes of Energy and the Environment, the central coordinating structure for energy and environmental research at Penn State. A few years later, in 2011, the EMS Energy Institute reorganized to better encompass various aspects of energy research ongoing within the institute and the college. New research areas were created, and directors were appointed to lead each area. Current areas are Carbon Materials, Clean Fuels & Catalysis, Coal Science & Technology, Economics & Energy Systems, Electrochemical Technologies, Nanomaterials, Petroleum & Natural Gas, Stationary Power, and Sustainable Energy. The Coal Sample Bank was expanded in 2013 when the Argonne Premium Coal Sample Bank was moved to the EMS Energy Institute from the Argonne National Laboratory.

While details about the research funding from 2010 to the present are discussed in subsequent sections, a brief description of some major projects that were performed over a decade ago (1989-2009) is included here. These projects were important in the growth of the EMS Energy Institute and influenced research careers for both faculty and students performing the research. The EMS Energy Institute has a long history of developing and managing private-public partnerships. These started in 1998 when NETL approached the EMS Energy Institute and requested that a carbon materials-based consortium be established. That consortium – Consortium for Premium Carbon Products from Coal (CPCPC) – operated for fifteen years (1998-2012) with \$8.6 million in DOE funding and \$5 million in cost share. The success of CPCPC resulted in NETL requesting the EMS Energy Institute establish the Stripper Well Consortium (SWC; 2000-2015; \$12 million in DOE funding and \$3 million in cost share) and the Gas Storage Technology Consortium (GSTC; 2003-2010; \$2.8 million in DOE funding and \$0.7 million in cost share). Members of these consortia came from forty U.S. states and ten foreign countries, and included universities, industrial companies, state organizations, and trade organizations. These three consortia operated over a period of twenty-seven years with \$103 million in NETL funding and cost share.

It is worth mentioning two major research development and deployment (RD&D) thrusts. One was a program to develop an advanced jet fuel thermally stable at 900°C for the Air Force. The other was a series of demonstration-scale RD&D projects that focused on emissions control, hardware development and testing, fuels, and emissions evaluation, etc. The EMS Energy Institute managed a major jet fuels program from 1989 to 2009. The program was titled Advanced Thermally Stable Jet Fuel, and over the twenty-year period, \$40 million in funding was provided by Sandia National Laboratory, NETL, Air Force Research Laboratory, Wright Patterson Air

Force Base, and the Air Force Office of Scientific Research. The demonstration-scale RD&D started in 1989 and ended in 2004. Over this fifteen-year period, four major activities were performed with a total of \$23 million in funding. The projects were: Superclean Coal Water Slurry Combustion in an Oil-Fired Boiler (1989-1996; \$6.1 million in NETL funding); Testing of an Industrial-Scale Coal-Fired Combustion System (1991-1995; \$1.3 million in NETL and ABB Combustion Engineering funding); The Development of Coal-Based Fuel Technologies for Department of Defense Facilities (1992-2004; \$15 million in NETL funding); and multiple industrial projects using the demonstration facility (1996-2001; \$0.6 million in funding from industrial sources). Some of the prototype equipment procured to complete those major projects is still being used for several other research projects in the institute as detailed below.

**3. Relationship with Other Institutes on Campus.** Research across Penn State is coordinated by the Office of the Vice-President of Research. That office funds the main research institutes across Penn State. These are the Institute for Energy and the Environment (IEE), the Material Research Institute (MRI), the Huck Institute of the Life Sciences, and the Institute for Computational and Data Sciences (ICDS). These institutes coordinate several centers and initiatives under their umbrella. The university also maintains the Sustainability Institute. In addition to these central units, colleges maintain their own college-level institutes. In the college of Earth and Mineral Sciences, the Earth and Environmental Systems Institute (EESI) and the EMS Energy Institute (subject of the current review) are the two research organizations sponsored by the dean of the college. While in the past, the directors of EESI and the EMS Energy Institute served as the associate directors of IEE, currently only the director of EESI serves in that capacity. Given the complexity of the research structure and the overlap in terms of focal areas of the institutes, it is important to distinguish between the scope of activities pursued in each of these units. IEE engages many of the researchers associated with the EMS Energy Institute. The focus of research in IEE is on the development of green technologies for energy production and the associated environmental sustainability of those systems. The EMS Energy Institute embraces a more holistic view of energy, including the sustainable development of conventional fossil fuel-based energy production technologies, the conversion of carbon into useful forms, including nanomaterials, the development of critical mineral resources needed for green energy production and storage as well as the optimization and planning of complex energy systems.

