BALANCING ECONOMIC BENEFITS WITH THE ENVIRONMENTAL IMPACTS OF THE SHALE GAS

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OUTLINE OF TALK

- What is the nature of shale energy production?
- What is the shale energy supply chain?
- What are the economic impacts?
- What are the observable economic impacts of shale energy development?
- What are environmental impacts & costs?
- What are costs & benefits of shale energy?
- Implications & strategies for economic development
1. NATURE OF SHALE ENERGY PRODUCTION
PRIMER ON SHALE DRILLING
Intensive drilling
  - Increased from 97 wells in late 2009 to 405 in late 2010

Production increased
  - 152 mmcf per day in late 2009
  - Over 2 bcf per day in late 2010

In three years PA becomes an exporter of natural gas

Industry is getting very proficient at drilling

Production is increasing faster than anticipated
THE PRODUCTION DECLINE CURVE

- Why is drilling so intensive?
- The steep production decline curve
- First example to right
  - Year 1: 511.9 mmcf
  - Year 2: 257 mmcf
  - Year 10: 88 mmcf
  - Year 30: 32 mmcf
- To keep increasing output, need to keep drilling – a treadmill effect
- Multi-stage fracturing is increasing well productivity
- More gas with fewer wells

Marcellus Production Decline Curves

Horizontal pre 2008 EUR = 2.8 bcf
Stimulated Horizontal 2010 EUR = 4 bcf
2. THE SHALE ENERGY SUPPLY CHAIN
LEASING ACTIVITY

- Goal is to obtain access to prospective properties for exploration
- Must define land and mineral rights & ownership
- People & businesses involved in leasing
  - Land men
  - Clerks & legal assistants
  - Real estate brokers
  - Lawyers
EXPLORATION ACTIVITIES

- Objective is to locate and define oil and gas deposits
- Exploration activities
  - Very advanced technology
  - Seismic survey crews
- Affected businesses
  - Local hotels
  - Restaurants
  - Coffee shops
  - Convenience stores
SITE PREPARATION

- Clearing land and building roads
- Providing access to water and utilities
- 5,000 tons of aggregate per well
- Businesses involved
  - Excavation equipment manufacturers
  - Contractors and dealers
  - Painters and haulers
  - Mulch and fertilizer suppliers
  - Safety equipment manufacturers and suppliers
  - Electrical equipment supplies & contractors
  - Surveying equipment suppliers and contractors
  - Surveying engineering companies
  - Aerial mapping services
WELL CONSTRUCTION

- Starts with a well “spudded” when the bit hits the ground
- Drilling to total depth may take anywhere from 2-4 weeks
- Businesses involved:
  - Crane manufacturers and leasing companies
  - Drill bit manufacturers
  - Steel manufacturers
  - Cement and concrete companies
  - Chemical manufacturers
  - Safety equipment companies
- Many companies contract out drilling operations
- 125 tons of concrete per well
WELL STIMULATION

- Hydraulic fracturing
- Businesses involved:
  - Hydraulic fracturing contractors
  - Trucking companies
  - Diesel fuel companies
  - Water management companies
- Water and material intensive
  - 25 rail cars of sand
  - Millions of gallons of water
WELL SITE AFTER DRILLING

- Companies try to restore land to original condition
- Footprint is rather small
- Grass is replanted
- An access road remains
- Forest fragmentation occurs – some benefits for wildlife
MIDSTREAM DEVELOPMENT

- Construction of compressor stations
- Lower pressure gathering lines
- High pressure steel pipelines
- Businesses involved:
  - Pipeline construction companies
  - Heavy equipment contractors
  - Steel pipe producers
  - Value and compressor manufacturers
NATURAL GAS PROCESSING

- Strip out valuable liquids
- Some products
  - Propane, butane, ethane, etc.
  - Valuable feed stocks for petrochemical production
- Businesses
  - Pipe fitters
  - Steel pipe manufacturers
  - Equipment producers
  - Contractors
EXPANSION OF DOWNSTREAM INDUSTRIES

- Abundant, low cost shale energy attracts additional industry
- Possible sectors:
  - Petro-chemical manufacturing
  - Fertilizer production
  - Metal and glass industries
  - Electric power generation
  - CNG use in transportation
- These industries have their own supply chains and would generate additional economic impacts
3. ECONOMIC IMPACTS
WHAT IS ECONOMIC IMPACT ANALYSIS?

