

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



**POWERFUL ASSETS**

IPEC  
16<sup>th</sup> Annual Petroleum and Biofuels  
Environmental Conference  
Houston, TX

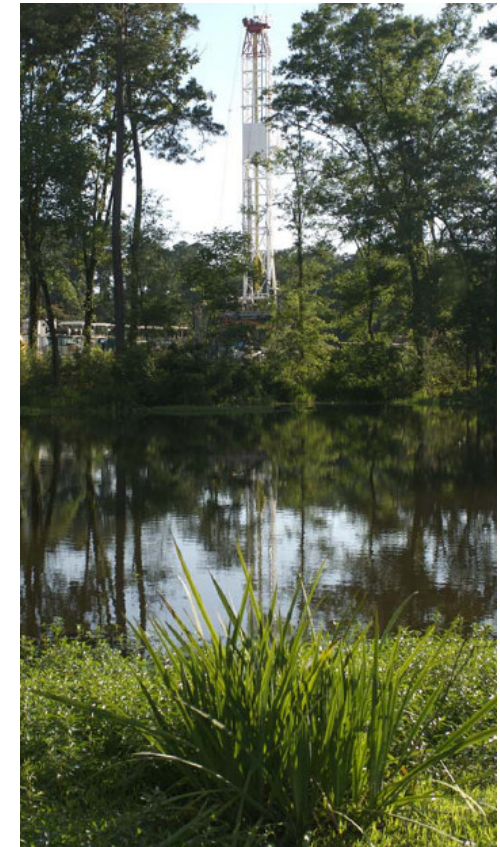
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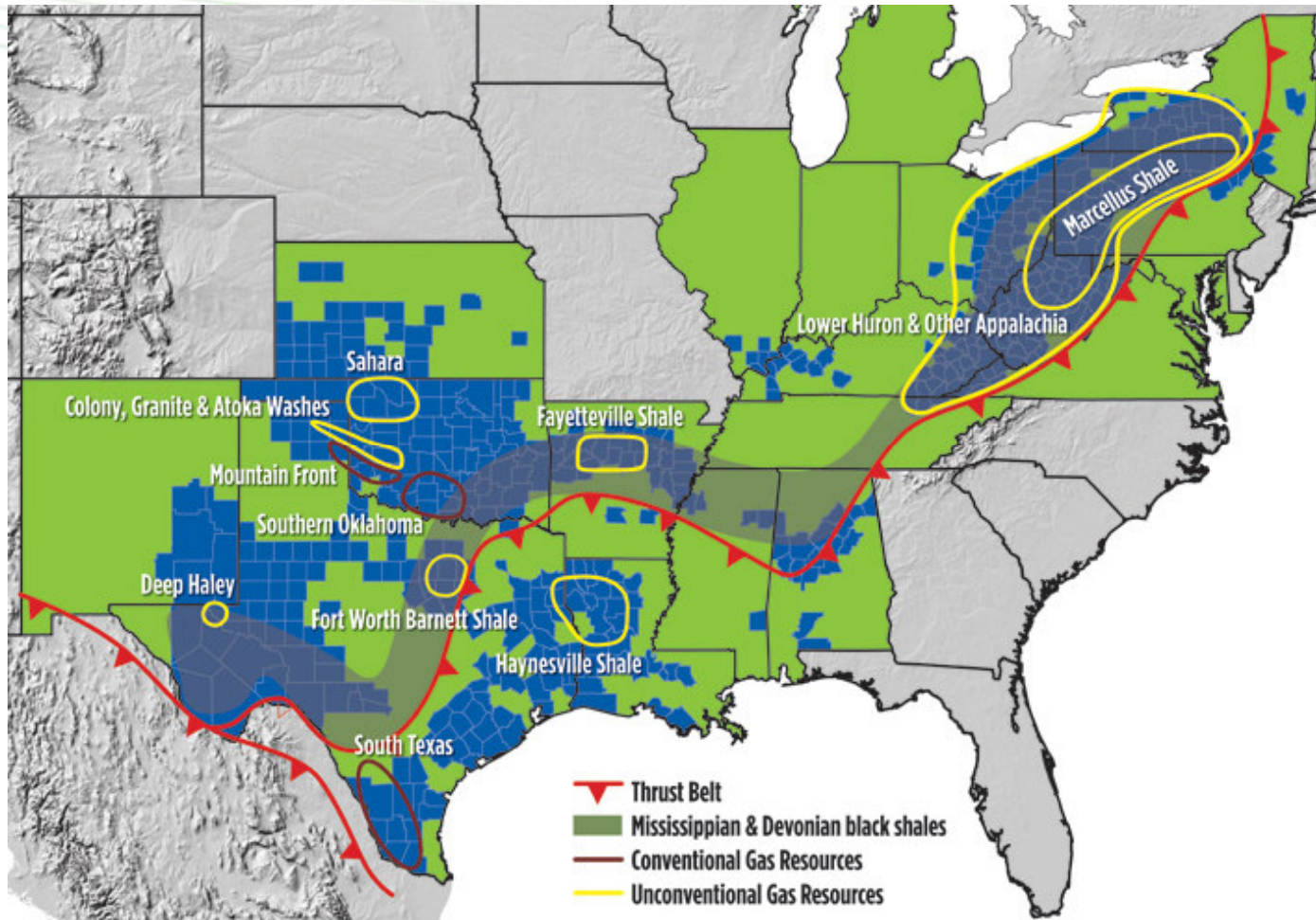
# Presentation Overview



