Shale Gas 101
What is the Marcellus Shale?
- Geological formation formed by accumulation of sediment into a sea almost 400 million years ago
- Compressed to produce an organic-rich black shale.
- Starts at NY, Catskills, stretches across toward Marcellus, New York then southwest to PA, West Virginia, Kentucky, and Ohio.

Why Now?
- Success of other shale plays has allowed companies to transfer horizontal drilling and technology to other areas.
- Proximity to high-demand markets along the East Coast make it an attractive target for energy development.
An Elusive Prize | Many nations are believed to have large shale deposits.

North America
1,931 trillion cubic feet

Canada
388

U.S.
862

Mexico
681

Argentina
774

Poland
187

France
180

Algeria
231

China
1,275 trillion cubic feet

Libya
290

Brazil
226

South Africa
485

Australia
396

Note: Data are shown only for countries included in the survey. Figures are estimates. Source: U.S. Energy Information Administration

The Wall Street Journal
Shale Gas Revolution Across the U.S.

Shale Gas Plays, Lower 48 States

Source: Energy Information Administration
Marcellus Shale: Geographic Footprint

Potentially The Second Largest Reserve In The World
Utica Shale

- Below the Marcellus
- Bigger, deeper, denser
- One of the latest U.S. unconventional energy fields
- Particularly attractive in OH
- Success in the Marcellus has led to success in the Utica
Industry Segments

UPSTREAM
- Gas Field Exploration
- Well Drilling and Hydraulic Fracturing
- Gas Recovery and Production

MIDSTREAM
- Gas Collection and Transportation Systems (Gathering Pipelines)
- Gas Processing (Dehy, Separation, Fractionation)
- Compression (Well Head, Gathering)

DOWNSTREAM
- Interstate and LDC Transportation Systems (Transmission and Distribution Pipelines)
- Compression (Transmission)
- Regulation
- Metering
Ohio Wells By County

Legend
Marcellus and Utica Wells
- 1-5 Marcellus Wells
- 1-9 Utica Wells
- 10-24 Utica Wells
- 25-49 Utica Wells
- 50+ Utica Wells

2006 - October 2012
Source: Ohio Department of Natural Resources
West Virginia Wells By County

Legend

Marcellus Wells
- 1 - 24
- 25 - 49
- 50 - 99
- 100 - 149
- 150+

2002 - September 2012

Note: Data includes Marcellus horizontal and vertical wells.
Source: West Virginia Geological Survey
Exploration/Production, Midstream, and Downstream 101
Shale Gas: Steps in Drilling

Land Acquisition/Site Preparation

• Obtain rights from landowner.

• Educated landowner is an ideal partner.

• “Production unit” - contiguous parcels of land combined for development.

• Production unit incorporated into a company’s drilling program.

• Site is prepared for drilling activity.
Shale Gas: Steps in Drilling

Horizontal Drilling

- More efficient production, smaller footprint.
- Conductor, surface casing protect drinking water source.
- Well is drilled vertically and horizontally as much as 5,000 feet.
- Wellbore is approximately 20 inches in diameter at its widest.
- 5 ac vs. 24 ac = 1 acre when done
Well Casing

- Multiple layers of steel and cement to ensure redundant protection
  - 1 – through fresh water aquifer
  - 2 – to depths of ~1,500 feet
  - 3 – to final depths

- Cementing to surface at each layer provides stability and protection, preventing the crossflow of hydrocarbons

- 25 PA Code, Chapter 78 rules have further strengthened standards
Hydraulic Fracturing

- Permits from state regulatory agencies for water withdrawal.
- New technologies allow producers to recycle most water.
- 30 State and federal agencies monitor hydraulic fracturing.
- Industrial process; properly encased well, along with proper containment at the surface is critical.
Shale Gas: Steps in Completion

Hydraulic Fracturing (HF)

- > 60 years: more than 1 million wells in 27 states
- 90 percent of oil and gas wells use HF technology
- 99.5 percent water/sand mix
- 3 to 5 million gallons of water fractures the shale.
- Well casing protects water supply
- PA Chapter 78 upgrades reflect best practices in well casing
MSC Commitment to FracFocus.org Bolsters PA Requirements

FracFocus.org is a Project of the Groundwater Protection Council and the Interstate Oil & Gas Compact Commission.
Center for Rural PA Study

- Comprehensive research over two years, published in 2011

- Suggested private water well standards are needed

- Pre-drill testing by natural gas companies – a public service

- Regulations require testing of all water supplies within 2,500’ of proposed gas well.

