Natural Gas Resources of the Marcellus Shale

Pennsylvania House of Representatives
GOP Policy Committee
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Testimony of
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Range Resources – Appalachia, LLC
Range Resources

• Natural gas production company
• Included in S&P 500
• Committed to Pennsylvania
• Regional Headquarters in Washington County
• Pioneered Marcellus Shale, 2004
• Over $1 Billion invested in Keystone State
• Employs more than 300 Pennsylvanians, support over 1,000 contractor jobs and many more indirect and induced jobs
What is the Marcellus Shale?

- organic-rich, shale
- 5,000 – 9,000 foot depth
- Mud that settled on ocean floor 380 million years ago; turned to rock
- Natural gas and hydrocarbons are trapped in tiny micropores between grains of mud
- Extremely low permeability
Marcellus Shale is big

- Marcellus fairway is 40,000 – 50,000 square miles
- Estimates of recoverable reserves up to 500 tcf; current U.S. natural gas demand is 23 tcf per year
How the Marcellus compares to the largest oil and gas fields in the world
(Bubble size approximates reserves)

Marcellus reserves could exceed those of the largest oil field in the world (Saudia Arabia) and be the 2nd largest natural gas field (largest in Qatar/Iran)
U.S. Natural Gas Drilling Activity vs. Pennsylvania Drilling Activity

Source: Baker Hughes North American Rig Count 3/26/2010

Marcellus Drilling Activity

NYMEX Natural Gas Price - $/dth
Marcellus Drilling Activity - 12/31/2009
1,201 wells drilled to date; 741 wells drilled in 2009
PA Marcellus Wells Spudded by Quarter

Significant ramp-up of activity despite gas price decline from over $9/mcf in 2008 to less than $4/mcf in 2009
Economic Impact Study by economists and industry experts at Penn State University
July, 2009

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jobs created - thousands</td>
<td>29</td>
<td>49</td>
<td>107</td>
<td>161</td>
<td>175</td>
</tr>
<tr>
<td>Expenditures (leasing, drilling, pipelines) - $billions</td>
<td>3,095</td>
<td>4,415</td>
<td>9,468</td>
<td>13,260</td>
<td>14,034</td>
</tr>
<tr>
<td>Gross Output - $millions</td>
<td>4,179</td>
<td>6,251</td>
<td>14,166</td>
<td>23,463</td>
<td>25,430</td>
</tr>
<tr>
<td>Value added - $millions</td>
<td>2,263</td>
<td>3,755</td>
<td>8,272</td>
<td>12,409</td>
<td>13,500</td>
</tr>
<tr>
<td>State &amp; Local taxes - $millions</td>
<td>239</td>
<td>396</td>
<td>872</td>
<td>1,308</td>
<td>1,423</td>
</tr>
<tr>
<td>Production rate - bcf/d</td>
<td>0.04</td>
<td>0.17</td>
<td>0.55</td>
<td>2.91</td>
<td>3.99</td>
</tr>
<tr>
<td>Gas price/mcf</td>
<td>$8.90</td>
<td>$5.39</td>
<td>$6.72</td>
<td>$7.24</td>
<td>$7.53</td>
</tr>
<tr>
<td>Wells drilled</td>
<td>364</td>
<td>621</td>
<td>1,200</td>
<td>2,534</td>
<td>2,814</td>
</tr>
<tr>
<td>Landowner royalty - $billions</td>
<td>$0.02</td>
<td>$0.05</td>
<td>$0.22</td>
<td>$1.23</td>
<td>$1.75</td>
</tr>
</tbody>
</table>
Economic Benefits

- Discovery of 100+ years of gas supply from U.S. gas shales since 2005 has caused a divergence of oil and natural gas markets since 2005
- Natural gas prices were $12/mmbtu lower than oil in 2009 and projected to be $9/mmbtu lower in 2010
- PA natural gas consumers will save nearly $7 billion in 2010; U.S. will save over $200 billion
- Natural gas is a bargain
Economic Benefits

Marcellus Shale development activity during 2010 is expected to generate $603 million in tax revenue to the Commonwealth and an additional $269 million in tax revenue to local municipalities, primarily cities and boroughs.