- Quantitative model of the inter-industry transactions between economic sectors
- Developed by Wassily Leontief who won Nobel Award for this in 1973
- Provides an estimate for how spending in one sector affects
  - Other sectors of the economy and
  - Household disposable income
- Widely used for many types of projects, from sports stadiums, wind turbines to coal mines
IMPACT ANALYSIS SCHEMATIC

Increase in spending

↓

Stimulate supply chain sales

↓

Increase in income and employment

↓

Induced increase in consumer spending

Feedback

PENN STATE STUDIES ON MARCELLUS

- Collected accounting data on what drilling companies spent and where they spent their dollars
- Conducted two subsequent surveys of Marcellus industry spending
- Estimated impacts of this spending on Pennsylvania economy
  - Jobs
  - Valued added
  - Tax Revenues
<table>
<thead>
<tr>
<th>Category</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Spending</td>
<td>3,224.6</td>
<td>5,283.9</td>
<td>11,477.1</td>
</tr>
<tr>
<td>Lease &amp; Bonus</td>
<td>1,837.7</td>
<td>2,172.4</td>
<td>2,068.5</td>
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<tr>
<td>Exploration</td>
<td>121.9</td>
<td>117.1</td>
<td>208.4</td>
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<tr>
<td>Upstream: Drilling &amp; Completion</td>
<td>857.8</td>
<td>2,151.0</td>
<td>7,377.0</td>
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<tr>
<td>Midstream: Pipeline &amp; Processing</td>
<td>329.4</td>
<td>698.6</td>
<td>1,303.9</td>
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<tr>
<td>Royalties</td>
<td>22.2</td>
<td>53.4</td>
<td>346.0</td>
</tr>
<tr>
<td>Other</td>
<td>55.5</td>
<td>91.4</td>
<td>173.3</td>
</tr>
</tbody>
</table>
COMPOSITION OF FIRST ROUND OF SUPPLY CHAIN SPENDING

- Construction: 30%
- Oil & Gas Support: 26%
- Wholesale Trade: 16%
- Oil & Gas Drilling: 12%
- Services: 7%
- Manufacturing, Utilities, Agriculture: 2%
- Transportation: 2%
- Retail Trade: 3%
## JOBS & VALUE ADDED (MILLIONS) 2010

<table>
<thead>
<tr>
<th>Sector</th>
<th>Jobs</th>
<th>Value Added</th>
<th>Sector</th>
<th>Jobs</th>
<th>Value Added</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag, etc</td>
<td>780</td>
<td>22.2</td>
<td>Real estate &amp; rental</td>
<td>5,360</td>
<td>1,192.30</td>
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<tr>
<td>Mining</td>
<td>14,886</td>
<td>1,411.00</td>
<td>Scientific &amp; tech services</td>
<td>11,042</td>
<td>1,058.10</td>
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<tr>
<td>Utilities</td>
<td>478</td>
<td>194</td>
<td>Management of companies</td>
<td>1,318</td>
<td>195.2</td>
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<tr>
<td>Construction</td>
<td>23,730</td>
<td>1,431.80</td>
<td>Administrative &amp; waste services</td>
<td>6,387</td>
<td>268.2</td>
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<tr>
<td>Manufacturing</td>
<td>2,936</td>
<td>370.7</td>
<td>Educational services</td>
<td>3,405</td>
<td>152.1</td>
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<tr>
<td>Wholesale Trade</td>
<td>9,974</td>
<td>1,338.80</td>
<td>Health &amp; social services</td>
<td>12,815</td>
<td>736.1</td>
</tr>
<tr>
<td>Retail trade</td>
<td>16,581</td>
<td>839.3</td>
<td>Entertainment &amp; recreation</td>
<td>2,641</td>
<td>91.6</td>
</tr>
<tr>
<td>Transportation</td>
<td>4,864</td>
<td>354</td>
<td>Hotel &amp; food services</td>
<td>7,767</td>
<td>229.9</td>
</tr>
<tr>
<td>Information</td>
<td>1,729</td>
<td>274.6</td>
<td>Other services</td>
<td>6,634</td>
<td>254.5</td>
</tr>
<tr>
<td>Finance &amp; Insurance</td>
<td>4,986</td>
<td>664.7</td>
<td>Government &amp; Misc.</td>
<td>1,577</td>
<td>81.9</td>
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<tr>
<td><strong>Total</strong></td>
<td>139,889</td>
<td>11,160.80</td>
<td></td>
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</table>
BENEFITS OF LOWER NG PRICES

- Used an econometric model of PA energy demand
- Higher Marcellus production reduced US natural gas prices by 12% in 2010
- These lower NG prices reduced bills for natural gas and electricity in PA by $633 million
- Additional economic impacts occur - similar to a tax cut for households and businesses
4. SHALE ENERGY, JOBS, AND TAX REVENUES
Unemployment Rates for Top Shale Producing States and US Average, September 2011

- North Dakota: 3.5
- Oklahoma: 5.9
- Louisiana: 6.9
- Pennsylvania: 8.3
- Arkansas: 8.3
- Texas: 8.5
- United States: 9.1
UNEMPLOYMENT RATE DIFFERENCES FROM STATE AVERAGE, 2007-2011

- Greene 215 Wells
- Susquehanna 227 Wells
- Lycoming 261 Wells
- Washington 363 Wells
- Tioga 481 Wells
- Bradford 691 Wells
CUMULATIVE DRILLING & UNEMPLOYMENT BY COUNTY 2011
5. ENVIRONMENTAL IMPACTS
ENVIRONMENTAL IMPACTS

