The Marcellus Shale
An Informational Presentation for Residents of Tompkins County, NY

Mussadiq Akram  Abe Moll

Hannah Jurkowicz  Sergio Mino

Francis Musa  George Stutz
New York State NG Overview

• NY is the fourth largest consumer of NG in the U.S.

• NY has 6,700 active NG wells
  – Produced 50.3 billion cubic feet of NG in 2008

• Supplied 5% of NY demand
• Tompkins county population: 100,135
  – Ithaca population: 29,952
• Economy: agriculture, education, high technology, manufacturing, tourism
• **Greatest energy expenditure is electricity**
  – NYSEG Milliken Plant generates 85-95% (300 Mwe)
  – Nuclear and other sources provide remainder
Ithaca Energy Consumption

Annual Energy Consumption, Ithaca, NY. (Million BTUs)

- Gasoline and Diesel
- Natural Gas
- Electricity

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Ithaca Energy Expenditure

Annual Energy Expenditure, Ithaca, NY
($ USD)

- Gasoline and Diesel
- Natural Gas
- Electricity

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Tompkins County Energy Sources

Milliken Electric Power Supply

City of Ithaca
Town of Ithaca
Lansing Village
Dryden
Town of Lansing
Ulysses
Groton Village
Newfield
Groton
Caroline
Danby
Enfield
Dryden Village
Trumansburg
Freeville

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What is the Marcellus Shale?

- **Marcellus is the least developed major U.S. shale basin**
  - Shale basins are layers of marine sedimentary rock containing NG reserves
  - Located in Pennsylvania, New York, Ohio, and West Virginia
  - 2000 - 8500ft depths with net thickness of 50 - 200ft
  - 10% porosity; <0.01 Millidarcies permeability
• Probability of NG reserve size
  - 90% probability of 262 trillion cubic feet (TCF) of NG
  - 50% probability of 489 TCF of NG
  - Less than 10% probability of 876 TCF of NG
Extraction Strengths and Weaknesses

- **Strengths**
  - Largest untapped shale
  - Best extraction technology available

- **Weaknesses**
  - Densely populated area, NIMBY
  - Requires substantial infrastructure
What will Extraction look like?

- **Site size**
  - Either one three-acre site per two hundred forty acres OR one five acre site per six hundred forty acres
  - Up to ten wells per pad
What will Extraction look like?

- **Required materials**
  - (Conservative estimates)
    - One to five million gallons of water per well
    - 50,000 gallons of chemicals
    - 1200+ truck trips
    - Road infrastructure
What will Extraction look like?

- **Timeline**
  - Complete drilling within three years
  - Each well requires four-five weeks of 24/7 drilling
  - Well will be in use for 70 - 80 years
**Drilling**
- Process of constructing a cylindrical hole, inserting tubular casings, and injecting cement suspension into the gap between the casings and the hole walls

**Hydraulic fracturing/frac’ing**
- Process of energy extraction in which sand-water mixtures are forced into wells; the pressure splits the NG-bearing shale, allowing NG to flow freely
Drilling the Marcellus

- Requires mainly horizontal drilling
  - Extracts more NG from a drill site
  - Requires a minimum depth of 2000ft
- Tompkins county is on the northern edge of producible gas land
  - Most of the shale under Tompkins county is too shallow for drilling


- **Operating companies**
  - Chesapeake Energy, Andarko Petroleum, Cabot
  - Major PA Players
  - Manage leases and resources, Drilling is performed by services contractors
    - Schlumberger, Baker Hughes
Frac’ing the Marcellus

- Hydraulic fracturing
  - In NY since the 1950s
  - 20,000 fractured shale wells in the U.S.
  - No explosions or “blasts” in the process
Frac’ing the Marcellus

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• The frac’s vertical growth potential is limited
  – Fracture height growth is mapped
  – Fractures cannot grow vertically above a depth of ~1500ft
  • Does not have the energy potential to break through the limestone layer 200ft above the Marcellus deposit, 800ft below the water shed
Frac’ing the Marcellus

