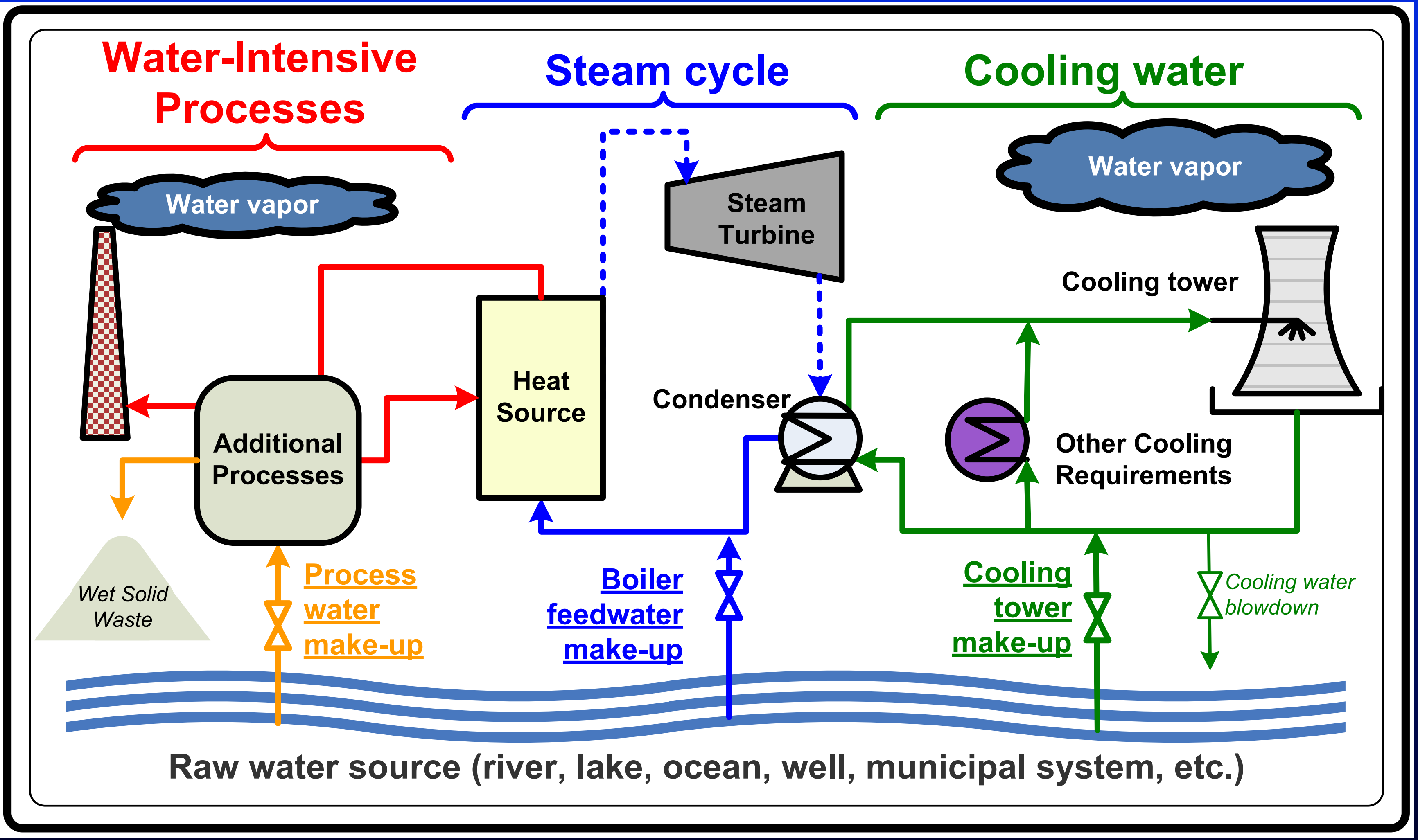
Existing and Emerging Technology Innovations

