Here Comes the Boom: shale gas, landscapes and an ecological planning imperative

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Introduction

Shale gas development in the United States is destined to bring about major long-term changes to the rural landscape. While popular media regularly reports on disputes over the role of hydraulic fracturing, "fracking", on domestic water supplies, we believe that the more significant impacts on landscapes and communities lie in the less noted but nevertheless extensive footprint of land use changes that accompany this massive economic development. Four land use conversion topics faced by communities in north-central Pennsylvania were examined in order to scope out fruitful directions for more comprehensive study. First we projected, based on the locations of existing road and pipeline infrastructure, the areal land use change that would result from access roads and pipelines to support projections of gas development developed by the Nature Conservancy. Next we investigated the watershed-scale impacts of those changes in land cover and using TR-55 estimated the likely downstream flooding at the mouth of a significant tributary of the Susquehanna River. Recognizing the importance of the tourism industry in Pennsylvania we then developed a regression model of visual quality for the region, based on land use and scenic attributes, and estimated the impact on visual quality of the same projected land use changes. Finally we examined the potential of this same landscape as a source of renewable energy and then the implications of reorganizing gas development to optimize land use change toward a sustainable energy future. The results indicate that impacts on timber and habitat resources are substantial as a result of the fragmentation resulting from development. Further, the potential flood effects are significant and can only be partly moderated by the application of best management practices for land restoration. The impacts on visual quality are dispersed and thus may result in gradual erosion of scenic benefits and, regrettably, go unnoticed. The potential for energy development is high but the opportunity costs of planning for future development probably far outweigh the net present value of the future benefits.

Background

The pace, scale and distribution of unconventional natural gas extraction in North America demands a concerted landscape ecological planning response. In the mid-Atlantic, this imperative has arisen in Pennsylvania, New York, Ohio and West Virginia as communities manage the feverish pace of development associated with the Marcellus Shale natural gas deposit. The applications of new technology to extract shale gas and the wide distribution of shale deposits, driven by national ideologies of foreign oil independence and job creation suggest we have only witnessed the early days of what is sure to be a dominant activity on the landscape. While many of the regions witnessing this new energy 'boom' are the same places where oil and coal extraction were carried out in previous years, the organization and structure of gas extraction is categorically different. Shale deposits and the associated extraction activities are relatively dispersed. While the individual site footprint of gas extraction is not as visibly shocking and demonstrative as mountain top removal, the thousands of well pads spanning the landscape generate thousands of acres of connecting infrastructure impacts. These impacts are not monolithic and highly related to the specific extraction task and geographic context. Furthermore, workers in this energy revolution will not be housed in coal towns near to pits and mines. They are far fewer in number, widely dispersed, and highly mobile. The complexities of developing this energy resource necessitate an equally complex landscape ecological planning strategy to address its substantial natural and cultural impacts. This paper details and describes our recent efforts to engage these complex issues, relying on primary research in Pennsylvania.

The emergence of this windfall of energy development comes at a critical time for the US and global economies, but has characteristics distinct from the timber, oil and coal booms that preceded it. The nature of this boom presents special challenges for land-use planning in the face of minimally regulated development. The current boom is the result of new technologies, precision horizontal drilling and hydraulic fracturing. Key to exploiting these resources is a highly capitalized industry with little local participation, and a fast-moving installation of extensive infrastructure that provides little in the way of ongoing jobs or other expenditures beyond maintenance—the industry appears, disrupts, and is gone. The impacts vary widely, influenced by both the process of extraction and the specific spatial context and while individually these activities small from an environmental review perspective [2], they are numerically and spatially much more extensive than the earlier energy boom. The speed of development coupled with the localized scale and temporary nature of major disruptions provides limited opportunities to intervene and negotiate to achieve community and environmental benefits.