#### **4. Research Profile of the EMS Energy Institute**

**4.1 Current People at the EMS Energy Institute.** Currently, approximately 130 people are working in or are affiliated with the EMS Energy Institute including faculty, research and administrative staff, students, and visiting scholars. There are seven tenure-line faculty members who have full-time appointments in the institute or joint appointments with an academic department and two non-tenure line research faculty members with standing appointments. Recently, the college has provided funds to add up to three co-funded faculty members to the institute budget but owing to the recently instituted strategic hiring freeze across the university, those co-funded positions remain unfilled. In the meantime, we have increased the number of affiliated tenure-line faculty members from ten in 2000 to fifteen in 2007 to forty-seven in 2023. We continue our efforts to engage more faculty members working in energy research areas college-wide and campus-wide.

Appendix 1 shows the research areas and representative publications of forty-six principal investigators (PIs) who are faculty members affiliated with the institute but work in different departments, mostly in the colleges of EMS and Engineering. About half of the PIs conduct their research regularly through the institute. Several of these researchers occupy laboratories in institute space, while many others participate in collaborative research projects using laboratory facilities in their home departments. About eight faculty members recently joined as new faculty affiliates.

There are currently six full-time and one part-time staff members providing support to researchers affiliated with the EMS Energy Institute. The EMS Energy Institute operates using a very lean staff and provides a wide variety of support. This support includes, but is not limited to, communications and marketing, laboratory support to students and faculty, safety, facilities coordination, post award, and budget monitoring. Details on the staff responsibilities are provided in Appendix 2.

**4.2 Current Research Programs/Centers/Initiatives.** Currently, there are nine research program areas, several centers, and multiple research initiatives along with college-wide, university-wide, and multi-university programs at the institute that can be grouped into the following three institute area clusters of faculty research activities. Appendix 3 provides a brochure with a brief introduction to the various programs, centers, and initiatives listed below. The process of reconfiguring the research thrusts in the institute into four thematic areas is currently underway and is detailed in a later section of this report.

#### **Energy Utilization and Downstream R&D**

Carbon Materials Program  
Clean Fuels & Catalysis Program  
Coal Science & Technology Program  
Energy Institute General Research such as CO<sub>2</sub> Capture, Utilization, and Storage

#### **Energy Materials, Systems and Economics**

Electrochemical Technology Program  
Nano Materials Program  
Center for Critical Minerals  
Stationary Power Program  
Economics & Energy Systems Program  
Clean Power Plan Impact Initiative  
Initiative for Sustainable Electric Power Systems

#### **Energy Production and Storage, Upstream, Geomechanics, and Mining R&D**

Center for Geomechanics, Geofluids & Geohazards  
Petroleum & Natural Gas Program  
Center for Quantitative Imaging  
Enhanced Oil Recovery Joint Industry Project  
Geostatistics & Geomodelling Applications  
Unconventional Natural Resources Consortium  
Non-grouped Energy Institute Upstream Research and Mining Research  
Subsurface Energy Recovery and Storage Joint Industry Partnership

**4.3 Research Funding at the EMS Energy Institute.** Table 1 shows the distribution of research funding at the institute during the last nine years. Research funding comes mainly from federal and state sources, industry, and overseas entities. Figure 1 shows the funding breakdown for a three-year interval during fiscal years (FYs) of 2020/2021 (July 1-June 30), 2021/2022, and 2022-2023.

