



SCHOOL OF ENERGY RESOURCES



SEPTEMBER 30, 2017

ANNUAL REPORT



UNIVERSITY OF WYOMING



School of Energy Resources

**THE UNIVERSITY OF WYOMING SCHOOL OF ENERGY RESOURCES
ANNUAL REPORT FY 2017**

SEPTEMBER 30, 2017

Presented to:

Joint Minerals, Business and Economic Development Interim Committee,

Joint Appropriations Interim Committee,

Joint Education Interim Committee



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The University of Wyoming (UW), School of Energy Resources (SER) was created in 2006 to enhance the university's energy-related education, research, and engagement. The Wyoming State Legislature provided authorization and funding for the SER in its 2006 session, through Senate File 37. W.S. 21-17-117(f), which requires a report regarding all revenues to and all expenditures by the school during the preceding fiscal year, accomplishments of the school and its benefits to Wyoming's energy economy.

SER directs and integrates cutting-edge energy research and academic programs at UW and bridges academics and industry through targeted engagement efforts. Since its inception in 2006, SER has worked to maintain flexibility in its focus and structure to meet the changing needs of Wyoming's energy industries – which is now more critical than ever. This report highlights SER's significant achievements from July 1, 2016, through June 30, 2017, in the areas of research, academics, engagement and newly emerging areas of focus to keep UW and Wyoming at the forefront of the energy sector.

A year ago, Wyoming was facing severe revenue shortfalls due to declining energy production and prices. In recent months, coal and natural gas production activity and hiring is starting to increase but will likely not recover to previous highs. With guidance from the Energy Resources Council (ERC), SER started re-focusing existing programs and added new ones meant to leverage Wyoming's natural resources to generate additional revenue opportunities for the state. This effort was assisted by a one-time appropriation from the Wyoming Legislature in 2016 of \$2 million over two years for research targeted toward building industries in Wyoming centered around the conversion of coal to value-added products.

After significant staffing changes last year, SER continues to streamline operations while staying focused on energy education and research to keep UW a leader in select energy-related technology and economics that are relevant to state, regional, national, and international energy agendas. SER has integrated the Carbon Management Institute (CMI) fully into SER and takes advantage of their expertise as a reliable source of energy policy and economic knowledge to decision-makers and the public. Also, the 3D Visualization Center is working to create a fee-for-service enterprise to generate revenue to cover the Center's expenses.



One of SER's goals is to provide seed funding to UW faculty to help them leverage external funding to grow their research programs in energy-related fields. In the last year, SER provided over \$700,000 to five Centers of Excellence, which resulted in capturing an additional \$900,000 of external funding primarily in the field of carbon capture, use and storage (CCUS). SER also allocated over \$2,000,000 from a one-time appropriation and from the standard budget to implementation a broad scope of Carbon Engineering research activities, with engagement of faculty, post-doctoral and graduate students.

A major accomplishment was the completion of the High Bay Research Facility (HBRF) which has significantly increased UW's energy-related research capability. The state-of-the-art HBRF is integral to the success of UW's slate of energy programs and allows growth of research targeting improved recovery of hydrocarbons from unconventional reservoirs. This new facility houses the Center of Innovation for Flow in Porous Media and contains laboratories focusing on improved oil recovery, geomechanics, petrology and structural engineering.

Instead of the historic annual increase seen over the last seven years, SER's academic program fall 2015 enrollment leveled-off as the energy industry continues to deal with multi-year low prices and subsequent employee lay-offs. Another major accomplishment is that eleven undergraduate students graduated in December 2016 and May 2017 – tied for the second-highest graduation rate in the program's history – and seven of those students were able to find jobs upon graduation. This is a testament to the value of the Energy Resource Management and Development (ERM&D) program given the current difficult job market in the energy sector. The SER academic program continues to promote K-12 energy education and renewed a partnership with the UW College of Education to promote energy literacy through teacher training and curriculum development.

SER's engagement program saw one of its busiest years by convening 19 events and hosting five speakers. Several of the conferences were international meetings with delegations from Japan and China to share technological information about advanced coal conversion and CCUS technologies.

SER appreciates the continuing confidence of the Wyoming Legislature. In the face of tightening budgets, SER's commitment to providing funding support for energy education, targeted research, and engagement across multiple colleges at the University of Wyoming is more important and effective than ever. SER's partnerships with UW faculty and industry representatives ensure the capability to be relevant and reactive, and are helping to keep energy a viable industry in Wyoming.



In the face of rapidly changing energy markets and implementation of new environmental regulatory requirements, SER must adapt its research priorities to meet new challenges facing the energy sector in Wyoming. SER has directed its research dollars to help UW faculty obtain external research grant funding through the research Centers of Excellence. The interdisciplinary research done by the centers and the funds they leverage provide UW with opportunities and facilities to compete in a wide range of research across traditional and emerging energy sectors in Wyoming.

Centers of Excellence

SER provides seed funding for the Centers of Excellence (COE) to be established as mechanisms to bring together faculty and graduate students from multiple disciplines to develop important energy research programs. With SER funding, the COE are expected to capture external funds and attain financial independence within a few years. COE evolve with time; new groups may form to work on emerging challenges, while some centers may disband as their programs are completed. Nine COE were active in FY2017:

- Carbon Management Institute
- Center for Air Quality
- Center for Biogenic Natural Gas
- Center for Energy Economics and Public Policy
- Center for Excellence for Produced Water Management
- Center for Photoconversion and Catalysis
- Shell 3D Visualization Center
- Wyoming Restoration and Reclamation Center
- Enhanced Oil Recovery Institute



Carbon Management Institute - Kipp Coddington, Director

Founded in 2010, the Carbon Management Institute (CMI) supports the University of Wyoming's land-grant mission by: (1) providing the University with a balanced and experienced applied geologic and geophysics research branch focused on energy studies; (2) building upon the Institute's international expertise in the geologic storage of carbon dioxide (CO₂); (3) striving to become a world-class center of techno-economic and policy carbon management solutions, including CO₂ capture technologies, for the benefit of Wyoming's energy resources; (4) assessing how carbon management laws and policies may be leveraged to the benefit of Wyoming's citizens and all of Wyoming's resources; and (5) providing the University's students with world-class education in energy and carbon management matters through teaching and collaborations with other University departments and programs. CMI also conducts grant-funded research related to the identification of rare earth elements (REE) in coal, coal by-products and produced water.

