



Summary of 2011-2012 Activities

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Section 1. Preamble and Background

Lehigh University is strategically located between two large shale gas plays in the State of Pennsylvania: the proven Marcellus Formation play in the Appalachian foreland to the north and the still exploratory Lockatong Formation play in the Newark Basin to the south. Lehigh's well-established excellence in Engineering, Natural Sciences, and Social Sciences can be leveraged to provide a venue for interdisciplinary research and scholarship on the natural resource, economic, environmental, health, and human impacts, both positive and negative, related to shale gas development. Participants agreed that our effort would be guided by our curiosity to determine governing phenomenon with a goal to improve processes with little partisan opinions. A group of faculty and staff from the College of Engineering and Applied Sciences, the College of Arts and Sciences, the Environmental Initiative, and the Office of the Vice President of Research dedicated AY 2011-12 to perform due diligence and explore all aspects of Lehigh's alignment with Marcellus Shale development through panel discussions, invited lectures, and a field trip to observe various activities related to shale gas extraction. This report:

- provides context for these activities,
- identifies the key stakeholders and leaders of the due diligence efforts,
- documents the results of two panel discussions, and
- identifies the emerging high priority issues.

Lehigh interest in shale gas development in Pennsylvania was proceeding on several, uncoordinated fronts prior to AY 2011-12. This included research of Prof. Arup SenGupta on treatment of "flowback" and produced water from Marcellus wells drilled in Pennsylvania. In many ways, a letter by a Lehigh Board of Trustees member inquiring about Marcellus research activities at Lehigh galvanized the Lehigh community to better coordinate its research efforts.

The major Marcellus-related events for 2011-12 included:

- the Fall semester panel session dedicated to technological aspects (summarized in Appendices I-II);
- the Spring semester panel session that revolved around social and economic issues (Summarized in Appendices III-IV);
- the invited lecture of PA DEP secretary Michael Krancer;
- several related geology, engineering, health, and social science presentations by Lehigh and non-Lehigh faculty;
- a field trip attended by 20 Lehigh faculty and research staff to experience shale gas drilling, road construction, water transportation, gas production, and water recycling, and the impact of the Marcellus play on infrastructure and infrastructural development (summarized in Appendix VI); and
- Lehigh representation at the Multi-State Marcellus Shale Research Conference in Pittsburgh, PA, in May 2012 (Summarized in Appendix VII).

These events were made possible by semi-weekly meetings of a core Marcellus faculty and

staff group who represented a larger group from Engineering, Arts & Sciences, the EI, and Office of Research. The broader Marcellus group met, on average, once every two months to provide guidance and input to the overall process. The inaugural meetings of these groups were started in September 2011.

In response to several logistical and time-sensitive matters, a decision was made to reach out to Lehigh alumni who are experts in engineering and natural sciences to participate in a fall panel discussion devoted to resources (including water), environment (mostly water), infrastructure, and diverse modes of shale gas extraction. In the spring, experts in environmental law, international relations, social and human aspects, health and planning participated in a panel. None were Lehigh graduates. The panels established a good starting framework for the process, were interactive, frequently fielding questions from the audience. Attendance for each panel was approximately 100 individuals.

Section 2. Lessons Learned and High Priority Issues to Pursue

The lessons learned are a culmination of the Fall 2011 panel, which focused on science, technological, and environmental issues, and the Spring 2012 panel, which focused on social science, policy, and economic issues surrounding Marcellus Shale development. The lessons learned are separated into different categories, and it should be recognized that there is necessarily some overlap among these categories.

Environmental

Environmental issues are a major concern to the industry with the potential to impact Marcellus shale gas production and profitability. While the industry does use best practices to minimize environmental impact at individual well sites, there was a general consensus among the panelists that concerns remain with the Marcellus Shale development that are not addressed by current research. Lessons learned and existing issues include the following:

1. Drillers are concerned about contamination of groundwater at their drill sites and they use multi-tiered precautions sites to prevent this from occurring. Examples include multiple impermeable water barriers underlying the drill site, berms to prevent runoff, and double-hulled containers for hazardous fluids, such as diesel fuel used on-site. While there is the potential for localized contamination if a failure occurs at a well site, environmental concerns typically focus on the regional scale, including water usage, treatment of flow-back and process waters, fate and transport of residual fracking fluid in the subsurface, and methane migration. A key difficulty in assessing regional issues is the lack of pre-drilling baseline data on water quality.
2. A key environmental concern is water usage and treatment of flow-back and process waters and the impacts on watershed preservation, groundwater and surface water contamination. Specifically, an innovative solution is needed to remove toxic waste products from water. Technologies do exist to treat and reuse process water, and one plant in Williamsport was visited by the Marcellus faculty interest group that treats produced water, but cost-effective technologies do not yet exist to treat water with very high salt concentrations.
3. Questions still abound regarding the fate and transport of fracking fluid in the subsurface. While it is likely that the residual fracking fluid will be contained in the deep Marcellus Formation, this issue has not been studied and the general public is very concerned about the potential for fracking fluid to follow natural faults and fractures in the rock and migrate to the surface, where it can negatively impact to drinking water aquifers.
4. No research on cumulative or synergistic effects of gas development activities on air quality, water quality or human health has been conducted (e.g., effects of truck traffic and compressor stations combined with regional ozone on childhood asthma).

Social Impacts and Human Health

The general consensus of the panelists is that research on social impacts and human health is uncoordinated, disjointed and underfunded. Lessons learned and existing issues include the following:

1. There is a paucity of baseline (pre-development) data on human health and social issues makes it difficult to attribute causality of negative impacts to shale development. This has complicated legal actions, policy development and planning.
2. No large-scale epidemiological study has been conducted on the impacts of Marcellus development. The Geisinger Health System is beginning this effort, with the focus on data mining of existing hospital records. Of particular interest are effects on psychological stress.
3. A key issue that needs to be investigated is the distribution of benefits and costs within the Marcellus development region. The area that needs to be investigated revolves around historical, cultural, socio-economic, and infrastructural variables that make some communities more likely to reap benefits of development while others bear disproportionate costs.

Economic

Economic issues range from the natural gas market itself to downstream use of natural gas to economic impacts of Marcellus development on communities. Lessons learned and existing issues include the following:

1. Economic trade-offs at the local level cannot be estimated without an analysis of opportunity costs (e.g., declining tourism), unanticipated benefits (e.g., additional investments in local agriculture by well leasers), or unanticipated costs (e.g., rapidly rising housing rents leading to rural homelessness). No one clearly understands how much revenue remains in communities and how many new jobs are filled by local residents. Combined with a lack of baseline social and health data, these shortcomings preclude any adequate risk evaluation or cost/benefit analysis.
2. Pennsylvania needs to capture more “downstream value” of the Marcellus gas. This includes development of post-processing (cracking) facilities for wet gas, building new electricity generation plants that use shale gas or retrofitting existing plants, and using gas to fuel motor vehicles. With the latter, an example is the development of localized fleets of vehicles that use a central filling station. At the moment, natural gas is a commodity without a market. This has had the effect of driving down the price of gas and throttling further shale gas development.
3. Other economic issues that require study include the effects of current overproduction, shale gas development in other countries, oil prices and climate change policy on the future of shale gas development in the U.S. and how this will impact local communities.
4. Although shale gas is promoted as a stopgap in long-term greenhouse gas reductions, it

appears that the low price of gas is discouraging investment in development of non-fossil fuel energies. The extent and duration of this effect are unknown.

