

University of Pittsburgh: Center for Energy & Energy GRID Institute 2017 Annual Report June 4, 2018

Introduction

The University of Pittsburgh's Center for Energy is a university-wide endeavor that leverages the energy-related expertise of approximately 100 faculty members across campus from multiple disciplines and departments among the Swanson School of Engineering, Dietrich School of Arts and Sciences, Law School, Business School and the Graduate School of Public and International Affairs.

Established in 2008, the Center is a unifying entity for faculty members to collaborate with each other, regional energy industry leaders, government agencies, and the community to address the many challenges and opportunities associated with the generation, transmission, and utilization of energy. The Center is ideally situated to accomplish this mission, given the Pittsburgh region's abundant natural resources and leadership in the development of clean energy technologies and energy infrastructure, the presence of leading global energy companies, and engaged community and government constituents. The Center serves as an easily accessible entry point for industry in identifying energy-related research and educational expertise, forming partnerships and collaborations, and participating in various energy programs at the University and throughout the community. In 2012, the Center for Energy was awarded a \$22 million grant from the Richard King Mellon Foundation to further advance the University's energy capabilities. The RK Mellon funding supports four endowed faculty positions; endowed graduate student fellowships; equipment, infrastructure and laboratories; commercialization activities; program management and outreach; and planning activities for future growth.

As the Center for Energy continues to advance, along with the development of the Pittsburgh region's energy nexus, it has achieved a strong track record of attracting and training high-quality undergraduate and graduate students, postdoctoral researchers, visiting scientists, and faculty, all of whom are important elements to evolving and sustaining the Center as an internationally prominent energy program.

A defining characteristic of the Center is its success in working closely with the concentration of energy-related industry and community organizations in the region. The next step in the maturation and expansion of the Center will be in taking this model nationwide and across the globe. To that end, the Center serves as an easily accessible entry point for external constituents in identifying energy-related research and education expertise, forming collaborations, and participating in activities at the University.

As in prior years, the Center for Energy continued to advance its mission and the various activities related to energy research, education, and outreach across the University and throughout the community. Highlights from the Center for Energy's 2017 efforts are summarized on the following page.

2017 Center for Energy Highlights

- \$21.3 million in new University energy-related research grants
- Established the Energy GRID Institute at the Energy Innovation Center (EIC)
- \$6.0 million in in-kind equipment and sponsored programs for the Energy GRID Institute
- 11.0 million of investments in Phase I construction for energy labs and facilities at the EIC
- Sponsored 8 RK Mellon graduate student fellowships
- Recruited new faculty hire in energy
- Hosted multiple major university-based energy conferences and symposia
- Expanded the energy-related certificate programs in power, nuclear, and safety engineering
- Sponsored several regional K-12 STEM events, including PJAS and PRSEF
- Expanded the City/Regional District Energy Initiatives in projects, now including approximately 20 sites
- Offered first energy related study abroad course in Scandinavia
- Developed new international partnerships with the Danish Ministry of Energy and Utilities and others

Center for Energy Mission

The Center for Energy's mission is to:

- Facilitate campus-wide energy-related research programs and initiatives
- Support educational program development and curriculum across energy disciplines
- Promote energy-related research and education through outreach and coordination of activities
- "Rise to the Challenge" of positioning our region as a national and global leader in the energy sector, working collaboratively with industry, government, and community partners

Richard King Mellon Faculty Positions

Four endowed faculty positions were originally established with the gift. These included:

- RK Mellon Chair (senior faculty) in Advanced Materials for Energy Applications
- RK Mellon Fellow (junior faculty) in Advanced Materials for Energy Applications
- RK Mellon Chair (senior faculty) in Energy Delivery & Reliability
- RK Mellon Fellow (junior faculty) in Energy Delivery & Reliability

The first two RK Mellon Faculty positions have been successfully appointed. Both of these are at the fellow/junior faculty designation, and include:

- Dr. John Keith was hired as a member of the Swanson School's Chemical & Petroleum Engineering Dept. in 2013, and
- Dr. Alexis Kwasinski joined the Swanson School's Electrical & Computer Engineering Dept. in 2014.

A third faculty member was hired in 2017:

- Dr. Heng Ban, hired as a member of the Swanson School's Mechanical and Materials Sciences Department.

Additional Energy-Related Recent Appointments

The University has also hired a number of other energy-related faculty over the past several years that were not directly associated with the four RK Mellon faculty positions, but who are providing valuable contributions to the Center for Energy's research and education portfolio. These include the following:

New Energy-related Faculty since 2012

<u>Name</u>	<u>Department</u>	<u>Research Focus</u>
Lei Li	Chemical & Petroleum Eng	Advanced Materials
Giannis Mpourmpakis	Chemical & Petroleum Eng	Advanced Materials
Christopher Wilmer	Chemical & Petroleum Eng	Advanced Materials
John Keith	Chemical & Petroleum Eng	Quantum Chemistry and Catalysis
Kyle Bibby	Civil & Environmental Eng	Methane Reformation
Andrew Bunger	Civil & Environmental Eng	Hydraulic Fracturing
Tom McDermott	Electrical & Computer Eng	Electric Power and Renewables
Alexis Kwasinski	Electrical & Computer Eng	Electric Power and Micro-grids
Brandon Grainger	Electrical & Computer Eng	Electric Power and Power Electronics
Joel Haight	Industrial Eng	Human Factors/Safety in Energy
Markus Chmielus	Mechanical Eng & Materials Sci	Advanced Materials
Xei Wong	Mechanical Eng & Materials Sci	Metallurgy and Materials
Bo Zeng	Industrial Eng	Energy Systems Optimization
Michael Matuszewski	Chemical & Petroleum Eng	Energy Systems Optimization
Susan Fullerton	Chemical & Petroleum Eng	Advanced Materials
James McKone	Chemical & Petroleum Eng	Advanced Materials and Catalysis
Heng Ban	Mechanical Eng & Materials Sci	Energy

Richard King Mellon Graduate Student Fellowships

Eight endowed RK Mellon Graduate Student Fellowships are awarded at max every semester.

