



Earth & Environmental Systems Institute Center Renewal Proposal

Name: Marcellus Center for Outreach and Research

Directors: Thomas B. Murphy, Co-Director, Andrew A. Nyblade, Co-Director (vitae attached)

Participants: David Yoxheimer, Extension Associate

Rationale: Natural gas is a critical resource in a changing global energy paradigm of a reduced carbon footprint and broader energy independence. Advances in horizontal drilling and gas shale stimulation techniques have increased access to North American and global shale gas reserves, but research is needed to develop more efficient and sustainable extraction methods that will reduce impacts on the natural environment. Research and public education also is critical to help communities minimize the potential problems and use the economic opportunities and wealth generated as the basis for transition to sustainable local economies, and lessen the risk of “boom and bust” commonly associated with extractive industries.

Penn State’s Marcellus Center for Outreach and Research (MCOR) is committed to expanding research capabilities on technical and socio-economic aspects of shale energy development, providing science-based outreach programming on the Marcellus and other unconventional gas shales, and protecting the Commonwealth’s water resources, forests and transportation infrastructure. Serving state agencies, elected officials, communities, landowners, industry and environmental groups, MCOR brings together much of the University’s extensive expertise in shale gas geology, water resources, environmental science, socioeconomic analysis, workforce development, market forces on development and exploration, educational programming, and natural gas development and utilization technology. MCOR aims to be the research, information and education leader for the Appalachian region, North America, and the world by fostering, supporting and advancing research and science-based outreach on shale energy development. Additionally, the Center promotes collaborations and cooperative initiatives among disciplines and stakeholders in order to address the opportunities and challenges in shale development.

Penn State has a significant and recognized global leadership role on issues related to Marcellus and other gas shale development. The University has leading scholars working on many of the most critical areas of research and on extending that information to stakeholder groups, federal and state legislators, the natural gas industry, and the public. However, much more research and education is needed to take advantage of the formation’s energy reserves and to address potential adverse environmental and social impacts. Areas that could benefit from additional research include advancing technical capabilities of natural gas production to improve efficiencies; developing new production practices to reduce impacts to Pennsylvania’s water and environmental resources; developing more environmentally friendly fracturing techniques; natural gas utilization technologies; and building international expertise in water resources and treatment. Assessing successful and evolving regulatory protocols and sharing that expertise with countries around the world with emerging interest in shale energy production is an equally important role being played by MCOR personnel.

MCOR seeks to coordinate on-campus research to address these issues through identifying relevant research RFPs, developing programs in conjunction with Penn State expertise at other University campuses, working collaboratively through state and national industry and NGO’s focused on shale, and in building collaborative partnerships with other institutions, as well as Federal government partners. Through MCOR

activities, Penn State is solidifying its reputation for innovative research and its role as a leader in outreach and educational programming associated with gas shale development in the Commonwealth and beyond. MCOR has had recent initiatives in over 50 countries related to shale energy and issues associated with its development and utilization.

The Marcellus Center's goals are four-fold:

- To coordinate University research and outreach on shale energy and its impacts, including environmental, economic, socio-economic, and workforce aspects.
- To spark additional cross-campus and international collaborations on shale energy.
- To address the issues related to the extraction and development of the Marcellus Shale in particular but of unconventional shale resources in general.
- To convey science-based educational outreach to a diverse and evolving stakeholder base globally.

By promoting collaborations and cooperative initiatives among disciplines and stakeholder groups, MCOR addresses the opportunities and challenges in shale energy development. MCOR is fulfilling this mission by coordinating and facilitating programs of outreach and research, holistically addressing issues generated by the exploration and development of the Marcellus and other unconventional formations. Major outreach, research and educational activities that the Center will focus on in the 2020-2023 time period are summarized below.