Fossil energy research R&D has been under pressure from the public and from the academic community. As a result, funds have become increasingly scarce and harder to develop for coal research, both from government agencies and industries. Oil and gas research has suffered from a similar decline. We have developed and implemented strategies to develop partnerships with government agencies and industry to support faculty research and contribute to energy technology development. For example, the EMS Energy Institute played a major leadership role in Penn State’s successful efforts in developing the Technology Alliance with Chevron Corporation on Coal Conversion (2007-2010), NETL Regional University Alliance, including Penn State as one of the six universities (2010-2015), and the DOE-NETL University Coalition for Fossil Energy Research (UCFER, 2015-2023).

Table 1. Research Funding at the EMS Energy Institute during 2014-2023

Period	Total Funds \$MM USD	Funds \$MM/Y	Federal \$MM USD	State \$MM USD	Industrial \$MM USD	Other-Intl. \$MM USD
<b>FY2020 -2023</b>	<b>27.34</b>	<b>9.11</b>	<b>16.20</b>	<b>0.82</b>	<b>5.36</b>	<b>4.96</b>
<b>FY2017 -2020</b>	<b>26.89</b>	<b>8.96</b>	<b>16.77</b>	<b>0.27</b>	<b>4.14</b>	<b>5.70</b>
<b>FY2014 -2017</b>	<b>19.60</b>	<b>6.53</b>	<b>12.01</b>	<b>0.31</b>	<b>4.59</b>	<b>2.73</b>

To offset the decline in fossil energy research, which historically was the strength of the institute, an effort has been made to diversify the portfolio of energy research. This is shown in Figure 1 where the projects awarded during FY 20/21 through FY 22/23 fall into twenty categories.

Fortunately, the COVID-19 pandemic did not have a significant impact on the institute’s operation. Research at the institute was shut down from March 2020 to summer 2020 when research transitioned to part-time access followed by full-time access to laboratory facilities. The PIs were still very active in writing proposals and securing additional funding as highlighted in Table 1. The three-year period, FY 20/23, was one of the most successful periods since data were kept from FY 97/98 on.

The funds to operate the EMS Energy Institute are general operating funds allocated by the college/university, and a portion of the overhead charged on research budgets that faculty researchers develop from external sources. That additional funding from research projects is allocated by the college in the form of research incentivization funds. Those funds mainly come from the co-funded faculty positions through the research contracts they obtain. The general

allocation made by the university administration is insufficient to meet the salary expenses and the difference is offset by charging institute personnel's time to projects, if permissible.

