Notes for Natural Gas

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Gamache (environmental conservation laws and royalty estimates)
De Leon (transportation issues)
Meek (water and cost-benefit analysis of the Marcellus Shale)
Regis (pipeline issues)
Vagilia (Utica Shale and retrofitting AES Cayuga)

(re-arranged, edited slightly by L. Cathles)

Outline

The Resource
The Issues
Laws and Regulations
Replacing AES Cayuga
References

The Resource

The Marcellus and the Utica

4-5 Natural gas is domestically abundant. The Marcellus is one of several large gas resources. It is deep enough to be tapped in the southernmost part of New York State, but in the Ithaca area gas in deeper shale units such as the Utica will be the resources of most likely interest because the Marcellus is probably too shallow to be tapped.


5-9 There is still a general lack of information on the Utica Shale due to the duration it has been under study. In areas where the Marcellus is not present, the Utica Shale is being targeted, but due to its depth, it is frequently cheaper to drill the Marcellus shale rather than the Utica. Even though the Utica Shale could be profitable, drillers would rather focus on the known source of hydrocarbons in the Marcellus Shale.

(http://geology.com/articles/utica-shale/)

10-12. The Utica contains oil as well as gas and it is attracting company interest. In the future, the infrastructure from the Marcellus development could be applied to the Utica Shale (i.e. wells roads, compressor stations).

(http://www.naturalgas.org/environment/naturalgas.asp)
Production and Royalites

#13-14 Range Resources estimates that horizontal wells can produce gas at a rate of about 4 MMCF/day. Over its lifetime, each horizontal well on an 80-acre surface spacing produces 2.5 BCF of gas at an estimated production cost of $1.00/MCF


#15 Wellhead prices for gas have risen from values of less than $2.00/MCF (1980s) to $10.82/MCF (2008)

#18-19 The low and high estimates of royalty payments/year were based on a computerized program from <http://geology.com/royalty/> where I entered the parameters shown in the PowerPoint (12.5 for royalty rate and 0.2 and 2 for average well production rate in millions of cf/day).

Revenues to the State – [Could add a few slides here but these figures don’t look right]

#20 Revenues in New York State will directly increase from lease payments under state-owned land and indirectly increase from increased tax revenues from natural gas development. Currently, New York State receives $746,000 in lease payments per year for all oil and natural gas developments on state-owned lands. Development of high-volume hydraulic fracturing operations for 30 years would increase employment and income in New York State between $621.9 million (low scenario) and $3.7 billion (high scenario.)

The effective personal income tax rate for all taxpayers in New York State was 5.0% in 2008. New York State could receive between $31 million and $185 million/year in personal income tax receipts, depending on the level of development.

Value Gas in Place and Well Economics

#21 Natural gas markets are highly regionalized (costly to transport gas over long distances) and divergence is high across and within regions.


#22 The graph and NPV values are derived from a report by the REX Energy Corporation. Assumptions are listed below:

- Drilling well and $2000/acre x 80 acres
- Leasing cost per well $2.7 10^6 $/well
- Operating cost 1 $/mcf
- Sales price 6 4/mcf
- Tax 5.00%
- Discount rate 10.00%

<table>
<thead>
<tr>
<th>Levelized break even sales price of gas</th>
<th>$3.30</th>
<th>1.076</th>
<th>0.390</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$2.36</td>
<td>0.769</td>
<td>0.880</td>
</tr>
<tr>
<td></td>
<td>$1.956</td>
<td>1.956</td>
<td>0.880</td>
</tr>
<tr>
<td>$/1000 cf before tax IRR</td>
<td>c/kWh</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Issues

CO₂

#25 Natural gas is the cleanest of all fossil fuels (according to EPA). Due to coal and oil’s complex structure, these forms release more carbon dioxide, nitrogen oxides, and sulfur dioxide. (see also slide #80)


#26 Another useful aspect to look into, is the amount of carbon dioxide emitted per year, by all the trucks working on the 2100 hundred wells that might be drilled in Tompkins County (see Trucking section, slide XX). I assumed that each truck trip to a well site would last at most 1 hour. This can depend greatly on where companies chose to source their resources from. I also assumed that the truck would be traveling at 20mph as it goes through local roads. All in all, this comes out to 18,000 tons of CO₂ per year. Sound like a lot, but the Millikan station produced 6 million tons of CO2 back in 2006.

