Consideration of Shale Gas Development Impacts in Long-Range Transportation Planning

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ABSTRACT

Through the combination of two technologies—horizontal drilling and hydraulic fracturing- the U.S. natural gas industry has been able to access vast quantities of gas in tight shale formations. Shale gas development has had and will continue to have impacts on the performance of the transportation system—directly through increased heavy truck traffic and freight rail movement to supply equipment, water and chemicals, and indirectly through increased employment, that in turn generates additional travel demand. The purpose of this study was to review the state of the practice for considering shale gas impacts in long-range transportation planning. Recent statewide, metropolitan and rural transportation plans in areas already undergoing shale gas development in Texas, Pennsylvania, West Virginia and Ohio were reviewed. The review showed that qualitative acknowledgement of shale gas impacts on transportation is being included in some recently updated long-range plans, but the level of coverage of this issue varies substantially in different locations. Most long-range plans are not yet addressing shale gas impacts on safety, congestion or transportation-related air pollutant emissions. Key challenges in addressing shale gas transportation impacts include the difficulty of predicting the pace and location of future well locations, and data on the locations of key inputs such as sand, water and chemicals. Further research and guidance is needed to provide a workable framework for transportation planning organizations to meaningfully address shale gas development in the long-range planning process.

INTRODUCTION

Through the combination of two technologies—horizontal drilling and hydraulic fracturing- the U.S. natural gas industry has been able to access vast quantities of gas in tight shale formations. The U.S. Energy Information Administration projects that shale gas production will increase from 5.0 trillion cubic feet in 2010 to 13.6 trillion cubic feet in 2035 (*1*). Shale gas development has had and will continue to have impacts on the performance of the transportation system—directly through increased heavy truck traffic and freight rail movement to supply equipment, water and chemicals, and indirectly through increased employment, that in turn generates additional travel demand.

Shale gas development has the potential to impact several issues considered in statewide and metropolitan transportation planning, including economic vitality, safety, congestion, preservation of the existing transportation system, linking transportation and land use, air quality/transportation conformity, environmental justice and determining the financial resources necessary to meet future transportation system needs. While some regions such as the Barnett Shale in Texas have been producing since 2001 and have some experience with the industry; other locations such as the portions of the Marcellus Shale in Pennsylvania have developed at a rapid rate within a few years. For example, less than 50 well permits were issued in the Marcellus Shale by the Pennsylvania Department of Environmental Protection in 2006, but within five years the annual number of permitted wells increased to 3,512 (*2*). The pace of shale gas development possess a challenge to statewide, regional and local planning to respond to changing conditions.

The purpose of this study was to review the state of the practice for considering shale gas impacts in long-range transportation planning. Statewide, metropolitan and rural transportation plans in areas already undergoing shale gas development in Texas, Pennsylvania, West Virginia and Ohio were reviewed. The review showed that qualitative acknowledgement of shale gas impacts on transportation is being included in some recently updated long-range plans, but the level of coverage of this issue varies substantially in different locations. None of the long-range plans reviewed explicitly incorporated shale gas development in quantitative performance metrics, modeling, or project prioritization. Numerous forecasting issues limit the ability of state Departments of Transportation (DOTs) and Metropolitan Planning Organizations (MPOs) to anticipate shale gas development patterns in sufficient detail to conduct meaningful analysis, including uncertainty in the yields recoverable in different geographic areas, the confidentiality of the industry models used to plan well development and the complexity of the gas well development cycle. The paper concludes with recommendations on research and analysis approaches to overcome these challenges and enhance the evaluation of shale gas transportation impacts in long-range transportation planning.

LITERATURE REVIEW

Given the emerging nature of the unconventional shale gas industry, impacts on the transportation system are just beginning to be understood. This section provides a summary of key findings to date relevant to long-range transportation planning.

Predicting Future Well Locations

To estimate transportation system impacts, it is first necessary to know where gas wells are likely to be developed. Predictions of well locations are complicated by the competitive nature of the energy industry--it would put a firm at a competitive disadvantage to publicly disclose future plans in advance. One approach to work around this lack of information on future development patterns is to apply the concepts of build-out analysis. GIS-based analysis of environmental constraints, regulatory requirements (such as minimum spacing units), existing wells, mineral rights leasing activity and other types of data can be used to define the range of potential well development possible within a specific area. The Nature Conservancy has applied the build-out analysis concept in Tioga County New York to study the habitat fragmentation impacts of the potential approval of HVHF in New York (17). This same approach could be used for transportation impact assessment purposes. Once hypothetical well geographic locations and the locations of water supplies, waste disposal, sand and other inputs are defined, the additional truck traffic on specific routes could be estimated. The truck traffic estimates could in turn be used to conduct planning-level assessments of congestion, safety, and air quality issues in long-range transportation plans.