CMI is funded almost entirely by grants, with the bulk of those grants in recent years coming from the U.S. Department of Energy (DOE). CMI has captured more than \$40 million in funding since its inception. Those dollars have not only supported CMI's research staff, but they have percolated throughout the UW campus to support numerous graduate students and undergraduates over the years. They also have funded Wyoming-based private sector team members, such as drilling contractors. Over the past year, CMI's research efforts have focused in two major areas: 1) Carbon Capture Utilization and Storage; 2) REE.

Unveiled by DOE about a year ago, the Carbon Storage Assurance and Facility Enterprise – or CarbonSAFE – initiative is intended to develop integrated CCUS complexes, constructed and permitted for operation over a series of sequential phases of development. The ultimate goal of CarbonSAFE is the siting and operation of several large-scale integrated CCUS projects throughout the United States by the 2025 timeframe, with coal-fired power plants as the preferred CO₂ source. Each project site must eventually meet minimum CO₂ storage goals (at least 50M metric tons) while putting forward business cases to make the projects economic to the extent feasible.

In late 2016, CMI was among 13 universities and other organizations selected to receive more than \$44 million for cost-shared CCUS research and development. CMI's two CarbonSAFE sites are in Phase I, or prefeasibility. The first site is at the Rock Springs Uplift in southwest Wyoming, and the second site is in Gillette. Each funded at a level of approximately \$1.2 million, both Phase I grants



run through the summer of 2018. During Phase I, CMI researchers and partners are: (1) conducting additional desktop geologic assessments; (2) building economic models; and (3) preparing a variety of legal and policy assessments. We are confident that both sites are competitive for a variety of reasons, including Wyoming's geology, Wyoming's existing CO₂-enhanced oil recovery (EOR) infrastructure, and Wyoming's favorable CCUS policy environment.

CMI also remains active in China under the DOE-funded U.S.-China Clean Energy Research Center, or CERC. Under the CERC initiative, CMI researchers are working on a CO₂-EOR storage project in the Ordos Basin, China. Over the years Wyoming and Chinese policymakers have built many bridges regarding CCUS policy and projects because of the two jurisdictions' shared interest in advancing coal usage and coal markets. CMI is at the leading edge of these ongoing bilateral efforts.

CMI is continuing its DOE-funded work related to REE in produced and geothermal waters. The funding is approximately \$1million over a two-year period. The research is a collaboration with Idaho National Laboratory and the Center for Advanced Energy Studies in Idaho Falls, ID.

Center for Air Quality - Shane Murphy, Director

The aim of the Center for Air Quality (CAQ) is to better understand and mitigate air quality issues related to energy production. This allows for continued energy production while minimizing air quality impacts. The CAQ recently completed participation in a project sponsored by the Research Partnership to Secure Energy for America (RPSEA) with additional sponsorship support from the Clean Air Task Force to assess variations in methane emission rates from four oil and gas producing basins in the West. Data from this project were combined into a paper just published in *Environmental Science and Technology* comparing methane emissions from oil and gas production facilities with varying compositions and production volumes in the Upper Green River Basin (UGRB) of Wyoming, the Denver-Julesburg (DJ) Basin in Colorado, the Uintah Basin in Utah and the Fayetteville (FV) Basin in Arkansas (<http://pubs.acs.org/doi/abs/10.1021/acs.est.7b00571>). The results showed that basins that produce wet gas (UGRB, DJ, Uintah) had higher methane emissions than fields with dry gas (FV) and wet gas fields that consolidated more wells per pad (UGRB) also had lower methane emissions. Members of the CAQ are completing additional papers summarizing volatile organic compound (VOC) emissions in Western basins. In May 2017, Dr. Shane Murphy was invited by the Advanced Research Projects Agency-Energy (ARPA-E) to the annual MONITOR



meeting to discuss CAQ's research findings on VOC emissions. In June 2017, Dr. Robert Field presented a joint seminar exploring recent advances in understanding oil and gas emissions at the Joint Research Center of the European Commission in Italy.

In January of this year, the CAQ received a generous \$100,000 gift from Jonah Energy, LLC. This gift is being used to support our work on understanding VOC and methane emission sources in Western basins. CAQ is currently carrying out field deployments and analysis with this gift.

This year, we performed a major renovation and upgrade of the Wyoming Air Quality Assessment Monitoring Laboratory (WAQAML). The improvements included a new (state of the art) instrument for measuring particulate matter, an updated data telemetry system, and an improved zero air delivery system for calibration. This renovation was performed to support the deployment of the WAQAML to a new baseline monitoring site in Carbon County, Wyoming. The data generated from this facility supports a cooperative agreement with the Wyoming Bureau of Land Management (BLM). Our current baseline monitoring is required for modeling efforts related to the Record of Decision for the Continental Divide-Creston Natural Gas Development Project, published in September 2016.

We plan to continue monitoring at the Carbon County site in the coming year, along with additional engagement and educational support activities. We are starting a program of undergraduate research assistantships. This endeavor aims to provide valuable experience for students, while supporting core CAQ program goals including data management, air quality monitoring, and engagement events with the general public in Carbon County and at high schools in Wyoming. The CAQ conducted our second annual engagement day at Laramie High School where students were able to see our mobile laboratory in action and be hands-on with some of our advanced air quality instrumentation. We plan to continue this event and expand our engagement activities, in the coming year.

Center for Biogenic Natural Gas Research - Michael Urynowicz, Director

Note: This center has achieved financial self-sufficiency and no longer receives funding from SER. The Center for Biogenic Natural Gas Research (CBNG) develops novel technologies that add value to Wyoming's natural resources by bridging the gap between renewable energy and fossil fuels. CBNG has been working closely with regulators and industry sponsors to produce low carbon



renewable natural gas from depleted coal seams in the Powder River Basin using existing coalbed methane (CBM) infrastructure. A field demonstration is currently being planned by EnWyo, a University of Wyoming technology start-up company with an exclusive license to commercialize technologies developed and patented by the CBNG.

Last summer a memorandum of understanding was signed between UW and the General Department of Geology and Minerals of Vietnam (GDGMV) and Hanoi University of Science and Technology to facilitate the advancement of CBM and coal biogasification research. The GDGMV has recently approved funding to support a field demonstration of CBNG technology in Vietnam's Red River Delta.

