Natural Gas Working Group

Development of Shale-Deposited Natural Gas:

Review of Potential

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Shale-Deposited Natural Gas:
What are Gas Shales?

- Geologic characteristics of shale:
  - sedimentary rock formation
  - consolidated clay and silt-sized particles
  - organic-rich containing vast quantities natural gas (significant deposit)

- Primary function of shale (pre-development):
  - trap and seal deposits in natural gas-bearing sandstone and carbonate reservoirs (pools or formations).

Shale-Deposited Natural Gas:
What are Gas Shales?

- Shale formations store natural gas in one of three methods:
  - Free natural gas within natural micro-fractures
  - Free natural gas within minute rock pores
  - Adsorbed gas: Methane molecules attached to organic material contained within solid matter
  - Most formations utilize all three storage mechanisms.

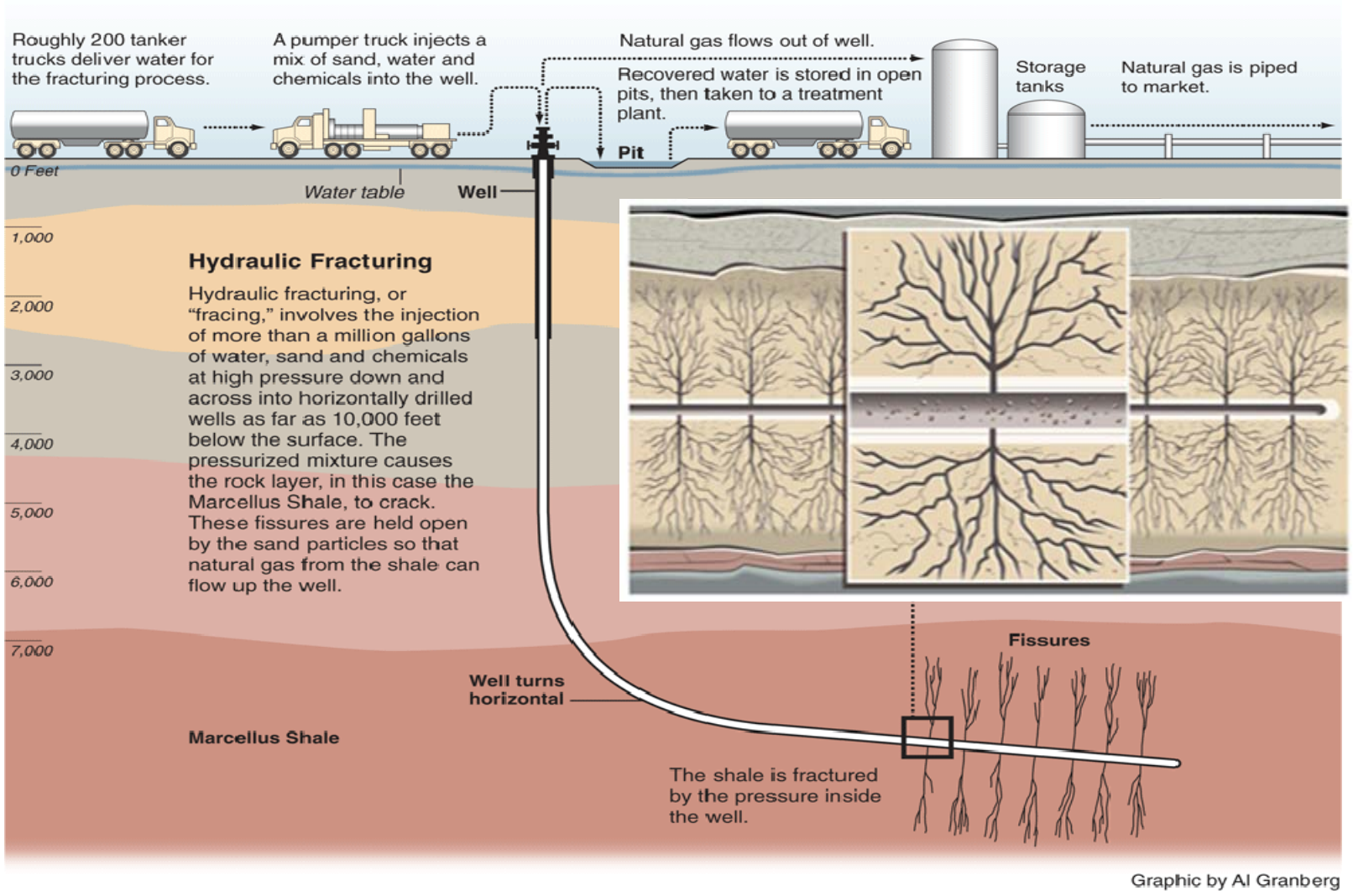
- Requirements for producing from a rock formation (reservoir):
  - Sufficient porosity (space to hold natural gas)
  - Sufficient effective permeability (connectivity to allow flow of natural gas).