Truck Trip Generation and Vehicle Miles Traveled

Forecasting truck travel is essential to the consideration of future safety, congestion, road condition and air quality. The National Park Service's Geological Resources Division estimates that the "average" oil and gas well requires 320 to 1,365 truckloads of equipment to bring a well into production (3). As part of a statewide environmental review, the New York State Department of Environmental Conservation (NYSDEC) has developed estimates of truck trip generation for high-volume hydraulic fracturing based on information provided by Independent Oil & Gas Association of New York. NYSDEC estimates that 1,148 heavy truck and 831 light-truck one-way loaded trips are generated per horizontal well (4). A North Dakota study estimated 2,024 truck trips per oil and gas well, with approximately half of the trips consisting of loaded trucks (18). The largest number of heavy trucks is necessary to move water (500 trips one way), assuming 5 million gallons of water used for fracturing per well. Truck trip generation can be substantially reduced if water is provided by pipelines instead of by truck (4).

Horizontal wells result in pronounced peaks during the fracturing phase for the transportation of water when compared with the more consistent timing of trips for vertical wells (4). It is important to note that the fracturing phase can occur multiple times at a single well to increase productivity. Wells in the Barnett Shale have been refractured after 3 to 4 years (3).

Once truck trip generation per well is estimated, substantial uncertainty still exists regarding the origin and destination of each trip. The trip length depends on the location of the well and the purpose of the trip, whether bringing construction equipment, pipeline, sand, water, chemicals or transporting waste. NYSDEC's environmental review suggests water trips would be relatively short and assumed an average trip distance of 24 miles for purposes of assessing mobile source air quality impacts (4). However, other types of trips associated with high-volume hydraulic fracturing (HVHF) such as waste disposal may require long-distance transport. A review of Pennsylvania Department of Environmental Protection (PADEP) waste reports for Bradford County show two primary final disposal sites for brines from wells in the county (5):

- Pennsylvania Brine and Treatment, Inc. in Franklin, PA (approximately 200 miles from Bradford County municipalities such as Troy).
- Waste-Treatment Corporation in Warren, PA (approximately 140 miles from Bradford County municipalities such as Troy).

These distant disposal locations could contribute to substantial vehicle miles traveled impacts at the statewide level. The industry is working to reuse wastewater as much as possible to minimize disposal costs (including transportation). A complicating factor in predicting transportation impacts is that the sources of water, sand and chemicals; and the waste disposal locations are not static. For example, new waste disposal facilities may open over time to meet demand, reducing the length of certain truck trips relative to existing conditions.

One of the more sophisticated efforts to model oil and gas traffic involved forecasting future well locations, defining locations of inputs such as water, sand and pipe, constructing an origin-destination trip table, and the assignment of trucks to specific routes (taking into account distance and travel time) (18).

A 2011 study of the northern tier of Pennsylvania provides a snapshot of the shale gas development impact on the transportation between 2007 and 2010 (6). This area is one of the most rapidly developing shale gas hot spots and the number of wells drilled increased from 4 in 2007 to 767 in 2010. Over this same period, average annual daily traffic in the region rose 12 percent and average annual daily truck traffic increased 22 percent. These impacts were concentration on the major US highways where overall truck traffic volume increased by almost 125 percent (6).

Pavement Condition Impacts

One of the most comprehensive assessments of existing energy development impacts on pavement condition has been conducted for the Texas Department of Transportation (7). This study found a significantly lower pavement condition along routes heavily used by the energy industry when compared to control group routes. Pavement condition was also found to be declining overtime in the 2002 to 2009 period in areas where shale gas development was occurring, such as the Fort Worth District of TxDOT. The research also provides an analysis framework for estimating the remaining life of pavement given certain assumptions about existing pavement condition and the number of future truck trips expected (7).

