Industrialization and the Shale Gas/Oil Operation

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Northwestern University
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Outline of Presentation

• Geology Rules !: Why Is the Process Called Unconventional, and Why Does It Require Heavy Industrialization?

• What Industrialization Is Needed: Upstream, Midstream, Downstream

• What Shale Gas/Oil Might Look Like in Illinois: Is It Worth It? Are There Constraints and Alternatives?
USGS Estimates of Oil/Gas in Illinois Basin

“For the Illinois Basin, the USGS estimated the quantities of undiscovered, technically recoverable oil and gas resources as follows: (1) a mean of 214 million barrels of oil, (2) a mean of 4.65 trillion cubic feet of natural gas, and (3) a mean of 24 million barrels of natural gas liquids.”

214 million barrels of oil is about 10 DAYS of U.S. consumption

4.65 TCF of nat gas is about 2 MONTHS of U.S. consumption

Why Is Shale Gas/Oil Development “Unconventional”?

Because it requires 4 technologies only recently combined to make gas/oil production from impermeable shales technically and economically feasible:

• **Directional drilling**: needed to access a thin layer of shale with long laterals.

• **High frac fluid volumes**: needed to stimulate hydrocarbon release from many natural fractures.

• **Slickwater**: needed to control the amount of power needed to pump large volumes of frac fluids, at high pressures, quickly, over long distances, through small diameter casing.

• **Multi-well Pads and Cluster Drilling**: needed to access as much of the inventory as possible, under constraints of leasing and capital.
High Volume, Slickwater Frac’ing from Long Laterals: The Concept

- Cap rock
- ~ 5000 ft
- Cap rock
- ~ 100 ft
- Pay zone
- Shale Layer
- Well is turned horizontal
- Hydrofrac Zone
- The Lateral >5000 ft

Not to scale
Producing Shales are Heavily Fractured Naturally

Geneseo-Burket (Devonian black shale)

Taughannock Falls State Park, Trumansburg, N.Y.

Photo Courtesy T. Engelder
3D Imaging of the Sub-Surface

From National Geographic, December 2012
Targeting the Shale Layer Via Multiple, “Horizontal” Wells from Clusters of Pads

From Cody Teff, Shell Appalachia, WELL CONSTRUCTION PRACTICES IN THE MARCELLUS
Example of Spatially Intense Development from Clustered, Multi-Well Pads:
Dallas/Fort Worth Airport Property, Barnett Shale Play

- 53 pads on 18,076 acres, 30 square miles
- Each red line is a well
- Each red dot is a pad
- Almost complete coverage
- Patchwork, mostly ideal units
- One leasor, One developer
Barnett Shale Play: Pad Density
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Horn River Area, NE British Columbia

Two Island Lake Operations Status

APA 70-K Pad
- Stimulation operations complete
- Total of 274 fracs placed
- 111 million lbs sand placed
- 5.6 million bbls water pumped
- Flow back & testing in progress
- 6 wells on production
- All wells on-prod early July

APA 52-L Pad
- 14 wells total
- 11 Muskwa wells

ECA 83-K Pad
- 14 Muskwa wells
- 11 wells drilled
World’s Largest Frac Job (?), Encana, Horn River Area, NE British Columbia

16 wells
417 million gallons of water
78,400 tons of frac sand
8 million gallons of fracking chemicals
500 frac intervals
10,000 foot laterals
40,000 hp for fracking pumps
Example of Upstream Industrialization: Frac Sand Mining in the Upper Midwest

http://www.huffingtonpost.com/2012/12/07/frac-sand-mining-wisconsin-health_n_2256753.html#slide=more234188
Example of Midstream Industrialization: Frac Sand Unloading/Loading in Wyalusing, PA

Photos Courtesy Prof. Yuri Gorby
http://www.youtube.com/watch?v=-iTCRJ6j_zM
Example of Midstream Industrialization: Pad/Support Construction

Photos courtesy of Bob Donnan
Fracing a Multi-Well Pad Is an Intense Industrial Process, 24/7, 365

Photo courtesy Bob Donnan
Pads Can Be Constructed Regardless of Terrain

"DCNR Lease, Tract 100, Loyalsock State Forest, PA

In the large U.S plays, shale gas/oil development has only just begun, and it requires a large number of large, multi-well, clustered pads and significant ancillary infrastructure.

