The Next Oilfield Step:

A Circular Economy Approach to Reuse, Recycle, and Reduce Production Water

IADC ART SPARK Tank
Houston, Texas
04-April-2018

A Fresh (Water) Opportunity – Supply Side

THE Limiting Factor for Resource Play Development
In addition to proppant availability and pipeline limitations, fresh water has become too costly for hydraulic stimulation operations. There have been shortages of fresh water for drilling and completion fluids as well as during emergency response operations such as a blowout.

Significantly Increased Costs for Frac Fluid Treatment
Chemical costs are between $8-$11 per bbl for using high saline produced water instead of starting with fresh water.

Post-Frac Plug Coiled Tubing Drillout Costs
Friction reducers and gelling agents are often ineffective when using high saline produced water.

Environmentally Sensitive Areas
More wells are being drilled in protected areas where water is simply not available due to drought or local watershed resources are prohibited for use by operators for drilling and completion activities.

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Water Weekly

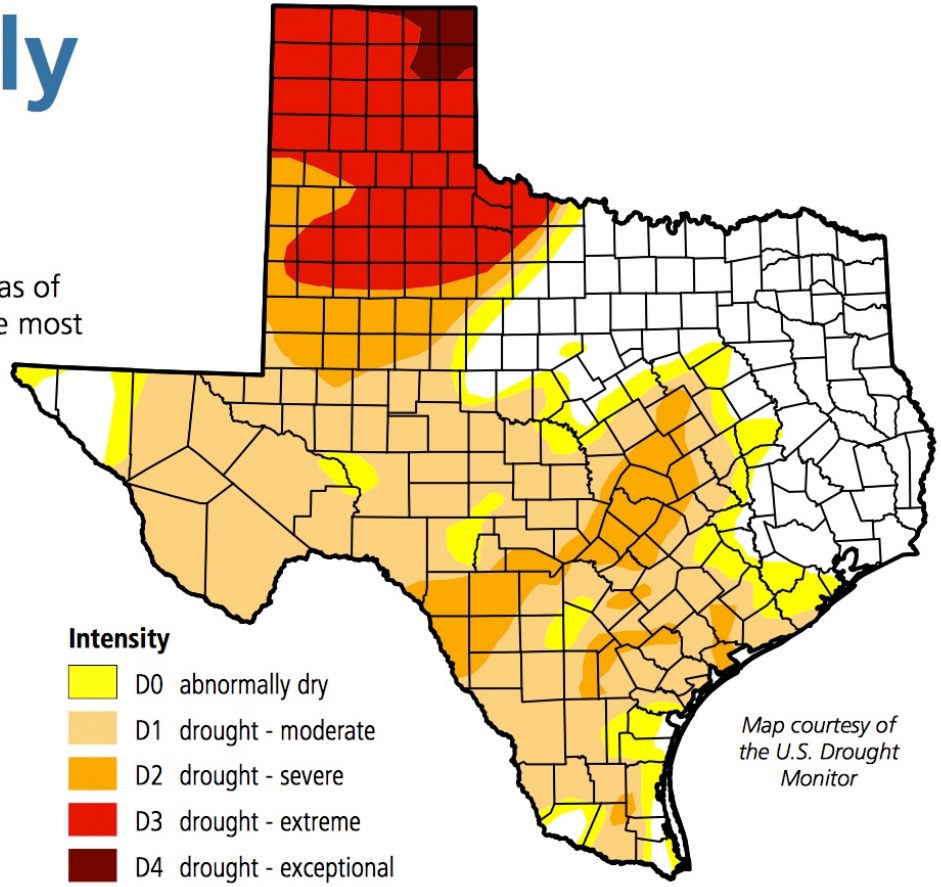
For the week of 04/02/18

Water conditions

Last week's drought map shows conditions as of March 27. By then, exceptional drought, the most extreme drought category, had appeared in the northeast corner of the Panhandle. Drought expanded three percentage points from the previous week and now covers 64 percent of the state.