How does it compare to the CO₂ generated if we were to burn all the natural gas these trucks help extract? To answer that, I looked at the production rate of a typical well (Slide #14). Assuming each well produces 1000 million metric cubic feet, 50,000 tons of CO₂ would be emitted when this gas is burned. The trucks produce 18,000 tons to complete all 2100 wells.

Water


#29 Ra levels were low in most surface waters and near-surface waters of Central NY state. One exception was the Syracuse/Onondaga area which had high Ra in bedrock wells (1464 dpm/L) penetrating shale. However, the water there is highly saline and non-potable so drilling for natural gas there will not significantly affect water demands.

#30-31 The K, U, Th are adsorbed on clays but U can also be authigenic. U is shown to increase with total organic carbon in the Marcellus Shale.

New York State Department of Environmental Conservation Division of Mineral Resources (2011). “Supplemental Generic Environmental Impact Statement On The Oil, Gas and Solution Mining Regulatory Program: Well Permit Issuance for Horizontal Drilling And High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs.”

#32 Other chemical contaminants of concern in hydrofracking fluids are nonylphenol and octylphenol ethoxylate surfactants. Degradation of these compounds by microbes removes the ethoxylate portion from these compounds to convert them into nonylphenol and octylphenol which are known endocrine disruptors that mimic estrogen.

#33 Figure 5.4 is based on data from the Marcellus Shale development in Pennsylvania. Approximately 84 to 90 percent of the fracturing fluid is water, 8 to 15% is proppant, and less than 1% consists of chemical additives (biocides, gels, corrosion inhibitors, slickwater, surfactant, breaker, acid, scale inhibitor, iron control).

The American Petroleum Institute (API) calculated the probability of fluid migration from a Class II injection well into an underground source of drinking water (USDW). The Appalachian Basin was found to have minor potential for corrosion with few instances of casing corrosion reported by the natural gas industry.

For a modern horizontal well completion with properly installed surface casings, the probability of fluid migration from a well into an underground source of drinking water ranges from $2 \times 10^{-5}$ (one well in 200,000) to $2 \times 10^{-8}$ (one well in 200,000,000) under the presumption that these wells are operated as injection wells.

Propane fracking has been used 1000 times since 2008, particularly in the Canadian provinces of Alberta, British Columbia, and New Brunswick. It has also been tested in TX, PA, CO, OK, and NM and is awaiting a patent in the United States. The propane gel is pumped into deep shale formations a mile or more underground to create the pressure necessary to crack the rocks and free the trapped gas. Like water, the gel contains proppant which holds the cracks open so that the gas can flow out. Unlike water, the gel reverts to vapor due to intensive pressure and heat and returns to the surface along with the gas where it can be captured, reused, and resold.


Estimates of consumptive use are based on available data for the Susquehanna River Basin and include both approved peak daily consumptive use and actual daily consumptive use. The five major categories of consumptive use are: utilities (comprised of public water supply out-of-basin diversions and power generation), recreation, manufacturing, mining, and education.


Return water can be treated or injected.

Trucking

Here is a breakdown of the number of truck trips necessary to carry a well to completion. The biggest contributor is the transportation of water, followed by the hydrofracking tanks. In total, this amounts to about a 1000 one-way trips. This data was obtained from the Bakken formation in Nevada, but it matches very closely with the number of trucks Tompkins County estimates it will need.