- Little or no natural permeability in gas-bearing shale formations.

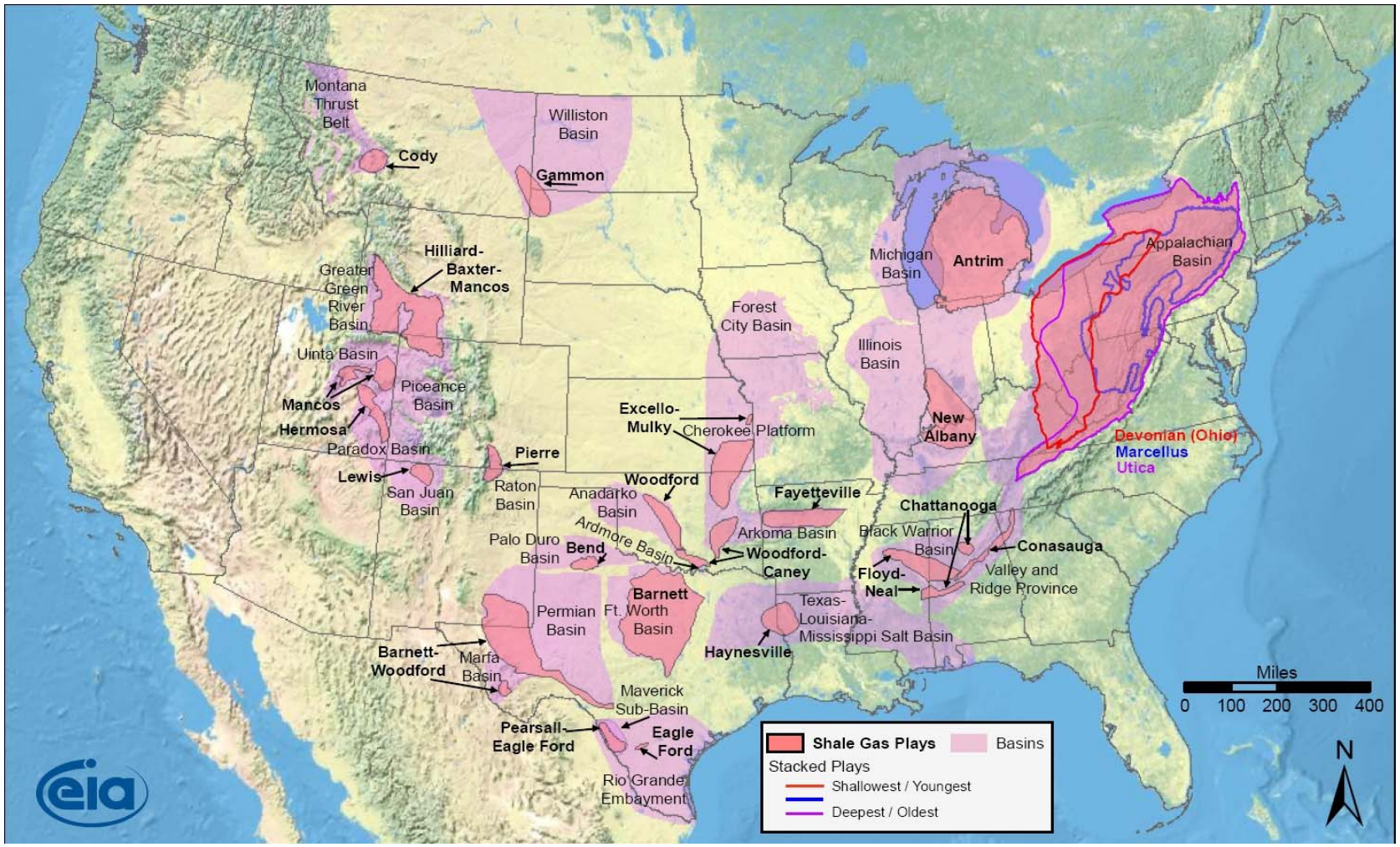
Shale-Deposited Natural Gas:
Accessing Shale Formations

- Technological innovations in *exploration:*
  - Development of 3-D and 4-D seismic led to enhanced capability to delineate the limits of the deposits.
- Technological innovations in *drilling:*
  - Horizontal drilling increased wellbore exposure by a factor of five to twenty times.
- Technological innovations in *well completions:*
  - Hydraulic fracturing creates network of artificial sand-packed fractures
  - Multiple-stage fracturing stimulations boost recovery rates.