Drought conditions

- 64% now
- 61% a week ago
- 33% three months ago
- 9% a year ago



Map courtesy of the U.S. Drought Monitor

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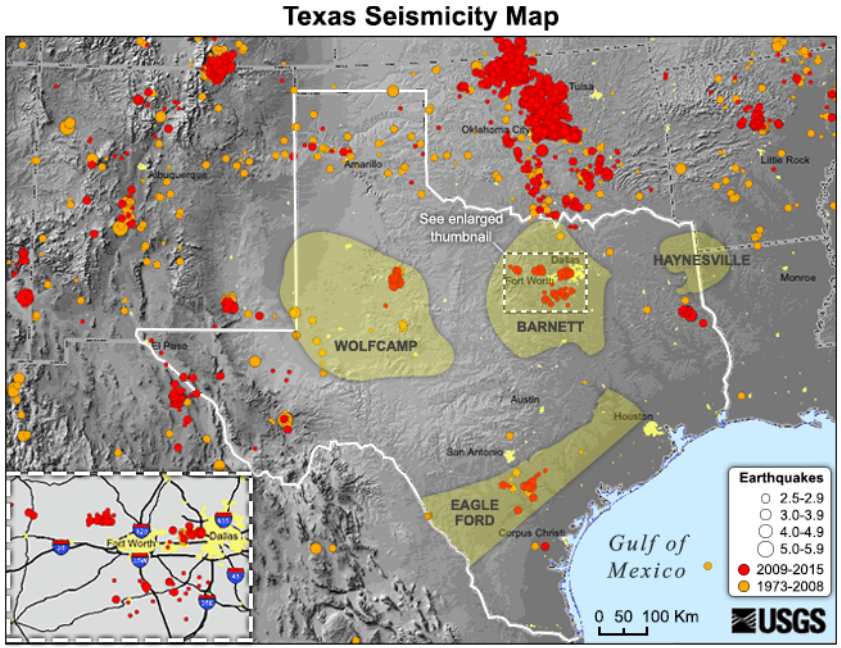
A Fresh (Water) Opportunity – Disposal Side



Source: U.S. Geological Survey, NGI

Skyrocketing Produced Water Rates
2018 U.S. production will rise to year end average of 10.7MM boepd – and water production is steadily increasing with both depletion and number of wells.

Earthquake Linked Disposal has <<Shaken>> Operators with Regulatory Authorities Limiting Injection Volumes
In Oklahoma, 1.6MM bwpd has been removed from disposal and has shown decrease in the number of daily recordable seismic events.

Coal Bed Methane Wells
Often produce water for 6 months before gas breaks through.

$150M Deepwater Disposal Wells
Many fields do not need secondary oil recovery due to strong aquifer support. Produced water cannot be discharged overboard and volumes are far too large for transportation to shore. Average cost is $6/bbl for deepwater produced water.

Objective Evidence

In 2007, fresh water was <$0.50/bbl

- 2017 fresh water is no longer available
- Operators are using up brackish water resources
- Prices in the Permian range between $3.00 - $4.50/bbl

In 2007, frac jobs were 20 - 30 stages and used <100,000 bbls of water

- 2017 frac jobs have exceeded100 stages per lateral and have used more than 1,00,000 bbls of water

Onsite frac pits can take up to 2 months to fill with up to 20% evaporative loss in the process

