Deep Shale Natural Gas: Abundant, Affordable, and Surprisingly Water Efficient

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Corporate Environmental Engineer
Presentation Overview

- Chesapeake Energy Operations
- Keys to Shale Gas Development
- Advantages of Shale Gas
- Water / Energy Nexus
- Water Use Efficiency by Shale Gas Play
- Raw Fuel Source Water Use Comparison
- Water Use Efficiency of Power Plants
- Water Intensity of Transportation Fuels
- Closing Thoughts
Chesapeake Energy Operating Areas
Keys to Deep Shale Natural Gas Development

● 1st Key: Horizontal Drilling

– Begins same as vertical well, but turns just above target reservoir zone

– Exposes significantly more reservoir rock to well bore surface versus a traditional vertical well

– Major advantage is fewer wells drilled to access same reservoir volume
Keys to Deep Shale Natural Gas Development

● **2nd Key: Hydraulic Fracturing**

  – Process of creating artificial cracks (fractures) in shale formations deep underground

  – Water with special high viscosity additives is injected under high pressure to fracture the rock

  – A “propping agent” (usually sand carried by the water) is pumped into the fractures to keep them from closing when pumping pressure is released.

  – Natural gas can then flow freely from the rock pores to a production well
Advantages of Deep Shale Natural Gas

- **Abundant in U.S.**
  - Haynesville Shale: 250 TCF (11 years U.S. supply)
  - Marcellus Shale: 50 TCF (26 months U.S. supply)
  - Barnett Shale: 30 TCF (16 months U.S. supply)
  - Fayetteville Shale: 20 TCF (10 months U.S. supply)

- **Affordable**
  - Natural Gas Price of $3 per MMBTU equivalent to $17.50 BBL Crude
  - Current Crude Price around $70 BBL

- **Emission Friendly**
  - Half the Carbon Dioxide of Coal
  - 30% the Carbon Dioxide of Gasoline
  - No Mercury or PM Emissions

- **Most Diversely Used Fuel Source**
  - Clean Burning Power Plants
  - Directly Use in Homes
  - Industrial Processes
  - Manufacturing of Products
  - Transportation Fuel (CNG)
The Water / Energy Nexus

● “Water is Essential for Energy Resource Development”
  – Fuel Extraction
  – Fuel Processing
  – Power Generation Cooling

● “Energy Resources are Needed for Water”
  – Development (raw water pumping)
  – Processing (treatment)
  – Distribution (potable water pumping)

● “Balance” or “Nexus” is Critical but Often Overlooked when evaluating Energy Resources
  – Many discussions on air quality and surface pollution impacts
  – Limited discussion on water availability
  – Improve One → Improve the Other
# Water Use Efficiency of the Four Major Chesapeake Deep Shale Natural Gas Plays

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<th>Shale Play</th>
<th>Average Water Use Per Well $^1$</th>
<th>CHK Est. Avg. Natural Gas Production Over Well Lifetime $^2$</th>
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Source: $^1$Chesapeake Energy 2009b, $^2$Chesapeake Energy 2009c, $^3$USDOE 2007

“BTU”: British Thermal Unit
“MMBTU”: Million British Thermal Units
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*Source: USDOE 2006 (other than CHK data)*

*Does not include processing which can add from 0 - 2 Gal per MMBTU*
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Raw Fuel Source Water Use Efficiency: Wind and Solar Notes

- Solar and Wind Power Not Included in Previous Table
  - Require virtually no water for processing
  - Therefore, “most water efficient”
  - Currently not “baseload” worthy
    - Wind: ½ of 1% of all U.S. Energy in 2008
    - Solar: 1/10th of 1% of all U.S. Energy in 2008
Raw Fuel Source Water Use Efficiency: Geography / Location

- Geography Plays Important Role in Fuel Source Water Efficiency
  - Values in table are location independent
  - Energy demands of fuel transport not considered
  - If considered:
    - Locally produced fuels would be given higher “value”
    - Imported fuels less water efficient → lower “value”
      » Foreign Oil, Alaskan Oil and Gas, Off-Shore Oil and Gas
Typical Efficiencies of Thermoelectric Power Plants

1. **Natural Gas Combined Cycle**
   - 14% Flue Gas
   - 36% Cooling Water
   - 50% Electricity
   - 100% Fuel

2. **Coal / Biomass Steam Turbine**
   - 33% Flue Gas
   - 33% Cooling Water
   - 33% Electricity
   - 100% Fuel