Center for Energy Economics and Public Policy – Robert Godby, Director

The Center for Energy Economics and Public Policy (CEEPP) provides objective information and analysis for energy policies at the local, state, national, and international levels. The goals of CEEPP are to evaluate the economic costs and benefits of developing state, regional and national energy resources and integrate them into society and build a research infrastructure to solve the economic challenges of energy development and policy-making in the state, region, and nation.

CEEPP has been involved in several projects of importance to Wyoming energy and economic development policy in the past year. These included the Wyoming Wind Development Report – estimating the tax and employment benefits of five potential wind developments in the state. The report analyzed the economic impact of an increase in the existing wind tax to account for revenue losses if any of the proposed projects ultimately were never developed. The report also identified comparative taxation policies in other states that Wyoming competes with for wind development. The study was funded by the Wyoming Business Council and Carbon County Economic Development Corporation and results were released in September 2016 (see http://www.uwyo.edu/cee/_files/docs/201609_wyoming-wind-competitiveness.pdf). An update to this report is being completed in summer 2017. CEEPP also completed a survey for Wyoming's Department of Workforce Services, developing a set of estimates of prevailing wages in the construction and energy industries to be used in the state's prevailing wage determination.

CEEPP also remained engaged in several externally funded research projects including a grant from US Department of Energy (DOE) for \$5.2 million over 3 years. This grant was awarded to CEEPP



Director Robert Godby, Dr. Roger Coupal, Professor of Agricultural and Applied Economics, and to affiliated researchers in the UW College of Engineering, and the UW Wind Energy Research Center, in collaboration with researchers at Montana Tech. The project considers: (1) wind energy generation improvements; (2) grid and transmission development; and (3) an evaluation of both types of development (generation and transmission to grid) on the overall social value of such activity. Expertise for the energy economics portion of the grant was made possible by past seed-funding from SER that allowed the development of an operating economic dispatch model and the development of computable energy economic and land use models to evaluate the relative social benefits of various types of energy system improvements. Previous SER seed-funding also allowed CEEPP personnel to participate in securing a new federal grant from the US National Science Foundation (NSF). This is a multi-institution award with UW's share being \$1.86 million over 4 years. The goal of the project is to develop climate change impact projections on a regional scale in the Upper Missouri Basin consistent with several global climate scenarios. CEEPP involvement includes economic modeling of how global climate change scenarios would impact the economy and production of the study area.

Center of Excellence for Produced Water Management - Jonathon Brant,
Director

The Center of Excellence in Produced Water Management (CEPWM) was established in the College of Engineering and School of Energy Resources as part of the Tier I Engineering Initiative in 2015. CEPWM's vision is structured around the management of produced waters with the end-goal being to maximize resource recovery and utilization. CEPWM focuses on reducing costs and waste disposal volumes during resource extraction and utilization and developing knowledge and technologies for recovering resources of value leading to sustainable management strategies for produced waters. CEPWM promotes collaboration among petroleum, chemical, civil, economic, and environmental engineers, as well as other disciplines having a stake in produced water management. Of particular interest is increasing revenue generation - adding new income streams or enhancing existing ones - from byproducts of oil/gas extraction, such as produced waters. Our efforts focus on designing management strategies around the concept of adding value to the industry, rather than purely reducing the unit cost of water management.

During the past fiscal year CEPWM leveraged funds provided by SER to advance two research thrusts. The first is a partnership with a pump manufacturer who is developing a new type of pump



aimed at reducing oil shearing during extraction. Using results from CEPWM, these new pumps will improve oil recovery from produced waters, while also reducing oil fouling in downstream treatment processes. The second area involves the development of novel nanocomposite membranes that will be used in non-pressure driven desalination processes like forward osmosis and membrane distillation. Once developed these membranes will lead to reduced energy consumption during the desalination of produced waters and other brines.

SER funds were also used to support three undergraduate researchers working on a variety of projects in Dr. Brant's lab. These projects include developing nanofiltration processes for recovering rare earth elements (REE) from brines and evaluating ceramic microfiltration processes for solids and oil separation from produced waters.

CEPWM was recently awarded a \$1.7 million dollar grant from Strategic Environmental Solution (Pensacola, FL) to develop and evaluate a new produced water treatment system. This novel system uses aligned magnetic fields and silver nanoparticles to disinfect produced waters prior to reinjection. This technology avoids the need for biocides, which are being linked with a variety of negative outcomes, such as the development of biocide resistant microbes in the subsurface. CEPWM has partnered with Rapid Services (Pinedale, WY) to evaluate electrocoagulation processes for removing suspended solids and dissolved metals from pit water. CEPWM teamed with the Carbon Management Institute and Idaho National Laboratory on a DOE project that was awarded this past year. In this project faculty and students from the CEPWM will study the recovery of REE from thermal brines.

Center for Photoconversion and Catalysis – Bruce Parkinson, Director and Carrick Eggleston, Associate Director

The Center for Photoconversion and Catalysis (CPAC) Promotes collaboration and experimentation in the fields of solar energy conversion, energy storage, and catalyst optimization – all with the aim of helping Wyoming and the world develop a more sustainable and efficient portfolio of both renewable and conventional energy resources. CPAC faculty and students work together to find new ways of generating and using energy, emphasizing conversion of light into both electrical and chemical energy as well as the closely related catalytic chemistry needed to use new and conventional energy forms more cleanly and efficiently.



The roof-top photovoltaics (PV) on the Energy Innovation Center (EIC), the installation of which was directed by CPAC, have been in full operation for just under two years, and have closely monitored its performance. In the first year of operation, the system ran at a capacity factor of 22% and was often producing above its peak rating. The system produces twice as much energy per year as an average system in Germany, where there is a large solar industry and installed PV base. The system output varied relatively little between winter and summer as well – speaking to the trade-off between longer days in summer but lower winter temperatures that enhance the energy output of the silicon photovoltaics.

The project to use solar-derived hydrogen from water to produce a liquid fuel (methanol) using synthesis gas derived from coal has been designed and the components have been obtained, but now await assembly and testing by a new group of engineering students in the fall.