- >40% of 1.2 million private water wells do not meet safe drinking water standard

- Another 20% percent of wells contained pre-existing methane
Site Restoration

- Involves landscaping and contouring the property as closely as possible to pre-drilling conditions.

- Property owners generally see:
  - Small wellheads on a level pad
  - Small amount of equipment
  - Two to three water storage tanks
  - Metering system to monitor gas production

Courtesy: Range Resources
Focus on Pennsylvania Roads

Before

After

Courtesy: Chesapeake Energy, NE Pa.
Pipeline Systems

Gathering and Transmission Pipelines

- Critical link between production and consumers
- Pipelines can transport gas before or after processing
- Designed and constructed to the latest pipeline safety standards
- Utilize new construction methods to minimize the environmental impact
- New coating technologies mean pipelines will last even longer
- Geographic Information Systems allow for efficient layout and accurate tracking of pipeline systems
- Subject to regulatory inspection (PAPUC, DOT PHMSA)
Focus on Land Reclamation

Gathering Line Construction – Spring/Summer/Fall 2010 Asylum Township, Bradford Co.

Courtesy: Chesapeake Energy, NE Pa.
Compression Systems

Compressor Stations
- State of the art sound attenuation
- Built to the highest welding, fabrication, and material standards
- 24/7 monitoring and control
- Automatic safety systems
- Annual inspections by regulating entities

Compressor Packages
- High tech integrated control systems (engine and compressor)
- 24/7 monitoring and control
- Produced and packaged in the USA
- Operated and maintained by local workers
Highly regulated. Highly sophisticated.

- Transparency in permitting
- Staffing, permit fee increases
- Advances in water recycling and reuse
- Protective well casing standards
- Focus on best practices
- FracFocus.org
Regulatory Framework

Site Construction
- 12 PA Regulations

Drilling Phase
- 18 PA Regulations

Hydraulic Fracturing
- 18 PA Regulations

Midstream
- 11 PA Regulations

Reclaimed/Completed Site
- 10 PA Regulations

MARCELLUS SHALE COALITION
## Less Reliance on Water Resources

<table>
<thead>
<tr>
<th>Source</th>
<th>Gallons per million BTU</th>
<th>Range</th>
<th>Mid-point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep shale natural gas</td>
<td></td>
<td>0.60 – 5.80</td>
<td>3</td>
</tr>
<tr>
<td>Nuclear</td>
<td></td>
<td>8 – 14</td>
<td>11</td>
</tr>
<tr>
<td>Conventional oil</td>
<td></td>
<td>8 – 20</td>
<td>14</td>
</tr>
<tr>
<td>Coal</td>
<td></td>
<td>13 – 32</td>
<td>23</td>
</tr>
<tr>
<td>Fuel ethanol from corn</td>
<td></td>
<td>2,510 – 29,100</td>
<td>15,800</td>
</tr>
<tr>
<td>Biodiesel from soy</td>
<td></td>
<td>14,000 – 75,000</td>
<td>44,500</td>
</tr>
</tbody>
</table>

Source: Ground Water Protection Council, U.S. Department of Energy
Environmental Protection

Water Use: In Perspective

The 5 million gallons of water needed to drill and complete a typical deep shale gas well is equivalent to the amount of water consumed by:

- New York City in approximately four minutes
- A 1,000 megawatt coal-fired power plant in 12 hours
- A golf course in 25 days
- While these represent continuing consumption, the water used for a gas well is a one-time use.

Source: CONSOL Energy, September 22, 2011
Land required (acres) to produce fuel to generate enough electricity to serve 1,000 households for one year

Source: CONSOL Energy
Short-term monitoring in Northeastern, Southwestern, and North Central PA:

- “Did not identify concentrations of any compound that would likely trigger air-related health issues associated with Marcellus Shale drilling activities.”

Air quality standards tightly-regulated:
- Gas Processing Plants: Plan approval/air permit
- Compressors: Covered by GP-5

Companies exploring “bifuel” rigs to reduce use of diesel
Environmental, Public Health Benefits of Natural Gas

- When used to generate electricity, natural gas emits just over half of the CO$_2$ per megawatt-hour (MWh) of a traditional power plant.

- Natural gas combined-cycle turbines emit 60 percent less CO$_2$ per MWh than a typical coal plant.

- Natural gas vehicles emit 25% less CO$_2$ than vehicles that run on traditional fuels.