- 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



- **1<sup>st</sup> 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



- **2<sup>nd</sup> Key: Hydraulic Fracturing**

- Process of creating artificial porosity (fractures) in shale formations deep underground
- Water with <1% 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 through production well to the surface

# Advantages of Deep Shale Natural Gas



- **Abundant in U.S.**

- Barnett Shale: 44 TCF\*  
(~ 2 years U.S. supply)
- Fayetteville Shale: 42 TCF\*  
(~ 2 years U.S. supply)
- Haynesville Shale: 250 TCF\*  
(~ 11 years U.S. supply)
- Marcellus Shale: 490 TCF\*\*  
(~ 21 years U.S. supply)



- **Affordable**

- Natural gas price of \$5 per MMBtu equivalent to \$30 Bbl oil
- Current oil price around \$80 Bbl

- **Emission friendly**

- 50% the carbon dioxide of coal
- 30% the carbon dioxide of gasoline
- No mercury or PM emissions

- **Most widely used fuel source**

- Clean burning power plants
- Residential use
- Industrial and manufacturing
- Commercial space heating
- Transportation fuel (CNG)

\*US Department of Energy (April 2009): *Modern Shale Gas Development in the United States: a Primer* p. 17)

\*\*Dr. Terry Engelder, Penn State University)

TCF = trillion cubic feet

# 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 in Natural Gas Plays



## Chesapeake's Four Major Deep Shale Plays

Shale Play	Average Water Use Per Well <sup>1</sup>	CHK Est. Avg. Natural Gas Production Over Well Lifetime <sup>2</sup>	Resulting Energy From Natural Gas Production Per Well (based on 1,028 Btu per Cubic Feet) <sup>3</sup>	Water Use Efficiency (in gallons per MMBtu)
Haynesville	4.0 million gallons	6.5 billion cubic feet	6.68 trillion Btu	0.60
Marcellus	4.1 million gallons	4.2 billion cubic feet	4.32 trillion Btu	0.95
Barnett	3.4 million gallons	2.65 billion cubic feet	2.72 trillion Btu	1.25
Fayetteville	4.0 million gallons	2.4 billion cubic feet	2.47 trillion Btu	1.60



Source: <sup>1</sup>Chesapeake Energy 2009b, <sup>2</sup>Chesapeake Energy 2009c, <sup>3</sup>USDOE 2007  
 British Thermal Unit (Btu)  
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# Raw Fuel Source Water Use Efficiency



Energy Resource	Range of Gallons of Water Used per MMBTU of Energy Produced
<b>Chesapeake Deep Shale Natural Gas *</b>	<b>0.6 - 1.6</b>
Natural Gas	1 - 3
Coal (no slurry transport)	2 - 8
(with slurry transport)	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
Oil 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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# Fuel Source Water Use Efficiency



## Wind and solar notes

- **Solar and wind power not included in previous table**
  - Require virtually no water for processing
  - Most water efficient
  - Currently not “baseload” worthy
    - Wind: 0.5% of all U.S. energy in 2008
    - Solar: 0.1% of all U.S. energy in 2008