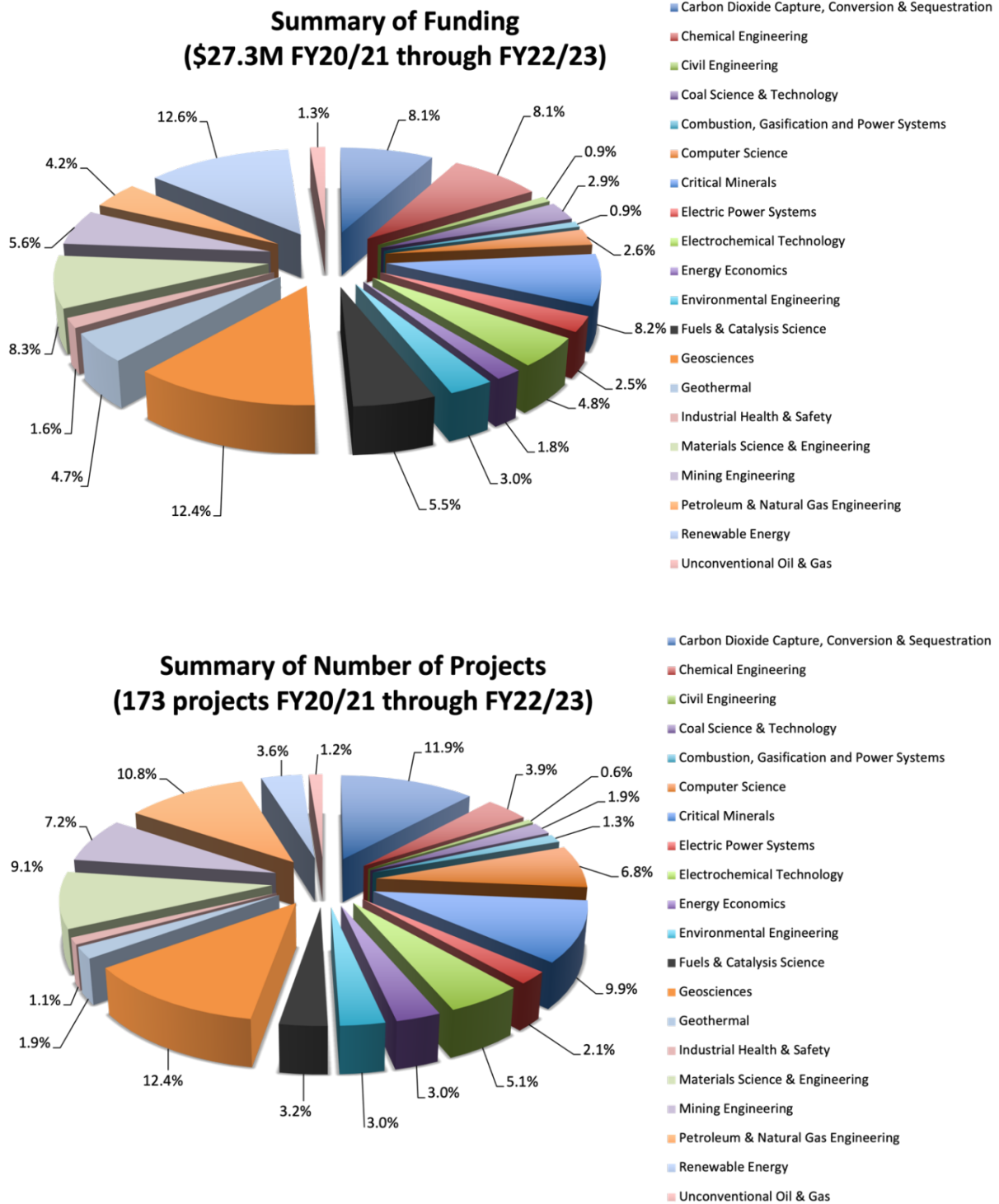


Figure 1. Distribution of research funds at the EMS Energy Institute by source and by number of projects in different research areas during fiscal year 2020-2023.

## 5. Infrastructure

The EMS Energy Institute is in four contiguous buildings (one wholly and three partly), a coal sample bank, and a fuel preparation facility. In the four buildings, the institute space is comprised of forty-six rooms/spaces (excluding offices and conference rooms) of which over half are laboratories. Non-laboratory space includes high-bay areas containing pilot-scale equipment and fuel processing facilities, machine shops, computing lab, electronic shop, sample storage, gas cylinder storage, and Hardgrove Grindability Index (HGI) Standard Reference Samples (SRS) preparation and storage facilities. Selected laboratories including shared laboratories are highlighted in Appendix 4.

## 6. Publications and Science Citations

**6.1 Publication in Research Journals.** The institute has always strived for publishing high-quality papers in refereed scientific journals. From 1998 to July 2023, over 4,300 publications have been captured by the institute’s database. Of these, nearly 1,500 publications (from 1998 to 2023) are refereed papers in research journals, where the institute is listed as an author affiliate or in the acknowledgements. Table 2 lists the number of publications in research journals by EMS Energy Institute researchers and the corresponding science citations in Web of Science as of October 2023. Figures 2 and 3 show the trend of publications and citations by year over this same period, respectively. The research results of institute researchers have been published in top-tier journals such as Science, Nature, Energy and Environmental Science, and Journal of American Chemical Society as well as top professional research journals in various areas of EMS Energy Institute research.