Outreach Activities

1) Translational Outreach for Pennsylvania Shale Energy Stakeholders

There is great demand from stakeholders in the state ranging from landowners to elected officials to understand the trends associated to shale energy development in PA and beyond, as they impact individuals and communities of people. Examples include construction of new pipeline infrastructure, understanding emerging research on health implications of shale energy production, revenue generation policy, new legal precedents impacting municipalities and/or landowners, water resource protections, fugitive methane emission reduction, regulatory education, and a host of other important issues. Additionally, there is an expanding interest by many stakeholders in understanding and adapting to the energy transitions underway in the Commonwealth and beyond, particularly at the convergence of natural gas and renewables. MCOR is a trusted entity for this education and provides the needed translational component as it has extensive experience with the topics and has earned credibility with a wide range of audiences. This will continue to be a priority program from MCOR.

2) Immersive Shale Experience

MCOR, in conjunction with the Penn State Extension Energy Team, has engaged over 1,500 participants in this educational outreach program, providing a rich opportunity to view shale energy exploration first-hand, see the impact of development in the community, and learn directly from key regional voices embedded in the shale dialogue. The experience is unique for each delegation, aligned and customized to address the priorities of the group. Conducted for international embassy staff, U.S. government agency personnel, elected officials, O&G industry partners, media representatives, and distant university collaborators, these programs will continue to be a focus for MCOR's outreach efforts. As a secondary benefit, these programs have generated immediate and longer term funding opportunities for Penn State shale energy initiatives.

3) International Initiatives –Shale Outreach Globally

As one of several global initiatives, MCOR has entered into a funded cooperative agreement with the U.S. Dept. of State to provide in-country and distant (digital) education to government officials in Argentina, related to the development of the Vaca Muerta shale resource in the western region of the country. This energy program, which is a priority of the U.S. and Argentine government's, also has a direct benefit to PA, as many companies from the Commonwealth are deploying technology, staff, and experience from the

Marcellus to the Vaca Muerta. This is generating a two way exchange of lessons learned in each respective location to benefit the other. Our multi-disciplinary Penn State team provides information about the creation of successful regulatory protocols, governance, attainment of social license, local workforce and business development, environmental/water risk mitigation, and legislative initiatives including revenue generation. More broadly, our experience and international networking has led to MCOR being recognized as one of the foremost entities in shale energy development issues, which reflects upon Penn State as a global leader in energy research, and is consistent with the Energy University concept. MCOR personnel have engaged with representatives from over 50 countries on 6 continents in order to exchange insights and research outcomes. Many of these efforts are in conjunction with PA's Department of Economic and Community Development. And we are often invited to speak on these themes worldwide.

4) Updated Maps and Graphics

MCOR has created multiple maps and graphics that appeal to the general public and a variety of stakeholders that depict number of wells drilled, well locations, natural gas production, among others things. We will continue to update them for use by researchers, industry, regulators, media, and other interested parties.

Research Activities

1) PASEIS – Seismic Network

The Pennsylvania State Seismic Network (PASEIS) is operated by Penn State for the Department of Conservation and Natural Resources (DCNR) Bureau of Geologic Survey (DCNR BGS) and the Department of Environmental Protection (DEP). The network consists of 30 broadband seismic stations spread across the Commonwealth recording data continuously. Data from the PASEIS stations are combined with data from 41 other seismic stations within and surrounding Pennsylvania to detect and locate seismic events in near-real time. Information about the network and seismic event locations can be found at paseis.geosc.psu.edu

2) PA Basement and Fault Mapping

The goal of this project is to improve the understanding of the depth to crystalline rocks (i.e. basement) underlying the sedimentary rocks of the Appalachian Basin in collaboration with the DCNR BGS. Existing maps of “depth to basement” for Pennsylvania are being improved by using seismic data and well log information to estimate the thickness of the sedimentary rocks in the basin. An improved understanding of the depth to basement is important for mitigating against seismicity induced by fluid injection into the subsurface at wastewater disposal wells and hydraulic fracturing wells. Coupled to the PA basement map project is a project to improve the database of faults within Pennsylvania, particularly within the Appalachian basin. The database of fault information is being assembled using existing open databases, published studies of faults, interpretations of regional seismic data, and well log information. An improved understanding of faults within the Appalachian Basin can be used to investigate natural gas emissions, groundwater systems, and induced seismicity.