- **Process**
  - Pump high pressure fluid and other materials (e.g. sand and chemicals) into the well
    - Water pressure fractures rock
    - Proppant material (Sand) keeps the fracture open, allowing the NG to flow into the well
• **Water Usage Comparison**
  
  - Marcellus frac’ing will consume 1-5 million gallons of water
  
  - For comparison: Rolling Hills Country Club Golf Course in Dhahran, Saudi Arabia uses 2 million gallons of water daily
• Frac’ing materials
  – Compounds added to the water
    • Biocides to prevent bacterial growth
    • Gel to carry the Proppants
    • Anti-corrosive materials
    • Friction Reducing material “slickwater”
• **Alternatives to using fresh water**
  - Seawater with limited processing (desalination has high costs)
  - CO2, N2 or liquid petroleum gas
    • Cathles Research: adequate for shallow field extraction
    • Karan Gas Field, Saudi Arabia; Gas Field, Montana
Perceived Threats

• **Environmental**
  – Chemicals, land and water usage, open wells

• **Financial**
  – State/local expenses, NG price transmission

• **Labor**
  – Importation

• **Social**
  – Man camps
Perceived Threats

- **Water Usage**
  - Frac’s use 50,000 bbls/well
  - Oil sites use 18 billion bbls of water a year

- **Water Shed Safety**
  - Protected from wellbore by casing and cement
  - Water and shale are separated by 1000+ft of rock
  - Maximum vertical frac’ growth is 300ft
  - No proven cases of water contamination by frac’s
Perceived Threats

- Chemicals in hydraulic fluid: 25,000 gal per well
Perceived Threats

- Forest destruction
  - Safeguard institutions and permits
    - Bureau of Land Management (Dept. of the Interior) and U.S. Forest Service (Dept. of Agriculture)
    - Requires drilling and operating permits, public information about fracturing, open site visits
  - Horizontal drilling and multi-well pads minimize site disturbance
Perceived Threats

- **Site negligence**
  - Open wells and production tanks
- **Safeguards**
  - NY requires
    » Operators to post a bond to insure compliance and proper well sealing
    » Operators to post a sundry notice about any new activity; project revaluation
Perceived Threats

- Expenses
  - Precedent of companies covering all directly and some indirectly related (public infrastructure) extractions costs
  - Only 1% per year increase in electric cost to consumers for first year, decreases after...
Perceived Threats

- **Labor importation**
  - 29,000 new jobs created in PA associated with Marcellus extraction
  - Indirectly related industries - restaurants etc.
  - Well labor is minimal after initial drilling
Perceived Threats

- **Man camps**
  - NY regulation requires
    - Noise permits and restrictions from residences and protected sites, site house-keeping and traffic control
  - Companies require
    - Employee background checks, drug tests, interviews
    - Barnett shale development in Fort Worth, Texas - success
Perceived Benefits

- **Environmental**
  - Lower GHG emissions, less pollution from Milliken Plant

- **Financial**
  - Cheap NG, capital investment in the community, land value

- **Labor**
  - Job growth

- **Social**
  - Reduced train traffic, public infrastructure
Perceived Benefits

- Reduced Emissions and Pollution
  - Lower CO₂ by 78%, Lower SOₓ, NOₓ and smog
  - NG is more energy efficient and cleaner than Coal
  - Reduces pollution from Milliken Coal Plant
  - NG turbine systems are twice as efficient as coal plants
  - Total surface disturbance is relatively low (200-670 km²/EJ*yr)[1]
• Perceived Benefits

• Potential energy generation
  – Milliken fired at ~27MMscfd
  – Marcellus peak: 8-12 Bscfd
  • Tompkins county use ~ 10MMscfd for residential, commercial, industrial space and water heating
Perceived Benefits

• Financial
  – Cheap NG for NY
  – Extraction companies invest in community
  – Land value increased by NG deposits
    • Buying out of struggling farms
    • Approximate income of $750,000 - $1,000,000 to landowners
    • Brings industry and economic growth to the community
Perceived Benefits