Table 2. Number of Publications in Research Journals by EMS Energy Institute Researchers and Corresponding Cumulative Science Citations in Web of Science as of October 2023

Year	Publications	Science Citations	Year	Publications	Science Citations
1998	1	0	2010	47	1350
1999	4	2	2011	72	1800
2000	16	10	2012	69	2180
2001	12	31	2013	82	2550
2002	21	35	2014	85	2900
2003	27	100	2015	85	3125
2004	30	180	2016	90	3725
2005	39	425	2017	98	4350
2006	31	550	2018	114	4750
2007	26	614	2019	140	5825
2008	37	925	2023	558	29,537
2009	57	1125	<b>Total</b>	<b>1,497</b>	<b>63,217</b>

\* Note that during the COVID-19 pandemic and the immediate period following, data was not collected for individual years 2020, 2021, and 2022; but data collection resumed in 2023.

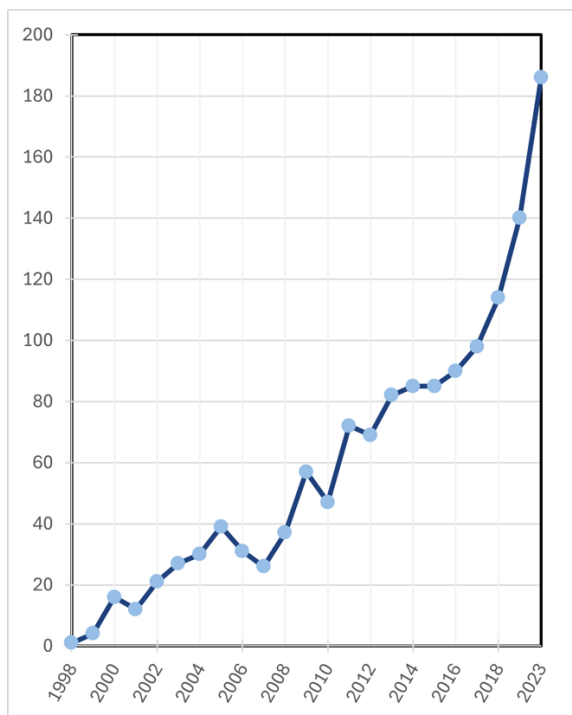


Figure 2. Trend of Publications

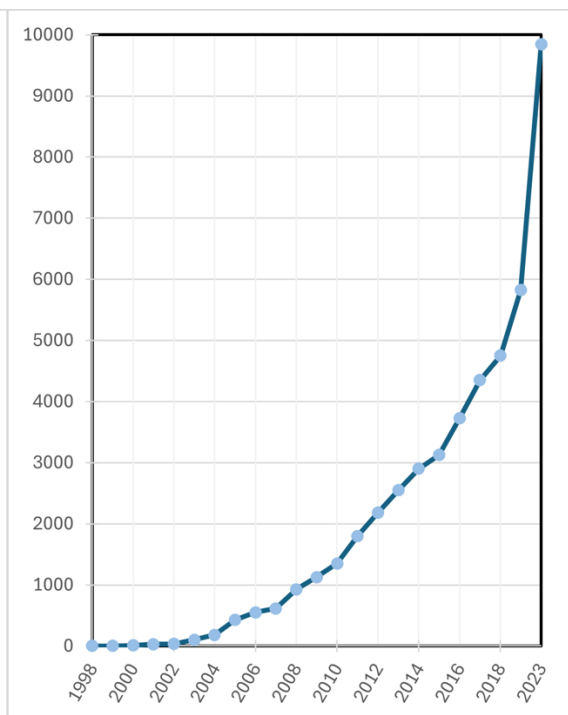


Figure 3. Trend of Science Citations

**6.2 Publication of Books.** Faculty members of the EMS Energy Institute also published books on various subjects related to energy, fuels, and materials. Appendix 5 includes a list of thirty-one books that have been authored/co-authored or edited by institute faculty members on a broad range of subjects such as energy, coal, clean fuels, catalysis, electrochemical technology, hydrogen production, enhanced oil recovery, geomechanics and geofluids, carbon (CO<sub>2</sub>) capture, utilization, and storage, and materials from coal.