In 2017, less than 10% of all produced water is recycled

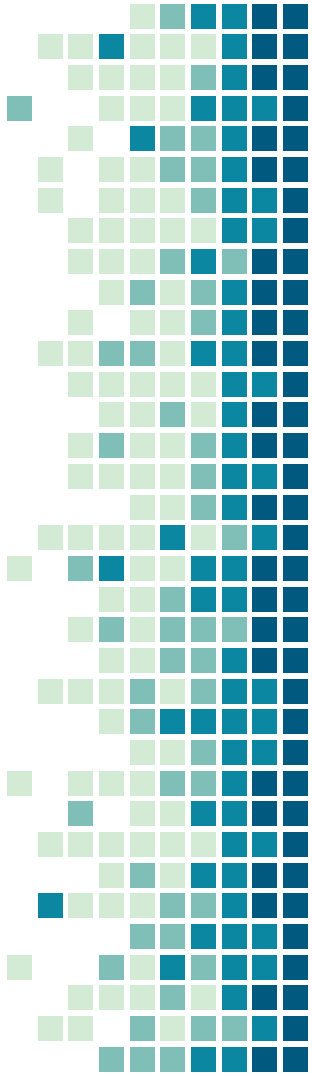


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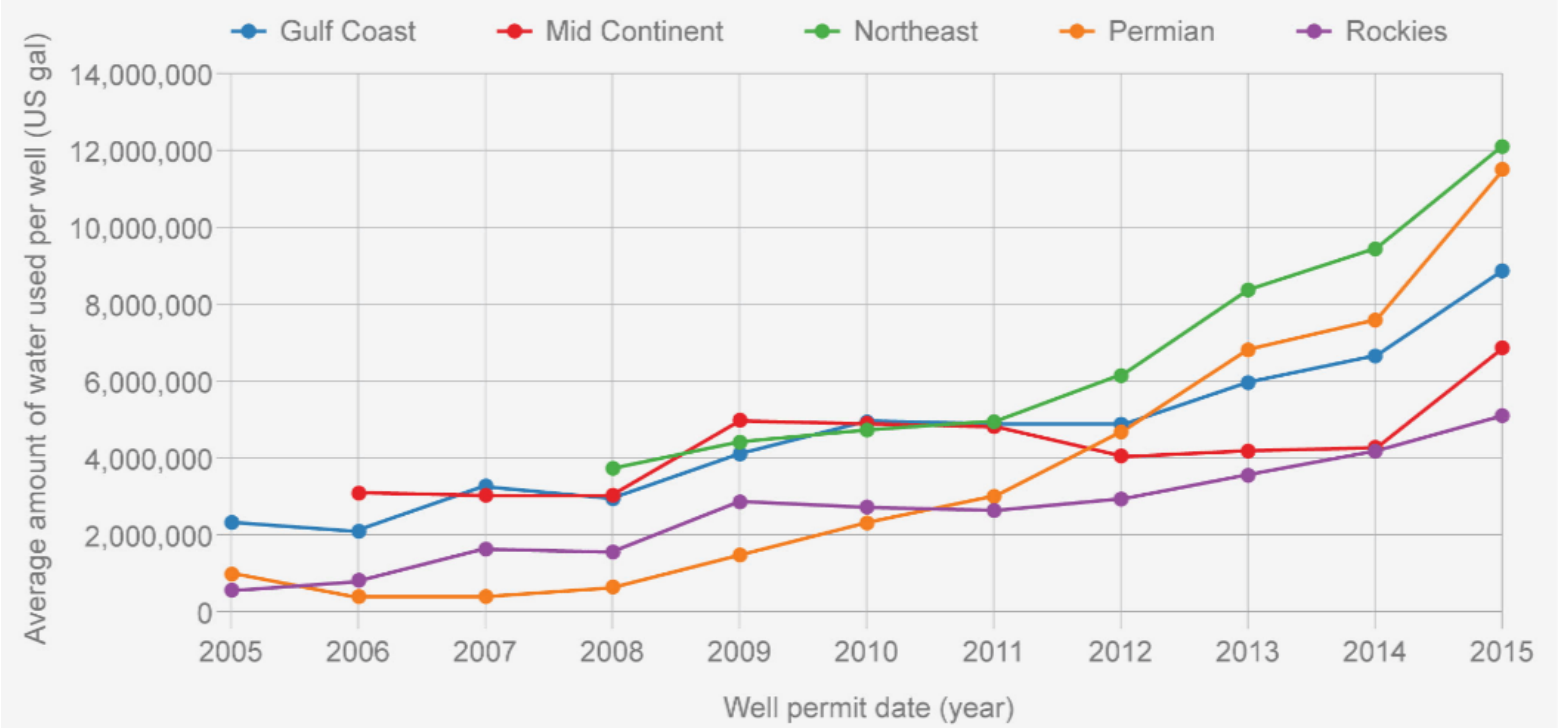
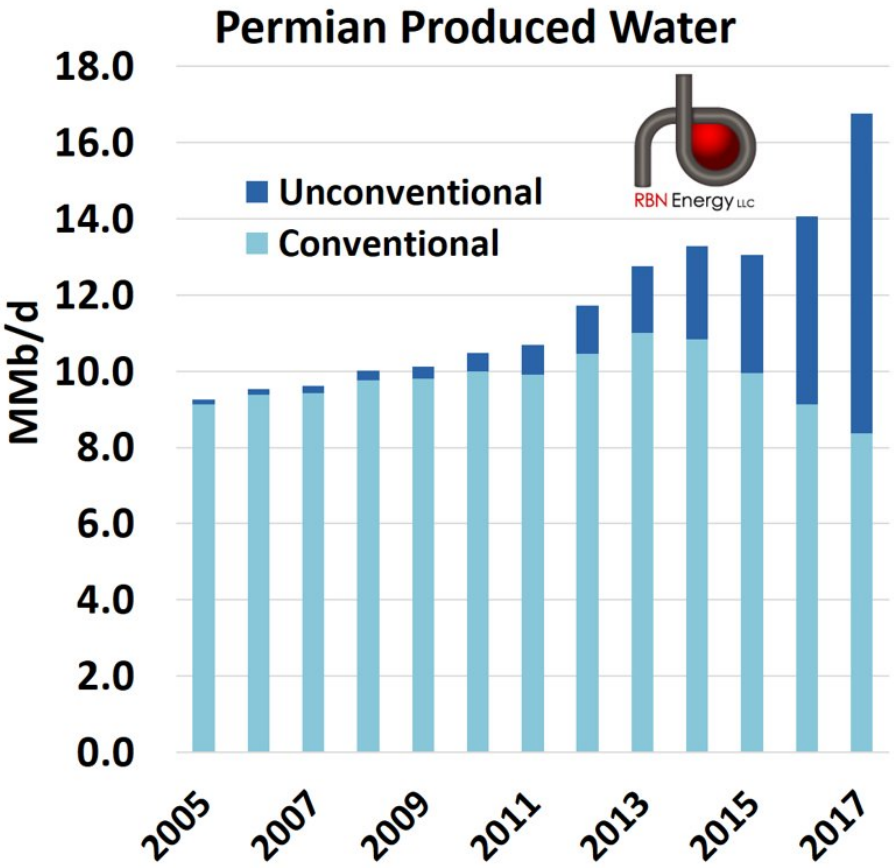
Figure 1: Hydraulic fracturing: average water used per well drilled (by production region)