- According to the Congressional Research Service, if U.S. doubled the utilization of combined cycle natural gas capacity to 85%, we could displace approximately 636 million metric tons of CO$_2$. This amounts to an 8.8% reduction of all CO$_2$ emissions in the U.S.
Research Collaborative

Industry
- Nationally-recognized technical experts
- Representations from state and national trade associations

Academia
- Nationally-recognized technical experts
- Leaders of university centers for collaborative research

Public Sector
- Research institutions such as N.E.T.L.
- Recognized technical experts from state and federal agencies

NGOs
- National research leaders such as RAND, Brookings
- Research funders such as charitable foundations
Know the Fundamentals

Three Industry Segments

**Upstream:** bringing natural gas to the surface (drilling)

**Midstream:** storing and transporting natural gas (pipelines, etc.)

**Downstream:** selling and distributing natural gas (your supplier)

Types of Natural Gas

**Dry Gas:** Home, business heating and fueling

**Wet Gas:** Contains Natural Gas Liquids, or NGLs; Raw material for other products (polymers, paints, plastics, fertilizers, etc.)
The Economics of Shale Gas
1. Electricity generation, heating
2. Combined heat and power applications
3. Light and heavy duty transportation applications
4. Feedstock for industries and other liquids use
Energy Consumption Overview

Quadrillion Btu

Clean, Abundant, and Versatile Resource

1. Electricity generation, heating

2. Combined heat and power applications

3. Light and heavy duty transportation applications

4. Feedstock for industries and other liquids use
Monthly coal- and natural gas-fired generation equal for first time in April 2012
Clean, Abundant, and Versatile Resource

1. Electricity generation, heating

2. Combined heat and power applications

3. Light and heavy duty transportation applications

4. Feedstock for industries and liquids use
Combined heat and power (CHP) plant: A plant designed to produce both heat and electricity from a single heat source. The term is being used in place of the term "cogenerator". CHP better describes the facilities because some of the plants included do not produce heat and power in a sequential fashion and, as a result, do not meet the legal definition of cogeneration specified in the Public Utility Regulatory Policies Act (PURPA).
## Pennsylvania CHP Summary

<table>
<thead>
<tr>
<th>Source</th>
<th>Sites</th>
<th>Capacity (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>135</td>
<td>3,276,430</td>
</tr>
<tr>
<td>Boiler/Steam Turbine</td>
<td>54</td>
<td>1,929,075</td>
</tr>
<tr>
<td>Combined Cycle</td>
<td>5</td>
<td>1,156,400</td>
</tr>
<tr>
<td>Combustion Turbine</td>
<td>10</td>
<td>97,715</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>3</td>
<td>580</td>
</tr>
<tr>
<td>Microturbine</td>
<td>14</td>
<td>4,290</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>231</td>
</tr>
<tr>
<td>Reciprocating Engine</td>
<td>47</td>
<td>85,139</td>
</tr>
<tr>
<td>Waste Heat Recovery</td>
<td>1</td>
<td>3,000</td>
</tr>
</tbody>
</table>

Source: ICF International, 2011
Clean, Abundant, and Versatile Resource

1. Electricity generation, heating

2. Combined heat and power applications

3. Light and heavy duty transportation applications

4. Feedstock for industries and other liquids use
## NGV Market Penetration

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>U.S NGV Population</th>
<th>U.S Market Penetration (by vehicle count)</th>
<th>U.S Annual NGV Fuel Use (thousand DGE)</th>
<th>U.S. Market Penetration (by fuel use)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Transit Buses</td>
<td>8,500(^b)</td>
<td>12,200(^e)</td>
<td>12.82%</td>
<td>17.43%</td>
</tr>
<tr>
<td>Refuse Trucks</td>
<td>1,300(^c)</td>
<td>1,500(^b)</td>
<td>0.95%</td>
<td>1.09%</td>
</tr>
<tr>
<td>School Buses</td>
<td>1,360(^d)</td>
<td>2,300(^b)</td>
<td>0.27%</td>
<td>0.46%</td>
</tr>
<tr>
<td>Medium-Duty Trucks/Vans</td>
<td>10,000(^b)</td>
<td>22,000(^a)</td>
<td>0.35%</td>
<td>0.76%</td>
</tr>
<tr>
<td>Other Heavy-Duty Trucks</td>
<td>1,600(^a)</td>
<td>3,651(^a)</td>
<td>0.02%</td>
<td>0.04%</td>
</tr>
<tr>
<td>Light Trucks/Vans</td>
<td>41,000(^a)</td>
<td>71,500(^f)</td>
<td>0.05%</td>
<td>0.09%</td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>31,000(^a)</td>
<td></td>
<td>0.02%</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>94,760</strong></td>
<td><strong>144,151</strong></td>
<td><strong>0.04%</strong></td>
<td><strong>0.06%</strong></td>
</tr>
</tbody>
</table>

