BOLD MOVES
BIG FUTURE





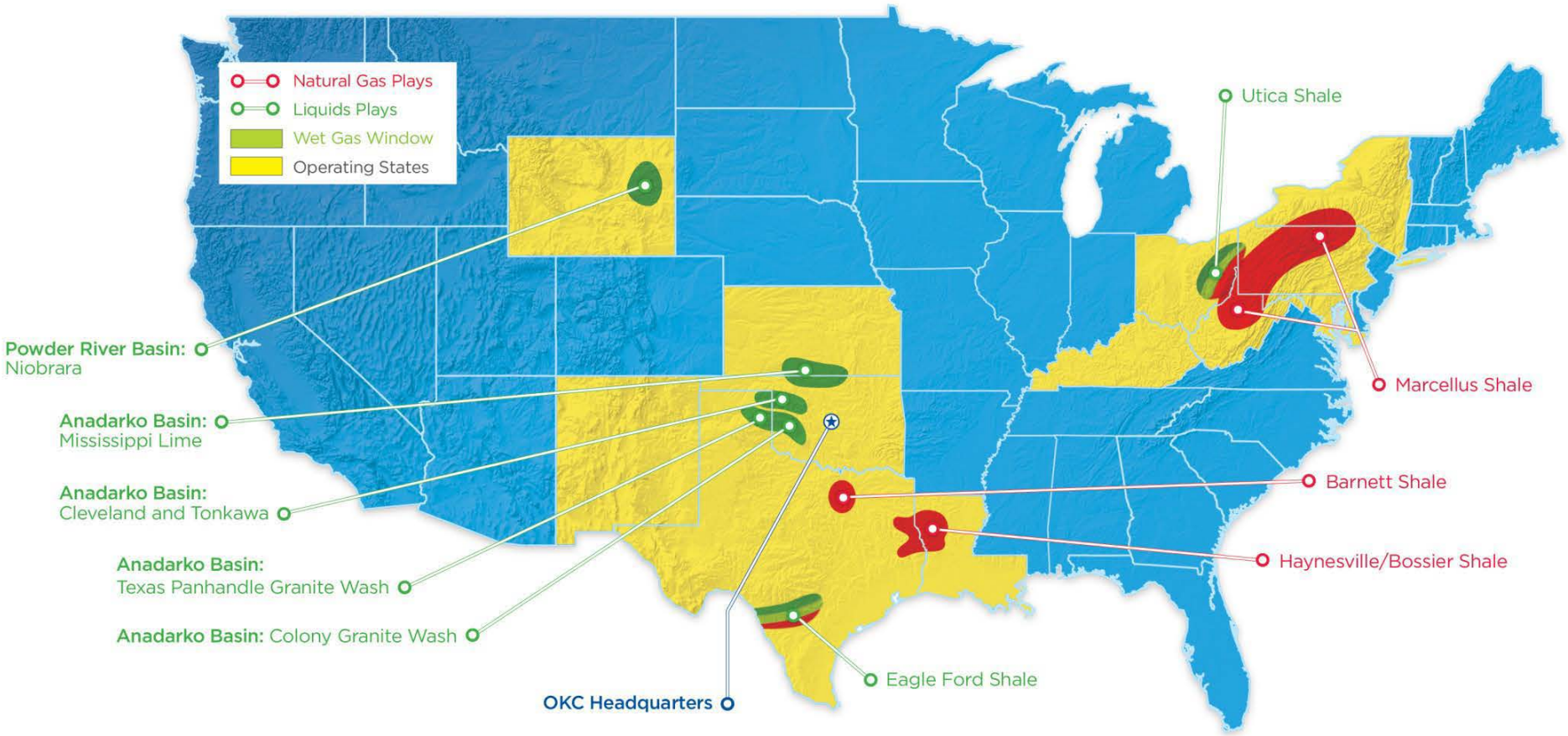

2013 EPA HYDRAULIC FRACTURING STUDY WATER ACQUISITION WORKSHOP

Chesapeake ENERGY

RECYCLING AND REUSE OF PRODUCED WATER TO REDUCE FRESHWATER USE IN HYDRAULIC FRACTURING OPERATIONS

MATTHEW E. MANTELL, P.E.
ENGINEERING ADVISOR - ENVIRONMENTAL

CHESAPEAKE ENERGY OPERATING AREAS



CURRENT CHESAPEAKE WATER USE BY PLAY

Chesapeake ENERGY

Gas Shales (Primarily Dry Gas)

Barnett Shale

250,000 Gallons used for Drilling
3,100,000 Gallons used for Fracturing

~ 3.3 Million Gallons Used Per Well

Marcellus Shale

85,000 Gallons used for Drilling
4,400,000 Gallons used for Fracturing

~ 4.5 Million Gallons Used Per Well

Haynesville / Bossier Shale

600,000 Gallons used for Drilling
4,800,000 Gallons used for Fracturing

~ 5.4 Million Gallons Used Per Well

Based on 2012 Chesapeake Energy Operating Data

CURRENT CHESAPEAKE WATER USE BY PLAY (CONTINUED)