A 2010 study prepared for the North Dakota Department of Commerce provides an example of forecasting paved and unpaved road damage and repair costs at a regional level (18). The study focused on county and town roads located in 17 oil and gas producing counties of North Dakota. In addition to information on existing drill rig locations, future drill rig locations were estimated based on lease data from the North Dakota Land Department and estimates of the number of wells to be drilled over the next 20 years from the North Dakota Industrial Commission's Oil and Gas Division. Following a traffic analysis, the authors used AASHTO equations and truck equivalent single axle load (ESAL) factors to project the impact on pavement life. An analysis was performed to determine the type road improvements that could be needed as a result of the reduction in pavement life attributable to oil and gas traffic, such as reconstruction of paved routes with the greatest impacts, structural overlays on roads with lower traffic volumes, and renewal/maintenance costs. The conclusion of the study was that $907 million in county and town road repair costs would be caused by the projected level of oil and gas development in North Dakota over the next 20 years.

NYSDEC's environmental review of HVHF contained a qualitative acknowledgement that road damage would be significant and that some, but not all repairs could be addressed through road maintenance agreements with industry (4).

Safety

There is circumstantial evidence of higher crashes on corridors heavily used by energy developments in Texas (7). Similar circumstantial evidence exists in the northern tier of Pennsylvania where region-wide truck crashes increased 61 percent between 2007 and 2010. Total crashes increased 12%, on par with the increase in traffic volumes over this same period (7).

Socioeconomics

Socioeconomic inputs are a key consideration in planning for the future transportation system and are used as inputs into travel demand models in regions with that capability. A study of the economic effects of the Barnett shale in Texas found gas development activity contributed $11.1 billion in annual output and 100,268 jobs in the region in 2011 (8). The Barnett shale and related activity was found to have been responsible for 38.5% of the growth in the regional economy in the past decade (8). In addition to the trips associated with employment itself, the employment growth in turn encourages population growth.

In the northern tier of Pennsylvania (Bradford, Sullivan, Susquehanna, Tioga, and Wyoming counties), Marcellus shale-related employment increased by 2,275 between 2007 and 2010, an annual rate of increase of 30% (6). By 2010, Marcellus-related employment accounted for 4% of Pennsylvania's total employment (9). Other socioeconomic effects of HVHF studied in Pennsylvania include increased income (10), and housing availability and affordability issues (11).

Economic analysis for NYSDEC's environmental review of HVHF reported the economic benefits from the development of 10,500 to 62,800 wells over 60 years (12). Assumptions about production rates were provided by industry. The results showed peak year employment of 13,491 to 80,510 (direct plus indirect, full-time equivalent jobs), or 0.1% to 0.8% of New York State's 2010 total labor force. Peak year employee earnings could be up to $3.7 billion. Population impacts would not be substantial at the statewide level, but could be significant in regions where drilling would be concentrated (12).

Air Quality

Shale gas development has the potential to affect regional air quality due to emissions from rigs during drilling, pumping trucks during fracturing, and flaring, generic multi-well site and its operations. The transportation-related mobile source emissions attributed to shale gas development are also significant and particularly important to MPOs covering nonattainment and maintenance areas subject to the transportation conformity rules. NYSDEC estimated the increase in statewide emissions from additional vehicle miles traveled associated with gas drilling as follows (excluding evaporative emissions): NOx- 686.7 tons/year, VOC- 70.0 tons/year, SO2- 2.5 tons/year, PM10- 34.4 tons/year, PM2.5- 33.3 tons/year and CO- 668.6 tons/year. (4). NYSDEC's environmental review document included a commitment to develop a regional air quality monitoring program to address the potential for significant adverse air quality impacts (4).

METHODOLOGY

To understand the degree to which emerging shale gas development impacts are being considered in long-range transportation planning, an inventory of potentially relevant long-range transportation plans was conducted. The purpose was to identify the best practices currently being used and to provide a baseline for measuring progress in addressing shale gas impacts in planning over time.

The focus was on areas within the Marcellus Shale currently undergoing development. The Barnett Shale in Texas was also considered given the slightly longer history of HVHF in that area compared to the Marcellus shale. The majority of the Marcellus Shale is located within New York, Pennsylvania, West Virginia and Ohio; with smaller portions in Maryland, Virginia and Tennessee (U.S. EIA). New York was excluded from the analysis because HVHF has not yet been approved and is the subject of an ongoing environmental review.

For the Marcellus shale, only plans published in 2009 or later were considered in this review. Given the rapid increase in Marcellus shale development since 2007, it was anticipated that older plans would not have been likely to be aware of the issue. This criterion eliminated a large number of potential long-range plans/regions, including the Pennsylvania statewide plan (2007), Williamsport Area Transportation Study (2007), Brook-Hancock-Jefferson Metropolitan Planning Commission (2008), Eastgate Regional COG (2005), Stark County Area Transportation Study (2005), Wood-Washington-Wirt Interstate Planning Commission and the KYOVA Interstate Planning Commission. Many of these organizations have updated long-range planning efforts underway, but the results were not available at the time of this study.