# Raw Fuel Source Water Use Efficiency: Geography / Location

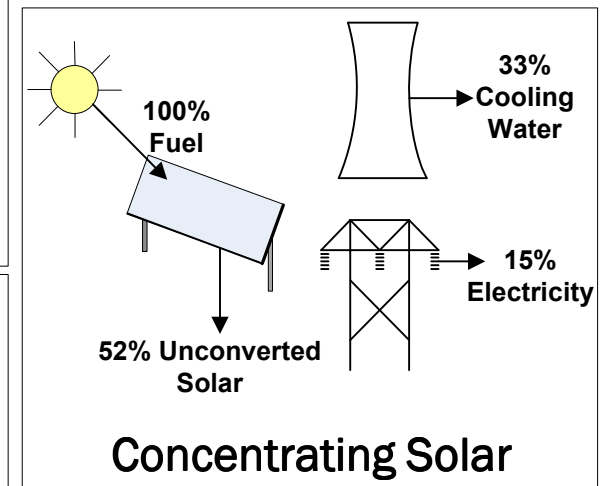
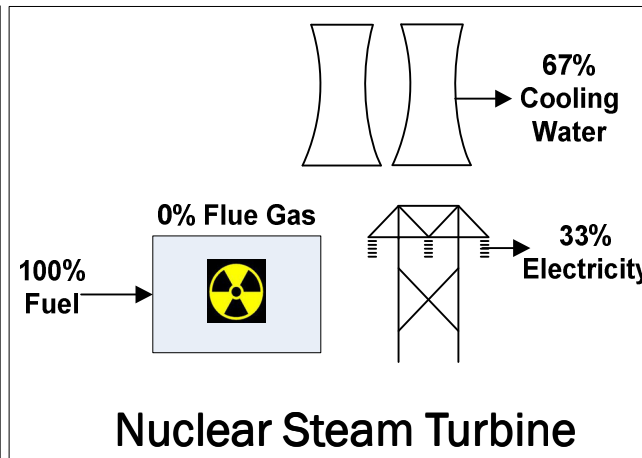
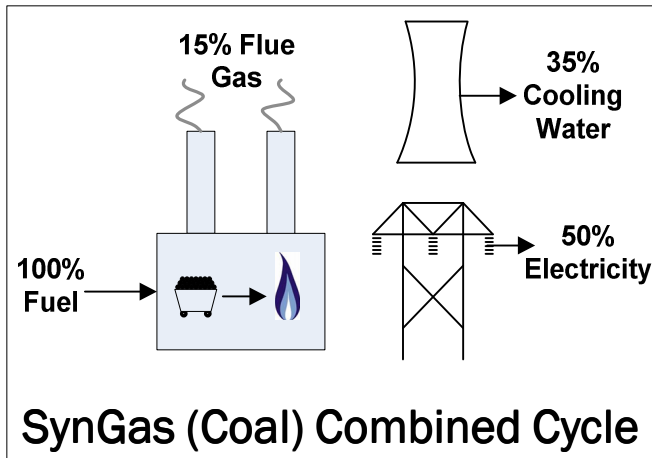
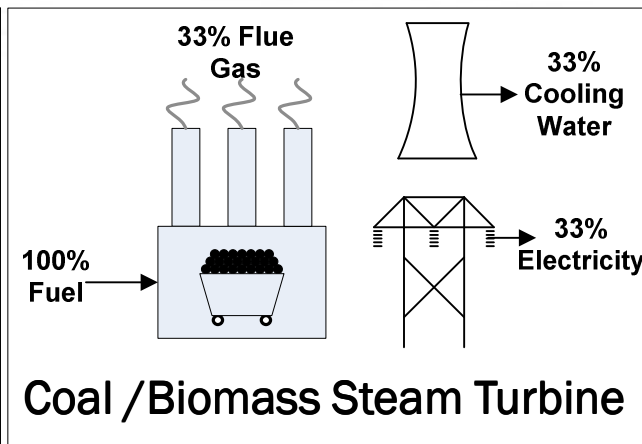
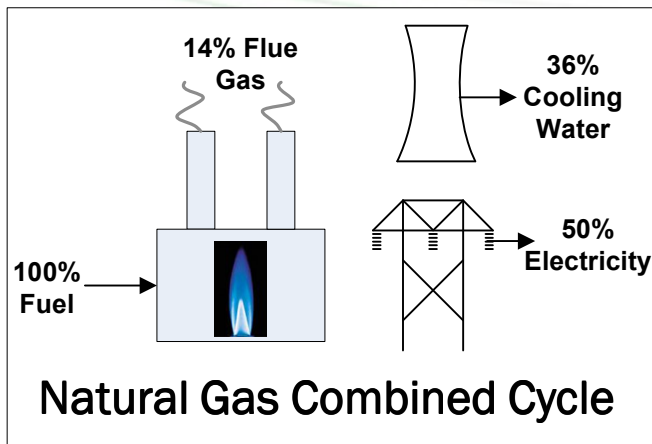