## 7. EMS Energy Institute Initiatives, Activities, and Services

The EMS Energy Institute has a long history of developing consortia, centers, and initiatives to support the research performed by the affiliates. The institute has also promoted research activities by providing seed grants and purchasing research equipment. The institute also engages in outreach activities and provides professional development opportunities for students.

**7.1 Consortia.** As discussed in the Introduction, the EMS Energy Institute has established several multi-organization collaborations. In addition to CPCPC, SWC, and GSTC discussed earlier, the institute has also managed several other public-private partnerships over the last ten years including the Unconventional Natural Resource Consortium (UNRC; 2011-2018), Enhanced Oil Recovery (EOR) Joint Industry Partnership (JIP; 2011-2023), the University Coalition for Fossil Energy Research (UCFER; 2015-2023, \$20 million in DOE funding), and the Subsurface Energy Recovery and Storage (SERS) Joint Industry Partnership (JIP; 2023-present). In some of these efforts (e.g., UCFER or SWC), funding is received from federal funding agencies (such as DOE) to promote research in an area of strategic importance. The institute administers the grant, issues calls for proposals, coordinates the proposal review process, administers the award made to researchers at several universities, and finally issues a report to the funding agency.

**7.2 Centers and Initiatives.** Similarly, the EMS Energy Institute has been at the forefront of establishing or assisting in the establishment of centers and initiatives. Over the last approximately ten years, these include (note that some of these have been discontinued) the Center for Quantitative Imaging (CQI), Center for Geomechanics, Geofluids, & Geohazards (G3), Clean Power Plant Impact Initiative, Initiative for Sustainable Electric Power Systems (ISEPS), Penn State – Dalian University of Technology Joint Center for Energy Research (JCER), and Penn State Initiative for Geostatistics and Geomodeling Applications (PSIGGMA). More recently, and with high visibility, the Center for Critical Minerals (C<sup>2</sup>M) was developed, and the Silicon Carbide Innovation Alliance (SCIA) is under development. Three other initiatives – the Repurposing Center for Energy Transition (ReCET), the Subsurface Energy Recovery and Storage (SERS) Joint Industry Partnership (JIP), and CO<sub>2</sub>-SMART: A New Industry-University Collaborative Research Center for CO<sub>2</sub> Storage Modeling, Monitoring, Analytics, and Risk Reduction Technologies are being formed and the proposals are being circulated for internal approvals.

**7.3 Education and Outreach.** The EMS Energy Institute is an active participant in education and outreach. The institute provides opportunities for graduate and undergraduate students to participate in research projects and individualized senior undergraduate and honor students' projects. The institute also works with various industrial partners to set up internships for undergraduate students. The institute actively supports honors and minority programs and, until recently, programs for elementary to high school students.

Institute faculty and staff, with their diverse range of expertise, assist and educate the public. The institute also assists with holding workshops, seminars, and conferences. The annual meeting of the International Association of Mathematical Geosciences, held in 2019, and the MiningPA conference, held in 2023, are examples of conferences organized by the institute's staff.

**7.4 Services.** There are a variety of services provided by the institute. The institute houses the Penn State Coal Sample Bank (PSCB), which has existed for over sixty years. The sample bank consists of thirty-eight well-preserved DOE samples along with 500 historical samples. In addition to the PSCB, the Argonne Premium Coal Sample Bank was transferred to Penn State and contains eight well-protected (never been exposed to oxygen) coals sealed in glass ampules or five-gallon carboys. Penn State is the world's sole provider of primary Hardgrove Grindability Index (HGI) Standard Reference Samples (SRSs), with each set containing nominally 40, 60, 80, and 100 HGI coals.