Source: Wood Mackenzie, 2016

In 2009, the National Energy Technology Laboratory reported that total water production from the United States, including the major onshore shale basins, Alaska, and the Gulf of Mexico, was roughly 21 billion bbls of water per year.


Permian Produced Water
MMb/d
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Unconventional
Conventional
RBN Energy LLC
2005
2007
2009
2011
2013
2015
2017

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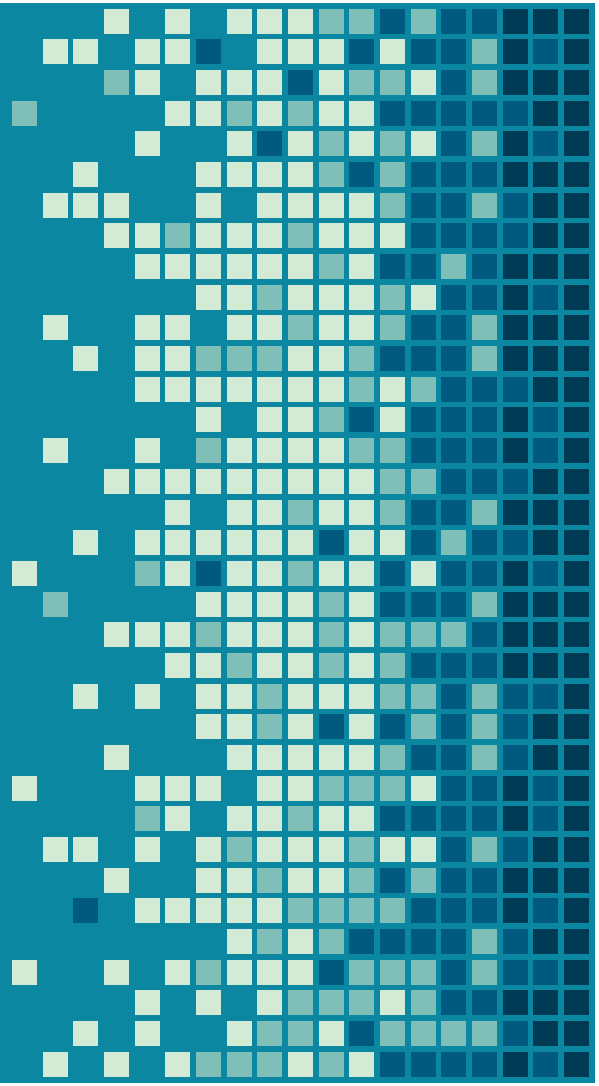
> That would translate into 2.5 billion barrels per year for the Permian by 2040, according to many analysts' projections.



