The Energy Water Nexus
Trends & Challenges

Presented by:
Jim Dobos, CPIM, CSCP, PMP
V. P. Corp. Learning & Development
Aquatech International Corp.

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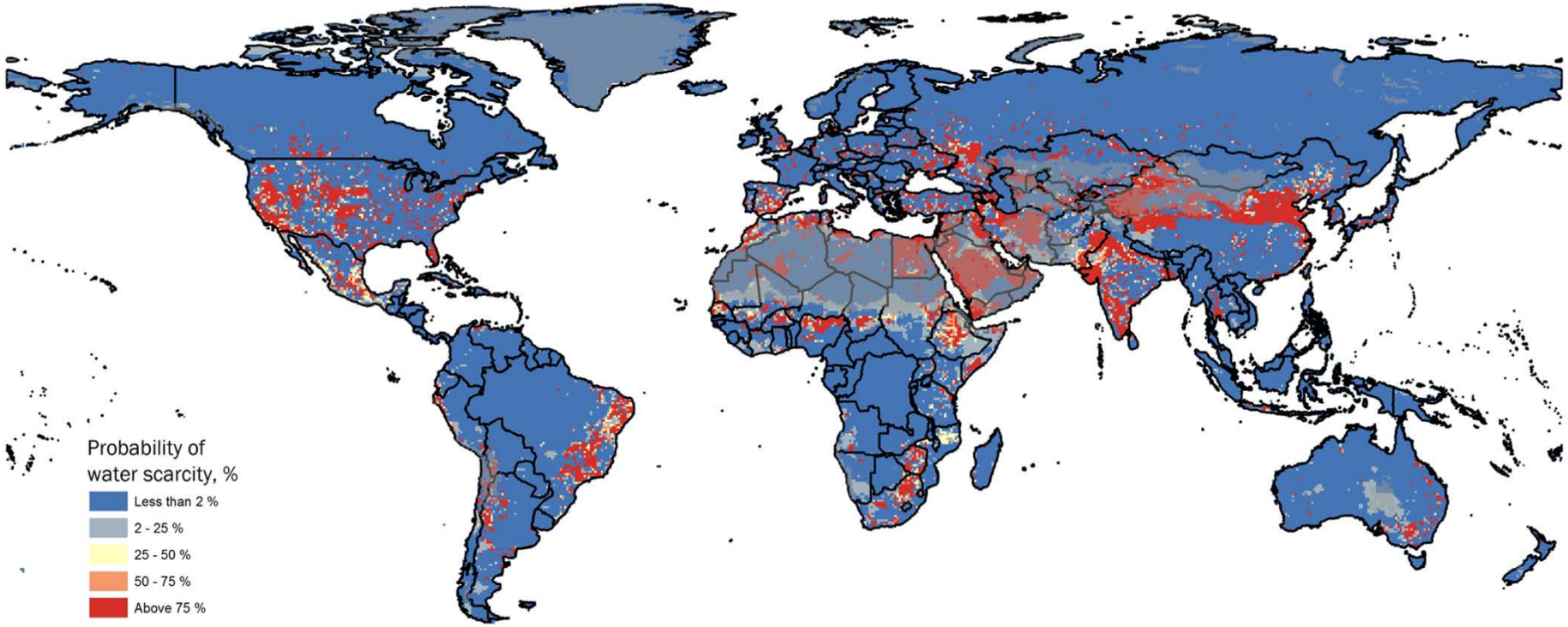
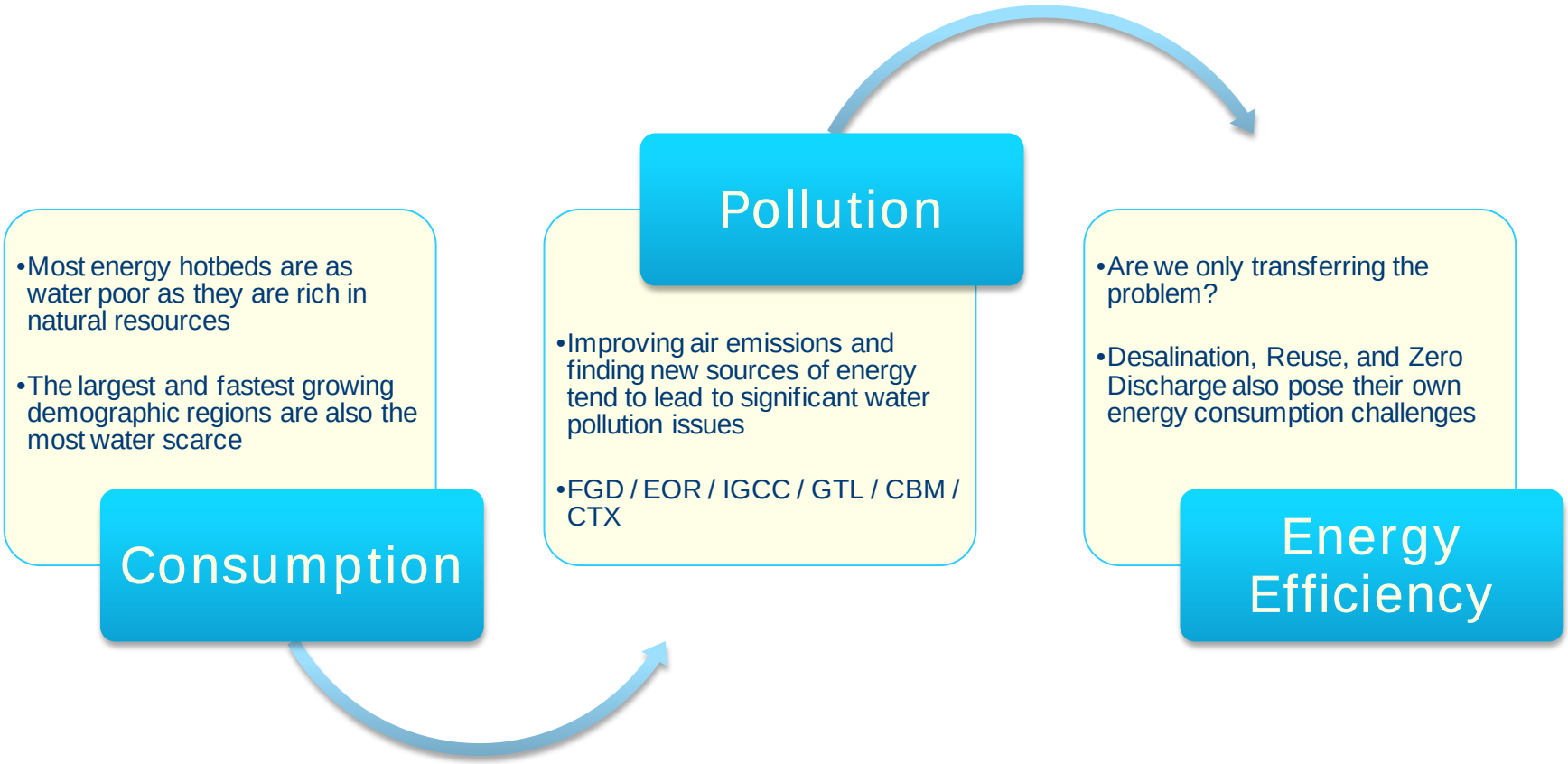
Global Water Risk Index: water risk in 2030