For those statewide, MPO and RPO plans meeting the location and date criteria, several search terms were used on the full text of each plan to identify potentially relevant sections for detailed review. The search terms included "gas", "shale", and "Marcellus". For those plans containing discussion of shale gas development, the content was analyzed to determine the specific types of impacts discussed (road damage, air quality, congestion etc.) and whether the consideration of impacts was qualitative or linked with any quantitative assessments performed for the plan.

RESULTS

Table 1 summarizes the results of the review of the three statewide long-range transportation plans that met the review criteria (Texas, Ohio and West Virginia). Of these plans, the most recent one (Ohio's 2040 plan released in draft form in 2012) contained the most discussion of shale gas issues, including truck trip generation information and a commitment to consider transportation impacts in future planning efforts when shale gas exploration and production expand in Ohio (13). Texas's statewide plan provided quantitative information on the trend in total natural gas production, but only in the context of the pipeline system (14). Shale gas development was not an explicit consideration in Texas's evaluation of future highway and rail system needs. None of the statewide plans addressed potential impacts related to congestion, safety or air quality. This finding is not surprising given the broad and generalized level of detail typical in statewide planning, but if shale gas production grows as currently projected by the U.S. Energy Information Administration, it may be a large enough "driving factor" behind growth in states such as Ohio and Pennsylvania to warrant a more comprehensive treatment in future plans.

Table 1
Statewide Long-Range Transportation Plans Reviewed (2009 and Later)

State	Plan Name	Date Last Updated	Consideration of Shale Gas Development
Texas	Texas Statewide Long-Range Transportation Plan 2035	2010	Natural gas production trends mentioned in the context of the pipeline system. Data presented on the growth in natural gas production in Texas overtime and the role of Texas as an exporter of natural gas. Not explicitly addressed as an issue for highway or rail system (FHWA FAF data used to forecast freight movement).
West Virginia	West Virginia Multi-Modal Statewide Transportation Plan	2010	Not addressed. Methodology for future highway demand based on Highway Economic Requirements System - State Version model and 2007 HPMS data.
Ohio	Access Ohio 2040 (public review draft)	2012	Subsection on Shale Gas Exploration and Production included in the economic profile section of the plan. Qualitative discussion of trend and information on average gas well truck trip generation provided. Not incorporated in quantitative measures of future travel demand. Includes commitment to address in future plans: "As the emerging market of shale gas exploration and production comes on line in Ohio, ODOT will seek to take the impacts on the transportation system into consideration during the transportation planning process. In turn, ODOT will work with agencies and local governments in planning so that that the transportation resources in Ohio are in place to develop this vital emerging market."

Table 2 summarizes the results of the review of the MPO and RPO long-range transportation plans that met the review criteria. The most recent plans (from 2011 and 2012) showed the most extensive consideration of shale gas development impacts. The Southwestern Pennsylvania Commission's treatment of shale gas issues was notable for acknowledging the importance of the industry to the region's future and using quantitative information to provide an understanding of recent trends (e.g. number of well permits issued in each county) (15). However, the Southwestern Pennsylvania Commission's plan did not attempt to explicitly account for shale gas development impacts in the transportation modeling process. Certain industry-level growth projections were made, but it was not clear what level of gas development was implied by those projections.

The Belmont-Ohio-Marshall Transportation Study was unique in the plans reviewed because it used population and employment forecasts that explicitly accounted for shale gas development impacts (16). The MPO determined a population growth rate of 1.5% per year was realistic given the level of shale development anticipated, reversing the prior trend of population decline. The MPO and FHWA coordinated with an interagency group and reached consensus that the modified demographic projections represented the "latest planning assumptions" required for transportation conformity.

The Northern Tier Regional Planning & Development Commission is a designated RPO in Pennsylvania (which PennDOT treats in the same manner as MPOs). The RPO's long-range plan did not address shale gas impacts, but has subsequently addressed them in detail in the "Marcellus Shale Freight Transportation Study" (6). This study provides a review of trends in traffic volumes, truck traffic, freight rail and crashes between 2007 (when shale gas development was just getting started) and 2010. Forecasts of future well development are made based on assumptions about the trajectory of drilling activity over the next 30 years. The well development forecasts are in turn used to develop truck and rail trip generation estimates by county. The study suggests key routes that may be strained in the future, but does not attempt to forecast traffic growth on specific roadways or the exact location of future wells (6).