RK Mellon Graduate Student Fellows for 2017:

- Alvaro Cardoza (Electrical & Computer Engineering – Dr. A. Kwasinski, advisor)
- Emily Cimino (Mechanical Engineering and Materials Science – Dr. B. Gleeson, advisor)
- Mitchell Groenenboom (Chemical Engineering – Dr. J. Keith, advisor)
- Casey Hansen (Bioengineering – Dr. P. Kumta, advisor)
- Patrick Lewis (Electrical & Computer Engineering – Dr. G. Reed, advisor)
- Gizem Ozbuyukkzyz (Chemical Engineering – Dr. G. Veser, advisor)

Establishing the Energy GRID Institute at the Pittsburgh Energy Innovation Center (EIC)

New office and energy laboratory facilities at the Pittsburgh Energy Innovation Center represent a significant opportunity for growth related to the Center for Energy’s research programs, industry and community partnerships, government support, and other activities. Significant efforts, which began in 2014, continued throughout 2017 toward the planning, design, business models, and initial construction of energy-related facilities at the EIC.

In December of 2015, the University of Pittsburgh committed to leasing approximately 20,000 sq. ft. of space at the EIC for the energy-related laboratories and facilities listed below. The initial construction phase took place throughout 2016, with anticipated occupancy in early 2017.

Also, as an additional milestone in relation to this venture, in July of 2016 the University announced the establishment of the *Energy Grid Research Infrastructure Development (GRID) Institute*, representing the energy-related activities associated with the EIC facilities.

<u>Laboratory</u>	<u>Faculty Sponsor</u>	<u>Notes</u>
Electric Power Technologies Laboratory	Dr. Gregory Reed	7,500 sq. ft. - High-voltage / high-power AC/DC and smart grid facility.
Energy Storage Technologies Laboratory	Dr. Prashant Kumta	4,000 sq. ft. - Advancements in battery storage technologies and advanced manufacturing for biomaterials
Materials for Extreme Environments Laboratory	Dr. Brian Gleeson	600 sq. ft. - Current facility at Iowa State University
Energy-Related University Incubator Space	Dr. Rob Rutenbar	3,000 sq. ft. – 6 spaces, each 500 sq. ft. for various incubator activities, special programs, etc.
Offices and Conference Area	All	3,800 sq. ft. of office space for faculty, post-doc and graduate students, and staff

Facility Description

The Energy Innovation Center (EIC), is a renovation of the former Connelly Center in downtown Pittsburgh, and is designed ...

“... to contribute to socially responsible workforce development, foster energy and sustainable technology advancement, and assist in job creation through a commitment to diversity, innovation and comprehensive education.” (from EIC web site)

In order to help contribute to that broad goal, the University of Pittsburgh’s Center for Energy / GRID Institute will be a key tenant, comprising approximately 20,000 sq. ft. on the first floor of the EIC, and advancing the modernization of electric power grids, battery technologies, and high temperature materials, along with incubator spaces for other promising new developments, commercialization activities, and start-ups. A layout of the proposed plans, along with photos of the current Phase 1 construction status, are shown on the following pages.

The Energy GRID Institute

The Challenge: Electric utilities across the U.S., as well as North America and many parts of the developed world that possess established legacy-based electrical power and energy infrastructure, are facing a dynamic period of change and uncertainty. This stems from the recent proliferation and expected continued growth of distributed and renewable energy resources, microgrid developments, increased consumer participation, and many other disruptive technological and regulatory paradigms that are affecting utility planning, design, operations, and policy.

The Vision: Create an international consortium focused on the electric utility industry to evaluate and assess both major industry-wide and individual utility issues, and work in collaboration with various partners towards the development, demonstration, and first-generation deployment of solutions across a broad area of grid technologies, systems, designs, operations, and regulation, as well as addressing market forces and business considerations.

Overview: The University of Pittsburgh’s Center for Energy and the Swanson School of Engineering are investing nearly \$9-million towards renovations for establishment of new off-campus facilities and laboratories at the Pittsburgh Energy Innovation Center (EIC). A significant part of these plans includes an extensive high-power/high-capacity AC and DC networked Electric Power Technologies Lab, which is being supported by various industry and community constituents through in-kind contributions and financial assistance, as well as an advanced energy storage materials laboratory and a materials testing facility.

Establishing the GRID Institute: An expanded vision for this facility beyond these initial plans, is to establish the “Energy GRID Institute” at the EIC for energy and power grid related research, development, demonstration, and deployment, creating value-added impact and national/international prominence. A world-class enterprise with comprehensive infrastructure and advanced capabilities for research, development, commercialization and related activities, in the form of expanded plans for the EIC labs and facilities, is instrumental in realizing the vision and creating opportunities the partner organizations. The GRID Institute was established and announced in July 2016, towards these goals.

Serving Industry and the Community: A core energy sector focus of the Energy GRID Institute is the electric utility industry. Part of the plan to achieve the vision set forth will be to expand upon and attract significant industry participation and corporate engagement at the EIC, to work in close collaboration and partnership with University programs, faculty researchers and graduate students, and other supporting academic personnel. The regional impact will be to leverage activities towards economic growth and job creation, as well as enhancing incubator, start-up, and technology commercialization potential. The national impact will be an opportunity to collectively move industry forward in key areas of energy and power grid related activities. A comprehensive strategy to realize this vision will require large-scale funding from both public and private entities, including opportunities to partner with federal, state, and local government; regional, national, and global industry organizations; the foundation community; and the University.