There are already barriers to planned development in rural areas between major cities. Sparse population has lost its "clout" with politicians in state assemblies, while lobbying campaigns of the gas industry strive to achieve relaxed regulation of its activities. Cultural traditions, such as an emphasis on individuals' freedom to determine the future of their land or community, can impede regional and local planning. Few municipalities have any form of zoning control. The Pennsylvania Governor has sought (so far unsuccessfully) to withhold compensatory payments of gas industry impact fees from municipalities whose zoning restricts gas development. Authors have long pointed to the challenges energy booms bring to rural communities (Gilmore, 1976; Perry, 2012). Simply, shale gas development is a high paced, extensive and relies on a larger footprint than perceived and its impacts vary both spatially and temporally not only because of the process of extraction, but also because of the natural and cultural contexts where it takes place.

Shale gas extraction is transforming not only the physical environment of energy decisions in North America but also the ideas that shape our thinking about energy investment and development. Although there are few government-inspired plans to achieve this, the opportunity afforded by this energy boom could still be the key to transforming an inherently ineffective mode of rural economic development into a new adaptive and sustainable landscape. We argue that the means to achieve this lies in informing and empowering individuals and communities to understand their central role in shaping the development of the landscape around them. To date

[2] The Pan-European Biological and Landscape Diversity Strategy, that was endorsed by 54 countries in the UN-ECE region on 25 October 1995, provides for the establishment by 2005 of the Pan-European Ecological Network.

these groups have neither understood their prime role, nor have had access to the information needed to help them make decisions. A landscape ecological planning strategy to achieve future sustainability requires a broader understanding of the shaping roles played by legislation vs. individual landowner decisions, and the necessity to articulate individual and community landscape values alongside the powerful rhetoric of energy independence and job creation.

About Marcellus Shale

The Marcellus shale is an organic rich shale underlying much of Pennsylvania and parts of New York, Ohio West Virginia and Maryland (Figure 1a). Named for a surface outcrop in Marcellus, New York, the formation dips to nearly 9,000 feet deep in southern Pennsylvania. Ranging up to 900 feet thick, the deposit varies between 1% and 11% organic content. While occurring as oil and "wet" gas (including higher order hydrocarbons such as ethane and butane suitable for plastics) in the west, the more thermally mature parts of the formation to the east yield primarily methane gas. The existence of the gas has been known for many years, but attempts to access the resource by conventional drilling were proven inefficient. The development of horizontal drilling and application of a technique called slick-water hydraulic fracturing (now widely known as "fracking") elsewhere showed that development of shale gases could be made economically viable. Estimates for how much extractable shale gas there is in the Marcellus deposit vary widely. In 2002 the USGS estimated the Marcellus contained 1.9 trillion cubic feet (TCF) and more recently Terry Engelder revised that estimate to 363 TCF, still enough to supply the entire US energy demand for fourteen years. Range Resources, a Texas company, drilled the first unconventional Marcellus well in 2007.

The economic benefits of development of the Marcellus are considerable, Engelder's numbers equating to $1.25 trillion at a market price of $4.00 per thousand cubic feet. Typical royalty rates of 15-18% landowners estimate $250 billion in gas royalty checks. The contribution to national energy security has also been used to argue for the imperative for immediate Marcellus extraction. This combined with other energy development in the US contribute to projections of the US reaching energy self-sufficiency. Evidence of the boom in fossil energy availability, of which natural gas is one facet, is seen in the plunge in natural gas prices that occurred between 2009 and 2013. This is a complex resource with an equally complex future. Utica black shale underlies the Marcellus and includes oil resources as well as natural gas. Moreover, drilling must respond to market demand and profit margins, so active drilling has currently shifted to those areas in Ohio and western Pennsylvania seeking the higher-value oil and "wet" gas.

Framing the energy benefits there are a range of known and unknown environmental impacts, some much publicized but localized such as instances of groundwater contamination, others perhaps less evident but potentially of much broader and long-term impact. The latter are the subject of this paper. In 1859 the Drake oil well in Titusville, Pennsylvania, was the birthplace of the oil industry in the USA. Since then, more than 350,000 oil and gas wells have been drilled in Pennsylvania. As of December 2012, 6012 of those are *unconventional* wells targeting gas in the Marcellus and Utica formations (Figure 1b). However, by comparison with the "footprint" of a conventional well, unconventional gas development is more dispersed and each site exerts a significantly higher toll in terms of land clearing, site compaction, infrastructure development and fresh water usage.

