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

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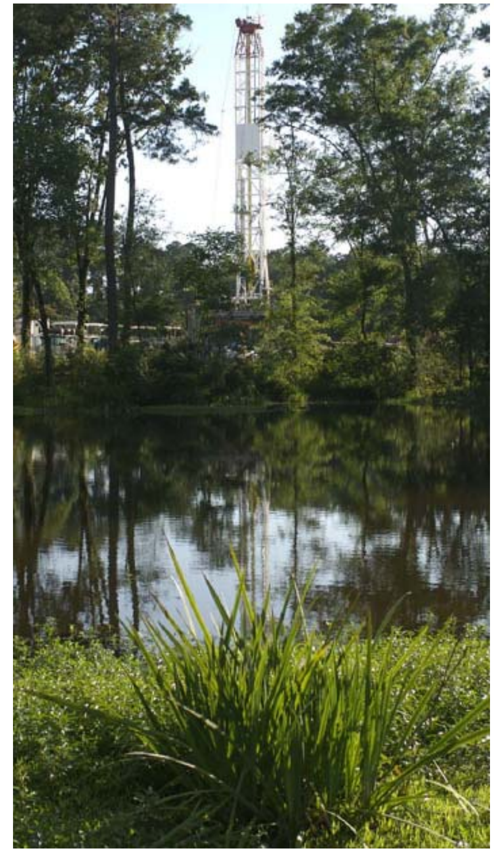
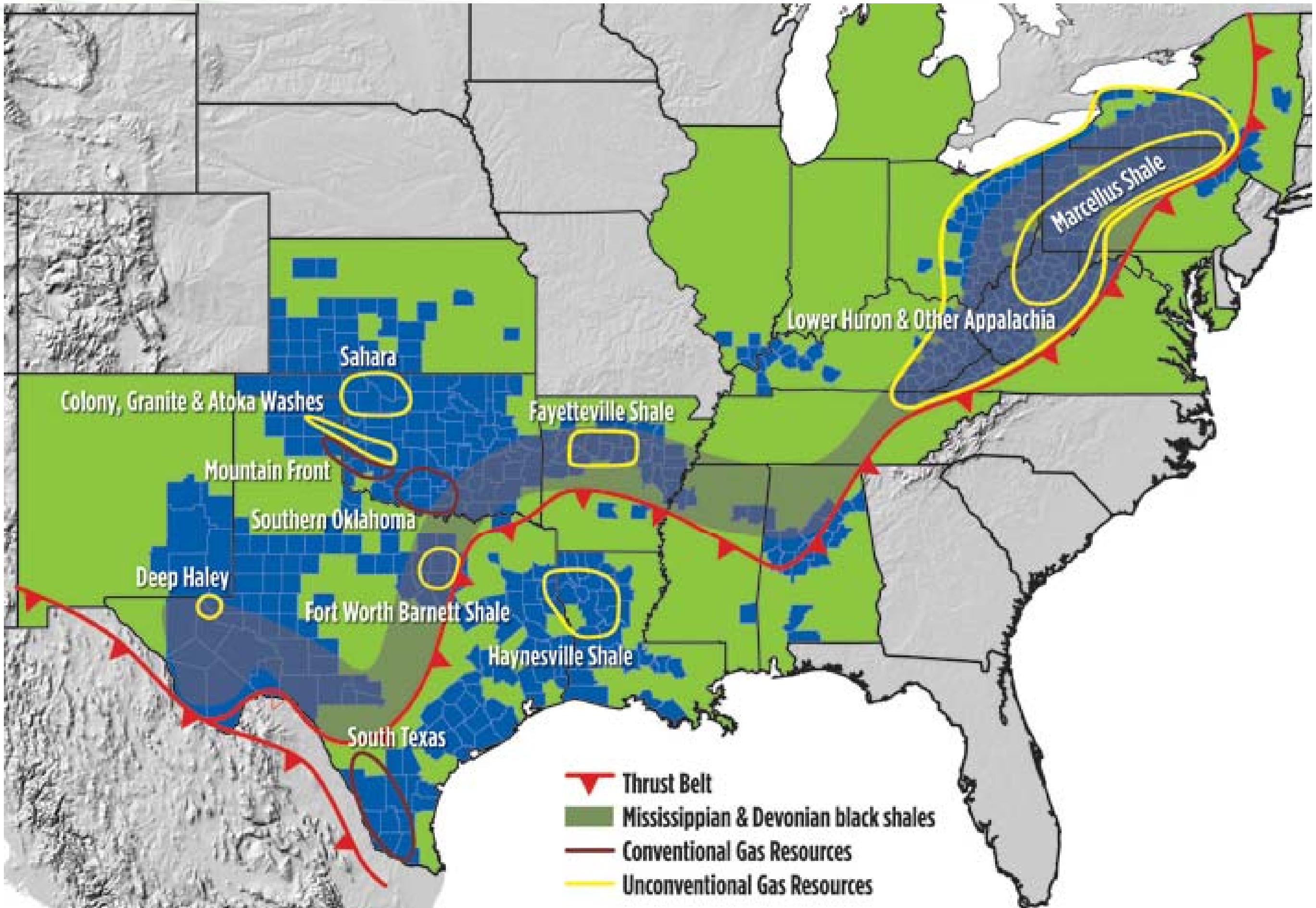
Chesapeake ENERGY