Source: Global Water Risk Index, GWI, 2011

The Global Water Risk Index would need to be matched with facility location information if it were to be useful as a corporate water risk assessment tool. However, from the point of view of this report, it gives a good indication of where scarcity is likely to be the strongest driver of investment in water technology.

The Energy Water Nexus – It's all Intertwined



Upstream Oil & Gas – Oil Sands

Steam flood (SAGD) Produced Water Treatment

- **Steam injection lowers the viscosity of heavy oil**
- **Fluid from wells heavily contaminated with dissolved solids and hydrocarbons**
- **Through MVC evaporation technology, *over 90%* of the produced water is recycled**
- **Due to the high efficiency of the process, the waste is concentrated to a minimum**
- **Key industry issues**
  - **Brine Management /Robust ZLD solutions sought.**
  - **Trend towards high salinity waters**

Heavy Oil SAGD Facility for SHELL, Alberta, Canada

Upstream Oil & Gas – Enhanced Oil Recovery (EOR)

Developments in W. Canada have paved the way for other regions

- EOR development in the Middle East, NA, and the Orinoco Belt
- Non Recycled Produced Water
  - Needs affordable and environmentally friendly treatment
  - Agricultural use or discharge without harm to environment
- ***Holistic solutions*** – Various technologies such as, MBR, bio-filtration, ultrafiltration, and ion exchange can treat produced water in economical and environmentally friendly manner

The MVC installation at the in Oman is the largest produced water recycle plant in the world

Oil & Gas Industry Refining and Downstream

Oil Refinery Wastewater Reclamation

- Need 22 Liters of Process Water for Every 3.78 liters of Oil
- Best Suited for Recycling & Reuse
- Discharge Limits for Refineries are More Stringent Worldwide
- New and Innovative Technologies are emerging- WWT

Recycling and reusing refinery waste rater is the emerging segment in the water industry

Power Industry (IGCC)

ZLD and Integrated Water Treatment for Integrated Coal Gasification Power Facilities

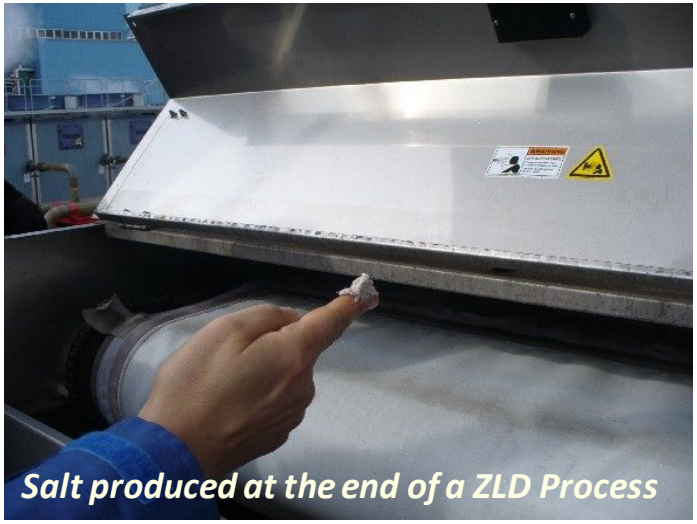
- **High Volume of Wastewater**
- **High Pollution of Waste Stream**
- **ZLD Technology, Best solution**
  - Maximum Reuse / Minimum Waste
  - Meet Discharge Requirements

Coal Gasification will make coal power cleaner and more efficient, but it will also create significant water pollution challenges

Power Industry

- Environmental Regulations becoming More Strict
- Power Industries Looking for Better Options
  - Eliminate Discharge of FGD Wastewater
  - Minimize Waste
  - Maximize Water Reuse
  - Lower Cost Solutions