We have also been working on an economic analysis of the impact of utility-scale solar installations in the state of Wyoming with colleagues from the College of Business including SER Dr. Tim Considine and graduate student Paul Bonifas. Graduating senior and Energy Resource Management and Development major Margaret van Amburg was also involved in this project. While this is still underway, it is likely that solar photovoltaics, like wind power, if installed at the utility scale, could benefit the state with both initial sales and later property tax revenues. Depending on the size of a project, revenues could be several hundred million dollars. Obstacles to solar, as with wind, include the capacity of available power transmission to target markets. Therefore, promising solar energy installation sites will be identified that have access to the electrical grid including the concept of co-location of solar arrays with wind farms.

Shell 3D Visualization Laboratory

The Shell 3D Viz Center (Viz Center) has continued to build upon previous years of success and has expanded its teaching and research use across UW. In addition, the Viz Center has developed a fee model and now has services listed in the UW fee book, which is the first step in being able to charge for the facility usage. Some aspects of the fee model are still in development and being reviewed by various UW administrators but should be resolved in the coming year. Once the fee model is complete, the Viz Center will offer professional short courses for the private sector.



The Viz Center continues to provide various opportunities for students and this summer has two paid interns who are working on creating a portfolio of virtual reality creative pieces and supporting the development of scientific simulations for research use. The Viz Center also has an intern earning college credit working on a 3D modeling project and a volunteer intern developing coding skills. Interns will be leading workshops in VR sculpting available for UW staff and students this summer. The Viz Center continues to support UW, K-12, and community college usage of our technologies. This includes supporting the high school summer engineering institute and the GearUp program that helps prepare high school students for college.

The Viz Center has been used for teaching by the following UW departments:

- Department of Zoology, 'Surfing the Green Wave' mule deer migration project supporting teaching and research.
- Department of Geography, 'Vortex Simulator' interactive virtual teaching tool combining a 2D map with 3D shapes of the atmosphere, to teach users about rising motions associated with clear skies, clouds, and precipitation.
- Carbon Management Institute, 'Greenhouse Effect' interactive simulation tool to support teaching.
- Department of Mechanical Engineering, 'Turbine simulation,' interactive real-time visualization of wind turbine data.

In the area of research, the Viz Center is collaborating with the Department of Computer Science, the College of Education, and the Department of Molecular Biology to submit a \$500,000 NSF proposal on cyberlearning. Notification of awards for this grant are expected in August 2017. The project aims to call on the expertise in the Viz Center and use the augmented reality technology called Hololens in new teaching methodologies.

The Viz Center is also a co-investigator on two research projects with other UW faculty. The first project is supporting data processing and visualization for anthropological research. The second is supporting the game logic development for molecular structures. In preparation for this activity, the Viz Center worked with the UW Digital Libraries and now has a digital object identifier which faculty can use to officially cite usage of the Viz Center in their work.



The Virtual Healthy Me (provisionally patented) project, which aims to be a commercial therapeutic treatment for obesity has progressed to the finals of the Wyoming Technology Business Center's (WTBC) Fischer Innovation Challenge. Ms. Alexander is working with two UW students who are entrepreneurial, business, and healthcare minded, and the WTBC is providing guidance to set up the business and seek financial support. If the current rate of progress continues, the project expects to be one of the recipients of the cash prize made available to finalists in January 2018.

Kyle Summerfield, Visualization and Virtual Reality Developer for the Viz Center, presented his work on point-cloud data at the SuperComputing international conference in November 2016. Ms. Alexander was invited to participate in the Wyoming Governor's Broadband Summit on a panel entitled, "The Relentless Change of Pace in Technology in IT." She was also invited to present at the Rocky Mountain Celebration of Women in Computing conference and was accepted to present her work on obesity to the Real Women, Real Bodies conference. The Viz Center was also delighted to have a presence at the UW Arts and Science Symposium where a new relationships with UW faculty were developed. Upon invitation, Ms. Alexander presented a TEDx talk in Gillette, WY in August 2016, which is a locally organized TED event. She presented a session entitled, "So you think VR is just for gaming?" The 15-minute session featured a discussion on research use of VR, empathy and VR, and the importance of getting kids into coding.

Ms. Alexander is the current president and founding member of The Higher Education Campus Alliance for Advanced Visualization (THE CAAV), which is the international group focused on developing good practice. THE CAAV has 133 members worldwide and is now in the final stages of incorporation to non-profit status and is hosting its second annual conference here at UW later this year.

Wyoming Restoration and Reclamation Center - Pete Stahl, Director

Note: This center has achieved financial self-sufficiency and no longer receives funding from SER. The Wyoming Reclamation and Restoration Center (WRRC) organized and participated in a number of engagement events this past year. The third Wyoming Wildlife Habitat Restoration Symposium was held at the Casper Events Center September 8-9 and featured speakers from across Wyoming and several other states talking about sage grouse habitat restoration. A workshop on the latest methods for rangeland vegetation analysis and reclamation was presented in Buffalo, WY in May. WRRC also



participated in the Rangeland Soil Health Workshop/ Tour in the Buffalo, WY area in early June. All workshops were well attended. WRRC is currently trying to plan an Ecosystem Restoration Pub Talk in Jackson for late summer or early fall with the Central Rockies Chapter of the Society for Ecological Restoration. WRRC has also been involved in engagement involving a number of state and federal agencies, including the WY Game and Fish Department, BLM, and US Geologic Survey to promote the use of online disturbance and reclamation tracking tools developed by the Wyoming Geographical Information Science Center (WYGISC) and WRRC.

Research being conducted by WRRC continues to focus on sage grouse habitat restoration, development of digital disturbance and reclamation mapping tools, and best management practices in reclamation. Two new projects involving carbon management and engineering, one of which is funded by the School of Energy Resources, have been initiated. The SER funded project is investigating uses of coal and coal residues as soil amendments and the other is examining impacts of ecosystem disturbance and reclamation associated with natural gas extraction on ecosystem carbon dynamics (additional funding is still being sought for this work). WRRC continues to be heavily involved in research conducted in association with the Douglas, WY Core Area Restoration Team. This work includes planting sagebrush and collecting data on best management practices for reestablishment of sagebrush. WRRC was recently funded by Jonah Energy (\$35,000) to conduct a study on recovery of ecosystem services on reclaimed natural gas well pads.