To date development has been most vigorous in the northeast and southwest parts of Pennsylvania. The resources have proven to be highly productive in these areas. Major infrastructure is in place regionally, but new pipelines are needed to bring the gas to market. For example, a new interstate pipeline, the MARC-1, is under construction running SW-NE. The studies reported below take that new infrastructure into account.

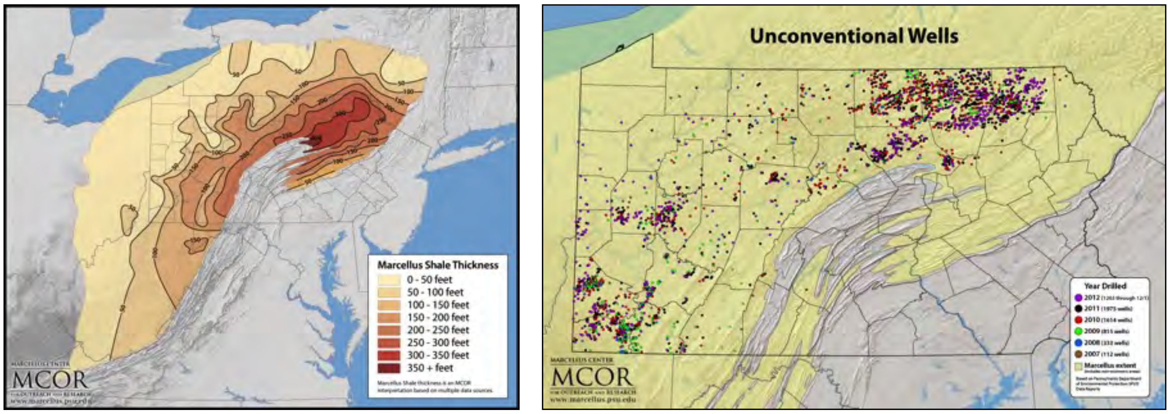

Figure 1. (a) Extent of Marcellus shale. (b) Unconventional wells as of December 1, 2012 (see MCOR 2012).

Despite the potential risks, natural gas development is exempted from key parts of the federal regulations normally applied to major development projects. Exemptions include portions of the National Environmental Policy Act (1969), Clean Air Act (1970), Clean Water Act (1972), and Safe Drinking Water Act (1974). Instead the burden of regulation falls on the individual states so that exploration and drilling in Pennsylvania is administered via the Bureau of Oil and Gas in the Pennsylvania Department of Environmental Protection. At the state level the major controlling law is the Pennsylvania Public Utility Commission Act 13 (2012), which enacts environmental standards such as setback requirements for unconventional gas development. While the federal laws regulated by the state require a range of important environmental protections, they affect a relatively small proportion of Pennsylvania's landscape, PA Act 13 does essentially exclude drilling from communities through the provision of set-backs to buildings and water bodies. Figure 2 (a) illustrates the protections provided by Act 13 in the small town of Laporte, Sullivan County, PA.