• Labor
  – Job growth in all industries
  – Competitive wages
  – Success in PA
  – Aids large unemployment in western NY
• Social
  – Precedent of companies installing and paying for public infrastructure
  – Business opportunities reinvigorate the community
**Resource Value**
- ~USD $1.5 trillion, depending on commodities market
- PA success
  - USD $2.3 billion in value generation
  - 29,000 jobs
  - In-state NG generation
  - Inexpensive energy for consumers
• Retrofitting Milliken Plant
  – Coal --> NG
  – Requires construction of combined cycle NG turbine systems
    • $600/kW h
    • Milliken Station is 300 MW = USD $350 million for retrofitting (savings from using Milliken)
- Retrofitting Milliken
  - Price transmission is minimal
  - 1% per year increase in electric cost to consumers for first year
Case Study

• Pinedale: developing a resource in an environmentally sensitive area
Sublette County, WY

- between the Wind River and Wyoming mountain ranges
- Large populations of elk, deer, moose, sage grouse, raptors, etc.
- Local farming, outdoor activities, gateway to Yellowstone
Case Study

• Air quality
  - Reduced emissions engines on rigs
  - Selective Catalyst Reduction (SCR) technology
    • Reduced NO\textsubscript{x} emissions by 90%
  - No bleed pump and production control devices
  - Expanded remote and automatic well control
    • Reduced traffic
  - Infrared cameras
    • Increased DEQ inspection
Case Study

- [www.wyvisnet.com](http://www.wyvisnet.com)
- Shows real-time data about local air quality
- Three monitoring sites in Pinedale
Case Study

- **Protecting Water**
  - Recycled and reused frac’ and production water
  - Supported groundwater/aquifer pollution prevention mitigation and monitoring plan

- **Wildlife**
  - Funded $5 million study in Mule Deer, Pronghorn and Sage Grouse habitat and behaviors
  - Implemented $36 million fund supporting the monitoring and mitigation of development activities
• Liquids Gathering System (LGS) at Pinedale
Case Study

- Liquids gathering system (LGS)
  - Subsurface Pipelines System
    - Gathers and Collects Condensate and Water at Central Facilities
  - Eliminated nearly all on-site storage tanks (leakage potential) and combustors (emissions reduction)
  - Estimated to eliminate 165,000 truck trips per year
  - Reduced human activity during production to the benefit of wildlife
• SEIS ROD
  - Supplemental Environmental Impact Statement Record of Decision
  - Sets up all standards
  - Sets goal such as 0 days visibility impairment
  - All mitigation and management funds
• **Outreach**
  – Questar Scholarship 2- $20,000 Scholarships for instate tuition
  – 100’s of Volunteer hours
  – Among the largest United way donors
  – USQ (Ultra-Shell-Questar) donations to build new community recreation center
  – Hire local employees and interns first
Discussion Questions

- Purpose of presentation
- Information sources
- Points of clarification

Tompkins County Overview
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#1 Our presentation will discuss the following areas: an Overview of Tompkins County and its energy needs, facts about the Marcellus Shale, about the Extraction Process, Threats and benefits of developing the Marcellus, a Financial Analysis, and a Case Study.

#2 Natural Gas is not something new to New York, internal wells have been meeting demand here, but is much beyond that. The new issue is the use of hydraulic fracturing. The natural gas consumption in NYS is, according to Statemaster.com, 1.171 TCF. 

#3 Greatest energy expenditure is actually not space heating, but electricity. 

#7 The Marcellus Shale is a marine sedimentary formation, developed during the Middle Devonian. The shale was deposited in a highly anoxic, eutrophic shallow intercratonic sea with it's sediment supply coming from the Acadian Mountains to the east. It was then covered by a succession of shales and limestones that acted as a cap stone to the natural gas that eventually matured in the marcellus.


#12 Drilling takes place in the period of 3-5 weeks, and the well will be in production for 70-90 years according to some sources.

#16 For the case of shale formations, the gas is trapped inside fractures and pores of the shale, as the shale itself is characterized as a very low permeability formation because it is form of fine grain. This property allows the shale to be cracked easily with out disintegrate it when is humidified. The principles of Hydraulic Fracturing has been used for more than 100 years, but the first commercial used was implemented since back in 1948. In New York State hydraulic fracturing has been used on vertical wells since that time, with partial economic benefits as usually the capital is two high for the yield of each well.
#17 Hydraulic fracturing is a well stimulation technique used to enhance recovery of mature reservoirs as well as to make economically and technically feasible to recover gas or oil from unconventional reservoirs. The basis of the technique is to enhance the permeability of a formation by first opening fractures and then stabilizing the fractures by injecting a low permeable matrix. This allows the gas to be released into the fractures and then transported through the injected permeable matrix towards the recovery well.