- Unavoidable impacts during drilling
  - Clearing of land for well pads and pipelines
  - Local congestion, noise, dust in rural communities
  - Emissions during drilling
- Environmental hazards
  - Stray gas – failures in casing & contamination of water
  - Containment pond breaches
  - Spills from petroleum liquids handling
  - Well blow-outs & resulting spills
- Environmental risk – perceptions
  - There have been problems
  - What is the proper context?
  - Can these problems result in widespread contamination?
## PA ENVIRONMENTAL RECORD

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2008–10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wells drilled</td>
<td>170</td>
<td>710</td>
<td>1,259</td>
<td>2,139</td>
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<tr>
<td>Serious violations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement and casing</td>
<td>2</td>
<td>6</td>
<td>64</td>
<td>72</td>
</tr>
<tr>
<td>Blowouts and venting</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Major spills</td>
<td>0</td>
<td>48</td>
<td>8</td>
<td>56</td>
</tr>
<tr>
<td>Stray gas</td>
<td>0</td>
<td>10</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>Subtotal</td>
<td>2</td>
<td>64</td>
<td>86</td>
<td>152</td>
</tr>
<tr>
<td>Other violations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erosion</td>
<td>84</td>
<td>111</td>
<td>155</td>
<td>350</td>
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<tr>
<td>Other spills</td>
<td>2</td>
<td>120</td>
<td>204</td>
<td>326</td>
</tr>
<tr>
<td>Water</td>
<td>10</td>
<td>61</td>
<td>126</td>
<td>197</td>
</tr>
<tr>
<td>Administrative</td>
<td>81</td>
<td>283</td>
<td>535</td>
<td>899</td>
</tr>
<tr>
<td>Subtotal</td>
<td>177</td>
<td>575</td>
<td>1,020</td>
<td>1,772</td>
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<tr>
<td>Grand total</td>
<td>179</td>
<td>639</td>
<td>1,106</td>
<td>1,924</td>
</tr>
</tbody>
</table>
CASING IS IMPORTANT

Conductor casings are cemented to prevent drilling fluids circulating outside the casing, causing surface erosion.

Surface casings are cemented to prevent hydrocarbons encroaching into fresh water zones, to anchor blow-out preventers and to support deeper casing strings.

Intermediate casing strings are cemented to isolate formations which might break down and cause a loss of circulation in the well.

Production casings are cemented to stop oil migrating to thief zones and to prevent the sloughing of formations causing a drop in productivity.
ENVIRONMENTAL VIOLATIONS

All Violations

- Administrative: 42.0
- Erosion: 16.4
- Other Spills: 9.2
- Water: 7.1
- Gas Migration: 0.7

Serious Violations

- Administrative: 3.4
- Erosion: 2.6
- Other Spills: 0.7
- Water: 0.4
6. BENEFIT COST ANALYSIS
ECONOMIC BENEFITS & ENVIRONMENTAL COSTS

- **Benefits**
  - Gains in real output, jobs, and tax revenues
  - Environmental – avoided emissions from coal

- **Costs**
  - Air emissions from shale energy production
  - Water pollution
  - Forest disruption
  - Noise, traffic externalities, etc.

- What level of benefits are necessary to accept environmental risks?
### BENEFITS & COSTS IN DOLLARS PER WELL

<table>
<thead>
<tr>
<th>Economic &amp; Environmental Benefits</th>
<th>Economic value added</th>
<th>Environmental costs:</th>
<th>Environmental costs:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3,957,746</td>
<td>Air impacts from upstream life-cycle emissions</td>
<td>2,796</td>
</tr>
<tr>
<td>Avoided air pollution</td>
<td>17,132</td>
<td>Air impacts from diesel use during hydraulic fracturing</td>
<td>7,245</td>
</tr>
<tr>
<td>Avoided community health impacts from coal</td>
<td>29,111</td>
<td>Water pollution using household values</td>
<td>193</td>
</tr>
<tr>
<td>Subtotal</td>
<td>46,243</td>
<td>Forest disruption</td>
<td>3,943</td>
</tr>
<tr>
<td>Total Benefits</td>
<td>4,003,989</td>
<td>Total Costs</td>
<td>14,178</td>
</tr>
</tbody>
</table>
ENVIRONMENTAL BEST PRACTICES

- Considerable learning by regulators & industry
- Must protect subsurface water – keys are casing design & cement
- Tighter well safety and construction standards
  - Blow out preventer stacks
  - Well control emergency teams
- Recycling water and using pipelines to move fresh and produced water – reduces traffic & may reduce spills from traffic accidents
- Avoiding erosion problems - closed system drilling – all water and materials are tracked – tarpaulins are used at well sites to capture spills
7. CONCLUSIONS
CONCLUSIONS

- Environmental impacts – infrequent in numbers with localized impacts but highly publicized
- Producing shale energy in close proximity to densely populated areas is feasible but problematic
- Risk of the unknown is very important – risk assessment is crucial
- Economic benefits are significant and the environmental risks appear manageable
- Regulation should be based upon sound science
  - Rigorous and transparent regulations are required, but
  - Flexible to encourage innovation
THANK YOU !!!