Amy Jacobs is in the process of writing her Master of Science thesis on best management practices for reestablishment of sagebrush in burned areas and is scheduled to complete it this fall. There are currently four PhD students in the Department of Ecosystem Science and Management working on Reclamation/Restoration related projects. The student Restoration Club, ROaR (Restoration Outreach and Research), still has about ten members and is involved in a number of community projects.

Enhanced Oil Recovery Institute – Steve Carpenter, Director

The report for the Enhanced Oil Recovery Institute will be submitted under separate cover.



US China Clean Energy Research Consortium – Advanced Conversion Technology Center (CERC-ACTC)

The School of Energy Resources continues its work with the US-China Clean Energy Research Center – Advanced Conversion Technology Center (CERC-ACTC), a joint research effort between the United States and China. The US membership consists of federal, private, and public sectors and is managed for the DOE by West Virginia University. The first 5-year phase of the CERC-ACTC was completed in December 2015. A second 5-year, \$5.5 million contract to UW for two CERC Phase II projects has just completed its first year. The Phase II projects include a carbon capture, utilization and storage (CCUS) demonstration project in the Ordos Basin of China, conducted by the Carbon Management Institute, and a project on a novel carbon capture technology led by a professor in the Department of Chemical Engineering. In the first year of work, researchers on the CCUS project evaluated existing technical and preliminary economic data for storage of carbon dioxide (CO₂) in the Ordos Basin. The first year of work on the CO₂ capture project has consisted of bench-scale testing of a novel catalyst to improve the absorption/desorption efficiency of CO₂ in an amine system using simulated coal combustion flue gas.

Integrated Test Center (ITC)

Details on this program are covered in the 2016 Advanced Conversion Technology Task Force Annual Report.



SER's academic mission is to develop innovative academic programs to meet the demands of the energy workforce and enhance societal literacy related to complex energy issues. Competitive success in the 21st-century energy sector requires deep foundational knowledge and enabling skills to adapt to rapidly changing technologies and an escalating knowledge base. Competency-based learning that integrates problem solving, critical analysis of uncertain and complex issues, and constant improvement in performance are overarching components of SER's academic programs.

Energy Resource Management and Development Bachelor of Science

The Energy Resource Management and Development program (ERM&D) is an interdisciplinary Bachelor of Science (BS) degree program that integrates training in engineering, geology, policy, economics, business, law, and natural resources. This degree connects energy sector problem-solving experiences with classroom learning to prepare students for the workforce needs of the energy sector.

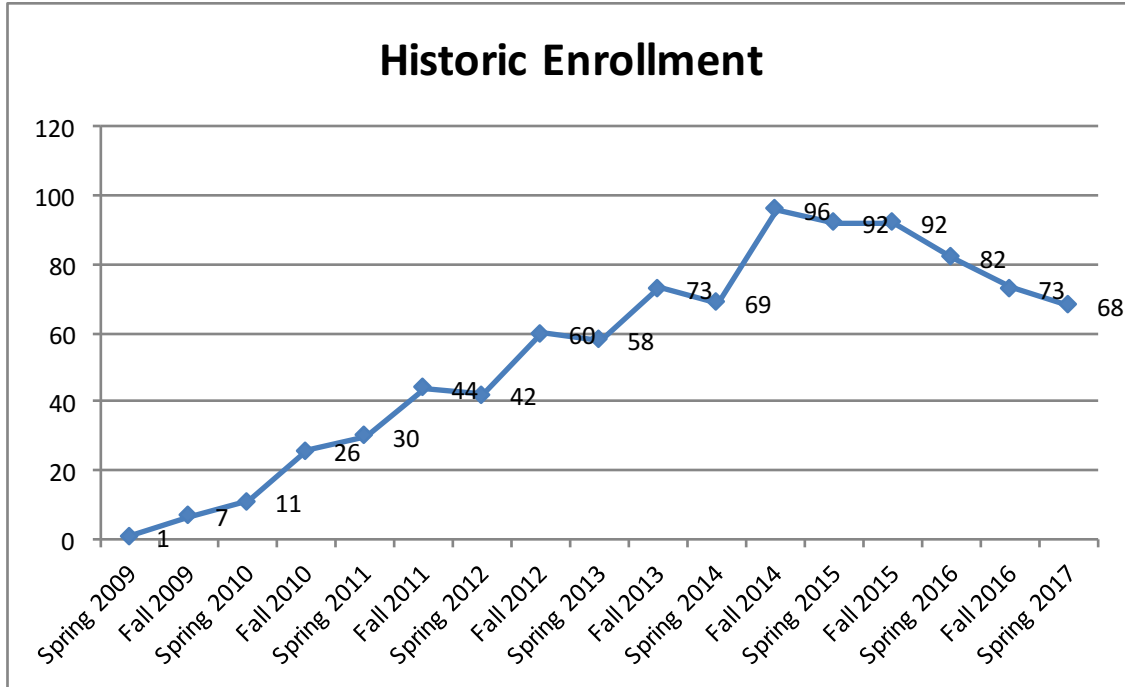
The program has four concentrations:

- Energy Air, Land and Water Management
- Professional Land Management (Landman)
- Fossil Fuels
- Renewable Energy

The Professional Land Management concentration is accredited by the American Association of Professional Landmen.

Enrollment

The ERM&D program began the fall 2016 semester with 73 enrolled students including 12 freshmen, 15 sophomores, 15 juniors, 29 seniors, and 2 second bachelor's candidates. Detailed information on student enrollment data and demographics for the 2016-2017 academic year is provided on page 16.