#18 Fractures will propagate perpendicular to the minimum in-situ stress, which below ~1,500ft will be one of the horizontal stresses. Above this depth, overburden will be the minimum stress resulting in what is commonly referred to as a pancake or horizontal frac. When overburden is the minimum, the fracture can no longer grow vertically. Additional, above the Marcellus is the Tully limestone. Limestone’s are notoriously difficult to fracture. Given the surface pressures observed during a Marcellus treatment, there is little chance that the fracture would have enough energy to break through the Tully. Fracture mapping in the area confirms this hypothesis.

The necessary pressure to initialize fracturing is determined by knowing all stress in the formation. This is determined using where: \( P_b \) is the fracture initialization pressure, \( 3s_{H,max} \) is the minimal horizontal stress, \( s_{H,min} \) is the maximal horizontal stress = minimal horizontal stress + tectonic stress, \( T \) is the tensile strength of the rock, \( P \) is the pore pressure.


#19 In order to enhance the operation conditions of the hydraulic fracturing and the recovery, as well as the necessary protection for the equipment, different types of substances are used in hydraulic fracturing in what is known as hydraulic fluid. Typically, this fluid is water, however other carriers such as oil, methanol and a water/methanol mixture have been used.

#20 Water usage for hydraulic fracturing of a horizontal well is between three to five million gallons per well. There are claims that the available water in the Marcellus Shale region is ideal for shale gas development in the area mainly because the annual precipitations ranges between 710 billion and 1,250 billion gallons of water. However, the New York State
Department of Environmental Conservation states in its Water Impact Assessment that the actual water demand for gas operations will only be known after applications are received, reviewed and approved or rejected by the appropriate regulatory agencies. But for projection purposes, data from the current applications approved for shale gas operations in horizontal drilling have been studied. The NYS DEC states that the Delaware River Basin (DRB) Commission received applications requesting up to one million gallons per day (MGD) to support development and extraction activities in the Delaware Basin. The Susquehanna River Basin (SRB) Commission has approved up to 8.86 MGD to 9.24 MGD for almost 20 different locations in Pennsylvania. Typically, range of water usage approval for this basin has been between 0.041 MGD to 3 MGD. The DEC report considered this usage low comparing other current daily usages approved in the SRBC as the largest identified use is for water supply at approximately 325 million gallons per day (MGD), followed by power generation at 150 MGD and recreation with 150 MGD. While the current estimate for water usage in gas operations related to the Marcellus Shale is about 30 MGD or near 6% of the total use for water supply.

#21 Special attention is centered in the use of various types of chemicals for hydraulic fracturing. The chemicals principally used are acids and additives as breakers, biocides, fluid loss additives, friction reducers, corrosion inhibitors, proppants, iron controllers, reducers, surfactants, gels, cross link and scale inhibitors