Clearing roadblocks to Marcellus Shale development and growing revenue from existing taxes will bring much more revenue to Pennsylvania than imposing a punitive severance tax that can only limit growth.

Source: Penn State Economic Impact Study (July, 2009)
Water Issues Related to Marcellus Shale Development

Preparation

Drilling

Completion & Production

Reclamation
Site Preparation

- Engineered site design
- ESCGP-1 Permits required
- E&S controls prevent sediment contamination of streams from runoff
Drilling

- Access road and drilling pad are stabilized with crushed rock
- Slopes are stabilized with vegetation and appropriate erosion and sedimentation controls
Ground Water Protection

- Fresh water is generally less than 500-foot depth; below that, water is salty
- Each casing string is cemented by pumping cement down pipe and circulating back up between the outside of pipe and the wellbore
Ground Water Protection

- PA casing and cementing regulations among toughest in the U.S. DEP has recently proposed additional regulations to specifically address shale drilling.

- 1,000’ rebuttable presumption rule; DEP aggressively investigates all claims

- DEP issued only 80 orders to repair or replace water supplies impacted by drilling in past 15 years; 32,000 oil and gas wells drilled; 0.25% incident rate; all impacted water supplies replaced by drillers

- By comparison, Penn State 2009 study indicates over 40% of PA’s 1.2 million private water wells and springs do not meet safe drinking water standards; common causes of contamination are on lot septic systems, agricultural practices, poor well construction
Horizontal Drilling – small footprint

- Total surface disturbance during drilling, including access road, drilling pad and required pipeline infrastructure:
  - Horizontal (yellow) develop 1,000 acres per pad with 1% surface disturbance
  - Vertical (purple) on 1,000-foot spacing develop 23 acres per well with 19% total surface disturbance
Water Requirements for Marcellus

- Fracing a typical horizontal well requires 3-5 million gallons
- Is that a lot of water?
  - 4 million gallons is 1.8 inches of water over an area of 80 acres, the approximate drainage area of a well
  - PA receives about 40 inches of rainfall per year
  - If the productive area of the Marcellus takes 50 years to drill, annual water use over the productive area would be 0.04 inches of water per year or 1/10th of 1% of annual rainfall
## Water Requirements for Marcellus

**Water use per million btu of energy:**

- Deep shale natural gas: 0.60-5.80 gallons
- Marcellus Shale gas – avg: 1 gallon
- Nuclear (uranium ready to use in a power plant): 8-14 gallons
- Conventional oil: 8-20 gallons
- Synfuel-coal gasification: 11-26 gallons
- Coal (delivered power plant): 13-32 gallons
- Oil shale: 22-56 gallons
- Tar sands/oil sands: 27-68 gallons
- Fuel ethanol from corn: 2,510-29,100 gallons (irrigation)
- Biodiesel from soy: 14,000-75,000 gallons (irrigation)

**Shale gas production uses less water than any other significant energy source**

*Source: U.S. Department of Energy*
How Our Water Usage Stacks Up

- Power generation: 5,930
- Industrial: 1,680
- Public water systems: 1,550
- Other: 268
- Mining: 182
- Marcellus Shale Drilling: 30

Estimated water use at the peak drilling rate achieved in the Barnett Shale (3,000 horizontal wells per year), 5 times drilling level in the Marcellus in 2009.