3) Depth to Brine Mapping

The depth to the interface between fresh groundwater and brine is not well characterized in Pennsylvania. The importance of having a well-defined depth to brine involves proper well construction to minimize the potential for adverse water quality impacts. This project entails use of magnetotelluric geophysical surveying methods to define this interface and facilitate improved shale well drilling practices and is being conducted in collaboration with DEP's Bureau of Oil and Gas personnel.

4) Shale Depth and Thickness Mapping

MCOR initially created geologic maps showing depth and thickness for both the Marcellus and Utica/Point Pleasant shales that have been available to the general public via MCOR's website. These maps are being updated with additional geologic data from more recent well logs for use by researchers, industry, regulators and other stakeholders.

5) DEP Dataset Analysis

A common challenge to conducting environmental research on shale energy development is the lack of publically accessible datasets. Regulatory agencies routinely collect large volumes of environmental data but often do not have the resources to analyze the data in a manner that facilitates public use of the data. MCOR will continue to update government datasets such as well location mapping, oil and gas production data, and waste management data for public dissemination and education. Another example of dataset analysis is the Shale Network's on-going efforts to develop the pre-drilling water quality database in conjunction with PaDEP for research purposes.

Resident and On-line Instruction

MCOR personnel have guest lectured in a wide array of classes ranging from accounting, communications, agricultural economics, engineering, geosciences, and petroleum and natural gas engineering. From this experience it is apparent that there is a demand for students to have a breadth of background in unconventional energy development, which has led to developing and teaching a general education course (397 level). This course covers a broad array of shale energy-related topics including geology, resource assessment, drilling technology, hydraulic fracturing methods, environmental impacts, economics, workforce needs, infrastructure, utilization trends, regulation, energy policy, energy exports, international geopolitics, societal considerations, the future of unconventional energy and its relationship with other energy forms. We have designed the course to meet Gen Ed requirements for all students and has been offered as both a resident class and a hybrid on-line course. MCOR personnel have also developed and taught a World Campus course on shale energy which is part of the Earth Sustainability certificate program and allows a broader audience to be reached, including both students and professionals seeking continuing education credits. In addition, MCOR has been running a three-week field geology course during the summer semester to provide students the necessary field experience to work in the oil and gas industry.

Funding Opportunities: The Marcellus Center for Outreach and Research is currently supported internally, either directly or in-kind, by the Colleges of Agricultural Sciences, Earth and Mineral Sciences, Penn State Outreach and by the Penn State Institutes of Energy and the Environment (PSIEE). External funding has been pursued and is now a growing component of our funding stream and will continue to be so going forward. To date, we have used our MCOR efforts to leverage over \$14 million in funds for collaborative work at PSU and partner universities.

MCOR does not currently seek any operating funds from the Earth and Environmental Systems Institute. MCOR requests continued use of the second floor office suite (217F) and two adjacent offices in the EES Building. There is a recognition that the office footprint will change somewhat with the planned 2nd floor renovations planned in the near term. Minimal financial support is requested for processing budget entries and review. As part of this center renewal proposal, MCOR is requesting new funding at the \$10K level for a newly proposed immersive education, e-learning toolbox_(please see below titled "New MCOR Initiative"). This video series will highlight EESI's expertise by providing public education on the complex nature of the national energy choices, implications, and what energy paradigms may provide a more sustainable future.

Management Structure: MCOR Co-Directors are Andy Nyblade, professor of geosciences, and Thomas Murphy, extension program manager. This co-leadership reflects the Marcellus Center's equal commitment to both outreach and research responsibilities. Dave Yoxtheimer, P.G., EMS Extension Associate, is an outreach liaison between the University, natural gas industry, environmental organizations, local government and the public to advise stakeholders on key environmental issues.