**Acids** One of the principal chemicals used in Hydraulic Fracturing operations is Hydrochloric Acid or a mixture of hydrochloric acid and acetic or formic acid. EPA 816-R-04003. The average amount of acid use is about 5,000 gallons (Arthur 2008 ALL Consulting). The principal use of acid is to increase treatment distance, but it is also use for to clean the perforations of the cement surrounding the well. **Breakers** The breakers help to degrade the fracturing fluid viscosity, which enhances the post-fracturing fluid recovery. The most typical breakers are acids, oxidizers, or enzymes. Some known constituents are ammonium persulfate, ammonium sulfate, copper compounds, ethylene glycol, and glycol ethers. (EPA 816-R-04003) **Biocides.** The presence of bacteria in the fracturing fluid is detrimental to the fracturing process as the bacteria secrete enzymes to breakdown the gelling agent as part of their metabolic process. The degradation of the gelling agent affects the viscosity of the fracturing fluid, resulting in a poor fracturing performance. As a method to inhibit bacterial growth biocides are use and mixed in the fluid. Most biocides are hazardous by nature and contain polycyclic organic matter and polynuclear hydrocarbons (PAH). The general dilute solution is composed of about 0.1 to 0.2 gallons per 1,000 gallons of water. (EPA 816-R-04003) **Friction Reducers** The most common friction reducers are latex polymers or copolymers of acryl amides. The average concentration is about 0.25 to 2 pounds per 1,000 gallons. (EPA 816-R-04003.) **Corrosion Inhibitors** With the corrosive agents that can attack steel, like acids, a corrosion inhibitor is needed. Acetone is a common chemical used as corrosion inhibitor. These chemicals are considered hazardous in their undiluted form. The dilution concentration is of 1 gallon per 1,000 gallons. (EPA 816-R-04003.) **Proppants** The purpose of to bring structure to an open fracture and to increase the permeability from the formation to the wellbore, in order to create a pathway for the gas stream. The most common proppant use in hydraulic fracturing is sand. Different estimates of the amount of proppant used can be found, but the average used is a range between 10,000 and 20,000 gallons per
stage. A total from 11,000 to 25,000 pounds of proppant are placed in the formation. (ALL Consulting 2008, and EPA 816-R-04003)

#22 Usually the hydraulic fracturing fluid is water, however other carriers such as oil, methanol and a water/methanol mixture have been used. There has also been research into the feasibility of CO₂. The fluid is injected at a high pressure over 10,000 psi into the formation to create a conductive path from the wellbore into the formation as well as carry the necessary proppant to create a conductive path for hydrocarbons.

#23 The main opposition to utilizing the Marcellus Shale has grounds in environmental, political and social issues. It is difficult to argue against using the Marcellus on financial grounds, but it is useful to investigate how extraction expenses and profits will be distributed.

#24 Two major concerns are that NG extraction from the Marcellus shale will contaminate the watershed which lies over a 1000 feet above the deposit. The closest the deposit will get to the watershed is when it is pumped out of the wellbore, and the wellbore will be insulated by several layers of metal casing and cement. All wells use these techniques, and they are well-tested and have not had leakage problems. Furthermore, frac’ing within the deposit layer, does not have the energy potential to grow through the 1000+ feet of limestone to reach the watershed. Hydraulic fracturing will not fracture far enough vertically to put the shale deposit and the watershed into contact.


#25 As this diagram shows, chemicals make up a small part of the fluid which is injected into the wellbore and the deposit. These chemicals will be diluted by the water, and the majority of these chemicals are organic, and there are no species to speak of that would be endangered by the chemicals resting within the rock formation. The chemicals do not have the ability to dissolve further into the rock formation.


#26 Hydraulic fracturing, with its horizontal growth capabilities can protect far more forested land than vertical drilling and extraction. Frac’ing uses multiple drill sites on each well-pad, increasing the density of drilling per site, keeping the sites to a minimum size.

ADBBC(2009)

#27 Sites are heavily monitored by local, state and federal regulations and oversight organizations. Companies must put down large capital assurances that they will comply with all rules. It is disadvantageous to the company to practice incomplete sealing methods, or to leave open wells, as it damages their public image and will make future operations more difficult. Ibid slide 25
#28 Since the Marcellus Shale deposit has such a large resource value, the companies are willing to input the necessary capital for extraction. After the first year of production, there will be no price transmission to consumers, and the NG produced by the Marcellus will create lower energy costs for New Yorkers. ADBBC(2009)


#29 Although companies will bring in men who are experienced and have already been working with their companies, the extraction process will continue for the next ~80 years, allowing for growth in the NG extraction industry. Further, the presence of the extraction site, ADBBC(2009), PDLI(2010)


#30 Some in the community have been concerned that extraction will lead to “man camps” which could be a threat. Extensive permits are needed for these sites, and they are regulated continuously by local and state government. Further, these are company employees, whose employment is contingent on their work product and liability. These companies will not employ men who are a potentially large liability. “Man camps” are not a danger to locals. ADBBC(2009), PDLI(2010)

#31 Retrofitting the Milliken coal plant to a natural gas plant will greatly increase the plant efficiency and also help minimize CO2 emissions (up to 78%) and consequently GHG emissions. Also, Milliken’s energy generation could potentially reach 27 MMscfd, which is enough to exceed the current consumption in Tompkins County, estimated at around 10 MMscfd.