Value Proposition: By focusing on the needs of the electric utility sector, the Energy GRID Institute can create a national and even international consortia of industry partners to evaluate and assess both major industry-wide and individual utility issues, and work in collaboration towards the development, demonstration, and first-generation deployment of solutions across a broad area of grid technologies, systems, designs, operations, and regulation, as well as addressing market forces and business considerations. Some of the needs and critical issues for the utility sector that are currently evolving and that have been identified as key areas of importance for which the Energy GRID Institute will be equipped to address include:

- Microgrid Developments and Integration
- Distributed Energy Resource Developments and Deployment
- Evolving Electrical Loads and Load Integration
- Renewable Technologies – Solar PV, Wind, Micro-Hydro, etc.
- Energy Storage Technologies and Applications
- Electric Vehicle-to-Grid Concepts
- Direct Current (DC) Infrastructure, Technologies, and Standards
- Hybrid AC/DC Systems and Network Interoperability
- Power System Security, Resiliency, and Reliability
- Distribution Feeder Infrastructure / Feeder Capacity and Analytics
- T&D SCADA and Systems Operations / Distribution Energy Management
- Protective Relaying and Substation Automation
- Advanced Control and Communications, micro-PMU Deployment
- Real Time Digital Simulator (RTDS) / Power System Modeling, Simulation, Analysis
- FACTS and HVDC Control Systems / Power Electronics Converter Technologies
- Independent Testing, Standards Development and Certification of New Technologies / Systems
- Economics, Policy, Regulation, Markets, and Business Models for the Utility Sector

A set of value propositions for the utilities along with the industry and community partners engaged in the Energy GRID Institute will provide significant contribution to the power and energy sector as a whole, while also offering opportunities for individual and specialized collaborations. These include the following, which can involve constructs for various levels and options of partnerships:

- Collaborative research and development programs
- Joint university-utility-vendor-government partnerships
- Various levels and constructs of agreements/consortia
- Technology development, prototyping, and demonstration
- Fee-for-service and contract R&D options
- Utility-grade investigations, failure analysis, and testing
- Industry standards development and certification
- Independent testing and third-party operations
- Commercialization and start-up opportunities
- Student development and access
- Education and training
- Other related services – consulting, business development, etc.

Impact: Considering the expansive nature of goals to modernize the nation’s electric power grid and other energy infrastructure; integrate higher penetrations of clean energy resources at all levels; enhance grid infrastructure, security, resiliency, and reliability; and adapt to changing consumer demands; the role of DC technologies, evolving hybrid AC/DC systems, microgrid developments, energy storage and related concepts create opportunities for various partnerships across campus and throughout the community, as well as with other universities active in these areas.

Future Potential: The program can, in time, expand beyond electric grid infrastructure and include other energy systems, including aspects of energy delivery and reliability for natural gas and even transportation networks. As utility of the future concepts continue to be developed, co-location of energy resources and delivery infrastructures of various forms create strong economic value-propositions. Whether it be microgrid deployments or large-scale national grid networks, various combinations of energy forms are considered in planning efforts. A need to enhance reliability, resiliency, security, efficiency, and sustainability of energy networks, while maintaining strong economic value for energy consumers, will require these kinds of cross-technology and infrastructure considerations, and will require the participation of various cross-institutional capabilities and collaborations among different energy sectors. From a national perspective, this will be a unique and important enterprise model. Through extensive and successful collaborations with the electric utility industry, government, and community partners, the University of Pittsburgh, through the Center for Energy, the Swanson School of Engineering, and the Electric Power Systems Lab, is well-position to expand to a significant scale of research, development, demonstration, and deployment in the areas of energy and power grid technologies and infrastructure.

Energy GRID Institute Consulting Analysis: This fall, the Center for Energy officially signed an agreement with Fourth Economy and Quanta Technology were selected to begin conducting analysis on the future business model for the Energy GRID Institute. Considering the current range of capabilities that can now be offered to industry partners out of the GRID Institute, these two consulting firms are working to identify the scope of the market that GRID is operating within. At the same time, the current business model and operations of GRID have not been finalized; there is a need to understand the intricacies of the relationships that are associated with GRID, primarily the Center for Energy, Swanson School of Engineering, and Pitt itself. Initially, the research is being focused on two main phases: first, in understanding how non-traditional University research labs are legally structured to retain their connections to a school but to remove legal, process, and time barriers that may be associated with existing University procedures. The second, is a gap-analysis to truly understand the breadth of the market GRID is operating within. This phase will give recommendations on target organizations and opportunities for partnerships initially. However, this phase will also consider the breadth of established/proposed partnership discussions and give recommendations as to how these relationships may affect the structure of the GRID Institute itself, including various models and agreement constructs that could range from individual collaborations to industrywide consortia models. By the end of February 2017, the consultants will have surveyed the market, internal stakeholders, external industry members, and competitive entities in order to identify the potential business models that GRID could operate. This phase will also identify remaining decisions that may need to be made in order to have GRID operational as soon as possible; the consultants will present their initial findings to the Pitt project team in the form of a “decision-tree”.

Industry Collaborations

The Center for Energy continues to be well-positioned to deliver upon the industry and community impacts as stated in its mission statement. Critical to this is the collaboration and coordination of industry-wide research and outreach. The launching of the Energy GRID Institute this spring at the Energy Innovation Center will act as a grounded cornerstone for Pitt's ability to expand and cultivate a higher degree of industry and community partnerships across the energy sector.

The Center has established many successful partnerships to-date – particularly those forged around the GRID Institute's research and laboratories focus – such as those with Duquesne Light, FirstEnergy, Dominion Virginia Power, EPRI, Eaton, Emerson, ABB, Siemens, Mitsubishi Electric, Westinghouse, Sargent Electric, ANSYS, Universal Electric, Opal-RT, Pitt-Ohio Express, Ametek, Danish Energy Association, Emerge-Alliance, Pepco, RTDS, Helioscope, HOMER Energy, and Winstax. In addition, the Center has taken a lead role in working closely with the City of Pittsburgh and other community partners related to district energy initiatives. Expanding on these already established relationships to conceptualize specific research projects related to the energy transition will be an important element of truly carrying out our mission into 2017 and beyond as a leader both in the region and nationally.