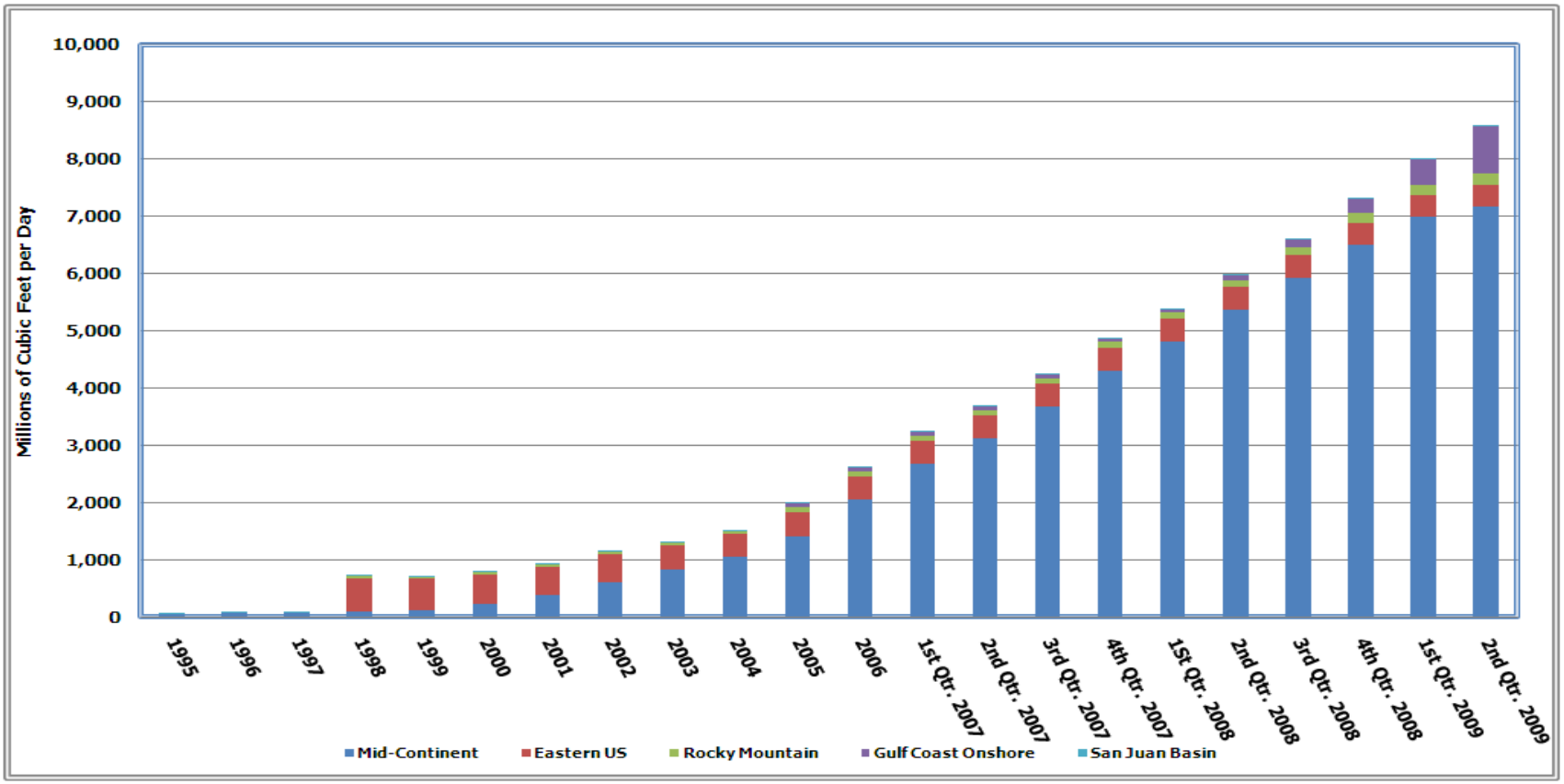
Shale-Deposited Natural Gas:
Accessing Shale Formations



Shale-Deposited Natural Gas:
Location of Lower 48 Shale Formations



Shale-Deposited Natural Gas:
Lower 48 Production



Source: Lippman Consulting, Inc.