MCOR utilizes an internal advisory committee that provides guidance to the Co-Directors and assists in evaluating the research and outreach missions of the Center. This committee offers input on Center activities from across the University and, by drawing on their external collaborations, from outside the University. It also functions to review and advise on the Center's strategic plan.

Advisory committee members are:

Brent Hales, Director, Penn State Cooperative Extension, College of Ag (committee co-chair)
John Hellmann, Associate Dean, College of Earth and Mineral Sciences (committee co-chair)
Lee Ahern, Associate Professor, College of Communications
Kathy Brasier, Associate Professor, Rural Sociology, College of Ag Sciences
Tom Richard, Director, Penn State Institutes of Energy and the Environment (PSIEE)
Ross Pifer, Professor, Center for Ag and Shale Law, Penn State Dickinson School of Law
Tracey Huston, Vice-President of Outreach
Stephen Tracey, Smeal College of Business
Sanjay Srinivasan, Department Head, Energy and Mineral Engineering

Prior expenditures and past work: Since MCOR's inception, our personnel have been involved with multiple shale energy funding opportunities that focused on public education and citizen science, including NSF-funded projects such as Marcellus Matters and The Shale Network. Other recent projects related to MCOR include evaluating produced fluids management trends (Sloan Foundation in collaboration with Univ. of Texas-Austin, \$10K) long-term watershed monitoring in Sullivan County, PA (Lake Mokoma Association, \$20K), orphan and abandoned well public education (SAFERPA, \$10K) and the Methane and Legacy Oil and Gas Infrastructure study (US EPA, \$91K). Additionally MCOR personnel have collaborated on several recently published studies that have focused on air emissions (Barkley et al., 2017), localized groundwater impacts (Woda et al., 2018) and national produced fluids management practices (Scanlon et al., 2019). MCOR's personnel currently serve advisory roles with the TOPCORP regulator training program, Pennsylvania Department of Environmental Protection Bureau of Oil and Gas Technical Advisory Board, the British Geological Survey EQUIPT4Risk project, and the U.S. Department of State and Department of Commerce for projects in Argentina and Colombia. Collectively these experiences reinforce the importance and need for public education and outreach tools on key energy topics. MCOR's proposal to develop a series of web-based e-learning tools will showcase EESI's expertise on energy choices and associated environmental implications, which parallels Penn State's Energy University initiative and associated Energy Extension work.

New MCOR Initiative and Funding Request

The United States' energy paradigm has experienced a rapid transition in the past decade as a result of unconventional energy development from shale formations coupled with increasing renewable energy capacity, primarily wind and solar. A balanced portfolio of energy sources is necessary to minimize environmental and climate impacts with sustained economic activity. The need for this balance has become clearly evident in light of the recent Covid-19 pandemic, where broad economic impacts have severely impacted the fossil fuel industry, which may broadly impact energy markets and create additional economic hardship.

This renewal proposal includes a funding request for the development of a series of e-learning tools designed for diverse audiences to understand the intricate complexities of our energy sources and the associated environmental and economic implications.

Elected officials, government agencies, industries, businesses, and individuals are not fully-equipped with the information to drive the policies and practices to develop the next generation energy portfolio. Penn State experts can play a significant role in providing education and outreach on energy solutions to key stakeholders to make changes that will “move the needle” on reducing society’s impact on the planet. MCOR, EESI and other Penn State faculty members have the collective expertise to provide a web-based educational series on our current and future energy paradigms. This proposal provides a conceptual framework to use existing as well as create new educational materials for this “e-immersion in energy education” initiative.