- **Geography Plays Important Role in Fuel Source Water Efficiency**

- 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



# 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)
- **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



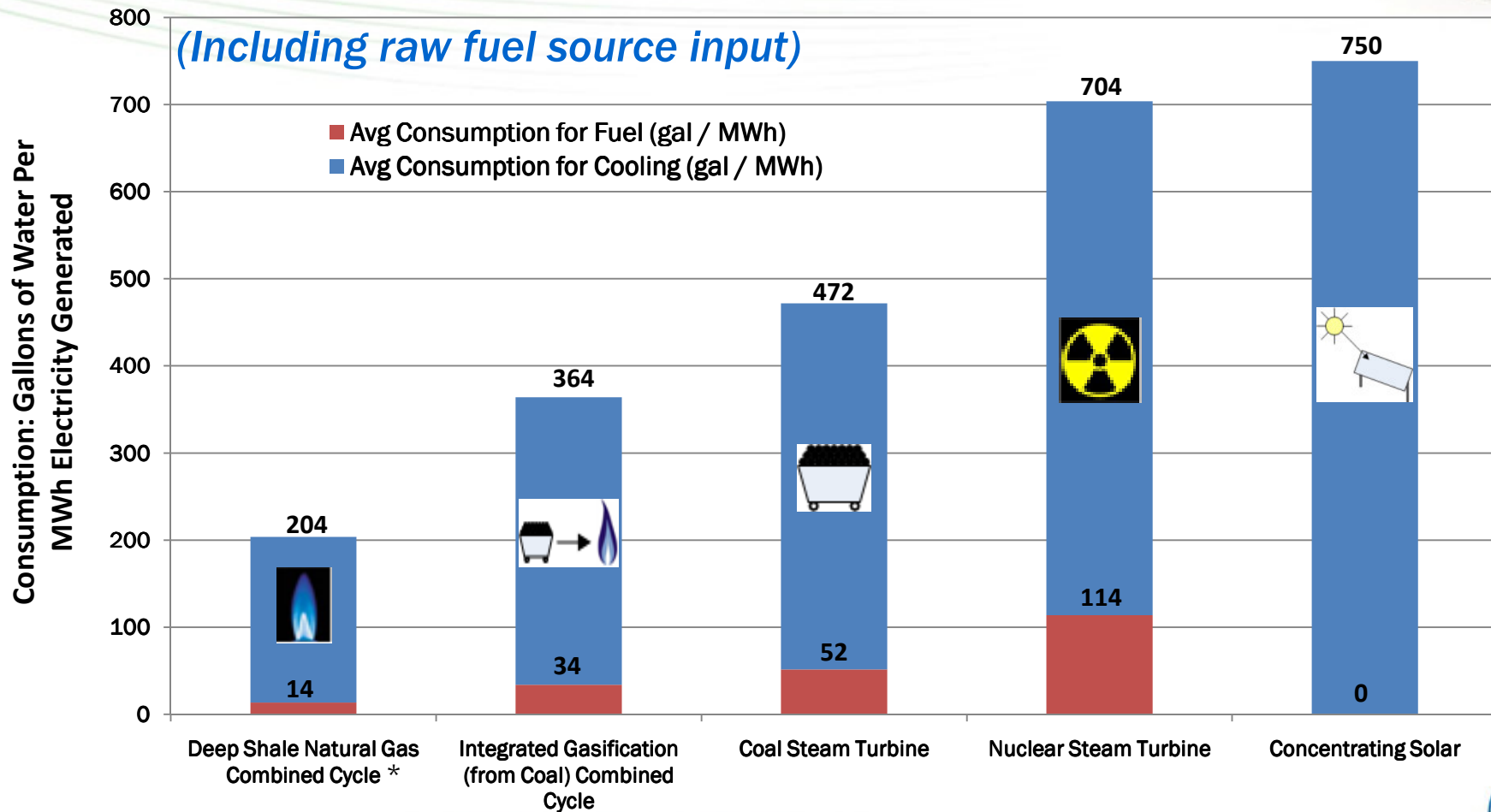
Power Plant Type	Average Gallons of Water <i>Consumed</i> in Power Plant per MWh of Electricity Produced
Natural Gas Combined Cycle (NGCC)	190
Integrated Gasification (SynGas from Coal), Combined Cycle (IGCC)	330
Coal / Biomass Steam Turbine	420
Concentrating Solar	750
Nuclear Steam Turbine	590
Geothermal Steam	1,400
Hydroelectric	4,500*