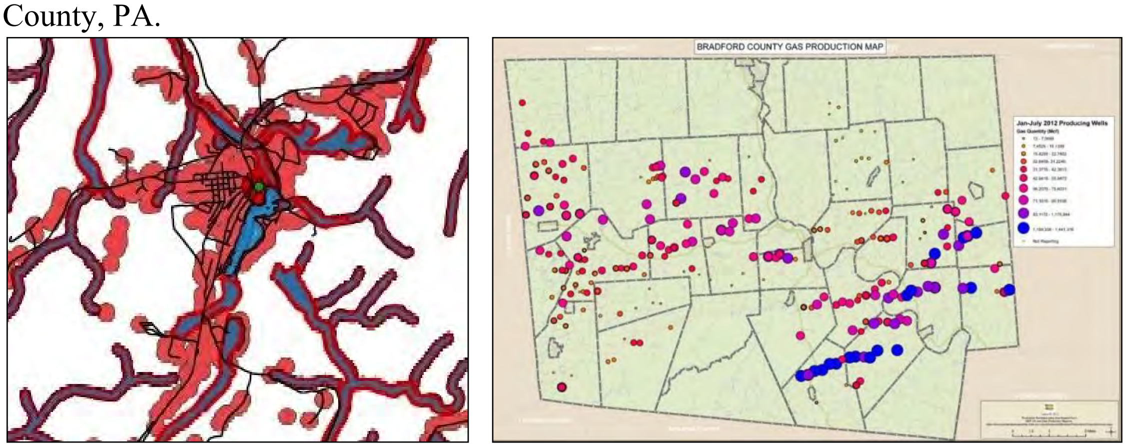

Figure 2. (a) PA Act 13 set-backs. (b) Unconventional gas wells in Bradford County, PA

Set against these protections is the primacy of mineral rights over surface rights in land use determinations. In places where surface and mineral rights are severed, oil and gas law requires that landowners provide access for the development of mineral resources, which may include the construction of drilling pads, access roads, water impoundments and pipeline access corridors. The optimal location of gas wells is driven by underlying geology so that, as seen in Figure 2 (b), the location of well pads will follow paths of preferential access to drilling units that are established by the mineral rights owners or lessees and may ignore surface landscape features.

Goals and Objectives

Planning for Marcellus Shale might be classified a "wicked problem" in that it is a unique situation; not informed by any precedent; and there is no identifiable set of solutions (Balassiano, 2011; Rittel and Webber, 1973). Rather than attempt to address the entire scope of Marcellus-related issues, we instead have undertaken four critical analyses that emerge from the single issue of pipeline placement in order to understand and interpret how one network of relationships has implications across a complex system of resource extraction-driven landscape changes. This work was conducted by the authors working with an advanced landscape design studio and also contributes to the development of a tool set intended to help inform the public about the role of land-use design and planning in this complex, fast-moving and un-planned energy boom.

Methods

Our approach generally follows the Geodesign framework described by Steinitz (2012). We conducted initial scoping exercises to identify salient land planning issues in the region of Sullivan County, Pennsylvania. The county is the second smallest, by population, in the state, encompassing 450 square miles split 60:40 between forest cover and rural farmland. Our first analysis documents the critical impacts of land cover conversion associated with gas pads and pipeline development. We use a projection of Marcellus gas activity provided by the Nature Conservancy (Johnson 2010) to estimate the location of proposed well pads under the Conservancy's fully developed scenario. While individual impacts might be viewed as contained, the repetition of impacts in numerous drilling locations and the linear extent of pipelines in a densely connected network accumulate to significant acreages of land conversion. We then investigate watershed scale issues of stormwater management and flooding, little addressed by the current environmental conservation efforts targeting methane gas pollution of drinking water. Our hydrological projections estimate the effects of the pad and pipeline developments identified above and project the downstream flooding implications of the resulting change in surface cover. We also examine the mitigating effects of applying the best management practices to the cleared areas.

The third analysis develops a model of landscape visual quality as a surrogate for the range of cultural landscape issues that would need to be considered in comprehensive planning. The model, based on existing landscape conditions, is used to evaluate the impact of the fully developed projection of Marcellus gas activity provided by the Nature Conservancy vs the current conditions in the *Endless Mountains* of eastern Pennsylvania. Our final analysis focuses on longer-term land-use decisions, sustainability and the potential of renewable energy resource development as antidotes to post-boom economic decline. In this case the eventual, post-gas, landscape infrastructure is optimized for the location of wind farms, solar energy and biomass generation for biofuels. In this scenario we examine design and planning responses where current natural gas development anticipates and funds future renewable energy infrastructure, avoiding redundancy and offering long-term benefits driven by longest-term land use changes.