Source: USGS, Pennsylvania Water Consumption
Water Impoundments

- Engineered design
- DEP construction standards
- ESCGP-1 Permits required
- Enhanced permit requirements with leak detection or groundwater monitoring if used to contain flow back water
Water Transfer

- Saves thousands of trucks on highways
- Can pump water several miles from impoundment to well during fracturing operation
- Aluminum irrigation pipe for fresh water
- HD Polyethylene or PVC for pumping recycled water
Water supply sources

- Larger streams and rivers
  - Pennsylvania has abundant water supplies
  - Water can be safely withdrawn at reasonable rates during all but the very driest periods
  - Susquehanna and Delaware River Basin Commissions have regulated water withdrawal for many years; no such regulation presently exists in the Ohio River basin
  - Industry and DEP have agreed to adopt SRBC rules; DEP is approving all water management plans
  - Protection of downstream uses

- Municipal water supplies

- Acid mine drainage – suitable for use with proper treatment
Frac Mixture

What goes into the well?

- Water: 90%
- Chemicals: 0.5%
- Sand: 9.5%

Primarily fresh water, with some sand, and a very small proportion of common chemicals, representing 0.5% of the mix. The chemicals are in very small quantities, low concentrations, used in highly supervised environments, and injected through multiple layers of cemented steel casings.
## Typical additives used in frac water

<table>
<thead>
<tr>
<th>Additive type</th>
<th>Main compound</th>
<th>Purpose</th>
<th>Common use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction reducer</td>
<td>Polyacrylamide</td>
<td>Reduces friction between fluid and pipe</td>
<td>Water treatment; soil conditioner; some children’s toys</td>
</tr>
<tr>
<td>Biocide</td>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water that produce corrosive byproducts</td>
<td>Disinfectant; sterilize medical and dental equipment and surfaces</td>
</tr>
<tr>
<td>Scale inhibitor</td>
<td>Ethylene glycol</td>
<td>Prevents scale deposit in the pipe</td>
<td>Automotive anti-freeze, household cleaners, de-icing agent</td>
</tr>
<tr>
<td>Oxygen scavenger</td>
<td>Ammonium bisulfite</td>
<td>Removes oxygen from the water to protect the pipe from corrosion</td>
<td>Cosmetics, food and beverage processing, water treatment</td>
</tr>
<tr>
<td>Diluted Acid</td>
<td>Hydrochloric Acid</td>
<td>Help dissolve cement and minerals and help initiate fractures</td>
<td>Swimming pool chemical and cleaner</td>
</tr>
</tbody>
</table>
Safe and Proven

More than 30 state and federal regulatory agencies have extensively studied hydraulic fracturing technology. There are zero confirmed cases of groundwater contamination in one million wells fraced over the last 60 years.
Water Treatment and Disposal

- Water flowed back after frac contains salt and other naturally occurring dissolved solids present in ancient sea water
- Water is gathered and removed from site by either truck or pipeline
- Traditional treatment of natural gas wastewater in PA:
  - Removal of heavy metal constituents, then discharge to large streams or rivers where safely diluted
  - Deep well injection (limited)
- DEP and Industry are aware and prepared for Marcellus waste water
## How much water?

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Est. % of flowback water recycled</td>
<td>50%</td>
<td>70%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>New wells drilled</td>
<td>700</td>
<td>1,200</td>
<td>1,700</td>
<td>2,200</td>
<td>2,700</td>
<td>3,000</td>
<td>wells</td>
</tr>
<tr>
<td>Fresh water requirement</td>
<td>6.7</td>
<td>10.8</td>
<td>14.9</td>
<td>19.3</td>
<td>23.7</td>
<td>26.3</td>
<td>M Gals/day</td>
</tr>
<tr>
<td>Fresh water requirement - % of annual PA rainfall</td>
<td>0.015%</td>
<td>0.024%</td>
<td>0.032%</td>
<td>0.042%</td>
<td>0.052%</td>
<td>0.057%</td>
<td></td>
</tr>
<tr>
<td>Fresh water requirement - % of total PA water use</td>
<td>0.070%</td>
<td>0.113%</td>
<td>0.155%</td>
<td>0.201%</td>
<td>0.246%</td>
<td>0.274%</td>
<td></td>
</tr>
<tr>
<td>Waste water generated</td>
<td>1.0</td>
<td>1.0</td>
<td>0.9</td>
<td>1.2</td>
<td>1.5</td>
<td>1.6</td>
<td>M Gals/day</td>
</tr>
</tbody>
</table>