Shale-Deposited Natural Gas: Recoverable Reserve Potential

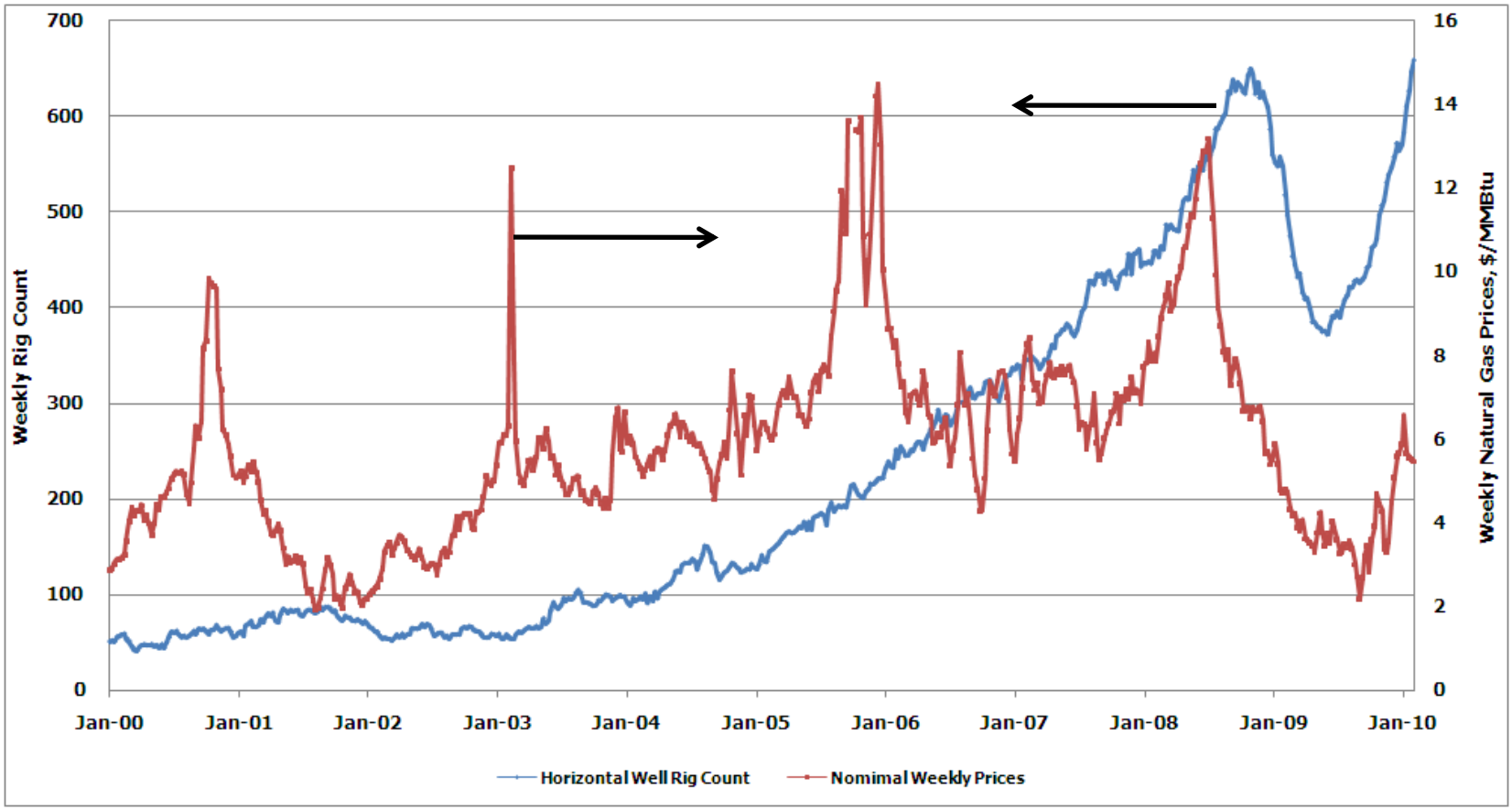
- Estimates of Original Gas-In-Place (OGIP) for shale formations exceed 3,000 Tcf
- Assessments of recovery (extraction) rates produce a wide range of values
- Estimates of recoverable reserves range from 267 Tcf to 842 Tcf
- Major differences arise from reserve estimates of two shale formations: the Marcellus and the Haynesville
- Potential Gas Committee places recoverable reserves from shale formations at 616 Tcf.