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

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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)

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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

Shale Play	Average Water Use Per Well [1]	CHK Est. Avg. Natural Gas Production Over Well Lifetime [2]	Natural Gas Production Per Well (based on 1,028 BTU per Cubic Feet)[3]	Water Use Efficiency (in gallons per MMBTU)
Haynesville	4 million gallons	6.5 billion cubic feet	6.682 trillion BTU	0.60
Marcellus	4.1 million gallons	3.75 billion cubic feet	3.855 trillion BTU	1.06
Barnett	3.4 million gallons	2.65 billion cubic feet	2.724 trillion BTU	1.25
Fayetteville	4 million gallons	2.2 billion cubic feet	2.262 trillion BTU	1.80

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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"BTU": British Thermal Unit
"MMBTU": Million British Thermal Units

Raw Fuel Source Water Use Efficiency

Energy Resource	Range of Gallons of Water Used per MMBTU of Energy Produced
Chesapeake Deep Shale Natural Gas *	0.60 – 1.80
Natural Gas	1 – 3
Coal (no slurry transport) (with slurry transport)	2 – 8 13 – 32
Nuclear (processed uranium ready to use in plant)	8 – 14
Conventional Oil	8 – 20
Synfuel - Coal Gasification	11 – 26
Oil Shale Petroleum	22 – 56
Tar Sands Petroleum	27 – 68
Synfuel - Fisher Tropsch (Coal)	41 – 60
Enhanced Oil Recovery (EOR)	21 – 2,500
Fuel Ethanol (from irrigated corn)	2,510 – 29,100
Biodiesel (from irrigated soy)	14,000 – 75,000

Source: USDOE 2006 (other than CHK data)

*Does not include processing which can add from 0 - 2 Gal per MMBTU

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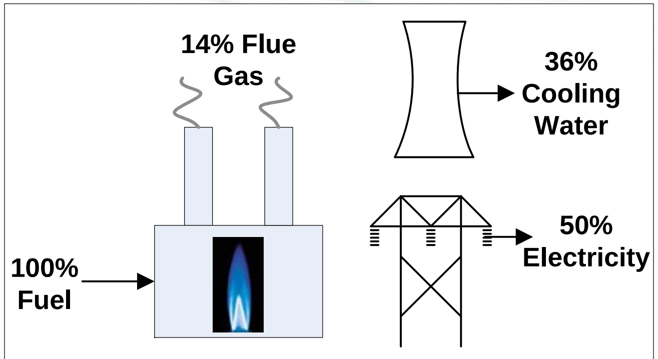
Raw Fuel Source Water Use Efficiency: Wind and Solar Notes

- **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

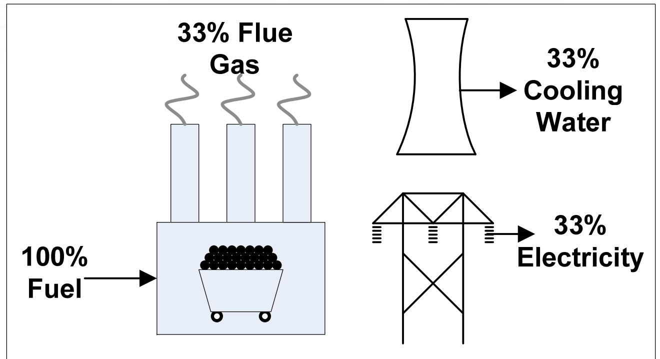
Raw Fuel Source Water Use Efficiency: Geography / Location