ZLD Facility for FGD WW at Largest Italian Power Plant

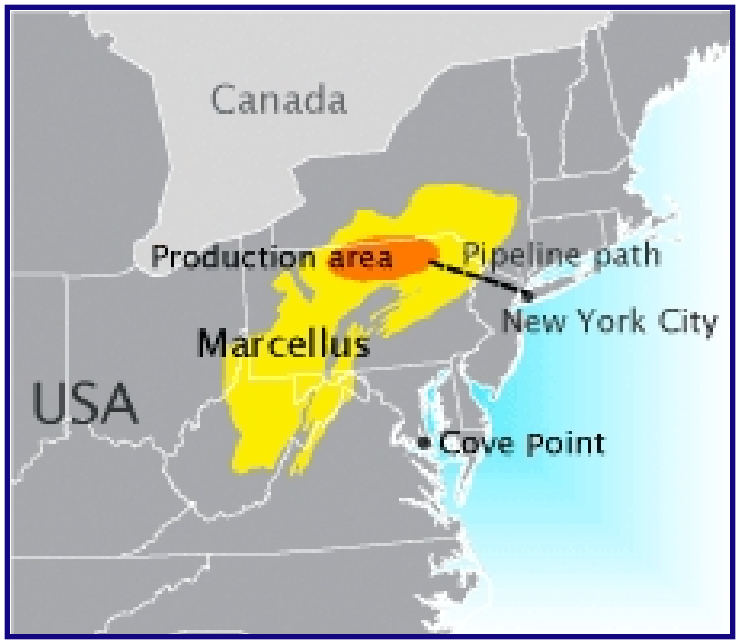


Salt produced at the end of a ZLD Process

Upstream Oil & Gas – Shale Gas

Average of 3-4 Million Gallons of Water used per Well

- Wastewater Returns (High Concentration of Barium, Strontium, etc)
- High Costs to Haul Large Quantities of Fresh Water and Disposal of Wastewater
- Environmental Restrictions for Disposal of Wastewater



Map of Marcellus Shale Region

- There is no greater example of the water-energy nexus than the juncture where water meets the hydraulic fracturing process, or fracking, of natural gas and oil.
- The challenge is about producing energy in the most environmentally-friendly manner, using less water more efficiently and responsibly
- Whether viewing the water-energy nexus through the lens of climate change or resource sustainability, the impact of energy development on water resources has reached an inflection point.

- At present, states have oversight of the water management issues in energy production, which includes fracking
- Two main problems that sometimes converge
  - Source water (Marcellus and Utica is the exception – for now!)
  - Wastewater
- Reuse of the water can address both issues

Shale Plays

- The Haynesville Shale requires close to 8 million gallons per well
- the Eagle Ford play at 5 million
- Barnett Shale at over 4 million gallons
- Water use for oil and gas and mining totaled 1.6% of Texas' total water use.
  - In the Eagle Ford shale region, these activities account for 6.5% of water demand, and are projected to increase by 26% from 2010 to 2060
- As valuable as oil and gas are, "we are worthless without water" (Mayor in small Texas town)

Shale Plays (cont.)

- Marcellus shale the water transportation costs can be up to 25% of the average $6 million cost per well.
- In 2010, Range Resources disclosed using about 3.8 million gallons of water per well.
- How to handle the wastewater?
  - Texas & Oklahoma – Injection Wells
  - Fewer injection wells in the Marcellus Play

- U.S. earthquake increase tied to disposal well boom
- Deep-water injection wells possible cause of minor quakes
- *An increasing number of small quakes near deep wastewater wells, used to dispose of industrial fluids used in the "fracking" boom, is raising questions about their use. The fracking process itself is not directly associated with earthquakes, rather the handling of wastewater during deep-water injection process.*
- USA Today July 11, 2013