Several examples of industry and community partnerships from 2016 activities are highlighted in this section, including Pittsburgh District Energy Initiative, the Duquesne Light Co. partnership, the DC-AMPS Program, and the Pitt-Ohio Express Inc. Renewable DC Microgrid Project. However, we will also focus on the development of new collaborations, both domestically and abroad and, as we seek to expand our overall portfolio of research activities and other services. By planning the GRID Institute's capabilities to be flexible in working successfully with industry, we can engage in a greater range of activities that can lead to larger projects and programs. In addition, coordinating larger multi-organizational opportunities with industry, government sponsors, and community partners will be another focus of the Center's reach and potential going forward. The ability to offer additional products to our constituents through the GRID Institute – such as fee for service activity, third party facility utilization, independent testing and certification, contract R&D, and other agreement constructs – will greatly enhance our overall growth potential.

As we continue to strengthen the Center for Energy as a national leader for energy development, a critical part of our efforts going forward will be coordinating larger multi-organizational opportunities with national and international industry, governments, and academic partners. A critical part of 2017 was expanding upon the national partnerships with strong international efforts in energy collaborations. The Center is already expanding to coordinate its research aims with the state of Pennsylvania and in the Capital. The Center has also begun to work on proposals for national international research collaboration with potential partners such as Alcoa, AEP, Duke Energy, National Grid, E.On, Himin, Enel, KEPCO, and Hyosung, among many others. Considering the breadth of the research capabilities within Pitt's energy portfolio, Pitt researchers have created excellent opportunities to engage with funding from international organizations.

Academic overview: research programs and related activities

The The research portfolio of the Center for Energy continues to grow. In 2015, approximately \$21 million in new grants were awarded to the University of Pittsburgh across a wide range of energy-related disciplines. The areas of research focus for the Center include the following:

- **Energy and Electric Power Delivery and Reliability** – An important component to advances in energy technologies are necessary improvements in the entire chain of electric power generation, transmission, distribution, and utilization. This includes the reliability of power and energy systems (fossil, nuclear, and renewable), together with the development and implementation of smart grid systems, advanced power electronics technologies, and renewable energy integration, micro-grids, and growing developments in direct current (DC) architecture.
- **Advanced Materials for Energy-Related Applications** – This includes experimental and computational efforts on structural and functional materials for use in harsh environments (including those associated with nuclear systems), robust solar materials and devices, materials for energy storage, thermo-electrics and sensors.
- **Clean Energy Development and Integration** – The increase in renewable and alternative energy resources is creating new markets and providing numbers opportunities for research and development. These include areas from solar and wind energy to wave and hydropower to geothermal and other alternative resources. In addition to developments for the resources themselves, opportunities are developing for controls, communications, protection, storage, and other aspects of future energy supply integration.
- **Direct Energy Conversion and Recovery** – The greatest immediate opportunity for impacting energy consumption and carbon emissions is in energy efficiency. Current research focuses on increasing the efficiency of energy production and utilization systems, processes, and/or equipment.
- **Carbon Management and Utilization** – This includes carbon capture and storage, carbon reduction and offsetting technologies such as hybrid systems that utilize nuclear or renewable systems, and the efficient conversion of carbon to alternative fuels.
- **Unconventional Gas Resources** – This area is primarily concerned with the safe and optimized procurement of natural gas from unconventional resources such as the Marcellus Shale. It includes exploration, well drilling and completion, water management, and gas extraction.
- **Energy Efficiency and Sustainability** – Advances at the consumer level of energy production, management, and end-use are creating opportunities for the development of new energy-efficient technologies that also lead to achieving important sustainability goals.

A critical aspect of the Center’s 2017-2018 academic year efforts will be to reorganize the center in a manner that is more “industry-friendly” and also, more easily convened in terms of cross-campus research efforts. The center will be reorganizing around the following themes going forwards, including:

- Resources
- Delivery and Infrastructure
- Utilization
- Materials and Storage
- Markets
- Education and Training

Summary of energy research activities, through 2016

External research funding information is presented in the following tables¹:

Energy R&D Funding (total grants & trends from FY 2009 through FY 2016)

	FY 09	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16
Government and Industry funded energy-related R&D contracts and grants	\$7,123,374	\$9,657,751	\$9,231,807	\$19,155,259	\$18,651,227	\$20,355,148	\$20,067,872	\$23,058,383
Philanthropic support for energy-related R&D programs	\$370,000	\$415,000	\$446,250	\$10,798,660	\$10,622,619	\$875,000	\$496,000	\$500,000
Total	\$7,493,374	\$10,072,751	\$9,678,057	\$29,953,919	\$29,273,846	\$21,230,148	\$20,563,872	\$23,558,383

Energy R&D Funding Breakdown (primary funding sources for FY 2014 through FY 2016)

Funding Source	FY 14	FY 15	FY 16
U.S. Dept. of Energy	\$4,718,511	\$3,758,025	\$3,141,563
U.S. Dept. of Defense	\$6,815,291	\$5,346,048	\$6,229,191
National Science Foundation	\$5,253,944	\$4,862,348	\$7,041,800
Industry	\$1,715,516	\$3,677,253	\$4,021,149
Philanthropy	\$875,000	\$496,000	\$500,000
Other Sources	\$1,851,886	\$2,424,198	\$2,624,680
Total	\$21,230,148	\$20,563,872	\$23,558,383

New research funding in FY-2016 resulted in an increase in energy-related totals of nearly 15% from FY-2015. As reported in 2015, the elimination of the NETL Regional University Alliance and the previous years' NETL funding levels (which had accounted for nearly \$3 to \$4 Million per year up until 2014), was overcome with some additional DOE funding and more than doubling of industry awards.