- **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

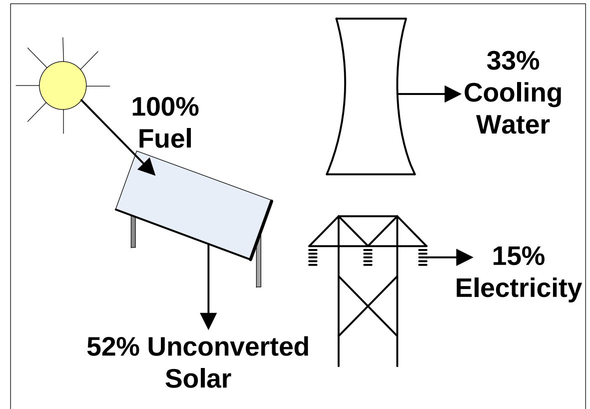
Typical Efficiencies of Thermoelectric Power Plants



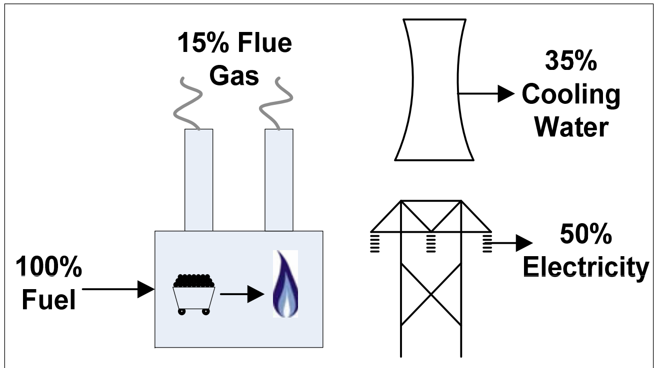
Natural Gas Combined Cycle



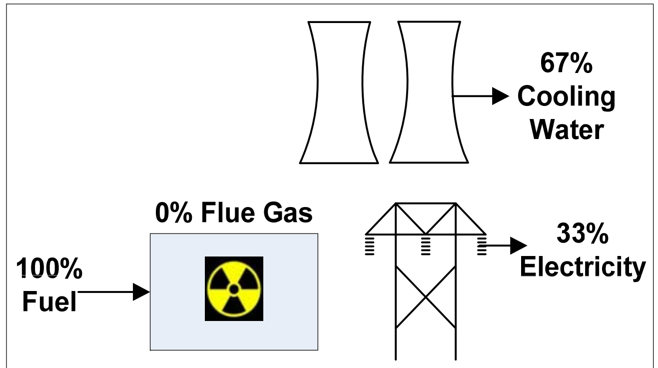
Coal / Biomass Steam Turbine



Concentrating Solar



SynGas (Coal) Combined Cycle



Nuclear Steam Turbine

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

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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

Power Plant Type	Average Gallons of Water *Consumed* in Power Plant per MWh of Electricity Produced	Average Gallons of Water *Withdrawal* in Power Plant per MWh of Electricity Produced
Natural Gas Combined Cycle (NGCC)	**190**	**240**
Integrated Gasification (SynGas from Coal), Combined Cycle (IGCC)	330	350
Coal / Biomass Steam Turbine	420	480
Concentrating Solar	750	760
Nuclear Steam Turbine	590	830
Geothermal Steam	1,400	2,050
Hydroelectric	4,500*	N/A

Source: Adapted from Hightower 2008

*Due to direct evaporation from multi-use holding reservoir
Note: Wind turbines and photovoltaic solar panels have negligible water demands
MWh: Mega-Watt-Hour