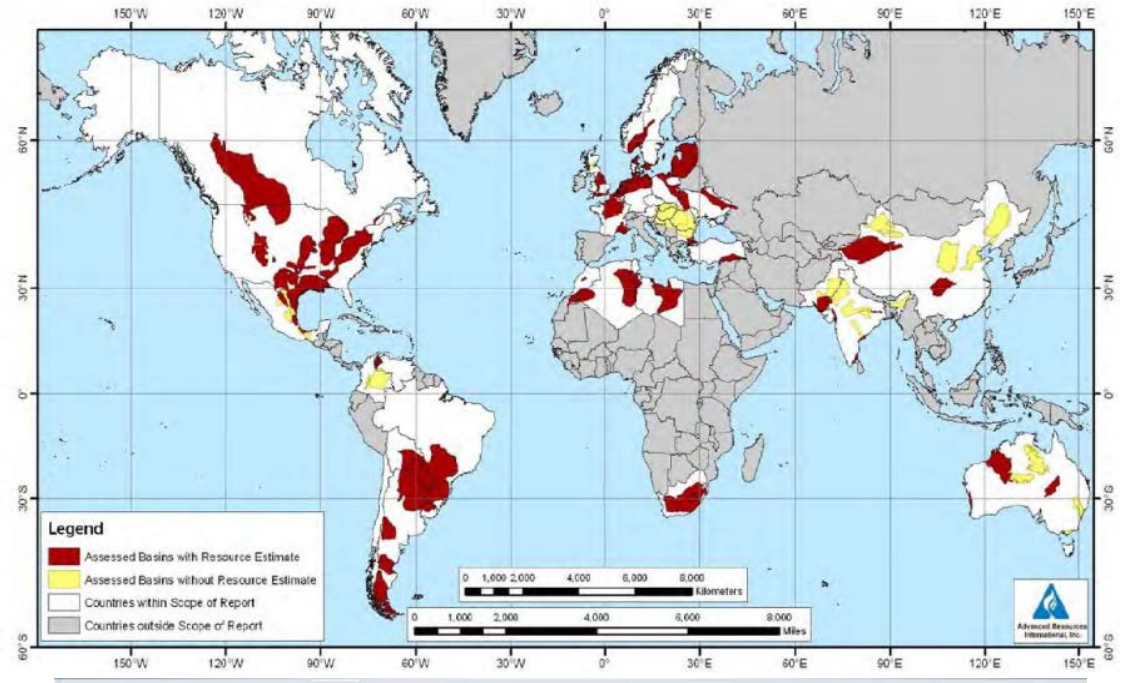
Reuse Can Be The Solution

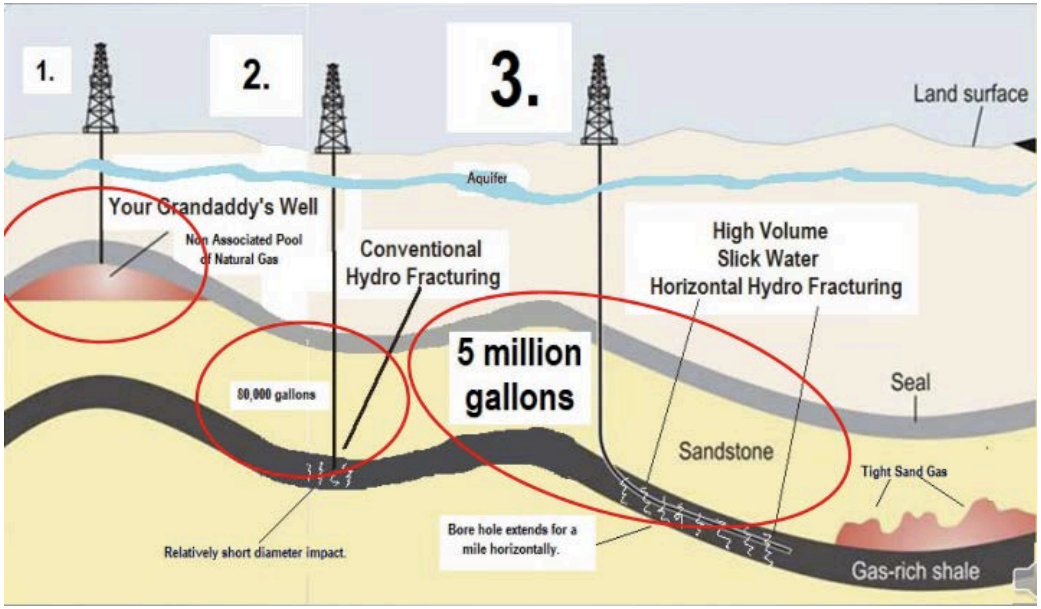
- In the first six months of 2012 drillers achieved a reuse rate of 90 percent (Scientific American)
- A Morningstar analyst estimates that produced water and fracturing waste levels exceeded 1.6 billion gallons in 2012, from 600 million in 2010.
- Morningstar calculates that 40% of wells recycle this water, up from 6% in 2009.
  - Numbers may not agree but the trend is increasing

- The water management market in this sector of energy is expected to grow from $11 billion in 2013 to $22 billion by 2018, according to the Morningstar analysis.

- Firms are expected to provide integrated consulting services related to the management of water, state regulations, monitoring, and the entire value chain related to water management and energy development.

Shale Gas showing up everywhere





Technically recoverable shale gas resources by country

Country	Technically recoverable reserves (billion m³)	Country	Technically recoverable reserves (billion m³)	Country	Technically recoverable reserves (billion m³)
China	36,104	France	5,097	Uruguay	595
United States	24,409	Norway	2,350	U.K.	566
Argentina	21,917	Chile	1,812	Others	538
Mexico	19,284	India	1,784	Tunisia	510
South Africa	13,734	Paraguay	1,756	Netherlands	481
Australia	11,213	Pakistan	1,444	Turkey	425
Canada	10,987	Bolivia	1,359	Morocco	311
Libya	8,212	Ukraine	1,189	Germany	227
Algeria	6,541	Sweden	1,161	Western Sahara	198
Brazil	6,400	Denmark	651	Lithuania	113
Poland	5,295				