Assumes drilling levels forecasted by PSU economic impact study (7/2009) and recycling at the percentages indicated above.
8 million gallons per day of flow back water = salt dumped on only state roads annually (750,000 tons)

With proper management and recycling, estimates of waste water from Marcellus drilling are expected to be less than 2 million gallons per day at peak drilling levels.
Water Disposal Solution

There won’t be a “silver bullet” or single technology, the solution will consist of a portfolio of disposal options, many of which are already being utilized including:

- Traditional disposal methods
- Recycling of flow back water (very promising - from zero to 60% in 6 mo.)
- Deep well injection
- Zero liquid evaporation, crystallization, and land filling
Final Reclamation
Production

- Site is reclaimed to a small fraction of its original size during drilling
- Production equipment will remain for life of the well
- Produced fluids will be removed and safely disposed
Is there adequate regulation?

Act 223 - The Oil & Gas Act of 1984

- Primary statute regulating oil and gas drilling activity
- Details permitting and operations requirements for the following:
  - Well drilling permits
  - Well registration and identification
  - Inactive status of wells
  - Well location restrictions
  - Well site restoration
  - Site restoration requirements
  - Casing and cementing requirements – Protection of fresh groundwater
  - Plugging requirements
  - Protection of water supplies
  - Reporting requirements
  - Bonding
  - Enforcement and remedies
PA Code 25, Chapter 78
- Detailed regulations promulgated under Act 223.

Act 214 - Coal and Gas Resources Coordination Act of 1984
- This Act covers governs placement of wells and special regulations in areas containing active coal mines and unmined coal seams.

Act 359 - Oil and Gas Conservation Law of 1961
- Governs spacing of deep wells which penetrate the Onondaga Formation (directly beneath the Marcellus Shale).

PA Code 25, Chapter 102
- Regulations with respect to erosion and sedimentation control for earth disturbance activities.
- Basis for Erosion and Sedimentation Control Manual for oil & gas development (well pads, pipelines, impoundments).
- Requires ESCGP-1 for earth disturbance over 5 acres; applies to all Marcellus wells, pipelines and water impoundments.
PA Code 25, Chapter 105
- Requires permits for stream and wetland crossings.
- Requires permits for stream and wetland encroachments.
- Requirements for dam permits for impoundments if the impoundment is to be used for collection/storage of flowback and/or produced water.
- Construction Guidelines for the construction of impoundments

Federal Clean Water Act and Pennsylvania Clean Streams Law
- These are the laws that allow Pennsylvania to enact the permitting requirements described above associated with Chapter 102 and Chapter 105.

PA Code 25, Chapter 287, Residual Waste
- regulates disposal of wastes from drilling or completion operations
- regulates transportation of wastes from drilling or completion operations and the record keeping
- annual chemical analysis of the waste stream.
Act 220 - Water Resources Planning Act of 2002

- Under Act 220, the PADEP has mandated that operators submit a comprehensive Water Management Plan for all Marcellus Shale wells prior to conducting hydro-fracturing operations on wells.

Title 40 of the Code of Federal Regulations, Part 112

- Mandates Oil Pollution Prevention and regulates by requiring Spill Prevention Control and Contingency Plans

SRBC - Susquehanna River Basin Commission

- Interstate Compact Commission that regulates all water usage within the Susquehanna River Basin in PA (and other states).
- Requires reports, plans and procedures to be filed and followed prior to any activity on a wellsit in the SRBC area. Also includes significant fees for water consumptive use.

US Army Corp of Engineers

- ACOE performs a review of the stream/wetland crossing General Permit applications submitted to the PADEP when impacts from the crossings exceed thresholds defined by the ACOE.
Thank You

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MyRangeResources.com

PaMarcellus.com

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