Wastewater Reuse in Electric Power Production and Unconventional Gas Extraction

Radisav D. Vidic

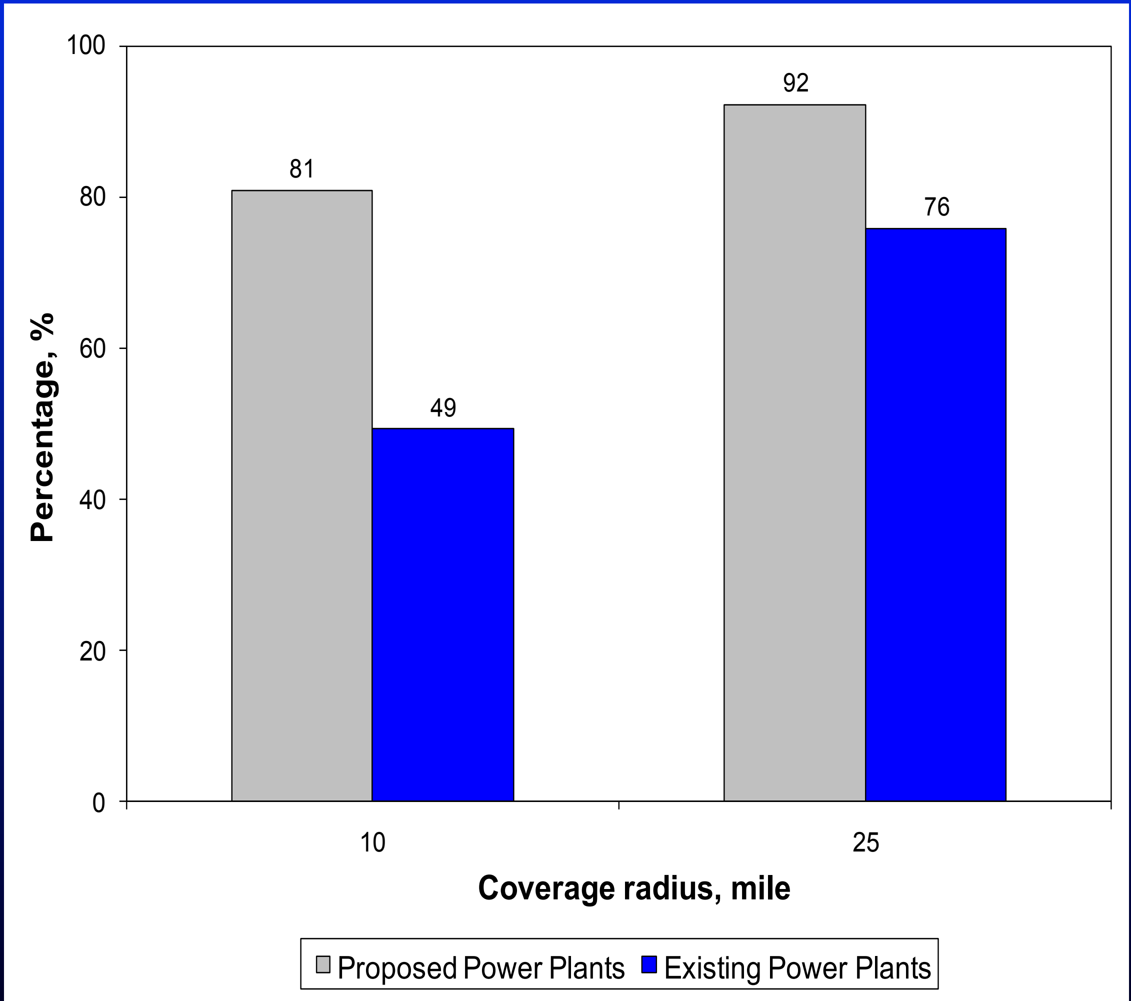
Department of Civil and Environmental Engineering
University of Pittsburgh, Pittsburgh, PA 15261

Water Use in Thermoelectric Power Plants



The use of Treated Wastewater Can Satisfy Water Needs

11.4 trillion gallons of treated wastewater produced annually!

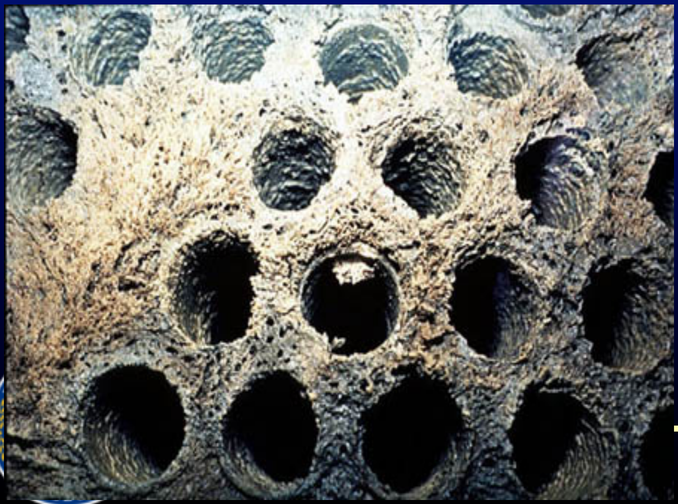


50% of existing and 80% of future plants can meet their water requirements from just one POTW nearby.