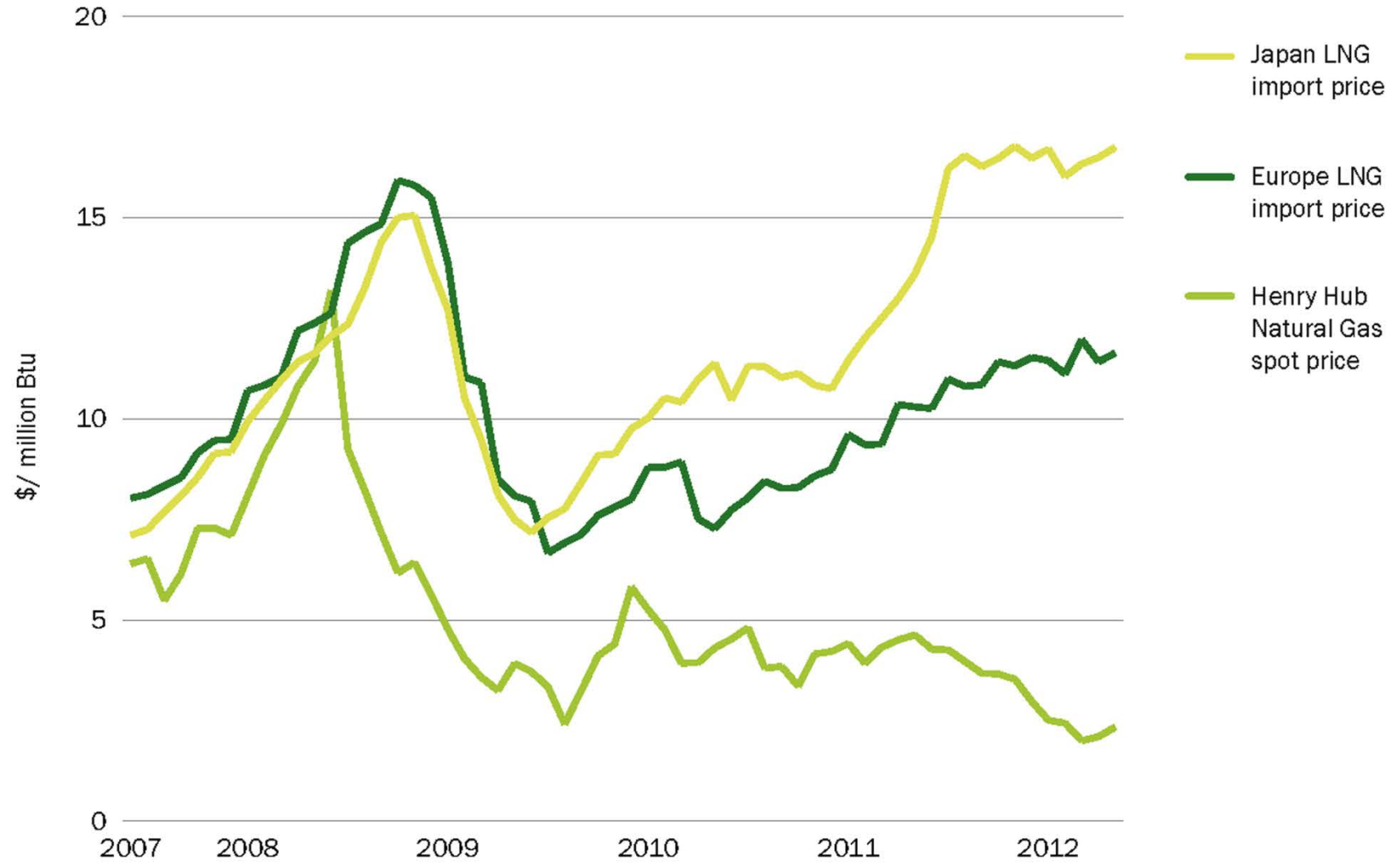
Source: EIA, 2011

Status of international shale plays

Country	Current status	Large scale production	Water challenge
China	Up to 20 exploratory wells in operation	2015	Scarcity and disposal
Poland	Up to 20 exploratory wells in operation	2014	Disposal not scarcity
Argentina	Early development	2015	Disposal not scarcity
Mexico	Early development	2018	Scarcity not disposal
South Africa	Early development	2020	Scarcity and disposal
France	Moratorium on new development	–	Disposal not scarcity
Canada	Up to 500 wells in operation	2014	Some issues