Policy and Planning

Policy issues have been at the forefront of Marcellus development and a key factor has been the rapid development of Marcellus gas without adequate planning. Lessons learned include the following:

1. The speed of development caught local planners by surprise resulting in a lag in infrastructure implementation that negatively affected both quality of life of local residents and gas production. Ample opportunities exist to apply lessons learned to future development in Ohio and New York. Of particular interest is how to turn short-term energy booms into long-term, sustainable development (i.e., how not to repeat the long-term economic mistakes of coal and oil development).
2. Shale gas development has been more politically polarizing than other recent environmental issue. The reasons for and implications of the controversial nature of this energy development are poorly understood. Marcellus development provides an untapped means to study how new technologies combine with unique political, socio-economic and environmental contexts to produce costs, benefits and political controversy and how knowledge gained from Marcellus can be used in future planning and policy development.

Technological

Technological issues and their solutions (e.g., horizontal drilling and fracking technologies) have been a dominant driver in the development of Marcellus gas. Lessons learned and existing issues include the following:

1. The drilling industry learns rapidly and has been continuously improving drilling technology. The industry is now well-versed in how to develop and produce Marcellus shale gas.
2. Technological and scientific issues still remain. One area that requires further study is crack propagation and fracture mechanics in in homogeneous media and how the fracking process can be improved. In order to reduce water usage and treatment, new materials need to be developed for fracking. CO₂ and N₂ are possible candidates but they are inferior to water due to their compressibility and higher cost. Ironically, the fracking process is not a major financial consideration for the industry so there is little economic incentive to move away from using water. Any financial incentive to use other materials would have to be driven by regulatory policy.
3. As stated above with the Environmental issues, an innovative solution is needed to remove toxic waste products from water. Technologies do exist to treat and reuse produced water, but cost-effective technologies do not yet exist to treat water with high salt concentrations.

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4. Opportunities do exist for greening of the industry. A direct example is with the Lehigh alumnus who has a water recycling company in Williamsport. Other opportunities might stem from the need to monitor water, capture initial gas releases, and develop new fracking media like nitrogen to replace water.
 5. Opportunities exist for investigating the efficiencies of the natural geologic seals that encapsulate the Marcellus Shale production interval in the subsurface. Analogue and numeric modeling of the stratigraphy and its response to fracking can illuminate problems related to gas, fracking fluid, and produced water migration along naturally occurring faults and fractures.

Infrastructure

Marcellus development is impacting infrastructure at the local, county and state levels. The influx of truck traffic and workers into the Marcellus region has affected the air quality, traffic congestion, and road and bridge maintenance. Lessons learned and issues requiring study include the following:

1. As natural gas production increases in the Marcellus region, truck volumes have increased. Each new well site requires approximately 1,600 truckloads of sand, gravel and water. While “numbered” highways are designed to handle truck traffic, local roads are not constructed for this heavy truck traffic and they have received significant damage.
2. Posting maximum weight limits on rural roads does help prevent wear and tear. Since 2007, approximately 4,300 highway miles have posted weight limits in response to increased volume posed by the growing gas industry. Companies can request exceptions, and in the process they are required to enter into a maintenance agreement with the DOT which outlines strategies to maintain roads. Through this process, drilling companies are rebuilding roads that experience heavy truck traffic and this has helped communities by increasing the quality of rural roads.
3. PennDOT has focused its efforts on highway damage but has not comprehensively studied the impact on PA bridges. Particularly for Pennsylvania's aging bridges, there is a need for structural engineering studies and solutions.
4. Pipeline construction in the locally steep topography that characterizes much of the Marcellus production region offers a particular challenge for new construction techniques and materials. Existing pipeline infrastructure is over capacity which will require building new pipeline, especially steel pipelines. Estimated cost for new pipeline construction is approximately \$150 million and requires a minimum two-year period for permitting before construction begins.
5. A significant amount of water is required for the drilling and fracking processes and this water is typically transported by trucks. There is a need to develop more localized water pipeline networks and distribution systems to reduce long-distance transport of water via trucks.

Appendix I. Summary and Notes from the Fall Marcellus Shale Panel

Location: Lehigh University, Packard Laboratory Room 101

Date: November 17, 2011

Topic: The Marcellus Shale Phenomenon and Opportunities for Research at Lehigh

On Thursday, November 17, 2011, a panel discussion took place at Lehigh University hosted by the College of Arts and Sciences Environmental Initiative (EI), the Office of Vice President and Associate Provost for Research and Graduate Studies, and the P.C. Rossin College of Engineering and Applied Sciences. This was the first of two planned panels focusing on Marcellus Shale and related opportunities for university research. The first panel focused on opportunities for science and technology and the second panel focused on opportunities involving policy, society and the economic impact of shale gas production. The event was attended by approximately 150 participants including Lehigh faculty, staff, students, and members of the community. A wrap-up and question and answer period followed each of the three topic areas and all participants were invited to continue discussion at the informal reception following the event.

Planning: Goals, Expectations, and Panel Moderation

The Unique Role of the University:

Ongoing development of the Marcellus Shale resource in Pennsylvania and neighboring states has led to a series of challenges in resources for environmental, technical, economic, and social policies. Universities occupy a unique niche where these challenges can be discussed in an open, objective, non-agenda-driven format. Lehigh seeks to take advantage of its ability to look further out into the future, and to take a broader view, than many involved in shale gas operations have the luxury to do.

Goals:

The goal of these panels was to explore the current and future challenges that surround development of the resource and seek alignment among these challenges and individual and institutional research and scholarship interests. Consistent with our role as a university, we convened panelists having a variety of roles, expertise, and perspectives with the intent that all participants learn from the session. The format was a panel populated by experts who have considerable experience in a broad range of shale gas issues.

Expectations:

We recognize the unique position of a University to moderate an objective discussion about existing and future challenges. Universities have tremendous intellectual and creative potential that can be brought to bear on the myriad of challenges. It is our hope and expectation that all stakeholders in the non-academic community will feel welcome to work with us in open

identification of the issues so that we can meet the challenges together.

Ground Rules of the panel:

The panel was for a duration of three hours and was divided into three one-hour sessions: (1) resource, water, and environment; (2) infrastructure; and (3) technology and modeling. While the panelists were selected for their ability to contribute to specific sessions, they were present for all three sessions.

Panel questions:

The overall question for the panel discussion was, “If we were to look forward 10 years from now, what will be the largest scientific, technical, and environmental challenges defined by Marcellus Shale development. Are these challenges present today and if not, how will they emerge?”

Topic 1: Gas, Water and Environmental Issues

Moderator: Sudhakar Neti, Professor, Department of Mechanical Engineering and Mechanics

Panelists: Matt Demarco, Project Manager, Advanced Geo Services Corporation; Chris Kocher, President, Wildlands Conservancy

Moderator’s questions:

1. Regarding chemistry and geochemistry (including radioactivity), what components are man-made and therefore manageable, and which components are a function of the natural environment?
2. How has Marcellus development been impacted by the widespread advent of water treatment and re-use?
3. What is the fate and transport of water not-recovered from the fracking process?
4. What strategies, if any, currently being applied offer the best hope for sustainable and safe management of water resources? Specifically, why have some drinking water sources been impacted by Marcellus development?
5. What examples, if any, exist to document landscape-scale impacts of the resource development?
6. Based on development and recent re-assessment of the scale of the resource what is the long-term sustainability and how does it impact the national energy portfolio. What role does the potential development of other Shale Gas deposits, including the Utica Shale, play in this assessment?

Discussion

Hydraulic fracking has been done since the 1950s. Marcellus and other non-conventional shale gas resources will be with us for 50 – 100 years. Natural gas uses 40-50% less carbon

dioxide and is less expensive to produce. Overall, this investment will have a large economic benefit for Americans over the next few decades. Environmental issues are a major concern with potential to impact production and profitability to the industry. Current research does not address some of the concerns involved with the Marcellus Shale development. One such area is in watershed preservation, groundwater and surface water contamination and water recycling technology. More specifically, an innovative solution is needed to remove toxic waste products from water.