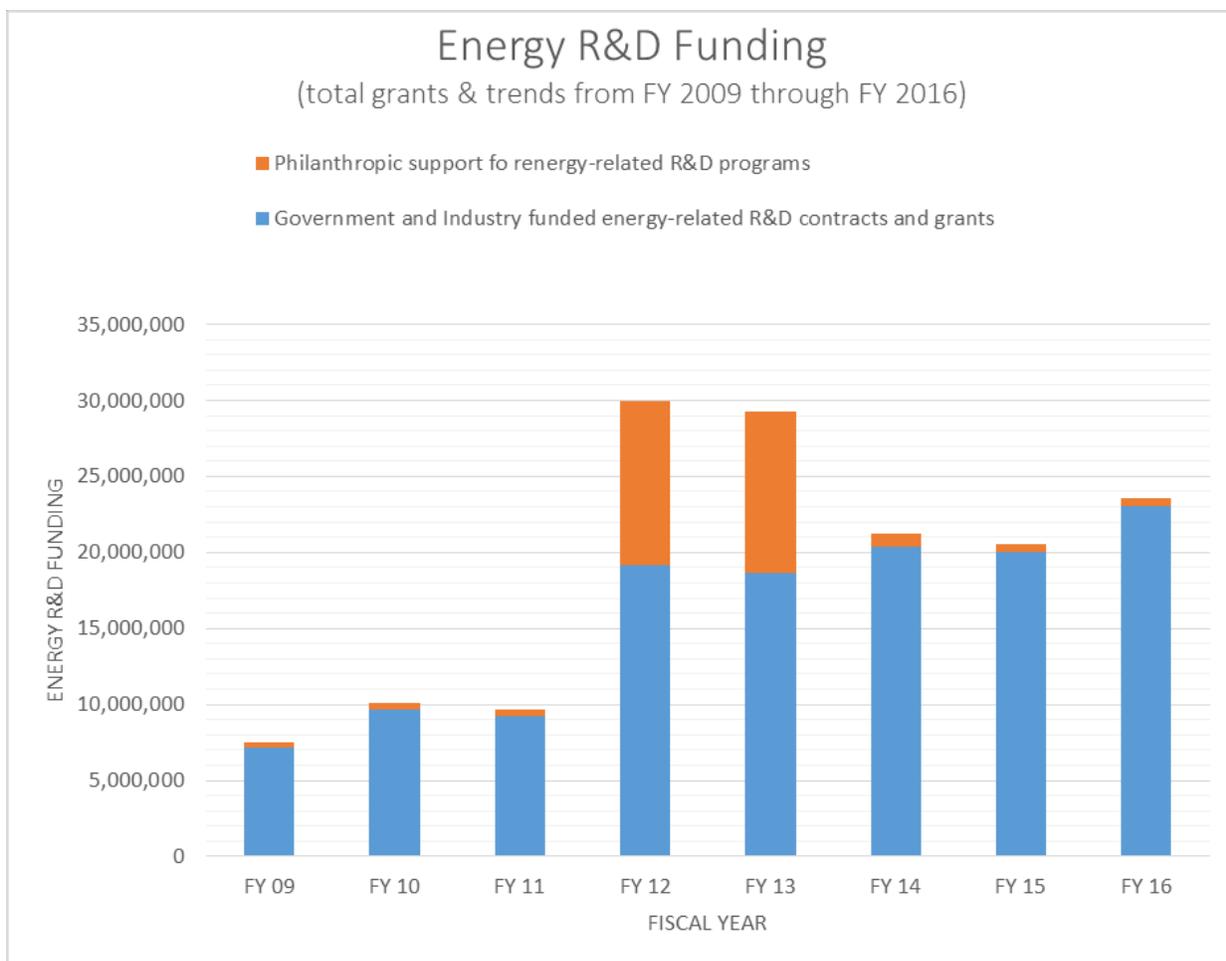
In FY-2016, upward trends in industry funding continued for the third year in a row, which was a major goal of the Center. In addition, while overall DOE funding continued to decline, an increase in DOD funding and a robust enhancement of NSF support helped to increase the Center for Energy's total research portfolio for FY-2016.

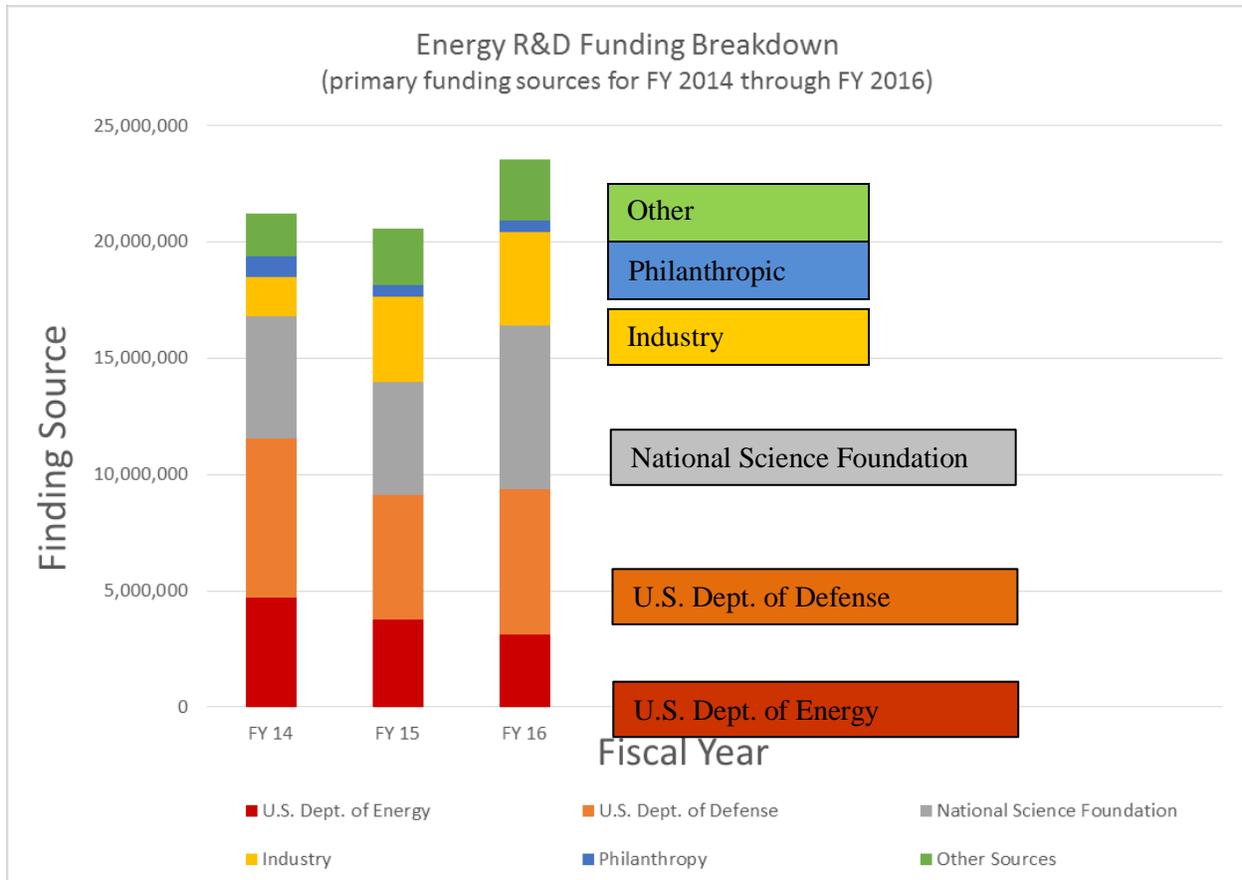
¹ Research expenditures measured on Financial Year (FY) basis. FY16 covers 1-July, 2015 through 30-June, 2016.