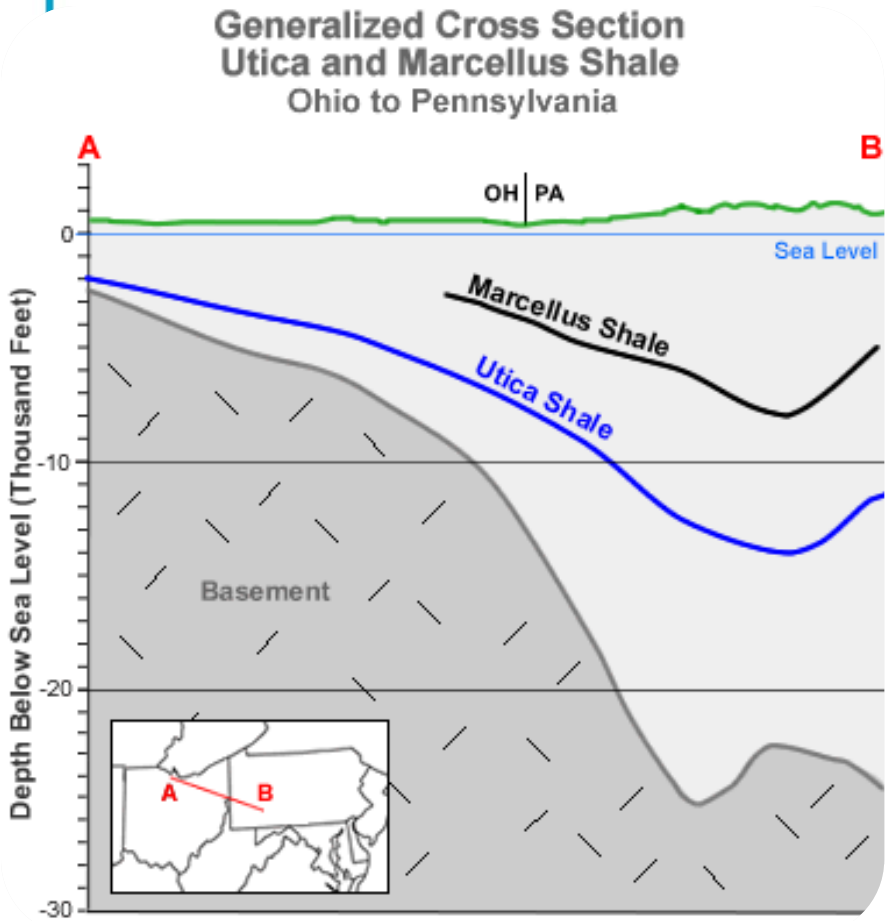
Source: GWI

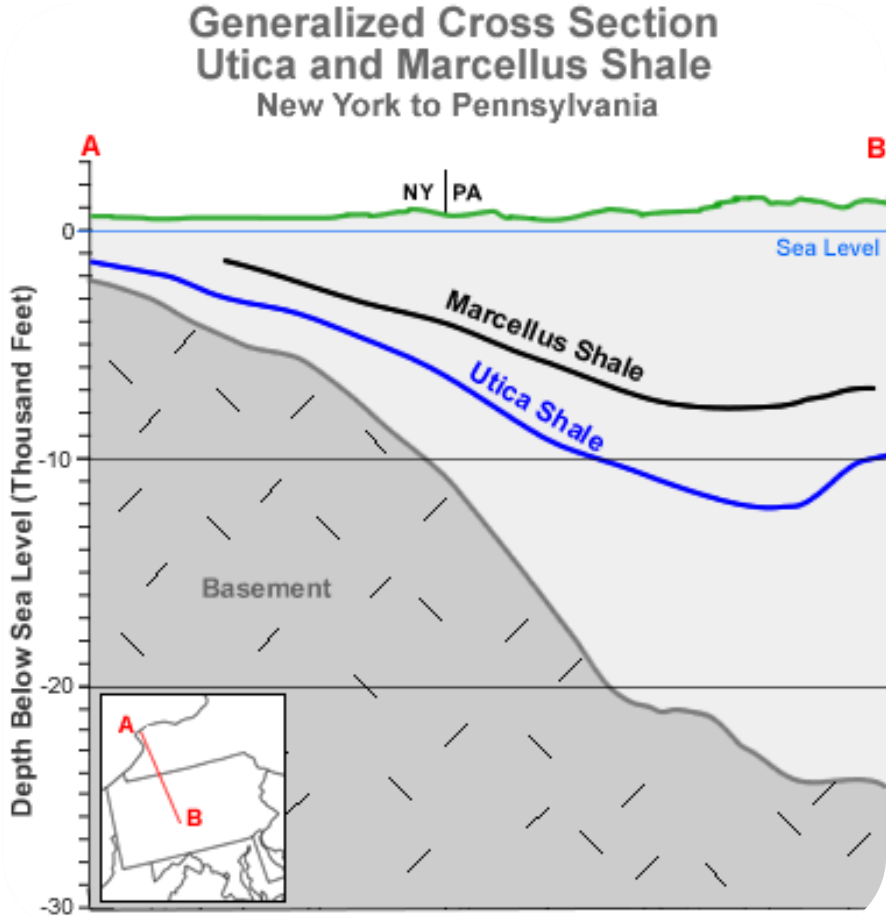
Natural gas price trends: Henry Hub spot price and LNG import prices in Europe and Japan