Another area requiring immediate attention is the need to enhance the market for natural gas use. Potential new uses would be in electric power generation and the use of natural gas for automobiles. Additionally, the panel discussed the potential impact on resource development. Space-based remote sensing offers an opportunity to quantify and manage these impacts at the appropriate scale.

Topic 2: Infrastructure

Moderator: Richard Sause, *Professor of Structural Engineering Director, Advanced Technology for Large Structural Systems (ATLSS) Center*

Panelists: Charles Goodhart, Director of the Bureau of Maintenance and Operations, Pennsylvania Department of Transportation; Terry Engelder, Professor, GeoSciences Department, Penn State University; Kristin Carter, Chief, Petroleum & Subsurface Geology Section of the Pennsylvania Department of Conservation and Natural Resources

Moderator's questions:

1. Are the quantities of materials and equipment needed to develop Marcellus significant relative to the quantities of materials currently transported on interstates, major highways, and local roads? What materials are used and what is the typical transport route?
2. What are the anticipated impacts of these transportation needs on highways and bridges? Is there a plan to mitigate these impacts?
3. What infrastructure is needed for transporting Marcellus gas from well sites to markets? Pipelines? Is other transport infrastructure needed? What are the technical challenges involved?
4. What are the environment impacts to be considered in developing well site infrastructure, material and equipment transportation infrastructure, and gas transport infrastructure? Are there successful approaches that we can consider to mitigate or reduce negative environmental impacts?
5. For drinking water sources that have been or could be impacted by Marcellus development, what infrastructural investments, if any, are necessary to (a) prevent more impacts from happening and (b) rectify impacted public drinking water sources.
6. Has there been micro-earthquake activity related to Marcellus development and if not, what plans, if any, exist to study and address the impacts of potential induced seismic activity?

Discussion - Utilization of infrastructure

Pennsylvania has been drilling since 1953 but with increased activity in the Marcellus region, the scale of land development is a growing risk. Each contaminated well is worth 1000s of gallons of gas to the industry. Highways have also been greatly impacted. As natural gas production increases in the Marcellus region, truck volumes have increased and significantly damaged the roads. Today 8000 engineers are responsible for road maintenance in 12 districts (approximately 40,000 miles) and bridges (approximately 20,000 miles). Currently, these roads are not constructed for heavy truck traffic. Each new well site requires approximately 1600 truckloads of sand, gravel and water. One possible solution would be the expansion of rail and freight systems to reduce the level of impact on roads and bridges. New materials are needed for road surfacing and new systems for remote sensing and monitoring of damage and repairs. Monitoring will require extensive data archiving providing another area for university research. As for water utilization, public water supplies in western Pennsylvania are rivers which are permitted and regulated. Concern here involves potential for stray gas mitigation and it is increasingly important to document and monitor where frack fluid is funneled. The gas industry prefers to use water in the most economical way and avoid trucking water to the site. The panel concluded that more information is needed about what is being put into the wells (if not water).

Discussion - Road repairs and funding

The significant increase in truck traffic over the last few years has affected the air quality, traffic congestion, and road and bridge maintenance. Particularly for Pennsylvania's aging bridges, there is a need for structural engineering studies and solutions. PennDOT has focused its efforts on highway damage but has not comprehensively studied the impact on PA bridges. Both old and new bridges are being impacted. For this reason, road re-construction, new materials, and techniques are needed to prevent further damage. Building temporary roads to sites is a significant challenge especially in winter conditions.

Pennsylvania Department of Transportation (PennDOT) meets with the Marcellus Shale board once a month. They try to work on safety issues since there are an estimated 1000 trucks on PA roads per week. According to PennDOT, there has been cooperation and companies are helping to rebuild roads that experience heavy truck traffic. Currently the Department of Transportation (DOT) does not restrict truck use on primary high traffic routes. Secondary roads were not designed to accommodate high traffic volume from heavy and sustained truck traffic. Posting maximum weight limits helps prevent wear and tear. Since 2007, approximately 4300 highway miles have posted weight limits in response to increased volume posed by the growing gas industry. Some exceptions are allowed, however, as each company is required to enter into a maintenance agreement with the DOT which outlines strategies to maintain roads.

Further study is needed, to determine the impact of the extra truck loading on bridges. Several challenging factors to consider include the possible risk involved in transportation of dangerous chemicals to and from well sites. New challenges arise especially during the thaw period every spring when roadways are particularly vulnerable. Winter maintenance is complicated by snow and ice conditions. It was suggested that a modernized policy for fair use of highways by all industries should be developed.

Discussion - Land impact

The Marcellus and Utica regions cover approximately 54,000 square miles including Ohio, West Virginia, Pennsylvania, southern portions of New York and sections of New Jersey. While one well site may only involve an acre of land, there may be 300,000 wells in the future, and drilling may continue for years. With regard to land impact another concern relates to seismic activity and small earthquakes generated by fracking. In July 2011, the Governor's Marcellus Shale Advisory Commission released a comprehensive report examining the overall impact on Pennsylvania. The review included examining and recommending efforts to mitigate environmental impacts; fostering efforts to promote market development; developing a trained workforce; enhancing emergency response; identifying and mitigating uncompensated local and community impacts; providing for appropriate public health monitoring and analysis; and the responsible and efficient deployment of infrastructure.

Discussion - Gathering and development of pipelines

Pipeline construction in the steep topography of the Allegheny Plateau offers a particular challenge for new construction techniques and materials. Existing pipeline infrastructure is over capacity which will require building new pipeline, especially steel pipelines. Estimated cost for new pipeline construction is approximately \$150 million and requires a minimum two-year period for permitting before construction begins. Another area of investigation will be the need for more pipeline transportation corridors and a gas "smart-grid" system for moving gas to market.

Discussion - IT Technology and development

A new IT infrastructure is needed which will allow industry and regulatory agencies to share data and information on geology, well production, and infrastructure. PennDOT plans to implement a new GIS model and facilitate data sharing and improve collaboration.

Discussion - Issues concerning water and wells

Public water supplies will also be impacted and will require extensive planning for community development. In western Pennsylvania, the major public resources are three rivers: Ohio, Allegheny, and Monongahela. There is a voluntary request for flow-back water producers to not take their water to sewage treatment plants. Small communities and privately owned wells in northeastern Pennsylvania, conduct their own testing, and do not necessarily require permits. Long-term water treatment of public resources will be required. This will differ somewhat between southwest and northeast PA but improved water treatment is achievable and current research seems promising. One recommendation is that there be a central source for treatment and processing of water and there are some examples of this in Louisiana and southern Texas. A central source of water treatment saves some cost to producer and offers consistent and clean water supply.

Discussion - Potential areas of further research

Most operators monitor their own wells for environmental contaminants but pre-monitoring of wells and installation of monitoring devices are also important. Sometimes on-line monitoring

of methane and conductivity are also done. Companies are using seismic arrays in drilling area to monitor pre-drilling, during drilling, post-drilling activities. The US Geological Survey (USGS) recently started a survey in Washington County located in southwestern PA. The survey will gather public information for remote monitoring of different levels of ground water. Monitoring is key to protecting water supplies and will require a much needed and dedicated IT network of sensors to measure “downhole” and seismic activity.