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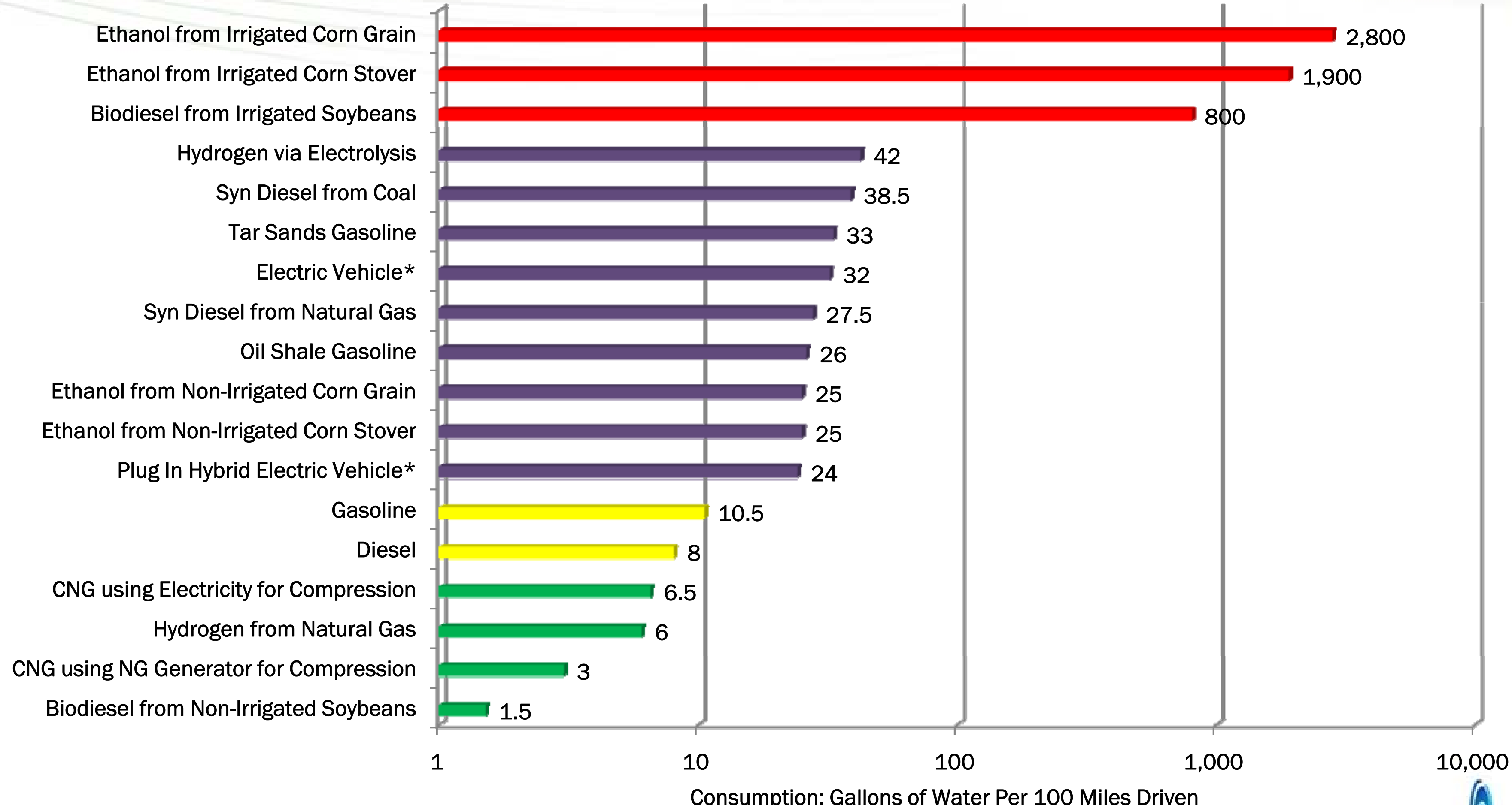
Transportation Fuels and Water Use

- **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-Conventional Liquid 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



"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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Open-Loop Cooling Power Generation Water Use Efficiency

Power Plant Type	AVG Gallons of Water Consumed in Power Plant (per MWh of Electricity Produced)	AVG Gallons of Water Withdrawal in Power Plant (per MWh of Electricity Produced)
Natural Gas Combined Cycle (NGCC)	110	13,760
Coal / Biomass Steam Turbine	280	35,030
Nuclear Steam Turbine	430	42,530

Source: Adapted from Hightower 2008

POWERFUL ASSETS

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