#34 The community will benefit greatly through job creation and infrastructural development as investors are attracted to the community. Tax payers can be rest assured that investors will be primarily responsible for infrastructural developments. Also, Land value is significantly increased by natural gas deposits and struggling farmers could easily make high profits by selling their farm lands.

#37 Marcellus has a very high resource value (about $1.5 Trillion) and could contribute about $2.3 billion dollars to Pennsylvania’s economy, thus creating up to 29,000 jobs.

#38 Retrofitting the Milliken requires a heavy investment. In Washington, DC, the Capitol Hill Power Plant was retrofitted from coal to gas this year and the GAO deemed retrofitting of coal plants uneconomical across the board. Estimates have been as high as $1 million per megawatt, plus other expenses added. The Cornell Heating Plant was able to do it in a way because they it is a co-generation facility and they are only seeking to break even.

That being said, the actual increase in cost to the consumer for electricity will be relatively low, but that is dependent upon a very high capital cost.

Pinedale is a small town of about 1,500 residents that sits at the foot of the Wind River Mountain Range. Gas production, on a large scale, began in the late 1990’s with the discovery of the Jonah Field south and west of the Pinedale anticline. Pinedale, while being geologically similar, is the progression of environmentally conscientious extraction efforts in southwest WY.

Prior the natural gas boom, farming, ranching, and tourism were the main economic activities of the county. Sublette county, with only 6,000 total people in an area nearly the size of Connecticut, is very sparsely populated. Before the Jonah and Pinedale development, large herds of deer, antelope, and elk were found in the area. Today with implementation of the Pinedale SEIS ROD, the populations of several species are on the rise, and steps have been taken to drastically reduce the impact to wildlife habitat.


Prior to the final decision on the Pinedale Supplemental Environmental Impact Statement, it was believed that natural gas operations in the area were contributing to the occurrence of ground level ozone and other smogforming pollutants. Until lately it was believed that smog was mostly a urban phenomenon that occurred largely in the summer months. But it was found that due to inversion and other environmental factors, the EPA recommended safe levels of 75 ppb were being exceeded in Sublette county. This lead to wide scale reduction and monitoring of emissions to improve air quality. Since mitigation plans and strategies have been in place for the last two years, no further incidences of ozone levels exceeding 75 ppb have been recorded.


This is one of the monitoring stations in the Pinedale area that monitor ozone and other pollutant levels. If rolling 8 hour averages exceed safe limits, there may be restrictions on production, drilling, and completing activities in the field until levels drop.


Water issues related to natural gas development have been popping up all over the country. And although contamination is highly unlikely in Pinedale, the community still fears hydraulic fracturing and other activities. As are salt several steps have been taken to prevent such occurrences These include constant testing of all water wells in the area for hydrocarbons, lower casing setting depths, and abandonment and re-drilling of contaminated water wells.


#46 After initial separation of fluids at each well site, they are pumped through the LGS system for further processing and clean up. The key reductions are fewer onsite tanks, and fewer truck trips. Both of these are large emitters of VOC’s and NOx, which only serve to worsen air and water quality. Once cleaned and processed, the oil and water are either sold or disposed of. After further cleaning, the water may then be re-purchased and used again in frac applications. The LGS helps to expedite this process by providing flows line throughout the field capable of moving fluids.

#47 This is the umbrella document that sets all standards for gas operations on the anticline. It requires all funds, all systems, and all procedures to be followed by anyone who wishes to operate in Pinedale. Although Pinedale and the Marcellus are very different, so much so that many techniques will not be transferable, it does show how government, industry and the community can work together to responsibly develop an important resource.

#48 The final lesson that cannot be overlooked is the intangibles. Things that we cannot glean from reading how many job were created or how much tax was collected. These are things that can have a great impact in the communities were these companies operate, and we should not over look them.

#49