Going forward – and especially with the opportunities presented by the Energy Innovation Center plans (and the establishment of the Energy GRID Institute) – a continued focus on industry partnership and collaboration is expected to provide a substantial increase in this sector for the Center’s overall R&D portfolio in the years ahead. This is very much in line with both the University’s and the Swanson School’s goals.

Over the past several years, it can be seen the RK Mellon grant in FY-2012 and FY-2013 greatly enhanced the total R&D portfolio for the Center, while at the same time additional R&D focus in energy increased the government and industry funded research. By leveraging the RK Mellon grant, beginning in FY-2014 and through FY-2016 (and with much less reliance on philanthropic contributions during this period), the Center for Energy’s total R&D portfolio remained at or above these the FY-2012 and FY-2013 levels, including this year’s 15% increase in funding, and representing more than double the amount of total funding in the years prior to the grant. The charts below provide a graphical illustration of these funding level trends.

Thus, it is with high confidence that the Center for Energy looks to the future in areas of strategic growth that are focused on the vision and goals of the Energy GRID Institute at the EIC. The GRID Institute will not only usher in the next era of energy leadership for the University, our partners, and the region, but it will help to fulfill the ultimate mission of the Center for Energy through the support of the RK Mellon Foundation.





As a general trend over the past three years (FY-2014 through FY-2016), industry funding has steadily increased, while U.S. Dept. of Energy funding has decreased slightly. U.S. Dept. of Defense funding has been somewhat consistent, and National Science Foundation funding increased significantly in the past year.

Education and Workforce Development

The Center for Energy continues to lead Pitt's development and delivery of energy-related educational programs specifically tailored to the needs of our regional energy economy. The development of programs in several areas – including electric power, mining, and nuclear engineering – have become some of the best in the country. A summary follows of the programs, course offerings, and future plans for energy- related education.

Energy-related Concentrations and Certificates

- Electric Power Engineering – undergraduate (BS) and graduate (MS and PhD) concentrations within the ECE department. Undergraduate concentrations represent 1/3 of all graduating BS EE's; a new synchronous distance learning (SDL) post-baccalaureate/graduate certificate program introduced in fall 2013 is exceeding enrollment targets. New course developments at all levels of the program.
- Nuclear Engineering– Undergraduate (BS) and graduate (MS) certificates and the Master of Science in Nuclear Engineering (MSNE) continue to remain steady with stable enrollments
- Mining Engineering – Undergraduate and graduate certificate programs will close in the 2017/2018 academic year, due to decreased demand.
- Safety Engineering Certificate - The graduate safety engineering certificate program targets engineers in the energy industry who find they need or want a background in safety engineering. The curriculum targets general industry injury prevention, catastrophic loss of containment prevention, mitigation and management as well as work environment design and focuses on the continuous process oil and gas industry, nuclear power and conventional coal and natural gas power industries.
- Advanced Manufacturing – New M.S. program is under development
- Honors College 'Energy: Science, Society and Communications' course in collaboration between Pitt and CMU was offered for the fourth time in 2016

Academic Indicators

The three energy-related programs all reside in the Swanson School of Engineering, each with a department home (electric in the ECE department, mining in the CEE department, and nuclear in the MEMS department). The table below shows the different degree types (and credentials) offered, along with current enrollment sizes and total number of degrees/certificates awarded to date.

Energy Program Academic Indicators (2016-2017 Academic Year)

Program / Department	Year Program Established	Degree / Credential Type	Total degree concentrations and certificates awarded to date
Electric Power Engineering	2007	Undergraduate (B.S.) degree in EE with concentration in Electric Power Engineering	158
Electrical and Computer Engineering Dept. (ECE)	2009	Master of Science (M.S.) degree in EE with concentration in Electric Power Engineering	26
	2011	Doctor of Philosophy (Ph.D.) degree in EE with concentration in Electric Power Engineering	18

	2013	Graduate Certificate in Electric Power Engineering	10
Nuclear Engineering	2007	Undergraduate Certificate in Nuclear Engineering	424
Mechanical Engineering and Material Science Dept. (MEMS)	2007	Graduate Certificate in Nuclear Engineering	86
	2012	Master of Science (M.S.) degree in Nuclear Engineering	21
Mining Engineering	2009	Undergraduate Certificate in Mining Engineering	64
Civil and Environmental Engineering Dept. (CEE)	2009	Graduate Certificate in Mining Engineering	10

External outreach

The Center has continued to organize key energy-oriented events on campus. Events this year included the following major activities, along with more detailed summaries of the two more significant hosted conferences listed (EPIC and PCC):