Results

All of the following analyses take a single set of assumptions for future well-pad location. The Nature Conservancy has projected probable well locations using three intensity models, low, moderate and high. We used high estimates for all of our analyses (see Johnson 2010).

Pipeline land use change

Gas wells are of little use unless the gas can be transported and sold and pipelines are the most economical means of conveyance. "Gathering lines" connect to the well head and transport gas to larger interstate pipeline systems that connect with major gas markets. While pipeline systems themselves are complex with compressor stations and other infrastructure, for this analysis we considered only the impact of the pipeline and its surface right of way. Using the projected well-pad locations and taking into account a new interstate pipeline running N-S through Sullivan County, three pipeline location scenarios were developed:

1. Shortest-distance from well-head to interstate pipeline
2. Industry-preferred—minimizing property lines crossed
3. Conservation—minimizing habitat fragmentation, especially forest areas

These three alternatives are simplified, but they address important design issues. In scenario 1 the only formal controls on placement are the needs to protect wetlands and water bodies. Otherwise, the requirement of oil and gas laws to allow access to the resource means that landowners have limited influence on location, which may cut through forests and across agricultural fields. Scenario 2 uses property lines as a surrogate for the challenges a pipeline company may face in minimizing land leasing costs, *i.e.,* the more owners, the higher the cost. Scenario 3 ignores property boundary issues but is designed to avoid areas of high habitat value, in most cases, minimizing divisions of continuous blocks of forest, a major habitat, tourism and timber resource in Sullivan County.

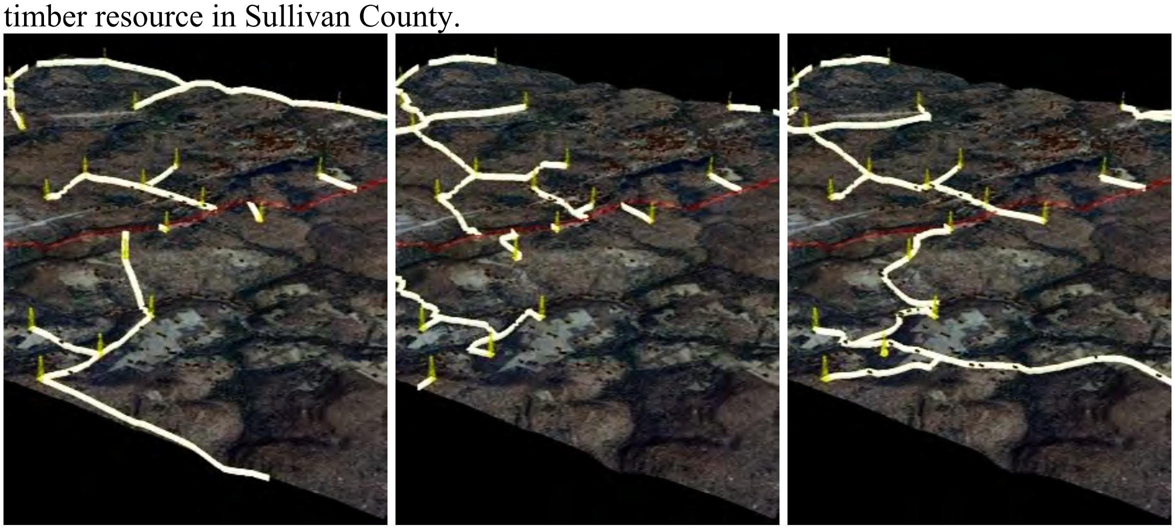

Figure 3: Pipeline placement scenarios: Shortest-distance, Market-preferred, Conservation

Shortest-distance	Market-preferred	Conservation
158 Stream crossings 18 Homes displaced 84 Wetlands impacted 1,648 Properties impacted 0.56 Miles per well	148 Stream crossings 3 Homes displaced 49 Wetlands impacted 1,248 Properties impacted 0.63 Miles per well	124 Stream crossings 10 Homes displaced 19 Wetlands impacted 2,198 Properties impacted 0.66 Miles per well