Chesapeake ENERGY

Liquids-Rich Plays (Gas, Oil, Condensate)

Eagle Ford Shale

125,000 Gallons used for Drilling
4,800,000 Gallons used for Fracturing

~ 4.9 Million Gallons Used Per Well

Niobrara Shale

300,000 Gallons used for Drilling
3,400,000 Gallons used for Fracturing

~ 3.7 Million Gallons Used Per Well

Utica Shale

100,000 Gallons used for Drilling
3,700,000 Gallons used for Fracturing

~ 3.8 Million Gallons Used Per Well

Cleveland / Tonkawa

200,000 Gallons used for Drilling
2,500,000 Gallons used for Fracturing

~ 2.7 Million Gallons Used Per Well

Mississippi Lime

100,000 Gallons used for Drilling
2,000,000 Gallons used for Fracturing

~ 2.1 Million Gallons Used Per Well

Granite Wash

200,000 Gallons used for Drilling
4,600,000 Gallons used for Fracturing

~ 4.8 Million Gallons Used Per Well

Based on 2012 Chesapeake Energy Operating Data

WATER USE EFFICIENCY IN MAJOR PLAYS

Play	Average Water Use Per Well [1]	CHK Est. Avg. Natural Gas Equivalent Production Over Well Lifetime [2]	Assumed % Energy from Source [2]	Resulting Energy Production Per Well Over Well Lifetime [3]	Water Use Efficiency (in gallons per MMBtu) [4]
Marcellus Shale	4.5 million gallons	5.75 billion cubic feet (gas)	~ 100% Gas	**5.91 trillion Btu (total)**	0.76
Haynesville Shale	5.4 million gallons	6.50 billion cubic feet (gas)	~ 100% Gas	**6.68 trillion Btu (total)**	0.81
Utica Shale	3.8 million gallons	4.2 billon cubic feet equiv (oil and gas)	~25% Oil ~75% Gas	**4.3 trillion Btu (total)**	0.88
Barnett Shale	3.3 million gallons	3.30 billion cubic feet (gas)	~ 100% Gas	**3.39 trillion Btu (total)**	0.97
Granite Wash	4.8 million gallons	3.8 billion cubic feet equiv (oil and gas)	~ 25% Oil ~ 75% Gas	**3.9 trillion Btu (total)**	1.23

Source: [1]Chesapeake Energy 2012, [2]Chesapeake Energy Data [3]Based on 1,028 Btu per Cubic Foot Gas and 5,800,000 Btu per BBL oil, USDOE 2011,
[4] Does not include processing
British Thermal Unit (Btu)
Million British Thermal Units (MMBtu)

WATER USE EFFICIENCY IN MAJOR PLAYS (CONTINUED)

Play	Average Water Use Per Well [1]	CHK Est. Avg. Natural Gas Equivalent Production Over Well Lifetime [2]	Assumed % Energy from Source [2]	Resulting Energy Production Per Well Over Well Lifetime [3]	Water Use Efficiency (in gallons per MMBtu) [4]
Cleveland / Tonkawa	2.7 million gallons	2.0 billion cubic feet equiv (oil and gas)	~ 50% Oil ~ 50% Gas	**2.05 trillion Btu (total)**	1.32
Mississippi Lime	2.1 million gallons	1.4 billion cubic feet equiv (oil and gas)	~ 40% Oil ~ 60% Gas	**1.44 trillion BTU (total)**	1.46
Eagle Ford Shale	4.9 million gallons	3.0 billion cubic feet equiv (oil and gas)	~ 75% Oil ~ 25% Gas	**3.1 trillion Btu (total)**	1.58
Niobrara	3.7 million gallons	1.5 billion cubic feet equiv (oil and gas)	~ 69% Oil ~ 31% Gas	**1.55 trillion Btu (total)**	2.39

Source: [1]Chesapeake Energy 2012, [2]Chesapeake Energy Data [3]Based on 1,028 Btu per Cubic Foot Gas and 5,800,000 Btu per BBL oil, USDOE 2011,
[4] Does not include processing
British Thermal Unit (Btu)
Million British Thermal Units (MMBtu)

RAW FUEL SOURCE WATER EFFICIENCY

Energy resource	Range of gallons of water used per MMBtu of energy produced
Conventional (vertical) natural gas	**1 – 3**
Chesapeake deep shale natural gas *	**0.76 – 2.97**
Coal (no slurry transport) (with slurry transport)	2 – 8 13 – 32
Nuclear (processed uranium ready to use in plant)	8 – 14
Conventional (vertical) oil	**8 – 20**
Chesapeake shale oil **	**7.88 – 20.39**
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
Biofuels (Irrigated Corn Ethanol, Irrigated Soy Biodiesel)	**> 2,500**