Natural Gas Shale Formations in the Lower 48

Shale Formation	Approximate Vertical Depth, feet	Approximate Recoverable Reserves, Tcf
Barnett	6500 - 8500	44.0
Wordford	6000 - 11000	11.4
Fayetteville	1000 - 7000	41.6
Antrim	600 - 2200	20.0
Huron	1000 - 7000	N/A
Marcellus	4000 - 8500	392.0
New Albany	500 - 2000	19.2
Bakken	>10000	N/A
Baxter	>11000	N/A
Pierre	2500 - 5000	N/A
Mancos	>13000	N/A
Haynesville/Bossier	>11000	251.0
Pearsall-Eagleford	>11500	N/A
Lewis/Mancos	3000 - 6000	20.0
Total		799.2

Source: Various, including EIA, Navigant Consulting and others

Shale-Deposited Natural Gas: Economics (Rig Count vs Prices)



Source: California Energy Commission (Derived from Baker Hughes and NYMEX)

Shale-Deposited Natural Gas: Development in Canada

- Western Canada/Western Canadian Sedimentary Basin
  - Identified shale formations:
    - Horn River Basin's Muskwa shale (northeast British Columbia)
    - Western Canadian Sedimentary Basin's Montney shale (British Columbia)
    - Colorado Shale in Alberta and Saskatchewan
  - In the Horn River shale:
    - initial test of several wells obtained flow rate up to 16,000 Mcf/d
  - In the Montney shale:
    - initial test of three wells flowed about 8800 Mcf/d, 6100 Mcf/d, and 5300 Mcf/d

Shale-Deposited Natural Gas: Development in Canada

- Eastern Canada
  - Identified shale formations: Horton Bluff, Utica, and Lorraine in Eastern Canada
  - Producers are testing the Horton Bluff Shale, the Utica Shale, and Lorraine
  - Discovery well in the Utica Shale flowed 1000 Mcf/d.

- Estimated Total Original Gas In Place: > 1000 Tcf

- Expected recovery rate: 20 to 25%

Shale-Deposited Natural Gas: Potential Environmental Threats

- Greenhouse gas emissions
  - Combustion of natural gas lead to emissions of CO_2 and NO_X
  - Methane emissions contribute to GHG emissions
  - Not unique to natural gas from shale formations

- Surface disturbance
  - Development requires surface preparation and creates environmental stress in some sensitive areas
  - Drilling moratoriums in the Rocky Mountains and proposals to limit development of Marcellus shale in New York's watershed area
  - Industry mitigates impacts by using smaller rigs and drilling multiple wells from a single site.

Shale-Deposited Natural Gas: Potential Environmental Threats

- Potential groundwater contamination:
  - Potential groundwater contamination as a result of hydraulic fracturing has generated an intense debate in the press.
  - Ground Water Protection Council, a non-profit association of state agencies, reported to congress:
    - that reports of groundwater contamination are "not accurate"
    - that strong regulatory framework remains in place for monitoring the development of natural gas from shale formations
  - Ground Water Protection Council also submitted to congress:
    - the statements of fifteen (15) state regulators that refute claims of groundwater contamination.

Shale-Deposited Natural Gas: Potential Environmental Threats

- Freshwater usage
  - Hydraulic fracturing requires between two and four million gallons of freshwater per treatment
  - Freshwater for hydraulic fracturing emanates from several sources including rivers, lakes, groundwater, private water wells, municipal water, and re-cycled water
  - Estimates of water requirement range from 0.1% to 0.8% of available water resources
  - Potential problems exist during periods of ***high withdrawal-low stream flow***
  - Jurisdictions are evaluating alternatives

Shale-Deposited Natural Gas: Potential Environmental Threats

- Disposal of retrieved water
  - After completion of a fracture treatment, operators retrieve about 30% to 70% of the injected fluid.
  - Disposal of the retrieved water raises environmental concerns.
  - State and local governments regulate water disposal by requiring industry operators to manage its ultimate fate:
    - underground injection
    - treatment and discharge
    - recycling.

Shale-Deposited Natural Gas: Regulatory Framework

- Federal
  - A network of federal laws regulates and monitors the environmental aspects of shale development:
    - Clean Water Act "…regulates surface discharge of water associated with shale drilling and production"
    - Safe Drinking Water Act "…regulates the underground injection of fluids from natural gas development activity"
    - Clean Air Act "…limits air emissions from engines, gas processing equipment, and other sources associated with drilling and production"
    - National Environmental Policy Act requires environmental impacts analysis on federal lands

Shale-Deposited Natural Gas: Regulatory Framework

- Federal (cont'd)
  - Fracturing Responsibility and Awareness of Chemicals (FRAC) Act
    - introduced in the US House of Representatives in June 2009
    - many in industry believe that this legislation is an "overreaction to a non-existent problem."
- State
  - Each state has its own regulatory framework aimed at environmental protection
  - Examples of states agencies that enforce the necessary laws include:
    - Texas Railroad Commission
    - Pennsylvania Department of Environmental Protection

Shale-Deposited Natural Gas:
Development of Natural Gas from Shale Formations

Questions and Comments?