Topic 3: Technology and Modeling

Moderator: Herman Nied, Professor, Department of Mechanical Engineering and Mechanics

Panelists: Josh Silverstein, Senior Director, Enerecap Partners, LLC; David Taylor, Vice President, Energy Businesses

Moderator’s questions:

1. Traditionally, hydrocarbon resource extraction practices have been empirically-driven and experimentally-based. What examples, if any, exist to demonstrate that research and modeling can play a formative role in the development of new technologies that directly address the resource, water, and environmental issues discussed above? Is the current technology amenable to optimization?
2. What is the developmental horizon for new, non-water based technologies for extraction of the shale gas resource? Can non-reactive gases like nitrogen be used?
3. What technologies need to be developed to isolate and protect shallow water resources that exist within 100 m of the surface from resource extraction that lies > 1000 m below the surface? This question aligns with questions regarding drinking water sources in the preceding discussions.
4. What opportunities, if any, exist for aligning the need to sequester CO₂ with the ongoing development of Marcellus Shale as a resource?
5. What specific challenges exist in the extraction of “wet” gas in the western part of the basin vs “dry” gas in the eastern part?

Discussion

Much is still unknown about crack propagation and fracture mechanics in homogeneous media. New materials other than water are needed for fracking. CO₂ and N₂ are possible candidates but are inferior to water which is incompressible and are more expensive to use. Ironically, fracking and use of different propens is not a major financial consideration for the industry so there is little financial incentive to move away from using water. Any financial incentive to use other materials would have to be driven by regulatory policy. There is also a need for the development of improved drilling tools and technology. Aligning the need for CO₂ sequestration with use of alternative fracking materials such as CO₂ should be researched to determine feasibility.

Summary of new research opportunities

A list of suggested new developments included:

- New technology, water recycling
- Productive models of environment important.
- Enhance market for gas use e.g. electric power and automobile use
- Bridges, roads, infrastructure
- smart grid development to reduce potential for gas disaster
- IT Center and system network
- New drilling tool technology
- New fracking materials

Appendix II. Fall Marcellus Shale Panel Announcement



The Environmental Initiative, the Office of Vice President and Associate Provost for Research and Graduate Studies, the P.C. Rossin College of Engineering and Applied Science, and the College of Arts and Sciences

are proud to announce the following panel on Marcellus Shale

Panel on Marcellus Shale Science & Technology Issues

Today's panel discussion will focus on science and technology issues related to Marcellus Shale gas development in Pennsylvania. The panel will consist of experts from academia, government agencies, consulting firms, and industry and it is open to the Lehigh University Community and guests. Panel members will discuss issues related to the topics identified below and the audience is encouraged to participate in the discussion.

This is the first of two planned panels on Marcellus Shale issues. The second panel will be convened in Spring 2012 with a focus on policy, society and economics.

Date: Thursday, November 17th, 2011

Location: Packard Laboratory, Room 101

Schedule:

3:00-3:10 pm	Overview
3:10-4:00 pm	Topic 1 – Gas, water and environmental issues
4:10-5:00 pm	Topic 2 – Infrastructure
5:10-6:00 pm	Topic 3 – Technology and modeling
6:00-7:00 pm	Reception – STEPS Lobby

Appendix III. Summary and Notes from the Spring Marcellus Shale Panel

Location: Lehigh University, Packard Lab Auditorium

Date: April 18, 2012

Topic: Marcellus Shale Development: Communities, People, Health, Economics

Panel: Edward Chow, Senior Fellow, Energy and National Security Program, CSIS; Diane McLaughlin, Professor of Rural Sociology and Demography, The Pennsylvania State University; Jill K. Kriesky, Professor, Graduate School of Public Health, University of Pittsburgh; Sheila Olmstead, Research Fellow, Resources for the Future; Andrew Stewart, Chief of the Litigation and Audit Policy Branch, Special Litigation and Projects Division, USEPA; Ray Stolinas, Director, Bradford County Office of Community Planning & Grants and member of the Bradford County Planning Commission

On Wednesday, April 18, 2012, a panel discussion dedicated to Marcellus Shale gas development was hosted by the Environmental Initiative (EI), the P.C. Rossin College of Engineering and Applied Science, the Cluster for Sustainable Development, and the Office of Research and Graduate Studies at Lehigh University. This was the second of two planned panels focusing on Marcellus Shale and related opportunities for university research. The first panel (Fall 2011) focused on opportunities for science and technology while the spring panel focused on opportunities involving policy, society and the economic impact of shale gas production. In the introductory remarks, Frank Pazzaglia, Professor of Geology and Chair Department of Earth and Environmental Science, provided a brief background about the various interdisciplinary research efforts at Lehigh University, general information about the panel and related events on campus. Dr. Pazzaglia also explained that the purpose of the panel was to focus on matters of people, society, community and related issues of safety, policy, and the environment. Moreover, this panel was designed to address concerns spanning large temporal and spatial scales ranging from individuals to communities, to municipalities to the national level. To conclude the program, Dr. David Casagrande of the Environmental Initiative and the Department of Sociology and Anthropology wrapped up the discussions with a question and answer period. The event was attended by approximately 100 participants including Lehigh faculty, staff, students, and members of the community.

Planning: Goal and Panel Format

The panelists were asked to keep in mind that the overall goal of the discussion would be to identify how the unique resources of University faculty and students can be leveraged over long time scales to positively impact the problems faced by people and communities in the ongoing development of this natural resource. The panel was scheduled for three hours, divided into six 30-minute blocks. Each 30-minute block devoted to a topic that was concluded with one or two brief questions from the audience. The biographies of the participating panelists are included as Appendix VI.

Topic 1. Realities and Pressures of Resource Development on Local and State Government

What are the broader geo-political impacts of shale gas development, not only in the

Marcellus but globally? What role will the Marcellus play in U.S. energy policy? What impact does shale gas development have on emerging alternative energy sources and technology?

Discussion Questions:

1. What are the realities and pressures of resource development on local and state government?
2. What are some long-term jobs?
3. To what extent is the pressure directly due to gas drilling versus ancillary effects?

Moderator: Thomas Hyclak, Professor, Department of Economics

Discussion:

On April 13, 2012 the United States White House released a memo linking three federal agencies (EDA, EPA, and DOE) to consider shale production as a potential resource aimed to revive the energy industry and to access gas at a lower cost. Within the last five years, communities throughout Pennsylvania have experienced changes as a result of these upcoming plans impacting employment and housing, among many other aspects. There have been several initiatives to survey the impact on society such as the Resources For the Future (RFF) initiative to identify the priority risks associated with shale gas development and recommend strategies for responsible development. Two million people from governmental NGOs, universities, and other citizens have participated in this study to assess major risks and the potential impact on service water quality across the states. RFF's recommendations and strategies are available at <http://www.rff.org/Events/Pages/Managing-the-Risks-of-Shale-Gas.aspx>.

Bradford County, located in northeastern Pennsylvania, has been changing with increased ancillary development including hotels, pipe yards, etc. These hotels are filled to capacity, noted the panelist. More importantly, members of the community can no longer afford the apartment rental fees, with rates now averaging more than \$1200/month. Therefore due to the increasing cost of living, residents have been displaced. It was also noted that, smaller counties are hit harder in housing than larger counties, which can more readily absorb displaced people.

When considering the different stages of natural gas extraction, the EPA looks at the initial impacts, including site grading and preparation and more broadly the entire life cycle of the well. One panelist defined the impact of drilling as three phases. "The first phase is where most impact occurs, during drilling. The second phase is maintenance and a smaller number of workers are required. Finally, the third phase is shutting down the wells." In addition to the three phases, one panelist described that within these phases there are specific levels of progress. He noted the distinction between regular gas and shale gas operations. For example, with traditional wells the gas production rate drops off slowly (6-7% per year) and once the majority of the gas is extracted the well is closed. With Shale gas, the production drops off dramatically after first couple of years (40-50% decline rate) and as a result companies need to come back and keep re-fracking the wells. This process is repeated over and over.

Another perspective of the impact from the process of drilling suggests a cumulative approach. This approach requires an analysis of the overall large-scale industrial development including all activities, as noted by one panelist, "before anyone picks up a shovel." From an economic perspective, this speaker explained the importance of assessing local costs.