Class Standing						
Semester	Freshmen	Sophomores	Juniors	Seniors	2nd Bachelors	Total
Spring 2017	7	16	9	34	2	68
Fall 2016	12	15	15	29	2	73
Spring 2016	16	15	17	32	2	82
Fall 2015	22	22	15	30	3	92
Spring 2015	19	25	14	31	3	92
Fall 2014	36	14	18	25	3	96
Spring 2014	17	12	16	23	1	69
Fall 2013	26	15	11	20	1	73
Spring 2013	13	12	9	23	1	58
Fall 2012	16	10	17	17		60
Spring 2012	8	6	14	14		42
Fall 2011	11	10	9	13	1	44
Spring 2011	4	8	11	6	1	30
Fall 2010	7	9	6	4		26
Spring 2010	2	6	0	3		11
Fall 2009	1	4	2	0		7
Spring 2009			1			1

Gender			
Semester	Female	Male	Total
Spring 2017	16	52	68
Fall 2016	18	55	73
Spring 2016	16	66	82
Fall 2015	18	74	92
Spring 2015	16	76	92
Fall 2014	19	77	96
Spring 2014	9	60	69
Fall 2013	10	63	73
Spring 2013	10	48	58
Fall 2012	9	51	60
Spring 2012	7	35	42
Fall 2011	9	35	44
Spring 2011	9	21	30
Fall 2010	9	17	26
Spring 2010	4	7	11
Fall 2009	3	4	7
Spring 2009	1		1



Concentrations (Added Spring 2012)							
Semester	Energy Air/Land/Water	Professional			Undecided	Original Program	Total
		Fossil Fuels	Land Management	Renewable Energy			
Spring 2017	21	3	28	11	5	68	
Fall 2016	25	3	25	10	10	73	
Spring 2016	25	8	34	10	3	80	
Fall 2015	23	10	34	12	8	87	
Spring 2015	22	15	35	10	7	2	91
Fall 2014	20	15	35	11	8	3	92
Spring 2014	9	13	22	8	9	6	67
Fall 2013	8	13	19	6	17	9	72
Spring 2013	1	12	11	3	7	25	59
Fall 2012	1	8	6	2		37	54
Spring 2012	2	4		1		36	43

Scholarships

Students received \$568,338 in scholarships, grants, and federal loans.

Awarded Scholarships - AY 2017	Total Amount
Nielson Scholarships	\$122,524
Hathaway Scholarships	\$70,939
Rocky Mountain Scholars	\$61,950
Trustees Scholars Award	\$23,806
Wyoming Association of Professional Landmen	\$12,500
American Association of Professional Landmen	\$7,500
York Future of Energy	\$10,000
Other Scholarships, Grants and Loans	\$259,119



Honor Rolls

Undergraduate students who achieve high scholastic grades are honored by being placed on one of the following honor rolls. During the Spring 2017 semester, 50% of our students were named to an honor roll, establishing the highest percentage since the program began in 2009.

- ✓ **President's** - 4.0 GPA and complete a minimum of 12 credit hours
- ✓ **Dean's** - 3.4 or better GPA, above freshman standing and complete a minimum of 12 credit hours
- ✓ **Dean's Freshman** - 3.25 or better GPA and complete a minimum of 12 credit hours
- ✓ **Provost's** - 3.5 or better GPA and complete 6 to 11 credit hours

Honor Rolls						
Semester	President	Dean	Freshman	Provost	Total	% Students
Spring 2017	5	17	4	8	34	50.0%
Fall 2016	4	14	5	7	30	41.1%
Spring 2016	5	17	5	1	28	34.1%
Fall 2015	4	15	4	1	24	26.1%
Spring 2015	5	14	4	4	27	29.3%
Fall 2014	3	6	6		15	15.6%
Spring 2014		15	3	1	19	27.5%
Fall 2013	3	8	4		15	20.5%
Spring 2013	2	8	1	1	12	20.7%
Fall 2012		13	3		16	26.7%
Spring 2012	3	4	2		9	21.4%
Fall 2011		9	1	2	12	27.3%
Spring 2011		2			2	6.7%
Fall 2010		2			2	7.7%
Spring 2010	1	2	1		4	36.4%
Fall 2009	1	1	1		3	42.9%

Graduation Statistics

Our largest graduating class of eighteen students graduated from the ERM&D program during the 2016-2017 academic year.

Graduates - First Destination					
Semester	Employed FT	Continue Education	Continue Job Search	Unemployed by Choice	Total
Spring 2017	13		4		17
Fall 2016			1		1
Summer 2016	1				1
Spring 2016	6		4		10
Fall 2015	1			1	2
Spring 2015	7	2			9
Fall 2014	1				1
Spring 2014	3				3
Fall 2013	3				3
Summer 2013	1				1
Spring 2013	8	1		1	10
Summer 2012	1				1
Fall 2011	0	2			2
Total	45	5	9	2	61
%	73.8%	8.2%	14.8%	3.3%	



AY 2017 First Destination Job Titles and Employers

- ✓ Campus Coordinator – The Post-Landfill Action Network, New Hampshire
- ✓ Contract Landman – LoneTree Energy and Associates, Colorado
- ✓ Foreman – Western States Reclamation Inc., Wyoming
- ✓ Independent Landman – Hoover and Stacy, Wyoming
- ✓ Lease Buyer – McDonald Land Services, Colorado
- ✓ New Business Development – D&D Oilfield Service, Wyoming
- ✓ Owner – Off the Hook Fish and Chips, Wyoming
- ✓ Procurement Specialist – Bright Agrotech Inc., Wyoming
- ✓ Project Management – ISEC, Colorado
- ✓ Supply Chain – Basin Oil and Gas, Texas
- ✓ Surface Land Negotiator – BP Lower 48, Texas
- ✓ Surface Landman – Anadarko Petroleum, Colorado
- ✓ Lands Restoration Technician – Great Basin Institute, Wyoming

Student Accomplishments

- ✓ Meghann Cranford was a finalist for the Rosemarie Martha Spitaleri Award for Outstanding Female Graduate. She also graduated Cum Laude with honors.
- ✓ Alexander Fullerton was named to the Steering Committee to develop consensus about a plan for transitioning the Honors Program to an Honors College.
- ✓ Cameron Sloan was highlighted in the April 2017 UWYO magazine.
- ✓ Schuyler Hamilton received the Rocky Mountain Coal Mining Institute scholarship

Faculty Accomplishments

- ✓ Tara Righetti, SER Assistant Professor in the College of Law, was honored by the University of Wyoming Cap and Gown Chapter of Mortar Board as a “Top Prof.”
- ✓ Dario Grana, SER Assistant Professor in the Department of Geology and Geophysics, is a 2017 recipient of the European Association of Geoscientists and Engineers (EAGE) Arie van Weelden Award. It is presented to an EAGE member “who has made a highly significant contribution to one or more of the disciplines in the association.”