Table 1: Impacts of alternative pipeline scenarios

Each existing well in Sullivan County requires, on average, 1.06 miles of pipeline. The right-of-way for protecting pipelines varies from 75 to 100 feet. Use of the right of way is restricted to annual crops once constructed, and much of the land impacted in unsuitable for agriculture due to various landscape factors. One mile of pipeline (100 feet wide) changes the land use of 13 acres of land for at least a sixty-year window while gas development continues. Our analyses above indicate the important role of design in minimizing quality and quantity of landscape change, but the land use change can become a driver for down the line impacts, including increased stormwater run-off and impacts on scenic beauty, among others. If planned appropriately infrastructure needs might provide opportunities for new land uses, which we investigate in the next three analyses.

Increased run-off and downstream impacts

The Lake Mokoma watershed contributes to the Loyalsock Creek watershed. Loyalsock Creek is a major tributary of the Susquehanna River. Montoursville, PA, at the confluence, has suffered major flooding in recent storm events and is vulnerable to increased run-off in the Loyalsock watershed. For this analysis the performance of sub-watersheds were modeled using TR-55 under three conditions: (1) current conditions, (2) the Nature Conservancy projections of gas development using customary minimal treatment of pipeline right of ways and (3) the same projections assuming best management practices for minimizing run-off. Extrapolating typical sub-watershed behavior to the entire watershed resulted in estimates of moderately increased run-off. Interestingly, applying BMPs reduced peak discharge, noticeably.

Visual quality changes

Our visual quality analysis was completed in several phases. First, photos from sampled sites throughout Sullivan County were scored by various groups in order qualitatively rank the visual quality of photos. Second, photos were analyzed for their composite elements in order to test correlation between coverage in the photo and visual quality (Figure 4). Here, photos were coded by key land use categories visible in the photo, such as forested, recreation and industrial and compared to the visual quality scores in phase one, using the approach of Shafer and Brush (1976). Third, photo locations were georeferenced and photo scores were compared to the existing land cover, taken from the 2006 NLCD. Using this analysis, we then projected potential future changes to visual quality for Sullivan County, based on changes in land use relying on the high impact estimates from the Nature Conservancy, including pipleline development. Recognizing the limitations of such a model to encapsulate the nuanced and important details of visual quality, we conclude that an approach like this is useful for identifying key spatial zones wherein substantial changes to land use (for infrastructure) can result in changes to the way in which these places are perceived.

Renewable energy potential

Our final analysis investigated the spatial and temporal dimensions of Marcellus extraction, not only as a resource goal, but as part of a larger and potentially renewable energy agenda. Essentially, we looked at the ways in which a full suite of energy decisions could play out spatially and temporally for a section of Sullivan County. At each step, landscape, energy and cost variables were compared. Figure 5 illustrates some of the ways we visualized and analyzed these decisions. There are a number of nuanced conclusions we will derive from these studies, but our key conclusions are: (1) landowners need broader context and information when evaluating, not just whether to lease, but how to lease in a way that reflects their key intersts and (2) energy decisions, while traditionally focused on fossil fuels **or** renewables, should be focused on leverage points to shift from fossil fuels **to** renewables. Therefore, the Marcellus resource questions no longer are focused on how much is there, but what can Marcellus provide on the path to sustainable energy development.

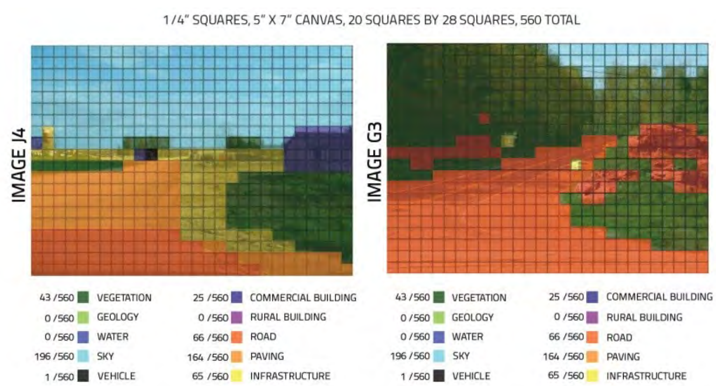

Figure 4: Photo analysis for visual elements.