25 Methods to Purify Water

Water Contaminants: Particulates, minerals, organic compounds, and bacteria.

FILTRATION

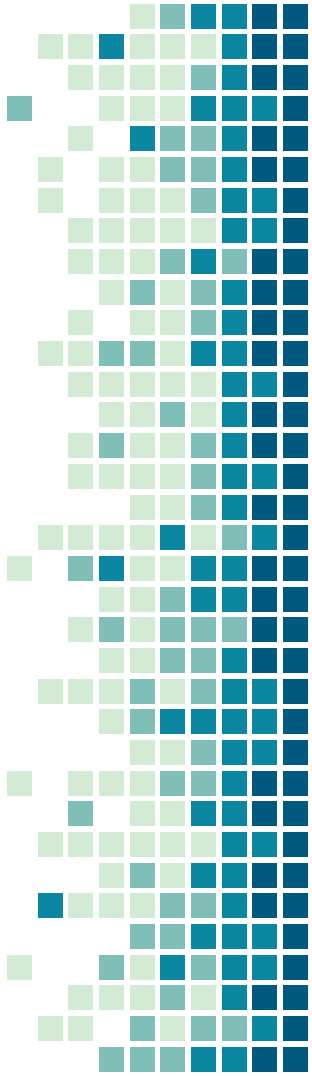
Reverse Osmosis uses a membrane with microscopic holes that require 8x the volume of water processed to wash it in order to remove minerals and salt, but not necessarily chemicals and bacteria.

SEPARATION

Distillation boils and re-condenses fresh water. Traditional techniques are far too energy intensive to boil and cool water.

CHEMICALS

Methods including oxidation can range from simple and inexpensive to elaborate and costly. Often to achieve fresh water, several technologies must be combined in a particular sequence.



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Why is Fresh Water Preferred?

Lower chemical treatment costs

Ability to build correct shale inhibition profiles for each unconventional reservoir

Better quality water source than brackish water

Operators already **OWN** the water

Safe in the event of a spill

Better infield development logistics with reduced transportation costs

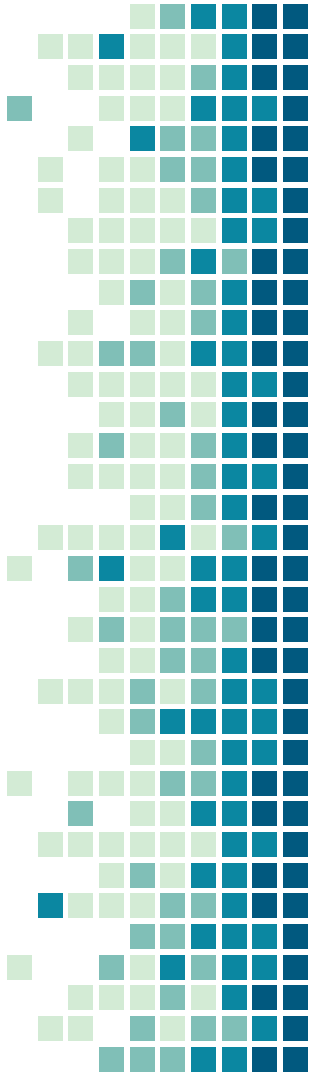
Can potentially reduce injection rates by 90%

Turn SWD wells into producing wells for fresh water recovery

Socially responsible development

Reduce or eliminate the need for new SWD wells in areas of high concern

Can provide land owners with potable water, supply for livestock and irrigation, as well as potentially help recharge depleted aquifers



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Unique patent-pending technology utilizing carbon nanotubes and low-energy input multi-stage flash distillation equipment to redefine the supply, recycling, and disposal of oilfield produced water

Scalable technology from low rate, individual wellhead handling systems to integration within existing large or offshore operating facilities.