SER seeks to engage broadly with experts in all sectors to disseminate knowledge that improves understanding and decision-making about issues currently facing Wyoming's and the nation's energy activities. Collaboration with UW colleges and local, national, and international industry and government leaders results in the convening of a dynamic selection of symposia, conferences, workshops and speakers.

Speakers

During FY 2017, SER hosted five professional speakers, bringing together students, faculty, researchers and the public to learn about a wide range of advanced energy technologies and industry trends.

Events

In FY 2017 SER hosted and sponsored 19 events held at UW, various locations around Wyoming and internationally. A few of the key events are listed below:

- *Stroock Sovereign Wealth Forum*, August 23-24, 2016, Spring Creek Ranch & Jackson Hole Center for the Arts, Jackson, WY. SER co-hosted this event with the Wyoming Treasurer's Office and the UW Stroock Forum. The event consisted of two days of private meetings at the Spring Creek Ranch and featured international experts and sovereign wealth fund managers from around the globe. The two days culminated in a public forum held the evening of August 24 featuring a panel of experts moderated by Kathleen Hays of Bloomberg Television and Anne MacKinnon, Adjunct Professor with the Haub School of Environment and Natural Resources. The public forum was free and open to the public, saw great attendance, and was broadcast on Wyoming Public Television.



- *SER Centers of Excellence Open House*, October 11, 2016, Encana Auditorium, Energy Innovation Center (EIC), Laramie, WY. The Open House was part of the Earth, Wind and Water: Energy Transitions Series co-hosted with the UW Center for Global Studies. The event highlighted the SER Centers of Excellence in a plenary session where each center director gave a brief overview of their center followed by an open house exhibition of demonstrations and interactive displays throughout the second floor lobby of the EIC. The event was free and open to the public.
- *6th International Advanced Energy Technology Conference*, June 4-6, 2017, Xi'an, Shaanxi, China. SER co-hosted this international conference with the Shaanxi Provincial Government. The focus of the conference was knowledge sharing in the areas of new technologies and uses for fossil fuels with capture, use and storage of carbon dioxide. Attendees of note from the US included Wyoming Governor Matt Mead; Andrew Minchener, General Manager of the IEA – Clean Coal Centre; and Jim Wood, Director of the US-China Clean Energy Research Center.



The Carbon Engineering Initiative focuses on transforming Wyoming coal into marketable non-combustible carbon-based products.

FY 2016-17 Achievements and Progress

In the 2016 budget session, the Wyoming State Legislature provided a special \$2 million appropriation to fund research and technology development focusing upon creating new markets for coal. During the first year of the biennium, starting July 2016, \$1.5 million of this Special Appropriation was expended on 15 carbon engineering projects led by faculty located in the Colleges of Engineering and Applied Sciences (CEAS) and The College of Arts and Sciences. An additional \$1.1 million from the School of Energy Resources (SER), and other available funds were expended on these same projects, making in total the sum of \$2.6 million for the 1st year of the carbon engineering initiative. Of the \$2.6million, nearly 25% was expended on capital equipment and fixed assets required to establish platforms for conducting research and developing technology.

In year one, the two main thrusts of the carbon engineering program were to characterize the properties of Wyoming Powder River Basin (PRB) coal and devise projects that:

- a) had potential to validate conversion into desirable products, that yield a greater worth than its Btu and fuel value; and
- b) beneficiate the natural decomposition characteristics to make useable intermediate products and/or saleable derivative products.

In addition, market and process modeling studies were performed to understand manufacturing configurations and the portfolio of coal derived products that make techno-economic sense; taking advantage of the characteristics and behavior of Wyoming PRB coal. Three compelling propositions have been framed, namely the use of Wyoming PRB coal to produce: 1) advanced composite materials and polymers, 2) construction and agricultural products; and 3) performance liquid chemicals. The processes being explored in those areas show the potential for hybridizing and mixing the production of non-energy and fuel products from Wyoming PRB coal such that every molecule of the feedstock is consumed optimally are being investigated.



In total, 15 faculty members are leading research and development projects, with another 7 providing valuable contributions. Seven post-docs are employed to work full-time on projects, together with support from 30 graduate and 20 undergraduate students.

In total, three provisional patents have been awarded to project members – two linked to making carbon fibers from coal and a further one associated with the manufacture of silicon carbide fibers. It is estimated that a further 12 inventions have been made in this first year with capacity for patent protection and are being processed. These include provisional patents for a dry reforming catalyst that converts CO_2 and methane (CH_4) into carbon monoxide (CO), an asphalt product for paving, and coal-based thermal insulation building and construction materials made from feedstocks of coal and trona. Other inventions being pursued at this time relate to conversion of biomass and coal to products using super critical CO_2 , a flash pyrolysis process for maximizing the yield of light aromatic hydrocarbons from coal, development of a 3D printing approach to make high temperature complex temperature resistant composite materials, the development of an icephobic coating from coal, and a Wyoming-bred algae and bioreactor system for converting low-value processed coal residuals into valuable products.

Approximately 11 non-disclosure agreements have been put in place to identify scope for working with technology companies and industry along with 3 memoranda of understanding (MOU's) which have been signed to evaluate existing proprietary technologies on Wyoming PRB coal. Three funding awards have been prepared and are currently in progress with federal agencies which are seeking funds of some \$2.5 million that leverage the state investment in carbon engineering. One successful federal award for \$0.75 million was made to Dr. William Rice in the Department of Physics and Astronomy by the National Aeronautics & Space Administration (NASA) to support his work on understanding ice adhesion on aircraft surfaces and supporting his carbon engineering project on the development of high performance surface engineered products (in this case an ice-phobic coating) from coal.

After the first year project review, one project (nitrogen-containing graphitic materials) has been dropped from the carbon engineering program as the research no longer comprehensively addressed one of the two project needs identified above. A further two projects (direct recovery of rare earth elements from Wyoming coal and high surface area materials such as graphene from coal) were re-evaluated to take advantage of unexpected findings from year one, allowing synergistic integration with other ongoing projects and leveraging of findings which permits extension of the work scopes in new directions for both these projects.