New technologies such as virtual reality, drones, and 360 degree camera views can be used to provide enhanced video footage of energy infrastructure that most people would not otherwise be able to access. MCOR personnel have been involved with initial efforts to capture footage of solar fields and shale gas drilling sites to pilot these technologies to create virtual reality videos for both class room and general public use. Survey results indicate that participants found these technologies to be very useful to better understand how energy development occurs in the field through the visual insights these technologies provide. This proposal will build on the identified strengths of these technologies to develop a comprehensive overview of the current energy scenario, pending energy transition option, and the associated long-term environmental and economic implications of those choices. This approach will involve using advanced video technologies to capture both aerial and ground-based footage of our primary energy sources including oil and gas sites, solar arrays, wind farms, pipelines, refineries, power plants, and other energy infrastructure to provide viewers a comprehensive look at where their energy comes from. Detailed narration will accompany this footage to provide an explanation on how these energy sources and technologies function and their significance in our energy picture. Additional footage will be captured that shows the footprint of energy, including land surface impacts, air emissions, and other environmental externalities. The footage and narration will be complemented with short interview-style discussions with key Penn State experts from a diverse array of backgrounds including energy, economics, environmental science, law, social science, and humanities to provide objective, state of the science information to the viewers. The overall intent will be to allow people to shape their energy opinions based on the best available information including the technology driving the process, the regulatory protocols monitoring them, and the long-term implications to society. This will be both an immersive educational opportunity for a broad audience that includes key stakeholders, while also showcasing Penn State’s and EESI’s research, capabilities, and dedication toward science and solutions toward an enduring future.

The ultimate outcome of the project is that participants will gain firsthand knowledge and a better factual understanding of how large amounts of energy are sourced and delivered to our communities and industries in PA and beyond. A more complete understanding of each energy source over its entire supply chain will allow participants the chance to compare and contrast different energy types and make sound decisions going forward based on objective information provided during these digital tours. The expected outcomes to viewers from the project include a better understanding of our energy choices, transitions and associated economic and environmental implications and impacts. This type of information can allow for a more informed public policy debate centered on energy and the risks and benefits derived from different sources. This “compare and contrast” option will offer stakeholders a foundational science-based resource vs. the many agenda-driven social media sources which often offer less than objective viewpoints. These materials will be widely available in web-based format for broad audiences such as a single at-home user, a town hall meeting, a government agency, or a classroom teacher seeking a more visual and immersive energy education experience.

Support letters: Since MCOR is an existing EESI center no support letters are provided.

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Education

Wittenberg University	Springfield, Ohio	Geology	B.A.	1982
Wittenberg University	Springfield, Ohio	Earth Science Education	B.A.	1982
University of Wyoming	Laramie, Wyoming	Geophysics	M.S.	1985
University of Michigan	Ann Arbor, Michigan	Geology	Ph.D.	1992

Appointments/Professional Experiences

2019-present	Head, Department of Geosciences, Pennsylvania State University
2007-present	Professor, Department of Geosciences, Pennsylvania State University
2004-present	Honorary Professor, University of the Witwatersrand, Johannesburg, South Africa
2002-2007	Associate Professor, Department of Geosciences, Pennsylvania State University
2003	Cox/Blaustein Visiting Professor, Department of Geophysics, Stanford University
2001-present	Faculty, Graduate Program in Acoustics, Pennsylvania State University
1997-2002	Assistant Professor (tenure-track), Department of Geosciences, Pennsylvania State University
1994-1997	Assistant Professor (fixed term), Department of Geosciences, Pennsylvania State University
1992-1993	National Science Foundation Postdoctoral Fellow, Department of Geosciences, Pennsylvania State University
1988-1991	Teaching and Research Assistant, Department of Geological Sciences, University of Michigan
1986-1988	Math and Physics Instructor, grades 9-12, International School Moshi, Tanzania
1985-1986	Exploration Geophysicist, Exxon Co. U.S.A., Denver, Colorado
1982-1985	Teaching and Research Assistant, Department of Geology and Geophysics, University of Wyoming