3. **SynGas (Coal) Combined Cycle**
   - 15% Flue Gas
   - 35% Cooling Water
   - 50% Electricity
   - 100% Fuel

4. **Nuclear Steam Turbine**
   - 0% Flue Gas
   - 67% Cooling Water
   - 33% Electricity
   - 100% Fuel

5. **Concentrating Solar**
   - 33% Cooling Water
   - 15% Electricity
   - 100% Fuel
   - 52% Unconverted Solar

Source: Adapted from Stillwell et al. 2009
Power Generation Cooling and Water Use

- **Water Withdrawal**: surface or ground water physically removed from a source for use in a power plant.

- **Water Consumption**: surface or ground water “lost” in the power generating process due to evaporation (no discharge)

Water Withdrawal and Consumption are directly proportional to:

1. Power plant efficiency,
2. Fuel combustion temperature, and
3. Flue gas emissions
Power Generation Cooling and Water Use

- **Open Loop Cooling**: given volume of water used only once through the cooling process. Water is discharged to receiving water body immediately after use.

- **Closed Loop Cooling**: given volume of water constantly recycled through cooling process (with little or no discharge)
# Closed-Loop Cooling Power Generation Water Use Efficiency

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<td>750</td>
<td>760</td>
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<td>590</td>
<td>830</td>
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<tr>
<td>Geothermal Steam</td>
<td>1,400</td>
<td>2,050</td>
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<td>Hydroelectric</td>
<td>4,500*</td>
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*Due to direct evaporation from multi-use holding reservoir

Note: Wind turbines and photovoltaic solar panels have negligible water demands

MWh: Mega-Watt-Hour

Source: Adapted from Hightower 2008
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Transportation Fuels and Water Use

● Conventional Petroleum and Gasoline Dominate U.S. Market
  – 97% of all fuels
  – Some contain 10% ethanol blend to reduce air emissions

● Currently Looking at “Unconventional” and “Alternative” Fuels
  – Non-ConventionaLiquid Fossil Fuels (fuels from coal, oil shale, tar sands)
  – Biofuels (ethanol, biodiesel)
  – Compressed Natural Gas
  – Hydrogen (carrier source)

● Major “Push” to Electric Vehicles and Plug-In Hybrids
  – Major focus of research and development
  – Perceived to be “green” (but how is electricity generated?)
  – Increase in water use “overlooked”
Water Intensity of Transportation Fuels

- Ethanol from Irrigated Corn Grain: 2,800 gallons
- Ethanol from Irrigated Corn Stover: 1,900 gallons
- Biodiesel from Irrigated Soybeans: 800 gallons
- Hydrogen via Electrolysis: 42 gallons
- Syn Diesel from Coal: 38.5 gallons
- Tar Sands Gasoline: 33 gallons
- Electric Vehicle*: 32 gallons
- Syn Diesel from Natural Gas: 27.5 gallons
- Oil Shale Gasoline: 26 gallons
- Ethanol from Non-Irrigated Corn Grain: 25 gallons
- Ethanol from Non-Irrigated Corn Stover: 25 gallons
- Plug In Hybrid Electric Vehicle*: 24 gallons
- Gasoline: 10.5 gallons
- Diesel: 8 gallons
- CNG using Electricity for Compression: 6.5 gallons
- Hydrogen from Natural Gas: 6 gallons
- CNG using NG Generator for Compression: 3 gallons
- Biodiesel from Non-Irrigated Soybeans: 1.5 gallons

"CNG": Compressed Natural Gas
Source: Adapted from King and Webber 2008a;
*Adapted from King and Webber 2008b
Closing Thoughts

● **Deep Shale Natural Gas**
  – Uses water primarily during drilling and stimulation
  – Produces tremendous amount of energy over the lifespan of a well

● **Raw Fuel Source Water Use Efficiency**
  – Natural Gas (including Shale Gas), Wind, and Solar are most efficient

● **Power Generation Water Use Efficiency**
  – Natural Gas Combined Cycle (NGCC) Plants are among most efficient

● **Transportation Fuel Water Use Efficiency**
  – Conventional fuels are relatively water efficient
  – Natural Gas based fuels are even better

● **Location is Important**
  – Tremendous amounts of water and energy used to transport people and products
  – When fuel is imported, there are unintended environmental impacts
Questions?

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