Table 2
Metropolitan and Regional Long-Range Transportation Plans Reviewed

MPO	**Geographic Extent**	**Plan Name**	**Date**	**Consideration of Shale Gas Development**
Southwestern Pennsylvania Commission	Allegheny, Armstrong, Beaver, Butler, Fayette, Greene, Indiana, Lawrence, Washington, and Westmoreland Counties, PA	2040 Transportation and Development Plan for Southwestern Pennsylvania	2011	Two page discussion of shale gas in section on regional conditions and trends acknowledges that development of the Marcellus shale (and the deeper Utica shale in the future) "will be a significant chapter of this region's future." Quantitative information provided on the number of well permits issued by year in each county of the region. Gas development recognized as a factor contributing to increased freight rail activity in the region.

MPO	Geographic Extent	Plan Name	Date	Consideration of Shale Gas Development
Belmont-Ohio-Marshall Transportation Study	Belmont County in Ohio and Ohio and Marshall Counties in West Virginia	Transportation Plan for 2035	2012	Four page discussion of shale gas development as the driver of economic growth. Relates development to population growth and employment trends. Latest planning assumptions updated and interagency coordination concurred with using census 2010 and growth from shale gas development instead of older Ohio Department of Development county-level control totals. Discussion includes -map of permitted wells, trends in permit issuance. - Acknowledges concerns-road damage, water usage, waste disposal.
North Central Texas COG	16-county region of North Central Texas around Dallas and Fort Worth	Mobility 2035	2011	No explicit discussion of shale gas impacts. May be incorporated in the underlying control total economic forecasts, but this is not apparent from the plan itself.
NORTHERN TIER Regional Planning & Development Commission	Bradford, Sullivan, Susquehanna, Tioga, and Wyoming counties, PA	Long Range Transportation Plan 2009-2035	2008	No explicit discussion of shale gas impacts.
		MARCELLUS SHALE FREIGHT TRANSPORTATION STUDY	2011	Quantitative analysis of existing impact and projection of future truck trip generation. Qualitative discussion of routes potentially most impacted based on existing and expected future well development patterns.

*Not a federally-designated MPO.

CONCLUSION

Tremendous uncertainty about the timing and location of future shale gas development limits the ability of transportation agencies to consider shale gas-related impacts in long-range planning. The state of the practice in addressing shale gas development impacts in long-range planning is rapidly evolving as the extent of the impacts becomes clearer. Nevertheless, there are some basic steps state DOTs, MPOs and RPOs can take to address shale gas issues:

- Obtain good baseline data on existing well development activity (permitted wells, drilled wells, production, waste disposal volumes, water usage, and waste disposal locations). Understanding the existing impact is a good start to "telling the story" of what the future impact could be. If inadequate data is available for existing conditions, this suggests a need to improve data collection in an area to allow for a meaningful planning assessment.

- Determine whether shale gas development is a large enough contributors to overall growth that it warrants special consideration in developing population and employment control totals at the regional level and allocation to smaller geographies. This is particularly important in areas that were declining in the recent past where shale gas could shift the direction of trends upward. Existing forecasting methods in use may already account for a certain level of growth in shale gas-related industries based on the existing conditions data utilized, but some documentation/explanation should be provided to demonstrate to reviewers that the latest planning assumption requirements have been satisfied.

- Consider the full spectrum of shale gas-related impacts on transportation, including socioeconomics, safety, congestion, maintenance and air quality.

- Encourage data sharing and collaboration across state agencies with jurisdiction or expertise relevant to shale gas development. For example, information on the potential intensity of shale resource development may be available from a state agency with jurisdiction over mineral resources, but not typically shared with the state department of transportation or regional planning organizations.

Future research needs in the area of shale gas transportation impacts in long-range planning include the following:

- Improved tools for forecasting the total level of gas well development in a region and predictive modeling of well locations within a region. The development of such tools would have benefits beyond transportation planning as this information would be useful to natural resource agencies, local governments and the public.
- Once estimates of future well development activity are available, guidance is needed on incorporating this information into population and employment forecasting and travel demand modeling. At the most detailed level, it may be possible to code well pad and waste disposal locations within travel demand models.

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