Publications

- West, N., E. Kirby, **A. Nyblade** and S. Brantley, Climate preconditions the Critical Zone: Elucidating the role of subsurface fractures in the evolution of asymmetric topography, *Earth and Planetary Science Letters*, doi: 10.1016/j.epsl.2019.01.039, 2019.
- Ortiz, K., **A. Nyblade**, M. van der Meijde, H. Paulssen, M. Kwadiba, O. Ntibinyane, R. Durrheim and I. Fadel, Upper mantle P- and S-wave velocity structure of the Kalahari Craton and surrounding Proterozoic terranes, southern Africa, *Geophys. Res. Lett.*, doi: 10.1029/2019GL08405, 2019.
- Emry, E., Y. Shen, **A. Nyblade**, A. Flinders, and X. Bao, Upper mantle earth structure in Africa from full-wave ambient noise tomography, *Geochemistry, Geophysics and Geosystems*, doi: 10.1029/2018GC007804, 2019.
- White-Gaynor, A.L., **A. A. Nyblade**, R. C. Aster, D. A. Wiens, P. D. Bromirski, P. Gerstoft, R. A. Stephen, S. E. Hansen, T. Wilson, I. W. Dalziel, A. D. Huerta, J. P. Winberry, and S. Anandkrishnan, Heterogeneous upper mantle structure beneath the Ross Sea Embayment and Marie Byrd Land, West Antarctica, revealed by P-wave tomography, *Earth and Planetary Science Letters*, doi: 10.1016/j.epsl.2019.02.013, 2019.
- Grijalva, A., **A. Nyblade**, K. Homman, N. J. Accardo, J. B. Gaherty, C. J. Ebinger, D. J. Shillington, P. R. N. Chindandali, G. Mbogoni, R. W. Ferdinand, G. Mulibo, J. P. O'Donnell, M. Kachingwe, and G. Tepp, Seismic evidence for plume- and craton-influenced upper mantle

- structure beneath the northern Malawi rift and the Rungwe volcanic province, East Africa, *Geochemistry, Geophysics and Geosystems*, doi: 10.1029/2018GC007730, 2018.
- Ramirez, C., **A. Nyblade**, M. Wyssession, M. Pratt, F. Andriampenanana, and T. Rakotondraibe, Complex seismic anisotropy in Madagascar revealed by shear wave splitting measurements, 215, 1718-1727, *Geophysical Journal International*, doi: 10.1093/gji/ggy367., 2018.
- Borrego, D., **A. A. Nyblade**, N. J. Accardo, J. B. Gaherty, C. J. Ebinger, D. J. Shillington, P. R. N. Chindandali, G. Mbogoni, R. W. Ferdinand, G. Mulibo, J. P. O'Donnell, M. Kachingwe, and G. Tepp, Crustal structure surrounding the northern Malawi rift and beneath the Rungwe volcanic province, East Africa, *Geophysical Journal International*, 215, 1410–1426, doi: 10.1093/gji/ggy331, 2018.
- Ramirez, C., **A. Nyblade**, E. Emry, J. Julià, X. Sun, S. Anandkrishnan, D. Wiens, R. Aster, A. Huerta, P. Winberry, P. Shore, and T. Wilson, Crustal structure of the Transantarctic Mountains, Ellsworth Mountains and Marie Byrd Land, Antarctica: New constraints on shear wave velocities, Poisson's ratios and Moho depths, *Geophysical Journal International*, doi:10.1093/gji/ggx333, 2017.
- O'Donnell, J.P, K. Selway, **A.A. Nyblade**, R. A. Brazier; D. A. Wiens, S. Anandkrishnan, R. C. Aster, A. D. Huerta, T. Wilson, and J. P. Winberry, The uppermost mantle velocity and viscosity structure of central West Antarctica, *Earth and Planetary Science Letters*, 472, 38–49, doi: 10.1016/j.epsl.2017.05.016, 2017.
- White-Gaynor, A. L., and **A. A. Nyblade**, Shear-wave splitting across the mid-Atlantic region of North America: A fossil anisotropy interpretation, *Geology*, doi:10.1130/G38794.1, 2017.