Source: USDOE 2006 (other than CHK data)
*Includes processing which can add 0 - 2 gallons per MMBtu
**Includes refining which consumes major portion (82% to 92%) of water needed (7-18 gal per MMBtu)
Solar and wind not included in table (require virtually no water for processing)
Values in table are location independent (domestically produced fuels are more water efficient than imported fuels)

PRODUCED WATER REUSE AND RECYCLING: THE CHESAPEAKE EXPERIENCE

Intevras' EVRAS unit at the Brentwood site in east Fort Worth

SEDIMENTATION AND FILTRATION

- **Sedimentation**
  - Most basic of all “treatment” processes (nothing added, no energy required)
  - Involves simply storing fluid for a period of time to allow suspended solids to “fall” out of solution
  - Only effective for suspended solids particles. If solids are entrained by any mechanism in fluid, they won’t settle out.

- **Filtration**
  - Porous media “sock” or “sand” column filters are most common
  - Inexpensive and disposable (filter sock) or back washable
  - Easy to operate → once a given pressure differential is exceeded, the filter is disposed of or backwashed

- **CHK Application: *Marcellus Shale***
  - Numerous service providers offering these “treatments”
  - Produced water quality is suitable for sedimentation and/or filtration (low hydrocarbon content, lower scaling tendency)
  - Tremendously successful program. Reduced water disposal volumes by over 95%.
  - Extremely cost effective: reduces transportation, water acquisition, and disposal costs

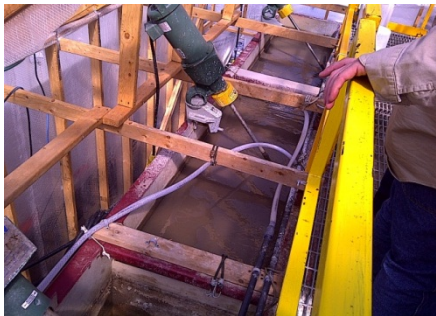
CHEMICAL PRECIPITATION

Treatment Specifics

- Traditional wastewater treatment processes, tried and true, many providers
- Chemicals mixed in to coagulate particles followed by a settling tank to allow for precipitation
- Typically less expensive than other options but does not treat for TDS or hydrocarbons

CHK Application: *Utica Shale*

- CHK currently working in the Utica Shale to use chemical precipitation to treat produced water and drilling wastewater for reuse
  - Chemical precipitation done with aluminum chloride to remove suspended solids
  - Simple 100 micron filter utilized for remaining solid removal
  - Biocide dosing throughout process to control bacteria
- Treated water is tested and blended in subsequent completion operations
- Costs are higher than simple filtration but much lower than more advanced membrane and distillation systems



OTHER TECHNOLOGIES

- **Dissolved Air Floatation**
  - Chemical/Polymer and air/gas driving process, works by "floating" contaminants to surface of tank for removal
  - Great potential in Niobrara and Eagle Ford plays

- **Evaporation**
  - From late 2009 to 2012 CHK tested and operated a evaporative system (EVRAS) at the Barnett Brentwood SWD site
  - Performance and economics were lacking
- **Thermal Distillation**
  - System utilizes low pressure to evaporate water and recompress steam to produce distilled water
  - Tested and being implemented in Anadarko Basin