Specifically, for occupational risks, where an individual is injured on the job, the wage should be representative of the risk. Secondly, distribution effects are very important. Although large landowners can be significant beneficiaries of gas development, others impacted by the gas development need to be considered in this analysis too. One panelist underscored the following, “[One] cannot underestimate the distributional impacts.”

Meanwhile, one panelist noted that Bradford County now leads the state in increased employment. New power plants have been proposed in Bradford for use of natural gas which will bring more jobs. A significant increase is also represented by the numbers of employees working with the gas companies themselves. Panelists concluded that two trends have emerged with regard to employment: a significant increase in short-term employment for workers who are transitory and move around, and increased longer-term employment which includes people who are now buying homes and settling into the communities.

Panelists noted several economic impacts including the increased need for trained emergency response teams, many of which in rural counties are made up of volunteers. With the increase in road accidents and accidents at the drilling sites, many of the volunteer personnel are not able to meet their volunteer commitment and remain employed. Many of these emergency response volunteers can no longer afford rising gasoline costs to drive to the increasing number of emergency sites. Another issue is that many local businesses have benefitted financially and are providing services to the drilling industry thereby depleting the availability of these services to residents of the community. For example, mechanics and heavy equipment operators have done very well financially, but at the same time it is becoming increasingly more difficult for local residents to have cars and trucks serviced or private development work done.

There has also been a significant impact on municipal offices and workload. One panelist exclaimed, “Our courthouse was inundated with land and title searches on properties.” At least 50% of the time is now devoted to title searches and mapping for properties. Due to the overwhelming request for and maintaining of information by county clerks and courthouse officials, the offices have been forced to expand hours sometimes into the evening. Without additional budget and staffing the volume can be too much for small municipalities and county offices to handle.

Another concern for all municipalities and counties is the extent of road usage and maintenance. Companies have invested millions of dollars to help with road maintenance. Bradford County hopes to receive funding from the state impact fees now assessed on drilling companies to help support road maintenance. Panelists noted that the extent to which these pressures on small communities are directly related to the drilling or to ancillary effects has not been fully determined.

Two main pipeline super highways for transporting extracted gas pass through Bradford County. This explains the phenomenal growth and development in the county. Yet very little value has been added by the growth. For example the County would like to see the gas being utilized in the area for new purposes such as gas fueled fleet vehicles and for heating homes. However, Bradford County does not have the ability to expand natural gas delivery to private residences across a rural community and natural gas as an alternative fuel for automobiles is still in development.

The panel also discussed the negative impact shale development has had on the eco-tourism

industry. Hotels and motels are filled with non-tourists and tourists are choosing to stay away because of the current situation. A member of the audience expressed concern about the availability and condition of hiking trails many of which have suffered by shale development, noting, “the increase in noise pollution, traffic, and sight pollution resulting from well pads being drilled right next to hiking trails.”

Panelists were also concerned with other environmental impacts including air quality. They referenced an area of Wyoming which mostly consisted of cattle ranches. Now due to natural gas development the air quality is so poor that the area doesn’t meet recommended ozone levels.

Overall, the panel agreed we need to continue to study cumulative impact. Industries are working with communities to minimize environmental and a real impact by minimizing the number of new well pads and looking closely at habitat to determine the location of those wells. One report by the Nature Conservancy “Pennsylvania Energy Impacts Assessment: Report 1: Marcellus Shale Natural Gas and Wind,” tries to address the impact shale development has as it is scaling up. See http://www.nature.org/media/pa/tnc_energy_analysis.pdf

Topic 2. Local Community Issues

What are the realities and pressures of resource development on local and state government infrastructure and economies? What is the appropriate scale to regulate the industry and generate revenue? How does Pennsylvania’s approach compare to those of other states?

Discussion Questions:

- 1) What are the impacts on public health, including protection of drinking water and beyond drinking water?
- 2) What do we need to do these types of studies?

Moderator: Sharon Friedman, Professor and Director of the Science and Environmental Writing Program in the Department of Journalism and Communication

Discussion

The second panel focused on the impact of shale development on public health, including the protection of drinking water. Panelists agreed that this is one area of research that is vital to community health. Comprehensive studies are needed to assess effects on health both before and after drilling, and what chemicals and concentration levels the public were exposed to both prior and during drilling. These studies tend to be costly and long-term and there has to be a lot of political will to move them forward.

For example, it is inevitable that there will be a cancer cluster at some point, and we won’t have the data to determine if it is due to shale gas drilling or another effect. These become issues for companies defending themselves against health claims and for individuals looking for answers. Fortunately, some research studies are starting to be done in this area. One example is a recent study on air quality within a half mile of a drilling site in Colorado. The Colorado School of Public Health monitored air quality over a three year period. Hydrocarbons found in the air included benzene, which is a known human carcinogen. This air pollution can impact the cardio-vascular and immune systems, but there is currently no data available on long term health

impacts. Another issue is flow-back water, which contains naturally occurring chemicals like arsenic and radium. For a while now flow-back water has been transported to public waste water treatment plants. Using chlorination process as treatment has led to the formation of dangerous residues and disinfection byproducts. To dispose of this contaminated water, companies have been re-injecting it into the deep subsurface. This disposal method has a whole other set of impacts and has recently been tied to earthquakes in Ohio.

There have also been studies on the types of chemicals used in fracking fluids. One study in *Human and Ecological Risk Assessment: An International Journal* looked at known chemicals and listed potential effects. But our knowledge is limited. We know these chemicals can cause health effects, but we don't know the doses, pathways, and long-term cumulative impacts. The results indicate that we need to do additional studies.

Another area of concern is in regards to the levels of methane in groundwater. In a recent EPA study led by Duke, results indicated that methane concentrations were 17 times higher in water wells near hydrofracking sites (Osborn et al., 2011, *PNAS*, 108(20):8172-8176). Methane is a "contaminant"; it is not toxic, but it is explosive and has significant effects as a green-house gas with effects much larger than CO₂. Methane is naturally occurring, but we have no baseline data to tell if methane buildup in a home (or wells) is pre-existing or due to drilling activities. This remains a complicated question because natural gas is seen as preferable to oil and coal it is considered much cleaner burning. It is vital to have robust scientific information.

Management of public health issues is another problem and currently there is no health advisory official on the PA state Marcellus advisory council. The Governor's report recommended that we need a public health registry for potential health impacts on drilling activities, but it did not become part of the Act 13 and the Department of Health did not receive funding to collect this data.

The moderator asked the panelists to expand on this discussion by elaborating on what is needed to conduct these types of studies. The panelists concluded that there is a need to conduct research on the conditions pre-drilling/post-drilling in order for individuals to have a greater understanding of the impact on health. Aside from the Duke study, baseline data is still in great need which is beyond the EPA. Firms sometimes do pre-testing of groundwater wells in the area of where they plan to drill. This is a large potential source of data – private data – but data. The private sector however is reluctant or unwilling to provide it. Another issue is that the number of EPA and U.S. Geological Survey (USGS) water quality monitoring stations has been slowly declining due to costs to maintain them over time. Peer-reviewed journal articles require good data in order to publish. A member of the audience expressed concerned about drinking water that comes from sources within the Marcellus Shale region flowing into other municipalities. Some of these like Bethlehem, have municipal testing facilities that use equipment so antiquated it would not be able to detect some of the chemical compounds found in contaminated water. Currently, the EPA is looking into this. Another aspect is to make sure the National Pollutant Discharge Elimination System (NPDES) permit program remains strong and clearly articulates and enforces what can and cannot be discharged.

Topic 3. Public Health Issues

What are the impacts on public health, including protection of drinking water resources?

How is public health currently being managed, what is the proper scale to manage it, and is there a better overall strategy that we should be considering?