Photos Courtesy of Bob Donnan
Additional Midstream Surface Impacts: Flares

Photos Courtesy of Bob Donnan
Industrialization on a Global Scale: Light Pollution and Waste of a Natural Resource

Credit: NASA Earth Observatory/NOAA NGDC © 2012
Midstream Surface Impacts on Health/Environment: Impoundments

Photo Courtesy of Bob Donnan
Midstream Surface Impacts: Pipelines and Compressor Stations

Buffalo, Pa, Compressor Station

Photo Courtesy of Bob Donnan
Midstream Impact: Processing Plant Burn-Off, Houston, PA

9/18/11
2:03pm

Photos courtesy of Robert Donnan
Midstream Impact: Processing Plant Burn-Off, Houston, PA

9/28/11
7:28pm
Downstream Methane Leakage from Aging Urban Distribution Pipelines: Boston MA

Natural background level is about 1.9 ppm
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"For the Illinois Basin, the USGS estimated the quantities of undiscovered, technically recoverable oil and gas resources as follows: (1) a mean of 214 million barrels of oil, (2) a mean of 4.65 trillion cubic feet of natural gas, and (3) a mean of 24 million barrels of natural gas liquids."

- 214 million barrels of oil is about 10 DAYS of U.S. consumption
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Notice NNW-SSE orientation of non-square, about 640 acre, spacing unit. Geology and leasing control.
An Industrial-Ideal Pad/Well Buildout Scenario: White County, IL
Clustering of Pads in Tioga County, PA
Clustering of Pads in Tioga County, PA
The Shale Play Life Cycle

- Discovery followed by leasing frenzy.

- Drilling boom follows to meet “held-by-production” lease requirements.

- Sweet spots identified, targeted and drilled off.

- Gas production rises rapidly and is maintained for cash-flow despite uneconomic full-cycle costs.

- Sweet spots become saturated and well quality and field production decline.

- Plays like the Haynesville become middle aged after just five years.

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Key Data for **Estimation of Well Productivity and Economics**: PA

4.2 bcfe EUR Type Curve
- IP Rate: 4.0 mmcfe/day
- First month average: 3.5 mmcfe/day
- Finding Cost: 1.28 ($/mcf)
- Well Cost: $4.5 mm

From: Chesapeake Energy (CHK) published *pro forma* data
Bakken/Three Forks Horizontal Well Type Decline Curves including North Dakota and Montana

- **Oil and Gas production (Barrels oil equivalent)**
- **Oil Production (Barrels)**
- **Gas Production (Mcf)**

**Oil**
- First year = 70%
- Second year = 36%
- Third year = 24%
- Fourth year = 19%

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(data from DrillingInfo/HPDI, March, 2013)
Estimated Ultimate Recovery for Pennsylvania Marcellus Horizontal Wells By County

- Remaining Well Life
- First 3 years

62%–77% produced in first 3 years
EIA EUR estimate of 1.56 bcf underestimates best Counties
# Annual Capex Required to Offset Overall Annual Decline by Shale Play

<table>
<thead>
<tr>
<th>Field</th>
<th>Rank</th>
<th>Number of Wells needed annually to offset decline</th>
<th>Approximate Well Cost (million $US)</th>
<th>Annual Well Cost to Offset Decline (million $US)</th>
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© Hughes GSR Inc, 2012 (well cost data from various sources and is approximate)
## Prognosis for Future Production based on Latest Rig Count

<table>
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<tr>
<th>Field</th>
<th>Rank</th>
<th>Number of Wells needed annually to offset decline</th>
<th>Wells Added for most recent Year</th>
<th>October 2012 Rig Count</th>
<th>Prognosis</th>
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</tbody>
</table>

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“Natural gas is a delaying tactic…There is no time to waste… We have to decide whether we are in the business of delaying bad outcomes or whether we are in the business of preventing bad outcomes.”

Ken Caldiera, Senior Scientist
Department of Global Ecology, Carnegie Institution, Stanford, CA
April 15, 2012
We Own the Wind, the Sun, the Water: Their Fuel Cost is Zero.

Wind, water and solar energy will provide a stable, renewable source of electric power not subject to the same fuel supply limitations as fossil fuels and nuclear power. Due to the eventual depletion of coal, oil, natural gas, and uranium resources, their prices will continue to rise.

We Own the Wind, the Sun, the Water: They Make Us Energy Secure and Independent
Where Can You Find Reliable Information?

Physicians, Scientists, and Engineers for Healthy Energy is dedicated to supplying objective, evidence-based, scientific information and resources on unconventional gas development (high-volume hydrofracking) and other novel energy production methods. PSE’s mission is to bring transparency to the important public policy issues surrounding such methods, helping to level the playing field for citizens, advocacy groups, media, policy-makers, and politicians.

http://www.psehealthyenergy.org/
Where Can You Find Reliable Information?

[Click to access EarthWorksAction.org website for more information]