## **8. Highlights of Recent Research Accomplishments**

EMS Energy Institute researchers have major accomplishments in upstream and downstream energy research, discovery and development of improved energy materials, innovative sustainable energy production technologies, optimized energy systems, and economics. The institute's research projects have included experimental research at benchtop scale and at pilot plant-scale or field testing. Several researchers are also engaged in modeling and simulation or computational studies.

Many institute faculty members have been recognized for their original research accomplishments with prestigious awards from professional societies and government agencies as well as international conferences, in addition to the Penn State awards for excellence in research.

Appendix 6 highlights the selected research accomplishments from multiple research areas, which are not discussed here due to space limitations.

Selected research accomplishments by institute faculty researchers will be highlighted during the presentation by the EMS Energy Institute director for the External Review Panel.

## **9. Future Vision**

As detailed in the previous sections, the EMS Energy Institute has a rich history of high-impact research on diverse topics related to production and utilization of conventional fossil fuels for energy use. Over the years, the institute has adopted a more balanced portfolio for energy research, emphasizing diverse areas such as electrochemistry, nanomaterials, biochemical processes for environmental remediation and resource recovery, critical mineral recovery, energy systems planning and optimization, environmental and energy economics, and policy. In the meantime, global societies are increasingly confronted with major challenges associated with the rapid rise in global temperatures triggered partly by the increase in concentration of greenhouse gases in the atmosphere. Increase in anthropogenic CO<sub>2</sub> concentration in the atmosphere due to increased energy demand and the use of fossil fuels to meet that demand is widely accepted as one of the major contributors to global climate change. The future vision for the institute is to work on this important challenge of mitigating climate change through the development and implementation of new technologies for energy production that have a reduced harmful influence on the environment, are sustainable over their life cycle, and provide equal access to low-cost energy to all sections of the society. To realize this vision, the EMS Energy Institute will organize its research activities into four thematic areas:

- Materials and Minerals for the Energy Transition
- Science and Engineering of the Energy Transition
- Socioeconomic and Environmental aspects of the Energy Transition
- Computational Science and Data Analytics for the Energy Transition

These four thematic areas are further broken down into several subcategories as highlighted in the thematic area poster in Appendix 3. It is expected that organizing the research activities and personnel into these thematic groups will foster greater collaboration within the areas as well as promote broad conversations across the institute that can lead to major breakthroughs in addressing the energy challenges. These thematic areas will also draw researchers from across the colleges from the Departments of Energy and Mineral Engineering, Material Science and Engineering, Geosciences, Geography, and Meteorology and Atmospheric Sciences. In addition, the thematic areas also have some overlap with the research focus of EESI (socioeconomic and environmental aspects), IEE (integrated energy systems), MRI (materials and minerals) and ICDS (computation and data sciences). The resultant collaborations will likely cement Penn State's position as a leading institution engaged in cutting-edge energy-related research.

To render this organization of the institute into thematic areas more effective, it will be necessary to identify leaders for each thematic area who can initiate and coordinate various activities within these areas. These area leaders will coordinate meetings of the thematic areas where topics such as allocation of graduate assistants, resources for seeding new research, allocation of laboratory spaces for research, and equipment purchase and maintenance can be discussed. The expectation is also that each thematic area will identify external stakeholders/collaborators and eventually launch a research affiliates program that can support

research projects in that area. To incentivize researchers to serve as area leads, they will be offered priority allocation of laboratory space and other resources for conducting their research, priority access to research administrative support, and access to technologists. The proposal is also for one of the thematic area leads to take on the role of associate director of the institute by rotation. In that capacity, they may be offered supplemental pay as remuneration. The thematic area leads along with the associate director and the director will constitute the executive council for the institute and that group will be primarily responsible for framing operating guidelines and procedures for the institute.