<table>
<thead>
<tr>
<th>Item</th>
<th>Number of Trucks</th>
<th>Inbound/Outbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (fresh)</td>
<td>80</td>
<td>Inbound</td>
</tr>
<tr>
<td>Water (waste)</td>
<td>400</td>
<td>Inbound</td>
</tr>
<tr>
<td>Frac Tanks</td>
<td>200</td>
<td>Outbound</td>
</tr>
<tr>
<td>Rig Equipment</td>
<td>100</td>
<td>Both</td>
</tr>
<tr>
<td>Drilling Mud</td>
<td>50</td>
<td>Both</td>
</tr>
<tr>
<td>Chemical</td>
<td>4</td>
<td>Inbound</td>
</tr>
<tr>
<td>Cement</td>
<td>15</td>
<td>Inbound</td>
</tr>
<tr>
<td>Pipe</td>
<td>10</td>
<td>Inbound</td>
</tr>
<tr>
<td>Scoria/Gravel</td>
<td>80</td>
<td>Inbound</td>
</tr>
</tbody>
</table>

http://www.slideshare.net/ptpblog/hydraulic-fracturing-infrastructure-and-transportation
In the present time, Tompkins county estimates that the development of wells in its property will require 1200 truck trips on average. Additionally, there are a total of 600,000 heavy truck trips county wide.

There are 2100 signed Hydrofracking leases in the county. Therefore, traffic due to heavy trucks is expected increase by 500,000. Thus, the county wide traffic of heavy trucks will almost double. This is assuming that it takes 10 years to extract all the economically feasible gas.

We must keep in mind that in terms of the total traffic in the county, a doubling in the heavy truck traffic is not really significant. For example, some sectors in route 79, which I am sure you know since it is the one used to LEAVE ithaca, experiences almost two million trips per year. This number seemed a bit large to me, but if you divide it out, it is equal to about three trips per minute, which seems reasonable.

A good listing of average annual daily traffic (AADTS) for Tompkins Country is at https://www.dot.ny.gov/divisions/engineering/technical-services/hds-repository/AADTs%20for%20Tompkins%20County.pdf

#49 A good analogy to help explain the relation between deflection angle and fatigue failure is bending a paperclip back and forth. The further you bend the paperclip (i.e. the greater the deflection angle), the quicker it breaks. It will take longer for the paperclip to break with smaller bends (i.e. smaller deflection angles). This can be applied to pavements as weak soils/thin pavements allow greater deflections and will fail quicker as a result.

The road user costs are defined as gas, oil, and tires. Time and insurance are not included and taxes are disregarded to avoid double counting.

**Summary**. So, to put it all together, the use of trucks for hydrofracking in Tompkins County will not significantly increase overall traffic. Nor will it emit enough CO₂ to make natural gas less attractive than burning coal. However, there will be significant road damage, and this is something the gas companies should pay the County for.

**Pipelines**

53. Pipeline system in the US.


57. Data from “Natural Gas Pipeline Technology Overview” p.11

58. Data from [http://www.marcellus-shale.us/Marcellus-gas-facilities.htm](http://www.marcellus-shale.us/Marcellus-gas-facilities.htm)


61. New construction standards include improvements to welds, coatings and pipeline inspections. [http://www.marcellus-shale.us/gas-pipelines.htm](http://www.marcellus-shale.us/gas-pipelines.htm)

62. The requirements addressed by the permits generally include local (building and road-crossing permits), state (land, water, stream crossing, endangered species preservation, air emissions, and highway permits), and federal (handled generally by USACE and the EPA) requirements. These data are from “Natural Gas Pipeline Technology Overview” p.18. Data and pictures from “Natural Gas Pipeline Technology Overview” p.17-25

63. Data and table from “Natural Gas Pipeline Technology Overview” p.11

Compressor Station data from “Natural Gas Pipeline Technology Overview” p.41


“Economic Impacts” data from “2011 PA Marcellus Economic Impacts.” report, p.28.

**Wildlife**

Improper installation of water withdrawal structures entrains aquatic organisms such as fish and macroinvertebrates. Loss of biota can also occur through impingement where organisms become trapped on intake screens.