Discussion Questions:

- 1) What are the impacts of shale gas development on communities?
- 2) What is the residents' knowledge of Marcellus drilling, science, and economics?
- 3) What about people who get the data but in the lease sign non-disclosure agreements?
(audience-question)

Moderator: Al Bodzin, Associate Professor, Department of Education & Human Services

Discussion:

Question Posed – What are the impacts of shale gas development on communities?

The first question raised during the third discussion focused on the impacts of shale gas development on communities. The inequality of distribution of money and profits coming from the drilling is a significant social problem. Only people who own land will receive lease income and this thus excludes renters or people who have small properties. It was noted that those people who do receive income put 40-50% of that into savings, so their profits do not fully flow back to the local economy.

This uneven income distribution generates a lot of stress within communities. Communities are divided between those benefitting from drilling royalties and those opposed to drilling who do not get royalties. Sometimes boroughs will vote to pass an impact fee. Township officials then agree to accept the impact fee so as not to create a rift between boroughs and townships. These tensions also carry over into personal and family conflicts. For example one person might inherit a family farm then decide to drill but not share drilling royalties with other siblings. In some communities neighbors don't talk to other neighbors because of opposing views around drilling. Locating a well near a neighbor's property line causes particular stress. And finally, imagined and actual environmental impacts are other important dividing issues within communities.

Mineral rights owners frequently don't live in the community and thus the money does not stay in the communities. Another stress is that people who have recently moved into communities may have different norms and now change the community dynamics.

Boroughs are receiving impacts on road usage and local police and fire services.. Communities want to strike a balance with Act 13 and not see a rift between more developed areas and rural areas.

One panelist discussed the documentary film about Haynesville, PA, which looks at the economic benefits of drilling. This film focuses on the sudden financial increase within families and communities (<http://www.haynesvillemovie.com/>.) One particularly interesting issue deals with the leases residents are signing with drilling companies; landmen are very experienced in getting people to sign leases, and they are much more skilled and knowledgeable about the process. Community education is vital in helping understand the leasing process as well as other issues around Marcellus Shale phenomenon. Water quality is one example. Industry is required to perform a pre-test of water supply before drilling and must go out 3000 feet from the drill site.

Property owners are receiving pre-drilling data on their water, but they don't know how to interpret the results. Education was brought up as an important concern when negotiating with a firm that has a lot of experience. Even if you are a lawyer or physician, you still may not understand all the issues and how to interpret groundwater data. The panel recommended that property owners invest in getting the baseline data.

Another issue with regards to obtaining data is related to chain of custody. Specifically, the method of sample collection, the expertise of the person collecting the samples, and the qualifications of the laboratory analyzing the samples must be of sufficient quality if the data is to be used as evidence in court. Education regarding reputable labs and how to get from one point to the next might be best done at the government level under environmental agency. There are state certified labs that should be able to help with this, and we need a structure in place for property owners to do this. It would be best for government to do this, but currently there is no political will. There are some environmental groups that try and help homeowners get this data.

One question from the audience concerned people who do have the data but have in their lease a signed non-disclosure agreement. This has become a major issue where many lawsuits are going on right now and lawyers may be working on contingency. One strategy that has been successful in getting cases into court is "Race ipso loquitor" translated as "the fact speaks for itself." For example, a citizen may explain that they had clean drinking water for thirty years and within days of drilling his/her water turned a strange color, got an unpleasant odor, and he/she is now not feeling well.

Topic 4. Economic and Local Community Issues

What are the impacts of shale gas development on communities? What are the effects on social problems including economic restructuring, demographic changes, family structure and income inequality?

Discussion Questions:

- 1) Has Marcellus gas "saved" us?
- 2) With gas prices going below \$2.00, are we hurting other renewable technologies, such as solar, wind, etc.?
- 3) There are many other discoveries of gas throughout the world. Do you see a much greater production of gas in the next few years?
- 4) Why in Pennsylvania do we give such large tax breaks? (audience-question)

Moderator: Henri Barkey, Professor, Department of International Relations

Discussion:

The fourth panel focused on the overall economic impact within the last 5-7 years. The panelists discussed the benefits of Marcellus gas on a broad scale – extending from local to global. The Marcellus shale is referred to as a "world class" resource. Years ago the oil industry predicted that the United States would be importing liquid natural gas (LGN). However, the United States is now producing more gas than Russia, which has led to a price drop from \$13 per MMBtu (million British thermal units) to just under \$2 per MMBtu. The industry response to a surplus is to drive prices higher via export – mostly to the European market, which could have a

geopolitical impact e.g. less dependence on Russian gas. Even with the surplus, the US will not move toward complete energy independence unless gas displaces our oil needs. We have only 4% of the world population and consume 20% of the world oil demand. It was also noted that often when we refer to energy independence we factor in Canadian oil sands and other reserves so while there may not be a need for us to import, there will still be a global impact. This may lead to national policy issues. The price of gasoline in the US is now about \$4/gallon at the pump while in Europe it is over \$10/gallon. The question then becomes whether as a country we are going to step up and do our part to sustain the global environment.

In addition, in terms of energy independence large scale conversion of trucking industry from oil to liquid natural gas requires an extensive new infrastructure involving networks of liquid gas pumps along the nation's major highways.

The moderator asked the panel to discuss the price of gas and how this is related to other renewable technologies, such as solar, wind, etc. One panelist described that the decrease in cost of LNG reduces the use of renewable energy sources, and is not just displacing coal and oil. Therefore, it's important to distinguish between oil and gas markets in the US. Gas does impact solar and wind. We have gas on gas competition in the US. It is worth considering exporting our LNG, as Europe is \$10-12 and Japan is at \$20 (\$2 in US). We will see impacts on our energy bills and we do respond to this. This past winter was mild. Companies who use natural gas are expanding those operations. This is helping the economy expand because natural gas is at such a low price. Our petrochemical industry has traditionally been a natural gas-based one. Ethane extraction has become profitable due to the low natural gas prices. There are secondary effects that are improving the economy. Because of the shift from dry gas to wet gas, there is a shifting of the industry to western PA.

The next question concerned other discoveries of gas throughout the world and whether these reserves will further increase drilling in the next few years. It is unlikely however that the US shale gas phenomenon can be mirrored elsewhere such as the Eastern Mediterranean region or Mozambique. One reason is that in the US, landowners own the mineral rights while in most other countries, mineral rights are owned by the government. Therefore, profits go to the government and the landowners get no benefit. So this is a tough sell to get the landowners to approve drilling. They get no benefits but all of the problems. Here, shale gas was not driven by the large companies, but by small groups of independent companies and big gas companies came in later. This provided incentives for venture capitalists/entrepreneurs to make millions of dollars. This opportunity does not exist everywhere in the world. A member of the audience asked why the state of Pennsylvania gives large tax breaks. The panel explained that this is done in order to drive economic growth and attract industry and business to a state. Some states have done a better job at this than others. But sustaining growth and retaining businesses is another issue. Some states have initiated "severance" taxes as a way to offset the economic loss. Act 13 in Pennsylvania establishes "legacy funds."

The moderator followed up and asked who owned the mineral rights in Pennsylvania. The panelists explained that this varies county by county.

Wrap-up Discussion

1. Theme 1 – Need for more baseline data. Even more interesting is the legitimacy of that

data, and can the public obtain that data.

2. Theme 2 – Economic tradeoffs, opportunity costs, distribution of benefits/costs. Does money stay in the community?
3. Theme 3 – How to define risk.
4. Theme 4 – Long-term trends in energy.
5. Theme 5 – How does all this global activity affect a place like Bradford County and how can we plan for the future. How to measure risk to individuals.