Helping both operating and service companies minimize costs on well construction, disposal charges, and operating fees and maximize profitability of field developments.

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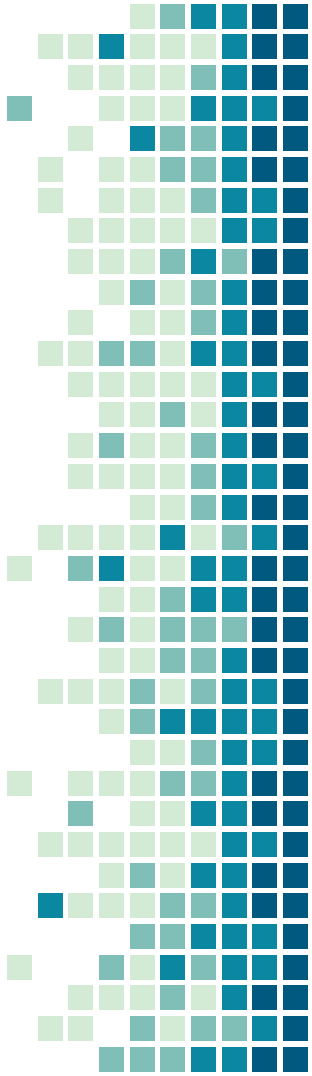
“Method and Apparatus for Heating Fluids”

Provisional application number 62/423,122 filed on November 16, 2016
Experiments achieved >>500° F within <5 seconds using 1,000 W transformer and 2.45 GHz magnetron
Prototype built April 2017
Field trial model in Summer 2018



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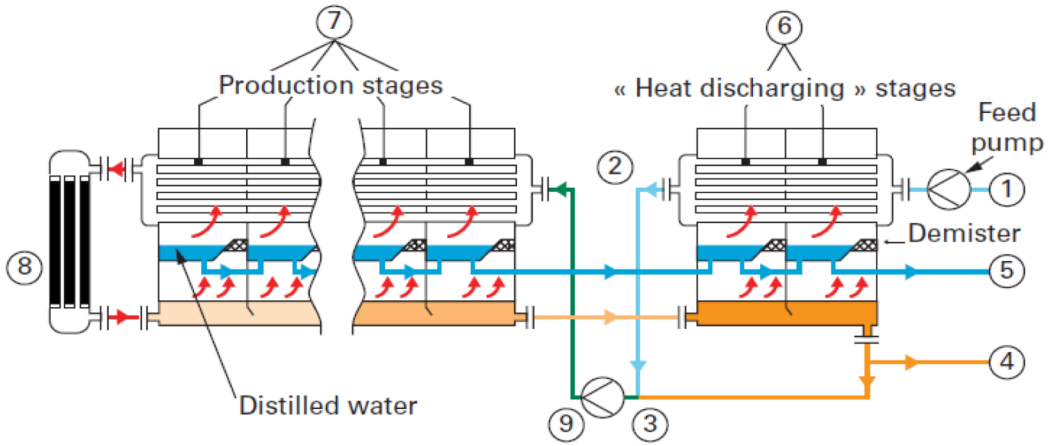
Multi-Stage Flash (MSF) Distillation



Heating

Instead of using typical steam based heat exchanger, the brine is passed through a series and parallel arrangement of carbon nanotube cylinders (#8) which are exposed to microwave radiation. Heat is transferred though conduction and emissivity to flash a portion of the incoming brine. Multiple production stages are used where each has a different pressure corresponding to the boiling points of water at the stage temperature.

