## Shale Energy Development in Pennsylvania: What? Where? How? Why? When and for how long?

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INSTATE Marcellus Cente for Outreach and Research

## PETROLEUM & NATURAL GAS FORMATION



Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.



Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas. Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and gas deposits.

## Types of Oil and Gas Reservoirs



# **Common Types of Reservoir Rocks**



Source: CAPP



#### GEOLOGIC FACTORS CONTROLLING HYDROCARBON PROJECT SUCCESS

- 1. THICKNESS
- 2. THERMAL MATURITY
- **3. GAS CONTENT**
- 4. AREAL/LATERAL EXTENT
- 5. DEPTH
- 6. STRUCTURAL COMPLEXITY7. ROCK PROPERTIES







## Shale Energy: A Global Play







Third edition, 1993

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#### Summary of OH Shale Production in 1H 2014

- 503 producing wells
- 4.42 MMBBLs oil

2000

1000

8000

.

6000.

2000.

000

- 156 BCF of gas produced
- 2.52 MMBBLs of brine produced
- 13.8 BBLs of brine/MMCF of gas

#### Utica Shale Depth

10000

2000

4000



Utica Shale depth is an MCOR interpretation based on multiple data sources.

# Site Construction









# Well Site in Operation



#### Examples of landscape disturbance from natural gas extraction



Non-Marcellus permits
 Marcellus permits

Groundwater

#### CROSS-SECTION OF A TYPICAL HORIZONTAL MARCELLUS WELL

**Background Not to Scale** 

Marcellus Shale Formation

@ marcellus.psu.edu

#### AT THE SURFACE

The hydrocarbons in the shale flow up to the surface under pressure where they are routed to be refined for use. Natural gas will be sent to a compressor station and then transported for use via pipelines.

installed through the soil and into bedrock to stabilize the upper portion

of the well.



SURFACE TO ±500'

SURFACE TO ±2000

SURFACE TO

±5000'-9000'



13<sup>3</sup>/4" diameter "surface" casing is installed and cemented within a 17<sup>1</sup>/2" diameter borehole to 50' or more below fresh groundwater (typically 500' to 1,000') to protect the aquifer from deeper brine and hydrocarbons.

9 %" diameter "intermediate" casing is installed and cemented within a 12 %" diameter borehole to a depth of approximately 2,000' to seal off shallow hydrocarbons and brines and prevent them from migrating upward.

5 ½" diameter "production" casing is installed within a 7%" diameter borehole that is drilled vertically and then gradually turned horizontally into the producing zone of the shale. Production tubing carries the hydrocarbons to the surface.



0' 20" diameter "conductor" casing is

#### **Multiple Wells Per Pad = Reduced Footprint**



Graphic from Range Resources



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# **Reclaimed Well Pad**



### **Shale Gas Development Water Use**



- 4917 producing wells in PA as of end of 2013
- Estimated total water use of 21.6 billion gallons of water (514 MMBBLs)\*
- 1,352 new producing wells in 2013
- Estimated 2013 water use of 5.9 billion gallons or 16.3 million gallons per day\*
- Approximately 6% of injected fluids return initially and 10 BBLs/1 MMCF of gas produced

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\*Assumes average of 4.4 million gallons of water used during hydraulic fracturing per SRBC



#### Source: Pa Fish and Boat Commission

\*Estimated based on current SRBC/DEP data

## **Shale Fracturing Fluid Composition**



For more info: www.fracfocus.org

# Water Intake Pumping Station



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### Water Transport and Storage





### Efficiency of Piping Water



- Each well could require ~1000 truck trips
- Cost to install 12 km pipeline was ~\$10MM
- Trucking water cost ~\$20MM
- Recognize ~50% savings while minimizing fuel missions, truck traffic, and road impacts

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1 000

2,000

3.000

4.000

Hydraulic fracturing often involves the injection of more than a million gallons of water, chemicals, and sand at high pressure down the well. The depth and length of the well varies depending on the characteristics of the hydrocarbon-bearing formation. The pressurized fluid mixture causes the formation to crack, allowing natural gas or oil to flow up the well.

- 6,000

5.000

7.000 feet

Hydrocarbon-bearing Formation Water Use in Hydraulic Fracturing Operations
Water Acquisition - Large volumes of water are transported for the fracturing process.
Chemical Mixing - Equipment mixes water, chemicals, and sand at the well site.
Well Injection - The hydraulic fracturing fluid is pumped into the well at high injection rates.
Flowback and Produced Water - Recovered water (called flowback and produced water) is stored on-site in open pits or storage tanks.
Wastewater Treatment and Waste Disposal - The wastewater is then transported for treatment and/or disposal.