- The 12th Annual Electric Power Industry Conference (EPIC) – Nov. 13-14, 2017: Attended by nearly 250 people, including over 70 different companies represented and 27 exhibitors. Keynotes by Mark McGranaghan, Vice President Power Delivery & Utilization, Electric Power Research Institute, and Daniel Carnovale, Manager, Power Systems Experience Center, Eaton, along with approximately 75 papers, posters, and presentations over various sessions and panels through the two days.
<http://www.engineering.pitt.edu/epic/>
- 34th Annual International Pittsburgh Coal Conference – September 5-8, 2017 at the Sheraton Pittsburgh Hotel at Station Square in Pittsburgh, Pennsylvania. <http://www.engineering.pitt.edu/pcc/>
- Experience America Ambassador Day – May 22, 2017 - University of Pittsburgh. Panel discussion focused on how Pittsburgh is planning to make progress by using energy diversity as a tool for economic development.
- Foundations for Engineering Education for Distributed energy Resources (FEEDER) Summer Institute – June 5-9, 2017. Pittsburgh, Pennsylvania. Students had the opportunity to tour Duquesne Light, Mitsubishi Electric, Eaton Power Systems Experience Center and the Energy Innovation Center.
- Danish Energy Governance Workshop – The Center for Energy has been deeply engaged with the Danish Energy Agency to position Pittsburgh as an official partner city for the Danish Energy Governance Partnership. This partnership exposes local experts and decision makers to their Danish counterparts in the energy sector. The Danish partnership would be anchored at the GRID Institute and would include graduate student engagement. Details are currently being drafted in a charter document.
- City of Pittsburgh Climate Action Plan Workshop - The Center for Energy has continued to support the release of the City of Pittsburgh's Climate Action Plan. Meetings have been coordinated with University of Pittsburgh Facilities Management group to catalogue efforts internal to Pitt. The Center has also submitted comments on the draft plan.
- County Executive visit to Pitt-Ohio – County Executive Rich Fitzgerald, along with Bob Hurley and Jennifer Liptak, visited Pitt-Ohio Express in Harmar Township. Pitt-Ohio and the Center for Energy led a tour and presentation on the retrofit project, with a focus on the energy components. The County Executive and his staff have continued to engage with the Center on a number of energy-related opportunities across Allegheny County.
- PEC Grid Modernization Workshop - In partnership with Pennsylvania Environmental Council, the Center for Energy hosted a workshop to discuss grid modernization efforts for deep decarbonization strategies. This workshop was held at the EIC January in early January and included a select list of invited presenters from across the state.
- IDEA Conference 2017 – The Center for Energy was invited to attend and present at the International District Energy Association's annual trade show in Scottsdale, Arizona. The manager of District Energy discussed challenges in Pittsburgh as they directly relate to additional development sites such as Hazelwood Green, and the downtown energy district (PACT).

Community Impact projects

The Center continues to engage in community projects via its undergraduate research projects. There were various students who worked for the CfE in 2017, and as such the Center is able to report various activities related to reach impact.

Millvale Moose Project – The Center for Energy in coordination with New Sun Rising and other stakeholders in the Millvale Community are working to scope an energy-focused project at the Millvale Moose. Staff and students are working to complete initial research and design elements for a solar, storage, and DC-based microgrid at the Millvale Moose. The research to date has been leveraging a newly acquired microgrid modeling tool (HOMER) at the Center for Energy.

Pitt-Ohio Express Installation Part II (Parma)– The Center is again partnering with Pitt-Ohio on their new distribution center currently under construction in Parma, Ohio. This will include an expansion of the renewable DC microgrid design first demonstrated at the Harmar facility. Plans are for the facility to include solar PV, wind, and battery storage at approximately eight times the size and capacity of the Harmar project, and will also take the direct current component completely to the plug load for lighting, computing, and other facility infrastructure, implementing new state of the art concepts and technologies.

Second Avenue Garage/EV Innovation Corridor Project – The Center for Energy in partnership with NETL developed an integrated RFI approach to aid in project development of a deployable DC microgrid at Second Avenue.

Duquesne Light Woods Run – The Center continues to support and play a role in the planning, development, and eventual construction of a proposed microgrid at DLC’s Woods Run campus. DLC is currently preparing to seek PUC approval for construction.

State Agency Engagement – Through new staff capacity, the Center has begun to develop relationships with state agencies critical to the DEI. Specifically, multiple meetings have been held with the PUC, PADEP, and PADCED to explore partnership and funding opportunities.

Electric Vehicle Committee – The Center is engaged at the state level, participating on two state-wide committees: (1) Electric vehicle infrastructure planning, and (2) electric vehicle marketing and outreach. Opportunities for the Center to lead a ‘vehicle to grid’ subcommittee are being explored.

Pitt Energy Master Plan – Pitt has recently completed an Energy Conservation and Master Plan. This plan examined supply and demand side energy consumption and projections. The Center for Energy served on the technical team supporting the plan. Part of the Center's role included serving as the link to the City’s sustainability office, and designing longer term project opportunities within the plan (microgrids, CHP, etc.). The Center also submitted an energy demonstration proposal to be included in the final version. Staff, graduate, and undergraduate students supported the efforts.

Invited Keynotes, Seminars, and Presentations

The following represents keynote addresses, and invited seminars and presentations by the current leadership team (Reed and Vesper) from the Center for Energy over the course of 2017, as examples of the types of events and invited opportunities, which help to provide dissemination of important scientific and engineering issues and that provide positive exposure for the Center's leadership in various energy arenas.