Synergistic Activities

- Founder and co-Director of AfricaArray (www.africaarray.org), 2004 - present.
- Chair, Polar Networks Science Committee, 2013-2015
- Member, Board of Directors, Incorporated Research Institutions for Seismology, 2015- 2017
- Tectonics Editor, Books Board, American Geophysical Union, 2003 – 2010
- Associate Editor, Journal of Geophysical Research, 1997 - 2000

Graduate Advisors and Postdoctoral Sponsors (Total - 3): Henry Pollack (Ph.D.) U. of Michigan; Peter Shive (M.S.) U. of Wyoming; Charles Langston (Postdoc), U. of Memphis

Postdoctoral and Research Associates (Total - 15): Natalie Accardo (NewGen Strategies), (Brian Bagley (U. of Minnesota); Richard Brazier (PSU- DuBois); Mulugeta Dugda (NCA&T U.); Erica Emry (Pacific Tsunami Warning Center); Samantha Hansen (U. of Alabama); Audrey Huerta (Central Washington U.); Alemayehu Jemberi (AFTAC); Jordi Julia (U. Federal de Rio Grando do Norte, Brazil); Gabriel Mulibo (U. Dar es Salaam); John Paul O'Donnell (Leeds U.); Yongcheol Park (KORPI, South Korea); Ranto Raveloson (U. of the Witwatersrand), Sharmin Shamsalsadati (PSU), Wei Wang (PSU).

Graduate Students (Past and Present; Total - 39): Aubreya Adams (Colgate U.); Nada Ahmed (U. Witwatersrand); Gabriella Arroyo (PSU); Margaret Benoit (College of New Jersey; NSF); Katie Boyle (Southwestern Energy); Cate Bressers (Shell), Priscilla Brownlow (RK&K); David Borrego (PSU); Kaelie Contreras (PSU), Christopher Casler (unknown); Mulugeta Dugda (NCA&T U.); Marco Finotello (Repsol); Juliette Florentin (unknown); Ashley Grijalva (PSU); Kyle Homman (PSU), Helio Inguane (U. Witwatersrand) Marsella Kachingwe (Chevron); Eldridge Kgaswane (Council of Geoscience); Ronald Knox (unknown); Robert Last (unknown); Andrew Lloyd (Washington U.); Erica Lucas (PSU), Lisa Ma (PSU), Azangi Mongongolo (Council for Geoscience); Gabriel Mulibo (U. of Dar es Salaam); Fenitra Ony (U. Witwatersrand); Kameron Ortiz (Parsons, Inc.); Yongcheol Park (KORPI, S. Korea); Tsitsi Rakotondraibe (U. Witwatersrand); Cristo Ramirez (PSU); Angela Reusch (IRIS/Passcal); Stewart Rouse (ESRI); David Soto (PSU); Fred Tugume (Uganda Geol. Surv.); Timothy Watson (Noble Energy); Austin White-Gaynor (Macys); Alys Young (ENSCO), David Yoxthimer (PSU).

Thomas B. Murphy
Marcellus Center for Outreach and Research
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University Park, PA

University Appointments

Director, Marcellus Center for Outreach and Research, Penn State Univ	2010 to present
Principal, Shale Education and Workforce Training Center	2008 to 2016
Chair, Penn State Extension Natural Gas Working Group	2008 to present
Extension Team Leader, Penn State Marcellus Education Team (MET)	2005 to present
Educational Outreach/Extension Educator	1986 to 2010

Professional Preparation

The Pennsylvania State University	B.S. (Ag Sciences)	1980
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Professional Interest:

Programmatic thrust is predominately centered on initiatives involving the science and technology utilized in unconventional natural gas extraction and the related issues including socio-economic, workforce, legal, regulatory, environmental, LNG exports, infrastructure buildout, and social license to operate(SLO). Assesses and instructs on how they impact the various stakeholder groups in the shale regions of the U.S., North America, and globally. Involves educational programming relating to a core focus targeting shale energy development and the many associated implications. Provides leadership in research and instruction-based shale related projects. Author of related subject matter articles directed to regional, state, and national publications.