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

# Power Generation Water Use Efficiency



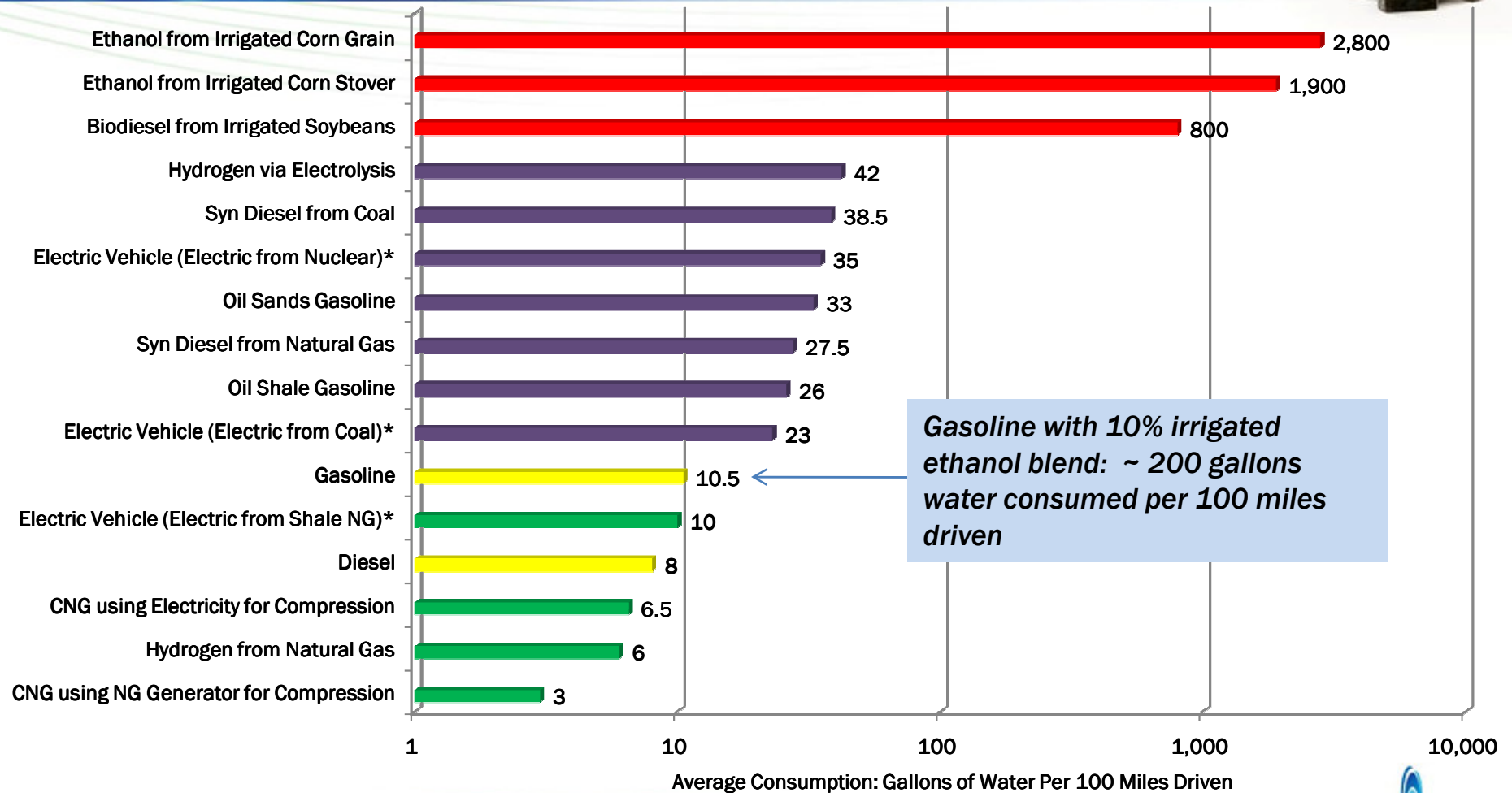
Source: Hightower 2008 (other than CHK data)  
 \*Average consumption for fuels; Chesapeake data  
 Note: Wind turbines and photovoltaic solar panels have negligible water demands  
 MWh = megawatt-hour

# 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



Compressed Natural Gas (CNG)  
 Source: Adapted from King and Webber 2008a;  
 \*Adapted from King and Webber 2008b, combined with data from USDOE 2006  
 Non-irrigated biofuels not shown on plot above

# Closing Thoughts



## ● Deep Shale Natural Gas

- Uses water primarily during drilling and stimulation
- Produces tremendous amount of energy over the lifespan of a well
- Misconception that drilling and hydraulic fracturing processes use a “large” volume of water

## ● 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

- Water and energy used to transport people and products
- When fuel is imported, there are unintended environmental impacts

# Questions?



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