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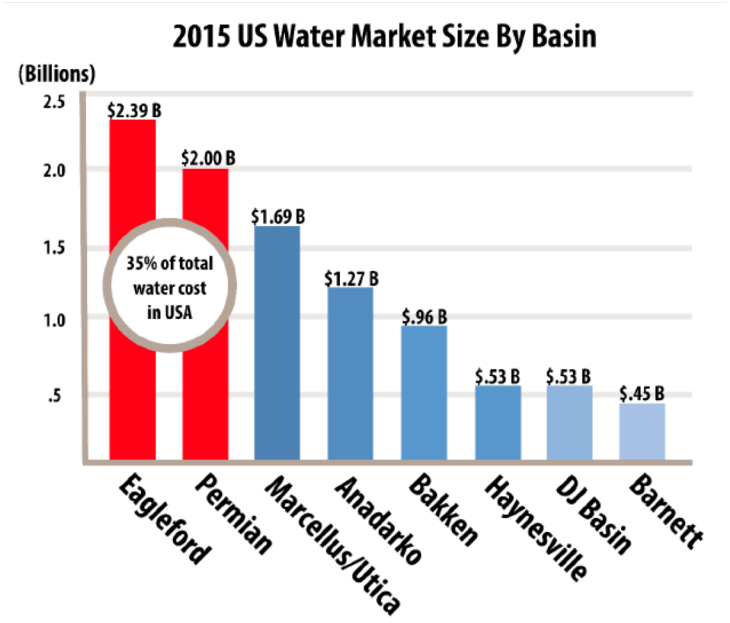
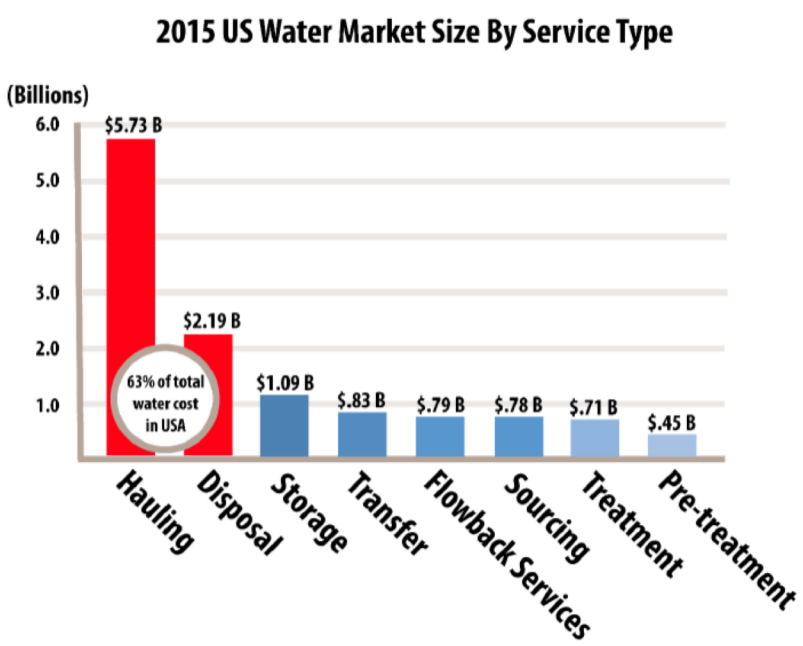
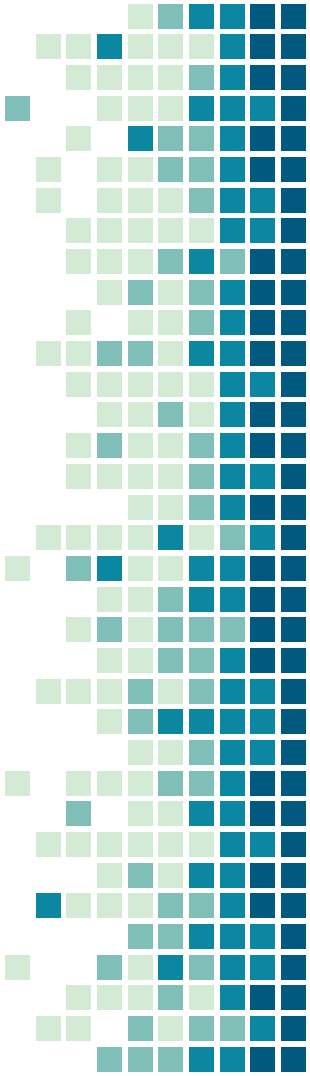




Across America, energy production might have doubled, but water logistic volumes (i.e. barrels of water being transported) exploded by at least 25x. In Texas, as much as **70x**.

These costs are especially troubling in the state of Pennsylvania where only **SEVEN** commercial disposal wells are active. Operators have no choice but to haul their water 200+ miles to the disposal-rich state of Ohio.



THANKS!

Any questions?

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