Related Research and Recent Publications:

- Northern Territories Australia Strategic Regional Environmental and Baseline Assessment -SREBA (reviewer) 2019
- South Africa Karoo Shale Basin -- Pending Shale Gas Regulations (reviewer)2018
- The Natural Gas Supply Chain –CSCR Whitepaper (collaborator) 2016
- South Africa Strategic Environmental Assessment for Shale Gas Exploration, Development, and Production (reviewer) 2015
- Establishing Thresholds for Negative Effects on Vegetation and Soils from Marcellus Well Production Water (collaborator) 2015
- South Africa’s Technical Readiness to Support the Shale Gas Industry (reviewer) 2015
- Pathways to Shale Development in Asia-Pacific (reviewer) 2015
- Continuous, Regional Methane Emission Estimates in Northern Pennsylvania gas fields using atmospheric inversions (collaborator) 2014
- Economic Impact Study in 5 Pennsylvania Counties (reviewer) 2012
- Pennsylvania Marcellus Shale Workforce Needs Assessment (co-author) 2011
- Impacts to Municipalities and Businesses in Marcellus Shale Region (reviewer) 2011

- Murphy, T., Yoxtheimer, D., *Eastern U.S. Shale Development – Implications for North America and Globally Involving Economic, Social License, Public Policy, Environmental Impacts, and the Influence of Social Media in These Issues*, Rowman and Littlefield Publishing, 2019, Global Impact of Unconventional Energy Resources, p. 39 -62
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- Murphy, T., *U.S. Shale Trends – Economic and Global Implications*, IOP Publishing, Journal of Physics:Conference Series 745, <http://iopscience.iop.org/article/10.1088/1742-6596/745/2/022004> September 2016
- C. Joel, R. Burcat, Stephen W. Saunders, Amy L. Barrette, Marc J. Bern, George A. Bibikos, Lauren M. Burge, Robert J. Burnett, John W. Carroll, Sean Cassidy, Brian J. Clark, Robert W. Diehl, Michael Dillon, Kevin J. Garber, Robert M. Jochen, Michael P. Joy, Tate J. Kunkle, Lisa C. McManus, Jeremy A. Mercer, Thomas B. Murphy, Joe Osborne, Ross H. Pifer, Jonathan E. Rinde, Russell L. Schetroma, Mark Szybist, Lauren M. Williams, Elizabeth U. Witmer, Matthew L. Wolford, Jordan B. Yeager, *The Law of Oil and Gas in Pennsylvania*, Second Edition, PBI Press, September 2016
- Lendel, Iryna; Thomas, Andrew R.; Townley, Bryan; Murphy, Thomas; and Kalynchuk, Ken, *Economics of Utica Shale in Ohio: Workforce Analysis*. Urban Publications. Paper 1330. http://engagedscholarship.csuohio.edu/urban_facpub/1330 October 2015
- Liss, J., Murphy, T., [The Expanding Circle of Stakeholders: Shale Gas, Information Flows, and the Social License to Operate](#), OGEL 3 (2014), www.ogel.org
- Ratner, M., Blumsack, S., Murphy, T., *U.S. Shale Gas Development: Production, Infrastructure, and Market Issues*, Congressional Research Service, July, 2014
- Tieman, M., Folger, P., Carter, N., Arthur, M., Blumsack, S., Murphy, T., Yoxtheimer, D., Pifer, R., *Shale Energy Technology Assessment: Current and Emerging Water Practices*, Congressional Research Service, July, 2014

Synergistic Activities:

- 830+ presentations (2005- 2019) representing over 50 countries on unconventional shale topics to stakeholders including landowners, business groups, First Nations communities, elected officials, state/federal agencies, and professional associations.
- Multi-day immersive educational tours(52) for elected officials, media reps, regulators, academics, and students. Offered as intensive, in-depth, holistic, field-based reviews of the key components of shale gas development and its broad implications.
- Legislative briefings (74) on shale energy development and related issues for various elected officials from PA, Congressional delegates and staff, legislators in surrounding states, various embassy staff worldwide, and global governmental delegations. Briefings focus on technical, workforce development, social, and community development implications of shale gas extraction.