\(^a\) Energy Information Agency, *Alternatives to Traditional Transportation Fuels 2008, 2010*


\(^d\) Monahan, P., *School Bus Pollution Report Card 2006, 2006*

\(^e\) American Public Transportation Association, *2010 Public Transportation Fact Book, 2010*

\(^f\) U.S. Census Bureau, *Vehicle In Use Survey, 2002*

Neighborhood Air Emissions

Base Case (Diesel) vs. CNG Case

- **NOx**: 42% Reduction
- **CO**: 88% Reduction
- **SO2**: 91% Reduction
- **PM10**: 91% Reduction
- **HC**: 91% Reduction
Dialogue & Education

MSC Pennsylvania Roadmap Study

• MSC’s contribution to nationwide NGV conversation

• Only 150,000 NGVs in U.S. with millions worldwide

• 17 new fueling stations for fleets

• Begin with fleet conversions and urban infrastructure focus to achieve better air quality, lower noise, lower cost

• $5 million reduction in annual fuel costs for PA fleet operators

• A direct impact on nearly 1,300 PA jobs

• A reduction of NOx emissions, particulate matter emissions, and greenhouse gas emissions
1. Electricity generation, heating

2. Combined heat and power applications

3. Light and heavy duty transportation applications

4. Feedstock for industries and other liquids use
“Wet Gas” Region of Marcellus Shale

Sources: Pace Global; Equitable Resources, MarkWest, Atlas Energy, Range Resources, and Caiman Energy.
Average Composition in Wet Gas Region

Methane, 74.2%
Ethane, 15.6%
Propane, 5.5%
Iso Butane, 0.7%
Normal Butane, 1.4%
Iso Pentane, 0.5%
Normal Pentane, 0.5%
Hexanes+, 1.1%
Liquids, 25.3%

Source: Pace Global; NiSource Gas Transmission and Storage Presentation to WVONGA Spring Meeting May 6, 2010 p.5
Gas Dehydration, Separation and Fractionation

- Northeast Marcellus is “dry” Southwest is “wet” (contains more Natural Gas Liquids)
- Gas processing is required to condition production gas to proper “pipeline quality” for end users
- Dehydration removes saturated water entrained in production gas (typically to below 7 lbs/MMcf)
- Cryogenic processing separates the NGLs from the production gas lowering the BTUs to proper levels (980 – 1100 BTU/cf)
- Fractionation separates the NGLs into individual marketable products (ethane, propane, natural gasoline)
The Ethane Factor

ETHYLENE CHAIN

Natural Gas

Ethane

Cracker

Intermediate Products
- PVC
- Vinyl Chloride
- Ethylene Glycol
- Styrene
- Polystyrene
- Polyethylene

Pool Liners
Window Siding
Trash Bags
Sealants
Carpet Backing
Insulation
Detergent
Flooring Pipes

Food Packaging
Bottles
Cups
Housewares
Crates

Footwear
Clothes
Diapers
Stockings
Toys
Textiles

Adhesives
Coatings
Films
Paper Coatings
Models
Instrument Lenses

Tires
Sealants
Paint
Antifreeze
Shale and manufacturing

• About 1/3 of all of the energy used in the USA consumed by manufacturing
• Lower feedstock and energy costs could reduce energy costs by $11.6 billion annually through 2025


Companies returning to USA:
1. Dow Chemical
2. Formosa Plastics
3. Chevron Phillips Chemical Co
4. Bayer Corp
5. Westlake Chemical
6. Shell Oil; CF Industries
7. Santana Textiles
Shale Gas Revolution

ENVIRONMENT SPECIAL

THIS ROCK COULD POWER THE WORLD

WHY SHALE CAN SOLVE THE ENERGY CRISIS

LIBYA'S CIVIL WAR
A GRAVE SCANDAL AT ARLINGTON

PEOPLE POWER FOR PALESTINE
BY JOE KLEIN

BATTER UP!
YOUR GUIDE TO THE 2011 BASEBALL SEASON

THE LAST GREAT WORK OF DAVID FOSTER WALLACE
BY LEV GROSSMAN

WWW.TIME.COM
Thank you!

Marcellus Shale Coalition

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