Induced Fractures

Source: Draft EPA Hydraulic Fracturing Study Workplan



### **Produced Fluid Management Options**



Brine Water Storage Tank



### Produced fluid management options

- Direct reuse (blending)
- On-site treatment w/reuse
- Off-site treatment w/reuse
- UIC well disposal

#### Treatment technologies include

- Filter socks
- Chemical precipitation
- Electrocoagulation
- Evaporation (MVR)
- Filtration
- Costs of <\$2 to \$10+/BBL</p>

During 2013 in PA ~87% of shale gas flowback and produced water was recycled and ~13% disposed (mainly via injection wells)

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# Gas Happens!

Photograph by Matthew Conheady (www.nyfalls.com)

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## **Sources of Methane in Groundwater**



Groundwater can contain both biogenic and thermogenic methane prior to drilling, it is important to verify pre-drilling water quality

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Graphic from Pittsburgh Area Geologic Society, Gas Migration in W. Pa.

#### Methane in Groundwater in NE PA



Many of these water wells with increased methane were near Marcellus wells with known methane migration problems. As a result the gas wells were either abandoned or remediated to seal off leaking zones, consequently reducing methane levels in groundwater.

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Jackson et al, 2013

**Topographic relationship of** methane and groundwater (Molofsky et al 2013)



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# **Groundwater/Pad Protections**







## Where Are We Getting Our Power





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## Northeast US Production

Northeast natural gas production (September 2011-September 2013)

billion cubic feet per day



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eia

#### **U.S. Natural Gas Production**

### U.S. dry natural gas production trillion cubic feet

billion cubic feet per day

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Source: EIA (2014)

### U.S. Oil Production

#### U.S. crude oil production

#### million barrels per day



### **Power Gen Trends**

#### U.S. Electricity Generation by Fuel, All Sectors

thousand megawatthours per day



Coal
 Natural gas
 Petroleum

- Nuclear
- Hydropower
- Renewables
- Other sources

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#### Marcellus - Proposed Infrastructure Projects through 2016



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Source: Range Resources



 Hackberry, LA: 1.7 Bcfd (Sempra – Cameron LNG) (CP13-25) 6. Cove Point, MD: 0.82 Bcfd (Dominion – Cove Point LNG) (CP13-113) 7. Astoria, OR: 1.25 Bcfd (Oregon LNG) (CP09-6)

- 8. Lavaca Bay, TX: 1.38 Bcfd (Excelerate Liguefaction) (CP14-71 & 72)
- 9. Elba Island, GA: 0.35 Bcfd (Southern LNG Company) (CP14-103)
- 10. Sabine Pass, LA: 1.40 Bcfd (Sabine Pass Liquefaction) (CP13-552)
- 11. Lake Charles, LA: 1.07 Bcfd (Magnolia LNG) (PF13-9)
- 12. Plaguemines Parish, LA: 1.07 Bcfd (CE FLNG) (PF13-11)
- 13. Sabine Pass, TX: 2.1 Bcfd (ExxonMobil Golden Pass) (PF13-14)

#### PROPOSED CANADIAN SITES IDENTIFIED BY PROJECT

SPONSORS

- 14. Kitimat, BC: 1.28 Bcfd (Apache Canada Ltd.)
- 15. Douglas Island, BC: 0.23 Bcfd (BC LNG Export Cooperative)

Office of Energy Projects

16. Kitimat, BC: 3.23 Bcfd (LNG Canada)

\* Filed Certificate Application

# **Economic Opportunities**



- New business opportunities
- New employment opportunities
- Increased business-to-business spending
  - construction, trucking, rail, steelmaking, engineering services, hotel, restaurants, groceries
- Increased tax revenues
  - Production taxes
  - Income taxes
  - Sales taxes
  - Pennsylvania has collected
    - \$630 million in well impact fees
    - Approximately \$2 billion in state and local taxes from 2006-2013

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## Shale Energy Development Trends in PA

#### PA Marcellus rig count now 55

- 30 month low in PA
- Almost half of 2011 count
- 2/3 not in wet gas

# PA now net exporter of methane and propane

- 12 bcf/d produced in PA
- 1.9 TCF in 1H 2014
- ~8,500 wells drilled to date
- ~5,500 producing wells



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### The End

#### Questions??

#### Thank you!!

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