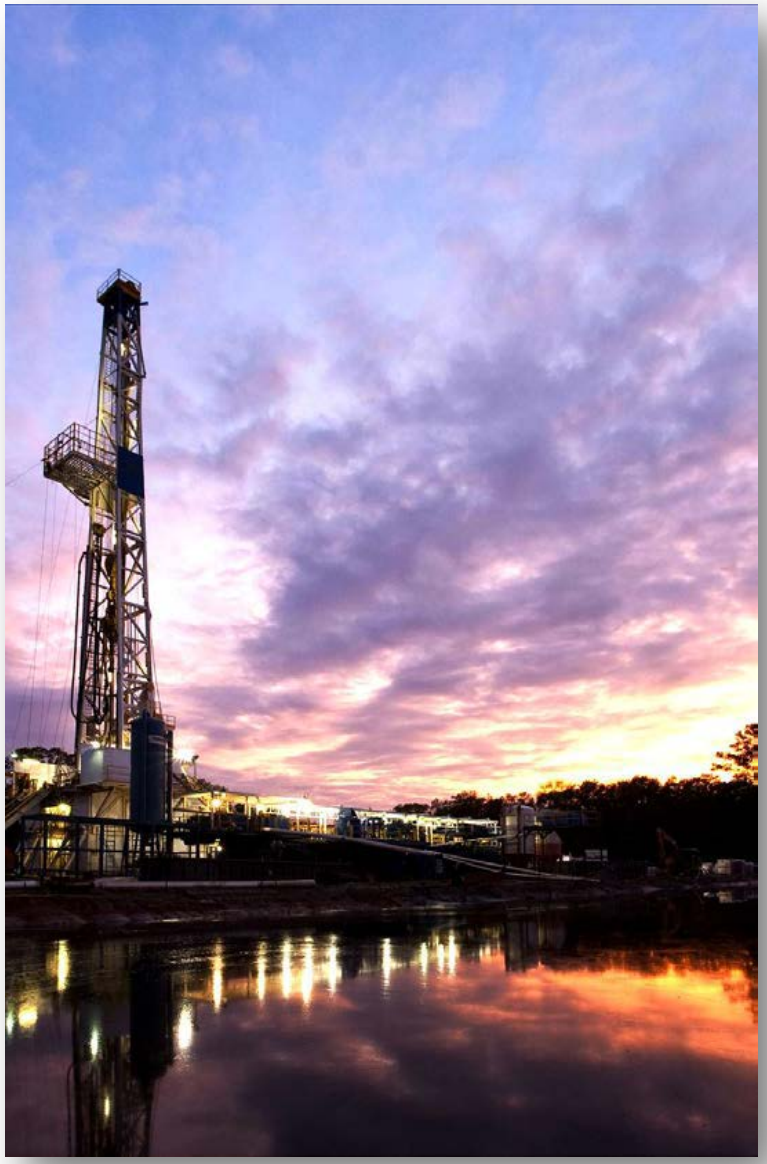
- **Electro-Coagulation**
  - Electrically driven treatment process that utilizes few chemicals
- **Crystallization**
  - Comprehensive system resulting in zero liquid waste discharge (only solid salt and distilled water outputs)

DIRECT REUSE (NO TREATMENT)

- **Specifics**
  - In operating areas where slickwater is the dominant fluid system, specially designed completion chemical packages are available that can handle high volumes of high TDS produced water without reduction in well performance.
  - Water quality must be good in terms of low suspended solids and hydrocarbon content, and bacteria must be managed with biocide
  - "Specially designed slickwater package" involves the substitution of a salt-tolerant friction reducer (now offered by numerous vendors)

- **CHK Application: *Mississippi Lime***
  - Since late 2011, CHK has implemented a direct reuse program on horizontal Mississippi Lime wells that utilized 100% high TDS produced water
  - Performance appears to be unaffected and no freshwater was required for stimulation of these wells
  - Direct reuse is particularly well suited for high water producing, low suspended solids produced water like the Mississippi Lime
  - Benefits include elimination of disposal needs/fees
  - Disadvantage is the slight cost increase for the salt-tolerant FR
  - Hydrocarbon content in produced water must be managed as it will cause issues with salt-tolerant FR

Criticism Of Oil and Natural Gas Water Use



- **Concerns of "permanent removal" of water from the effective hydrologic cycle:**
  - Most water used in natural gas and oil development either remains in the formation or returns as produced water
  - The preferred method for disposal of produced water is through permitted Class II Salt Water Disposal wells
  - Argument that this is a different type of "consumption" than the evaporation of water from a power plant and other types of water consumers

Natural Gas Combustion and Water Vapor Generation

- **Balanced Methane Combustion Reaction:**

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

- **Volume of water vapor produced per million cubic feet of natural gas:**
  - 10,675 gallons
- **Need to combust 525 MMCF of natural gas to produce an equivalent amount of water (as vapor) used to drill and complete a typical Marcellus Shale well**
  - Based on current production trends, it takes an average Chesapeake Marcellus Well < 6 months to produce 525 MMCF of natural gas

Water Use Planning & Regulation – A States Rights Issue

- **State water use policies evolved since statehood based on unique understanding of local needs and resources available**
  - Surface Water Law
    - Riparian (East of the 100th Meridian)
    - Prior Appropriation (West of 100th Meridian)
  - Ground Water Law
    - Ownership Theory – Private Property / Rule of Capture
    - Appropriation Doctrine
  - State water agencies administer permitting / registration / state water planning process programs
    - Allocation of water available
    - Permit / registration conditions
    - Pass-by flow requirements
    - Reporting
    - Consistency with State Water Plans
  - Water users must comply with state water programs

Summary

1. Despite the perceived large volume of water used in drilling and hydraulic fracturing, unconventional oil and gas is very water efficient compared to other available energy sources

2. Produced water quality varies from play to play and no single technology exists that is best for all produced waters in all operating areas

3. State water use policies are based on a unique understanding of local needs and resources available, and all water users (including the oil and gas industry) must comply with state water programs

Questions?