For the activities within thematic areas to be sustained, it is important that the institute pursues various avenues to attract research funding. Stakeholder groups will be constituted within each thematic area made up of experts in the various aspects of research being pursued within each thematic area. These experts can be from the industry, research organizations, federal and state agencies, and foundations. These stakeholder groups will be responsible for advising the researchers within thematic areas about research priorities, review research progress, and explore avenues to support the research within each thematic area. Examples of these stakeholder groups are the Silicon Carbide Research Alliance and the Power and Minerals stakeholder groups that have already been formed. Additionally, the institute will also pursue major funding opportunities such as those to support critical minerals research and become an active participant in the carbon sequestration hubs and hydrogen hubs that have been recently announced. One grand challenge is to support Appalachian communities as they transition from traditional coal and fossil fuel-based economies to the new opportunities presented through large scale implementation of renewable energy portfolios. Perhaps the institute can play a key role in helping with the transition. Conversations are ongoing with the Appalachian Regional Council and federal and state entities as well as key players in the regional hydrogen hubs to explore avenues for Penn State and the Energy Institute to be involved in such regional efforts.

For the institute to fulfill its future vision and for it to stay in tune with the latest developments in the energy realm, it is necessary that a strong advisory board be constituted with members from several sectors that are the focal areas of the institute. The advisory board will be charged to help guide the institute's activities, to provide input into the strategic plan for the institute, and to suggest guidelines for operation consistent with best practices in other similar organizations. An initial advisory board was formed for the institute, and the member profiles are included in Appendix 7. The operating guidelines for the board are being discussed.

To fulfill the research vision for the institute and to render it nimble to respond to major shifts in technology paradigms or community needs, it is necessary that the institute have some flexibility in dedicating its resources to address these challenges. While having co-funded faculty positions is necessary for the long-term health of the institute and to render it more useful to the departments in the college, it is also necessary to develop a cadre of non-tenure line research faculty members who are top-notch researchers and can also contribute to the teaching mission of the departments and college. Negotiations are currently ongoing with the university administration to recruit two non-tenured faculty lines who will be supported for two years on the institute budget and later transitioned to research projects.

It is imperative that the institute maintain a work and research environment that is supportive of researchers of all backgrounds. The institute has a long history of attracting researchers from diverse backgrounds and additional activities and initiatives are planned to make the research environment even more diverse and inclusive. Collaborative spaces in various parts of the institute, coffee hours, team building activities such as an institute "clean out" date,

professional development activities focused on DEIB themes are planned. Good practices such as starting institute meetings with a mindfulness minute and encouraging attendees to be inclusive and accommodate diverse ideas presented during discussions will be emphasized. Given the budget realities and the inability of the institute to do much for each research affiliate, what the institute can offer is a collaborative work environment and an environment where everyone feels welcome and respected. A central vision for the institute is a vibrant research organization where every researcher feels that they belong and that they are supported.

## **10. Concluding Remarks**

The EMS Energy Institute has a long history of innovative research in various aspects of energy exploration, production, and optimal utilization. Since its inception, the institute has successfully achieved significant advancement and growth in scientific outputs and impacts on global research and development, through strategic engagement of more research affiliates, investment in strategic research areas and development of collaborative partnerships. Institute faculty researchers, their students, and their collaborators have developed new approaches, published in leading journals, solved major challenges, and facilitated new technology development in traditional and renewable energy areas.

The decline in support for fossil energy research and the associated decline in societal support has had a definite impact on the amount of research funding that the institute has raised over the past ten years. A considerable effort to diversify the research portfolio to include more sustainable and renewable energy research and to focus on energy systems is underway. Four thematic areas covering various aspects of the energy transition that is confronting societies today have been developed. Changes in the university's budget and business model have brought about other challenges that we are currently negotiating. Strategies to engage faculty members in collaborative research is an ongoing challenge and that is exacerbated by the geographically remote location/isolation of the institute. Various activities are planned soon to promote more collaborative research and to instill a culture of diversity and inclusivity.