Moderator: David Casagrande, Associate Professor, Department of Sociology and Anthropology/Environmental Initiative

Discussion:

The first topic of discussion during the wrap up session focused on weighing the risks to individuals and local communities. The panelists explained that society is willing to accept risk if the phenomenon is perceived to be for the greater good. It is important to note however, that there is no permanent environmental protection. To this day, panelists agreed that there is no clear understanding of all the possible impacts that could result from the Marcellus Shale development. Pennsylvania has been at the forefront of shale gas development. Benefits are evident but costs are harder to define. Most of the burden is borne by the rural counties and municipalities while the benefits of gas extraction are enjoyed more by urban areas. Communities are dealing with current issues and can't spend time planning for the future. Not all states within the Marcellus region are sharing in this risk. New York and New Jersey still have a moratorium on drilling and are keeping a close eye on how PA handles risk, long term impact, and economic benefits of drilling. Pennsylvania has decided to move ahead but doesn't necessarily understand all the risks."

Panelists agreed that it is important to balance what is important for our society to lead quality lives while remaining cognizant of industry needs. Specifically, we cannot assume that the shale gas industry will self-regulate so investments should be made to be sure that regulatory policies are in place. Pennsylvania is experimenting with regulations, and as researchers we can learn a lot from this. This creates an opportunity for research universities.

Panelists were then asked to expand on the concept of baseline data. They indicated that land areas remain which have not yet begun drilling, and these can be used to provide baseline data. However, most areas have already started drilling and this does not allow us to understand the conditions which existed prior to drilling. If drilling continues, the new baseline then becomes the current state of affairs. With regard to public health, there is no longer an opportunity to gather baseline data. There is no way to access data on morbidity and mortality. We may need to gather this data in other states, such as Ohio, where baseline studies are still possible in areas where drilling has not begun and will not be fully developed for a while. In terms of immediate impacts, this requires timely research gathering baseline and comparative data on air quality and surface water.

One audience concern which surfaced during the wrap up session was whether anyone was looking at long-term impact to water resources. Because fracking uses tremendous amounts of water, companies are looking at ways to recycle the flow-back water. Recycling is key to moving

forward. One way to incentivize companies to recycle water, would be to institute a hefty fee for flow-back water removal. This fee would also cover cost of water treatment and recycling.

Finally with regard to global activity and local risk, panelists noted that each shale deposit, whether it is Marcellus or Utica, is so different, it remains hard to assess. How each well is worked varies almost from one site to the next, different chemicals are used to frack, etc. This makes it more difficult to assess global risk other than economic risk or impact.

Appendix IV. Spring Marcellus Shale Panel Announcement



The Environmental Initiative, the P.C. Rossin College of Engineering and Applied Science, the Cluster for Sustainable Development, and the Office of Vice President and Associate Provost for Research and Graduate Studies

are proud to announce the second panel on Marcellus Shale

Today's panel discussion will focus on social science, policy, and economic issues surrounding Marcellus Shale development in Pennsylvania. The panel will consist of experts from academia, government, agencies, consulting firms and industry and is open to the Lehigh University Community and guests. Panel members will discuss issues related to the topics and questions identified below and the audience is encouraged to participate in the discussion. This is the second of two planned panels on Marcellus Shale issues.

Date: Wednesday, April 18th, 2012

Location: Packard Laboratory, Room 101

Agenda

- 3:00 – 3:30. Introductions and 5 minute presentations from panelists regarding their specific work and how it applies to the topic in the broadest sense.
- 3:30 – 4:00. Question/Topic 1. What are the broader geo-political impacts of shale gas development, not only in the Marcellus but globally. What role will the Marcellus play in U.S. energy policy? What impact does shale gas development have on emerging alternative energy sources and technology?
- 4:00 – 4:30. Question/Topic 2. What are the realities and pressures of resource development on local and state government infrastructure and economies? What is the appropriate scale to regulate the industry and generate revenue? How does Pennsylvania's approach compare to those of other states?
- 4:30 – 5:00. Question/Topic 3. What are the impacts on public health, including protection of drinking water resources? How is public health currently being managed, what is the proper scale to manage it, and is there a better overall strategy that we should be considering?
- 5:00 – 5:30. Question/Topic 4. What are the impacts of shale gas development on communities? What are the effects on social problems including economic restructuring, demographic changes, family structure and income inequality?
- 5:30 – 6:00. Wrap up and question/answers from the audience.

Appendix V. Lehigh University News Article by Kurt Pfitzer

"The Many and Varied Impacts of Marcellus Shale Development"

Lehigh University News Article, Kurt Pfitzer, April 20, 2012

The development of the massive natural gas deposits in the Marcellus Formation in the eastern United States is affecting rural communities, public health, the environment, and national and local economies. That was the consensus reached by six health and energy experts, economists and government officials at a three-hour panel discussion April 18 in Packard Lab Auditorium. The event, “Marcellus Shale Development: Communities, People, Health, Economics,” was sponsored by the Environmental Initiative (EI), the P.C. Rossin College of Engineering and Applied Science, the Cluster for Sustainable Development, and the office of research and graduate studies. The goal of the discussion, said EI co-director Frank Pazzaglia, was to promote research collaborations between Lehigh faculty and students and outside experts. Panelists discussed the impact of Marcellus shale development on public health and the environment, on local communities and their economies and infrastructure, and on geopolitics and U.S. energy policy. A related event—an address on the impact of Marcellus Shale development by Michael Krancer, Secretary of the Pennsylvania Department of Environmental Protection—was sponsored by the EI today. The Marcellus Shale, one of the world’s largest underground gas deposits, is estimated to contain 250 to 500 trillion cubic feet of natural gas. About 60 percent of the land area of Pennsylvania is contained within the Marcellus Formation. In 2010, the state’s Department of Environmental Protection issued 3,314 drilling permits for Marcellus Shale.

A boom that few expected

The development of Marcellus Shale gas deposits has been compared to the California Gold Rush and the construction of the Alaska pipeline in the 1970s. The pace of development in the last six years, and the use of hydraulic fracturing and other drilling techniques that extract gas more efficiently, raise multiple concerns, panelists said. “In 2008, we were hit by a freight train,” said Ray Stolinas, director of the Bradford County Office of Community Planning and Grants. “Our county has the most drilled wells in the state with 2,000 drilling permits issued. The courthouse is inundated with title seekers. Hotels are filled and apartment rents have tripled. “On the other hand, Bradford County has one of the lowest unemployment rates in Pennsylvania.” The scale of activity has caught communities and regulators flatfooted, panelists said. “There is not yet much peer-reviewed literature on the risks of Marcellus Shale to the environment or on its potential to disrupt communities,” said Sheila Olmstead, a research fellow with Resources for the Future. The environmental risks, panelists said, include contamination of underground drinking water supplies, wetlands and parks. Potential community disruptions include increased traffic and noise, decreased tourism, greater demands on police and emergency personnel, unequal distribution of wealth from resource development, and population fluctuations caused by arrivals and departures of large numbers of workers.

Edward Chow, a senior fellow in the Energy and National Security Program at the Center for Strategic and International Studies, said the development of Marcellus Shale gas has had a global

impact. “Five to seven years ago, the U.S. was expecting to import liquefied natural gas,” said Chow. “Now it’s producing more natural gas than Russia. And the price of gas is about \$2 per 1,000 cubic feet, down from \$13.” Other panelists were Diane McLaughlin, professor of rural sociology and demography at Penn State University; Jill K. Kriesky, senior project coordinator at the University of Pittsburgh’s Graduate School of Public Health; and Andrew Stewart, chief of litigation and audit policy in the U.S. Environmental Protection Agency’s Office of Civil Enforcement.

The discussion was moderated by Thomas Hyclak, professor of economics; Henri Barkey, professor of international relations; Sharon Friedman, professor of journalism and communication; and Alex Bodzin, associate professor of education.