Source: World Bank Commodity Markets Review

Marcellus & Utica Shale

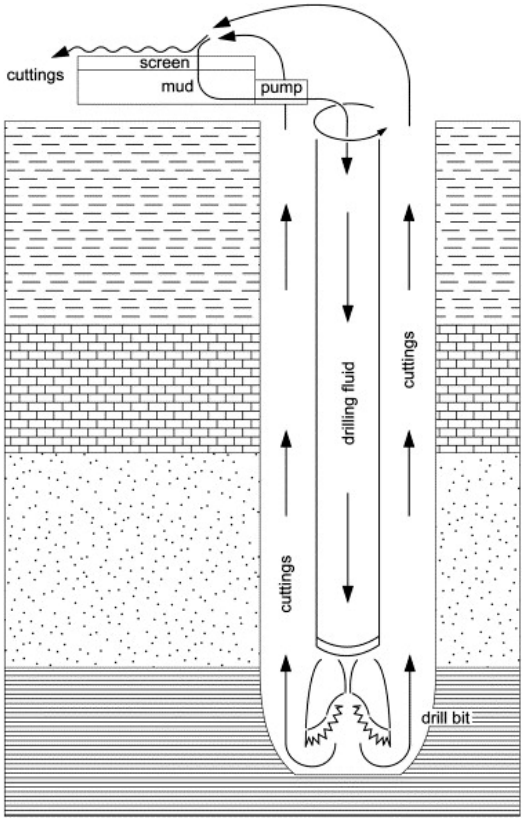




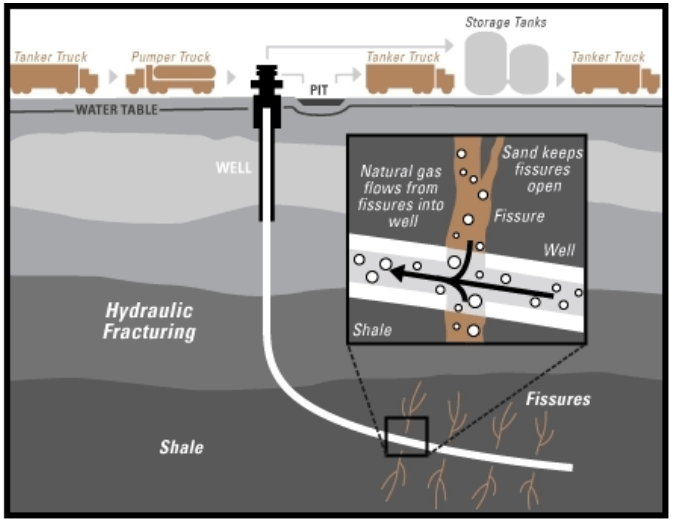
Need to *consider* Conventional & AMD

Water & Wastewater in Shale Gas

Drilling



Fracking



Production

-Drilling fluids
-Top Hole Water

-Source Water
-Flow Back

-Production Brine

The real problem is Production Brine

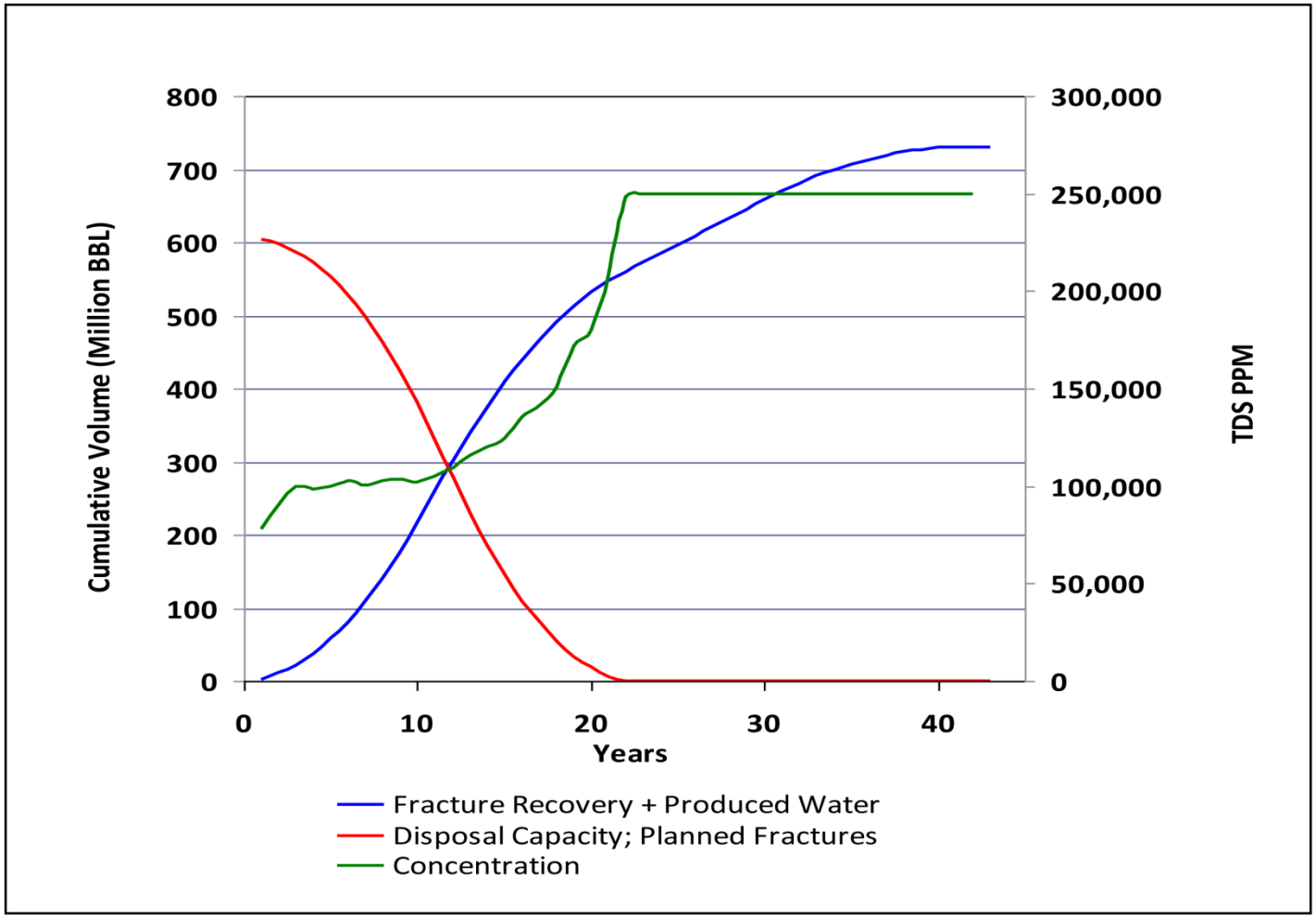
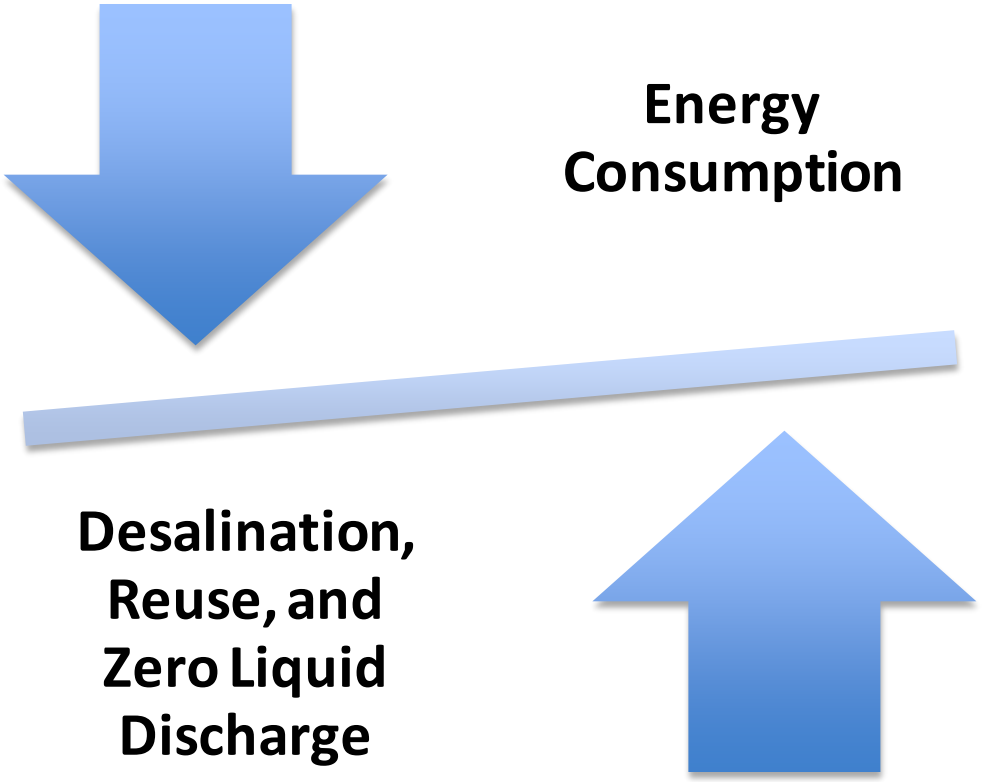


Figure 13: Cumulative Fracture and Process Water Recovery vs Projected Reuse Capacity in a 19,200 Fracture Play Assuming 33% Blend of Recovered Water in Each Fracture

Production Brine Crystallization

- Long term disposal solution
- 1.5 year development cycle
  - Off takes are an issue
  - Courage under fire
- Capital intensive
  - Requires modularity
  - Past experience essential
- Co-product determination
  - Dewasted distillate
  - Reusable salt products