New York State Department of Environmental Conservation Division of Mineral Resources (2011). “Supplemental Generic Environmental Impact Statement On The Oil, Gas and Solution Mining Regulatory Program: Well Permit Issuance for Horizontal Drilling And High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs.”

The impact of hydraulic fracturing on wetland resources depends on: the amount of water contained within the wetland, the amount of water withdrawn from the catchment area of the wetland, and the hydrology of the wetland.

Aquifer depletion reduces groundwater discharge into streams and lakes. This will reduce water availability in wetland areas which aquatic organisms rely on for survival. Groundwater wells prevent groundwater from entering a stream. Headwater streams rely entirely on groundwater flow in the summer so aquifer depletion will severely impact aquatic biota in headwaters during the summer.

Knowing the hydrologic relationship between surface water, groundwater, and wetlands within a watershed is important for sustainable water withdrawals. When water withdrawals are transported out of a water basin from which they originate, groundwater and surface water are depleted. This disrupts the natural hydrologic cycle as transported water no longer flows downstream or returns to the original watershed to recharge the aquifer. The natural flow regime shapes the stream channel and maintains the aquatic biota of the stream so any alteration will have adverse effects on the aquatic community.

Complete lists of terrestrial and aquatic invasive plant species in New York State are included in Tables 6.4 and 6.5 in SGEIS 2008

**Summary:** Environmental concerns are relatively minor and trumped by potentially large economic benefits accrued from hydraulic fracturing in the Marcellus Shale

**Laws and Regulations**

New York State Department of Environmental Conservation Division of Mineral Resources (2011). “Supplemental Generic Environmental Impact Statement On The Oil, Gas and Solution Mining Regulatory Program: Well Permit Issuance for Horizontal Drilling And High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs.”
A full environmental assessment of proposed oil or gas wells within 2000 ft of a municipal well and a supplemental environmental impact statement of proposed oil or gas wells within 1000 ft of a municipal water well is required according to the Environmental Conservation Law in New York State. As a result, problems reported in other states such as instances of groundwater contamination from previous horizontal drilling or hydraulic fracturing projects have been prevented in New York State.


History of legislation. Rachel Treichler ~ Attorney at Law ~ 7988 Van Amburg Road ~ Hammondsport, NY 14840 ~ 607-569-2114

Replacing AES Cayuga

Natural gas is the cleanest of all fossil fuels (according to EPA). Due to coal and oil’s complex structure, these forms release more carbon dioxide, nitrogen oxides, and sulfur dioxide. (see also slide

Contamination from the other hydrocarbon fuels impact life expectancy measurably.

Power plants run depending on what is cheapest at the time. As a result, the base load plants are usually nuclear, coal, and geothermal. Renewables can also be thrown into this mix if they are capable of generating any power. Then, the high efficiency natural gas combined cycle turbines are activated to handle intermediate loads placed on the system. These are typically powered up and down several dozen times a year but that does not make NGCC a fast solution to immediate power needs. For peak power consumption, single pass gas turbines are used to handle the largest loads of the day. These turbines are used as infrequently as possible due to their high fuel demand.


Retrofitting would cost ~$350 million

A new gas plant should cost between $140 and 280 million (not counting demolition). Gas price is competitive with coal and nuclear. Natural gas technologies are sensitive to fuel prices and price
volatility rather than uncertainties in future demand in the short term (low short-term elasticity of demand). The volatility of natural gas prices increases short-term risks associated with natural gas production where an increase in natural gas price coupled with a decrease in electricity price will produce severe financial consequences for investors. In the long term, however, demand and supply economics apply. This phenomenon is known as “mean reversion” where power prices and fuel costs are less uncertain in the long term than would be predicted based on their short-term volatility.


Summary: Concerning Cayuga, it would not be necessarily wise to convert the plant to an NGCC unit unless prices for natural gas have stabilized.