1. Northeast Ohio Energy Storage Cluster Meeting, Invited Speaker, "The Pitt Center for Energy and the Energy GRID Institute – Industry Collaboration Successes," Case Western Reserve University, Cleveland OH, October 26, 2017
2. Gannon University SEECs guest speaker, Erie, PA - January 31, 2017
3. MIT Speaker Series, Cambridge, MA - February 6-8, 2017
4. Eaton E3, Future of Grid Modernization, Pittsburgh, PA - March 27, 2017
5. Cummins Presentation - August 30-31, 2017
6. EOE Turbine Conference - November 1, 2017
7. T & D World Conference – Chicago, IL - November 7-8, 2017
8. On Demand Energy Annual Meeting, Invited Keynote Speaker, "Electric Power Grid Reliability in a New Era of Energy Development – Old Stonewall, Cranberry Twp. PA - May 24, 2017
9. CMU Energy Week, "Innovation Round Table," Invited Panelist – CMU, Pittsburgh PA - March 27, 2017
10. Society of Environmental Journalist tour – an event designed to showcase research and development activities, Energy Innovation Center – GRID Institute, Pittsburgh PA - October 5, 2017
11. Economic Development Forum – Pittsburgh airport/tour of Beaver Valley Nuclear Power Station – October 11, 2017
12. Pennsylvania Junior Academy of Science (PJAS) Region 7 Science Fair, Judge and Pitt Center for Energy Special Awards Presentation – Duquesne University, Pittsburgh PA - February 4, 2017
13. Aquinas Academy of Pittsburgh, High School Career Day Seminar, "An Introduction to Engineering and Energy" – Aquinas Academy, Gibsonsia PA - February 1, 2016
14. "Intensifying Natural Gas Upgrading", Invited keynote, WVU Shale Gas network Forum, Morgantown WV - March 22, 2017.
15. "Natural Gas Upgrading and CO2 Utilization via Chemical Looping", invited plenary, KOPRC Forum 2017, royal Society of Chemistry, London, UK - July 24, 2017.
16. "Impact of Pore Diffusion on Reactivity in Core @ Shell Nanocatalysts", invited presentation, MNA25, Denver, CO - June 5, 2018.
17. "Pittsburgh's Place in Climate Leadership", invited presentation, Clean Energy Ministerial, Copenhagen, May 22-23, 2018.

Center for Energy Advisory Council

The Center for Energy’s external Advisory Council held one meeting in 2016, during the fall term, which was held at the EIC. The purpose of the Advisory Council is to provide advice and advocacy in support of the Center’s mission in energy education and research.

Mr. Morgan O’Brien (CEO Peoples Natural Gas and a member of the Pitt Board of Trustees) serves as Chair of the Advisory Council.

Current Advisory Council members include:

<u>Name</u>	<u>Organization</u>	<u>Title</u>
Morgan O’Brien	Peoples Natural Gas and Pitt Board of Trustees	President & Chief Executive Officer
John Swanson	Pitt Board of Trustees	Founder, ANSYS
Frank Petraglia	RCM	Vice President
John Paserba	Mitsubishi Electric Power Products	Vice President, Power Systems Group
Scott Izzo	RK Mellon Foundation	President
Steve Johnson	CONSOL Energy	Executive VP, Diversified Business Units
Dave Karafa	FirstEnergy	President, Pennsylvania Operations
Bill Van Landingham	Eaton	Senior VP & General Manager
Rich Riazzi	Duquesne Light	President & Chief Executive Officer
Tom O’Toole	US Steel	General Manager, Engineering
Scott Waitlevertch	Columbia Gas	Manager of Government Relations
John Sims	ATI	Executive Vice President
Jim Drake	Curtiss Wright	General Manager
Murry Gerber	Retired	(USS and Halliburton Boards)
Mike DeWitt	Shell Appalachia	General Manager
Kate Jackson	KeySource	Director Energy & Technology Consulting
Bill Lambert	MSA	Chief Executive Officer
David Roger	Hillman Family Foundations	President
Cindy Pezze	Westinghouse	Chief Technology Officer
Brian Gemmell	National Grid	Vice President, Strategy and Performance
Andrew McElwaine	Heinz Endowment	Vice President, Sustainability

Future Vision

The Center for Energy has tremendous opportunities for future growth and programmatic expansion, including consideration of the newly planned labs and facilities at the EIC and through the Energy GRID Institute. A defining characteristic of the Center is its impressive track record of working closely with the concentration of energy-related industry and community organizations in the region. The next step in the evolution and development of the Center will be to take this model to industry organizations from across the country and around the globe, with continued strong support from federal, state, and local government institutions, as well as the foundations and community partners.

An initial goal of approximately doubling the Center’s total research grant portfolio to \$50 million within 3 years (accelerating this goal that was established in 2016 over 5 years) – and aspiring to establish a national center for multi-disciplinary energy technology research, development, demonstration, commercialization, and deployment – is the foundation for a future vision that aligns with both the Swanson School’s and the University’s priorities and plans. A longer term 10-year plan envisions the Center for Energy and the GRID Institute as a leading national and global enterprise across multiple areas of focus that leverage the University’s strengths and core competencies.

This vision will require cross-institutional cooperation and support to create a veritable energy “community” at the University with a unified goal. In this manner, the Center will provide opportunities for faculty and trainees in various disciplines, programs and other centers at the University to provide synergistic collaborations, including areas such as: energy resources and development, energy storage, energy materials and devices, catalysis and energy conversion, energy delivery and infrastructure, advanced manufacturing, sustainability and energy efficiency, information technologies, communications and controls, computing and data, cyber and physical security, energy policy and law, business and economics, and many other programs and disciplines.

Through this type of multi-disciplinary collaboration, the Center will facilitate and create value-added impact and national/international prominence that will mutually benefit our constituents and the Pitt energy community at-large. While this vision is based upon the continued growth and success of strong industry collaborations, government support, and community partnerships that have been the hallmark of our programs in recent years, it will require the addition of new faculty, graduate student researchers, and other supporting personnel, as well as additional new facilities and laboratory capabilities. Part of this plan will be to attract strong participation and engagement within our existing programs, along with the new programs at the EIC and through the GRID Institute, to work in close collaboration and partnership with various constituents. The regional impact will be to leverage activities towards economic growth and job creation, as well as enhancing incubator, start-up, and technology commercialization potential. A strong regional success will lead to larger-scale national and international opportunities.

As the region, the nation, and the world continue to experience wide-ranging challenges in an era of dynamic energy transition, the Center for Energy is well-positioned to create new opportunities for strong future growth and to have continued impact and success in supporting the region’s role as a global leader in energy-related education, research, development, and demonstration.