Energy Efficiency – The Critical Future



Energy Efficiency - The Critical Future

- **Solutions to optimize energy**
  - Hybridization of major desalination facilities
  - Hybrid ZLD
  - Emerging Technology – Merging Desalination, Reuse, and ZLD **with renewable energy sources**

Technology Portfolio

Filtration **Chemical Precipitation** **Solids Removal** **Sludge Compaction**

NORM Reduction **Evaporation** **Storage** **Crystallization**

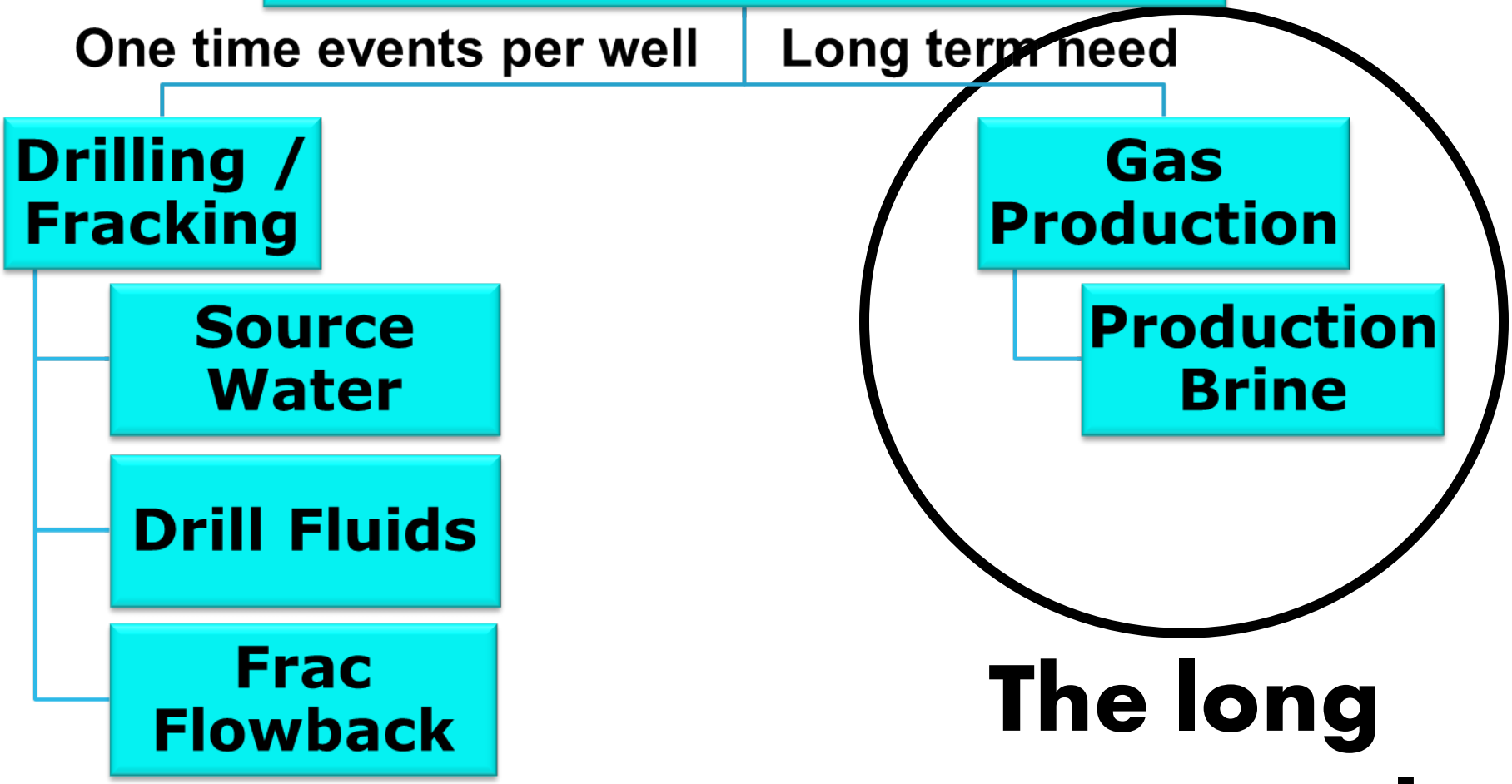
Marcellus Water Play

- Subsurface water
- Source water
- Drilling, Completion & Production
- High total dissolved salts (TDS)
- Conventional fluids
- AMD – Acid Mine Drainage

Typical Water Characteristics

Parameter	Flowback	Brine
TDS in ppm	40,000 to 110,000	150,000 to 300,000
Hardness in ppm as Ca	15,000 to 25,000	20,000 to 35,000
Barium in ppm as Ba	3,000 to 5,000	4,000 to 10,000
Chlorides in ppm as Cl	20,000 to 70,000	80,000 to 150,000

Shale Total Water Management



The long term need

Taking our Industry from Good to Great....Get one Voice

End-users

- Be progressive, promote reuse, its still not the mainstream in key markets
- Be Prepared to be an Early Adopter- mange Risk
- Facilitate Industry Hardware Standards
- Demand Life Cycle Cost Optimized Solutions

Policy Makers

- Incentivize for Zero Discharge – this will naturally drive reuse
- Offer incentives for water efficient facilities and eliminate subsidized water – part of the problem is there is often no real "cost" of water, particularly in emerging markets

Water Technology Companies

- Measure Holistic Value
- Drive down the energy cost of desalination, water reuse, and ZLD
- Local Presence
- Move away from Hardware
- Move towards Process
- Invest in R&D and Applied Development

Power Industry- Global Issues

Utilizing Recycled Sewage to Feed

- To Reduce Fresh Water Consumption, Plants Reuse Sewage Water as Feed Water
- Industry Offering Many Technologies to the Industry to use this Water, Resulting in Less Water Intake

India is one of the fastest growing power markets in the world, it is also, per capita, one of the most water scarce.