Article can be accessed online at: www.lehigh.edu/news/archive.

Appendix VI. Marcellus Field Trip Report

Lehigh University sponsored a field trip to Bradford and Lycoming Counties, Pennsylvania on April 30, 2012, to gain a more complete understanding of the scale of drilling, transportation, infrastructure, community, and environmental impacts. The tour was arranged and sponsored through the Marcellus Center for Outreach and Research (MCOR) at Penn State University. Our point of contact was Carol A. Loveland, head of the Energy Development/Special Projects for the Penn State Extension office in Lycoming County. Our field trip leader was Jim Ladlee of MCOR. The industry host was Mr. Mike Narcavage of Chesapeake Energy who granted access to an active drilling rig and a completed well production facility.

The trip was attended by 20 faculty and research scientists (identified below). The itinerary included three stops and a narrated tour. Stop 1 was at a drilling platform near Towanda, Bradford County, where we were able to tour the drilling rig and watch a crew prepare for directional drilling. Spirited conversation regarding the technical aspects of the drilling, safety, industrial footprint, and economy occurred in small groups and with the rig personnel. Chesapeake was very gracious in accommodating excellent access to rig operations and were happy to answer any and all questions.

Stop 2 followed in southern Bradford County where a completed well production facility is now in operation. Conversation and learning here centered on issues of water, namely the water needed to develop a well, and then the long history of produced water and its ultimate fate in recycling or disposal facilities. At this stop, participants were beginning to form a picture of magnitude of water transportation both on and off drilling sites.

The trip then took a meandering path through Bradford, Sullivan, and Lycoming counties en-route to Williamsport. Along the way discussions continued regarding road infrastructure and the ubiquitous hauling of water by tank truck.

Our destination and Stop 3 in Williamsport was arranged and hosted by Lehigh Alumn Keith Kuzio, President and CEO of Larson Design Group (LDG). At LDG corporate headquarters we first participated in a presentation by Kurt Hausammann, the chief planner for Lycoming County. Discussion centered primarily on the economic, social, and community impacts of the Marcellus energy boom for a community like Williamsport. That discussion was followed by a tour of the TARM waste water recycling facility by Mr. Kuzio. TARM is a leading innovator in the recycling of drilling and produced water from Marcellus Shale gas wells. Their innovation has lead to reduced pressure on water resources for drilling and the need for deep injection disposal. However, their centralized facility in Williamsport necessitates truck transport of water to and from the facility. They are taking steps to reduce the impact of truck traffic by coordinating times of delivery to not coincide with peak commuting for the greater Williamsport area.

Overall the trip was a success in meeting its goals to illustrate the scale and impact of Marcellus development in north-central Pennsylvania. One tangible result of the trip is a research proposal collaboration between Neid, Pazzaglia, and Bocchini that was inspired by a discussion that Neid and Pazzaglia had with the Chesapeake drillers.

Appendix VII. Report of the Multi-State Marcellus Shale Research Conference

The Multi-State Marcellus Shale Research Conference took place in Pittsburgh, PA on May 30-31, 2012. The goal of this conference was to build networks among researchers interested in Marcellus shale development impacts and identify research priorities. The conference was organized by Cornell University, Penn State University and West Virginia University. It was structured around four working group themes: changing communities, changing landscape, changing environment, and policy environment. Working groups in the four topic areas were charged with prioritizing research areas. Keynote speakers and panelists were also featured. The conference was attended by approximately 100 government, private-industry and academic researchers from Pennsylvania, New York, Ohio, West Virginia and other states.

Attendees from Lehigh University included David Casagrande and Roxann Steelman (masters degree candidate in Environmental Policy and Design). Our goal was to follow up in more detail the research themes on Marcellus shale gas impacts that were raised during the Lehigh panel discussions and to identify potential research areas.

General themes emerging from the conference include:

1. Public and private consumption of almost any Marcellus-related research results is immediate and politically charged. This creates challenges as well as outstanding opportunities for researchers. Neighboring states yet to experience the rapid pace of development unique to Pennsylvania are particularly interested in results from research on impacts.
2. Air quality is a major area for future research, especially related to greenhouse gas emissions.
3. Water monitoring has been uncoordinated and lacks scientifically-based prioritization. Monitors range from private citizen groups to state agencies, each with unique agendas.
4. Positive benefits are mostly economic, and include the ability for local landowners who receive payments to channel investments into sectors of the economy like personal farms or local businesses unrelated to shale. Estimates of local people directly employed by the industry are unclear. Local employment from industries supporting shale development is likely very important, but is also poorly documented.
6. Negative social impacts include housing shortages, exacerbation of political and economic divisiveness within communities, human physical and mental health effects, and stress to local infrastructure, social services, and emergency response.
7. Most evidence on positive and negative impacts is anecdotal. A serious remaining challenge is to find research methods that directly link the causality of economic and non-economic social impacts to shale gas development.
8. Research shortcomings include calculating economic opportunity costs, quantifying local employment effects, cross-community comparisons of health and quality of life, and identifying drivers of political support or opposition to shale development. Most notable is

the lack of a comprehensive study that links shale gas development to human health, although Geisinger Health System is beginning one study.

9. An overarching and re-occurring theme, although difficult to operationalize for research, is how shale revenues can be used to diversify economies. There is a need to capture more midstream and downstream economic value from the industry to provide more local benefits and to distribute benefits between urban and rural areas more equitably.
10. Social science research and the application of results are value-laden. For example, an advocate for the rural poor might argue that tripling of rents in a county is a negative effect. An economist or developer would consider this positive. This makes interdisciplinary research design and communication of results problematic.
11. Some counties and communities have been heavily studied, leading to fatigue of residents. Others are relatively unstudied. There is a need for inter-institutional coordination and information sharing to prioritize geographic location of research and share data.
12. Some researchers have developed strong relationships with communities and industry, but lack topical expertise to ask additional questions. This also points to a need for collaboration.
13. Some research efforts are redundant, while important topics are not being addressed, which also points to a need for coordination.
14. There is a need to synthesize research to enable meta-level analyses. This would facilitate a more complex understanding of relationships between social and natural processes not visible within the domains of individual disciplines. In addition, there is a need to analyze cumulative effects of shale development. Meta analyses are complicated by widely varying research methods and geographic scales. Social science approaches in particular can range from qualitative in-depth ethnography of a community to large-scale quantitative survey methods.

Plans for action included:

1. Short-term: developing a 'meta-knowledge base' that would include only general information about research projects, such as brief summaries of the goal, scale, methods, potential users, location of research, funding source, and contact information, but not actual data.
2. Long-term: Developing a meta-database that includes existing data to allow for meta-analysis.
3. Develop a social impact white paper that focuses on the scale of community.
4. Enhance existing online literature database at Bucknell University.
5. Target the National Institutes of Health for funding on physical and mental health research.
6. Continue to network among institutions to develop individual research ideas.

Recommended actions for Lehigh

Lehigh conference attendees consulted with other faculty and staff to recommend the following actions for Lehigh:

1. Lehigh University should take the lead in developing and hosting the 'meta-knowledge base'.
2. Bloomsburg University is exploring developing a meta-database in consultation with other institutions including Lehigh. Lehigh University should also have an internal discussion about this opportunity, including increased involvement with faculty in computer science.
3. Lehigh personnel made extensive contacts at the conference and were invited to meet further with researchers from Bucknell and Bloomsburg Universities to discuss research development. We recommend hosting a workshop at Lehigh.
4. Subsequent to Lehigh's spring panel and prior to this conference, several faculty at Lehigh began developing a GIS database to evaluate social impacts and apply quasi-experimental methods to identify causality. The discussion at this conference clearly indicated a need for this analysis and that the chosen methodology is appropriate. The team should pursue long-term funding for this research.