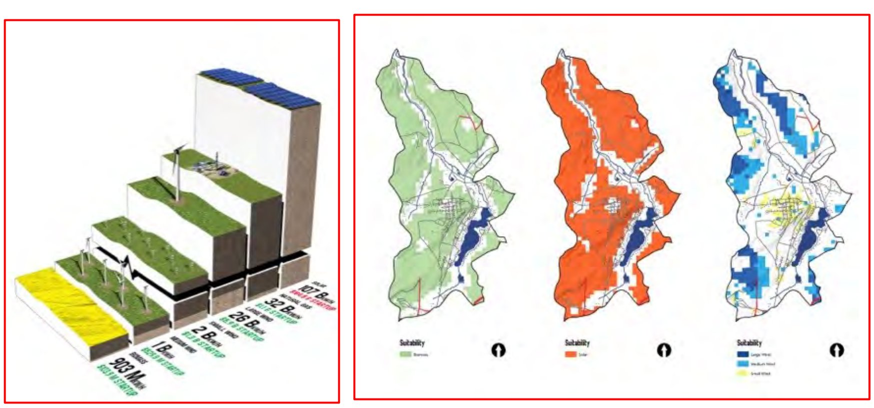

Figure 5: Energy potential and land-use potential in Lake Mocoma watershed

Conclusions

We conclude that while much public attention has addressed fracking technologies and issues associated with well pad construction, the potential landscape impacts from changes in transportation infrastructure and the development of required pipelines will be substantially greater, transforming landscapes largely perceived to be 'natural'—the *Pennsylvania Wilds* in the west, the *Endless Mountains* in the east—irrevocably impacting wildlife habitat and fisheries as well as cultural and aesthetic resources. We also recognize a need to develop a complex set of planning tools that addresses the spatio-temporal variability of shale gas development. These tools need to address broad water systems, aesthetic and cultural elements of the landscape, and provide a broader context for resource use.

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References

Balassiano, K. (2011). Tackling "Wicked Problems" in Planning Studio Courses. Journal of Planning Education and Research. 31(4) 449-460.

Drohan, P. J., M. Brittingham, J. Bishop, and K. Yoder. (2012). Early Trends in Landcover Change and Forest Fragmentation Due to Shale-Gas Development in Pennsylvania: A Potential Outcome for the Northcentral Appalachians. Environmental Management 49:1061–1075.

Gilmore, J. S. (1976). "Boom Towns May Hinder Energy Resource Development: Isolated Rural Communities Cannot Handle Sudden Industrialization and Growth without Help". Science (0368-6396), 191, p. 535.

MCOR. (2012). Marcellus Center for Outreach and Research. www.marcellus.psu.edu. Accessed 12/10/2012. http://www.marcellus.psu.edu/images/Marcellus_thickness.gif and http://www.marcellus.psu.edu/images/Wells-all.gif

Rittel, Horst W. J., and Melvin M. Webber. 1973. Dilemmas in the general theory of planning. Policy Science 4: 155-69

Schafft, K. A., Y. Borlu, and L. Glenna. (2013). The Relationship between Marcellus Shale Gas Development in Pennsylvania and Local Perceptions of Risk and Opportunity. Rural Sociology. Article first published online: 18 JAN 2013 DOI: 10.1111/ruso.12004.

Shafer Jr, E.L. and Brush, R.O., 1977. How to measure preferences for photographs of natural landscapes.Landscape Planning., 4: 237–256.

Johnson, N. (2010). Report 1: Marcellus Shale Natural Gas and Wind. Pennsylvania Energy Impacts Assessment. The Nature Conservancy.

www.shalegas.energy.gov/resources/tnc_energy_analysis.pdf (accessed December 12, 2010).