FY 2017-18 Outlook

The remaining \$0.5 million of the special legislative appropriation for carbon engineering together with a nominal \$2.8 million of SER funding has been ear-marked for funding a second year of research and development projects and for building intellectual capital capacity. The SER funds are being split equally to continue funding research and technology product developments within the individual projects and to establish a dedicated carbon engineering research laboratory in the Energy Innovation Center. One of the objectives of the upcoming year is to increase collaboration between all the funded projects, ensuring researchers working on coal primary processing understand how they can contribute to those working on making intermediate and derivative products and visa-versa. It is expected that co-locating experimental work from all projects in the same (carbon engineering) space will facilitate these needed interactions to motivate collaboration.



The Wyoming State Legislature provided funding for SER over the 2017-18 biennium in the 2015 Legislative Budget Session in the amount of \$21,874,188. Of this, \$2,000,000 was a one-time appropriation for the Carbon Engineering Initiative. After adjustments for retirement, health insurance, EORI salary shifts, and mandated UW and state budget cuts, SER was left with \$20,231,560. In Fiscal Year 2017, \$9,076,711 was spent. The remaining \$11,154,849 is set to be utilized in Fiscal Year 2018.

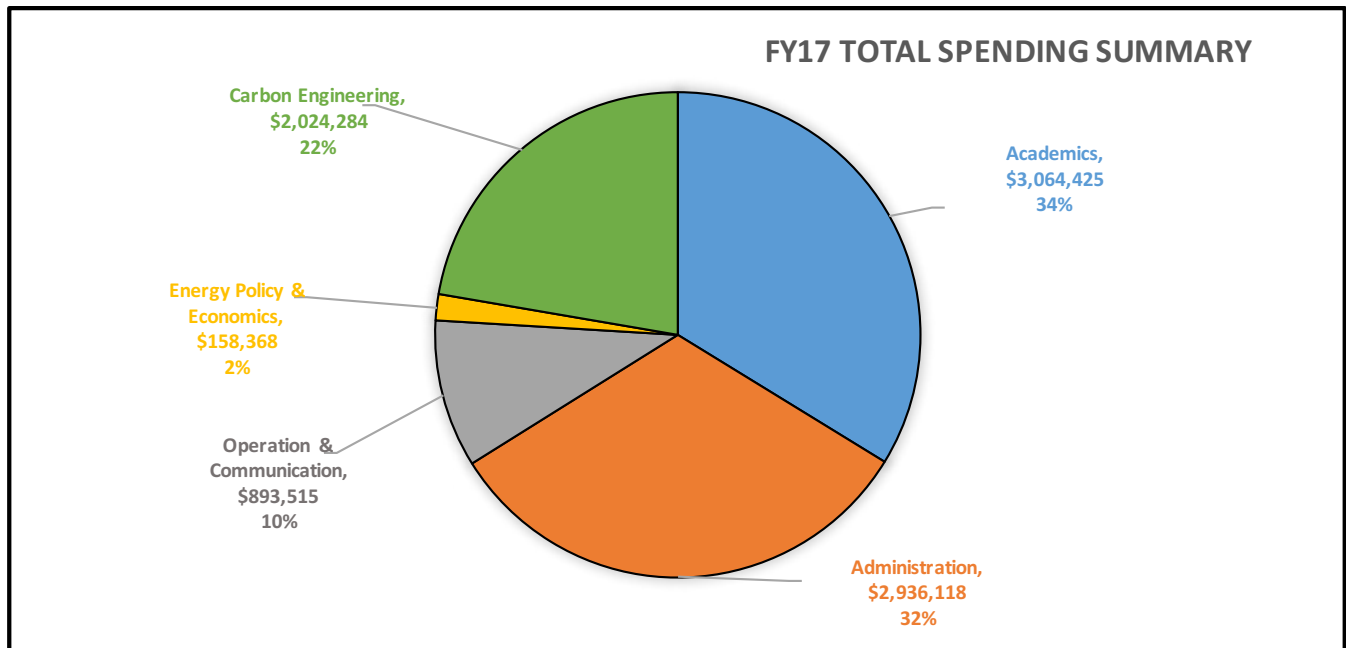
Expenditures for the 2017 Fiscal Year totaled \$9,076,711. Of that total SER disbursed:

- \$3,725,647 for salaries and benefits for SER staff and faculty
- \$570,390 for UW faculty start-up commitments
- \$410,158 to support research activities of the Centers of Excellence
- \$202,221 in cost share support for state and federal research grants
- \$217,576 for events and sponsorships
- \$2,024,284 to support carbon engineering research
- \$1,926,435 in remaining expenses that include graduate assistantships, recruiting, travel, publications, office support, etc.



FY17 Total Spending Summary

	Jul 16 - Jun 17	
Account		
Academics	\$	3,064,425
Administration	\$	2,936,118
Operation & Communication	\$	893,515
Energy Policy & Economics	\$	158,368
Carbon Engineering	\$	2,024,284
Total	\$	9,076,711





Fiscal Year 2017 was one of new successes for SER, even with the pressure of a reduced standard budget. With guidance from the Energy Resources Council (ERC), SER re-focused existing programs and added new ones meant to leverage Wyoming's natural resources to generate additional revenue opportunities for the state. Chief among our accomplishments this year are:

- Completion and occupancy of the High Bay Research Facility with a full slate of funded research programs underway targeting improved recovery of oil and gas.
- Implementation of a broad scope of Carbon Engineering research activities, with engagement of faculty, post-doctoral and graduate students. Significant outcomes include inventions and patents, non-disclosure agreements to evaluate partnerships with technology companies and industry, and memoranda of understanding to evaluate existing proprietary technologies on Wyoming coal.
- Addition of new grant dollars to continue investigating CCUS technologies suited to Wyoming's coal-fired energy generation facilities.
- Nine diverse Centers of Excellence are active. Some have achieved financial independence, and others are successfully competing for grants.
- Establishment of the 3D Visualization Center as a fee-for-service enterprise to generate revenue to support the Center's expenses.
- Graduation of 18 students for the Energy Resource Management and Development BS degree program, the largest class to date. Most of the graduates found jobs in a difficult job market, or chose to continue their education.
- A successful year of knowledge transfer and engagement through domestic and international events, and hosting of distinguished speakers.

Looking forward, we anticipate even greater outcomes in FY 2018. SER leadership and the ERC are putting the final touches on a five-year strategic plan that advances the mission of SER, aligns with that of UW, and focusses heavily on workforce and technology development that will aid Wyoming's efforts to diversify and stabilize its economy.