Li et al, ES&T, 45, 4195-4200, 2011

Key Technical Challenges with the Use of Impaired Waters

- Precipitation and scaling
- Accelerated corrosion
- Biomass growth



Current Approach

- Treat secondary municipal wastewater extensively (e.g., softening, membranes) to achieve fresh water characteristics
- Advantage
  - Well established practice
- Disadvantage
  - Capital cost
  - "Same old approach"

Alternative Approach

- Use impaired waters (tertiary municipal wastewater, process water, etc.) with water quality control in the system
- Advantage
  - Lower capital and O&M cost
- Disadvantage
  - New approach
  - Skilled workforce requirement

Alternative Approach

- Various strategies for controlling scaling and corrosion to acceptable levels (inhibitors; pH control; removal of PO_4, NH_3, organic matter)
- Tradeoffs (e.g., PO_4 reduces corrosion, but increases scaling; lower pH reduces scaling but increases corrosion)
- Chloramine found to be an effective biocide and much less corrosive than chlorine
- Determining optimal approach requires testing and modeling

Use of Impaired Waters for Cooling

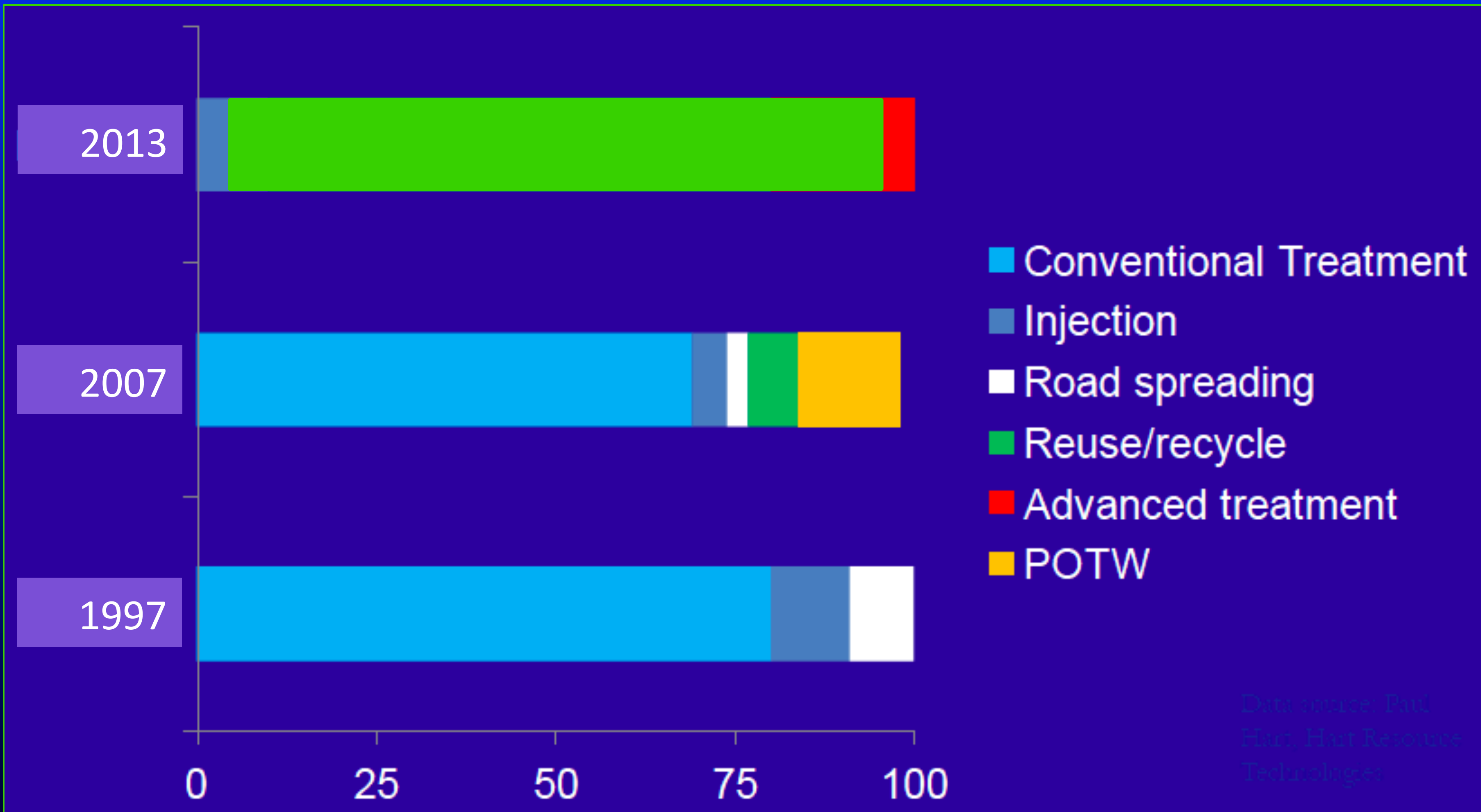
- Optimization problem: Extent of pretreatment before use and chemical addition for control
- Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) of the alternatives
- Regulatory issues
- Social acceptance issues

Water Supply Issues for Marcellus Shale Development in PA

- Need 3 to 6 Million gallons of water per well for a multi-stage hydrofracturing

Water-use category	Water withdrawal (MGD)	Percentage (%)
Public supply	1420	15
Domestic	152	1.6
Irrigation	24.3	0.3
Livestock	61.8	0.6
Aquaculture	524	5.5
Industrial	770	8.1
Mining	95.7	1
Thermoelectric power plants	6430	67.7
Marcellus Shale exploitation in 2013	18.7	0.2

Gas Drilling Wastewater Management

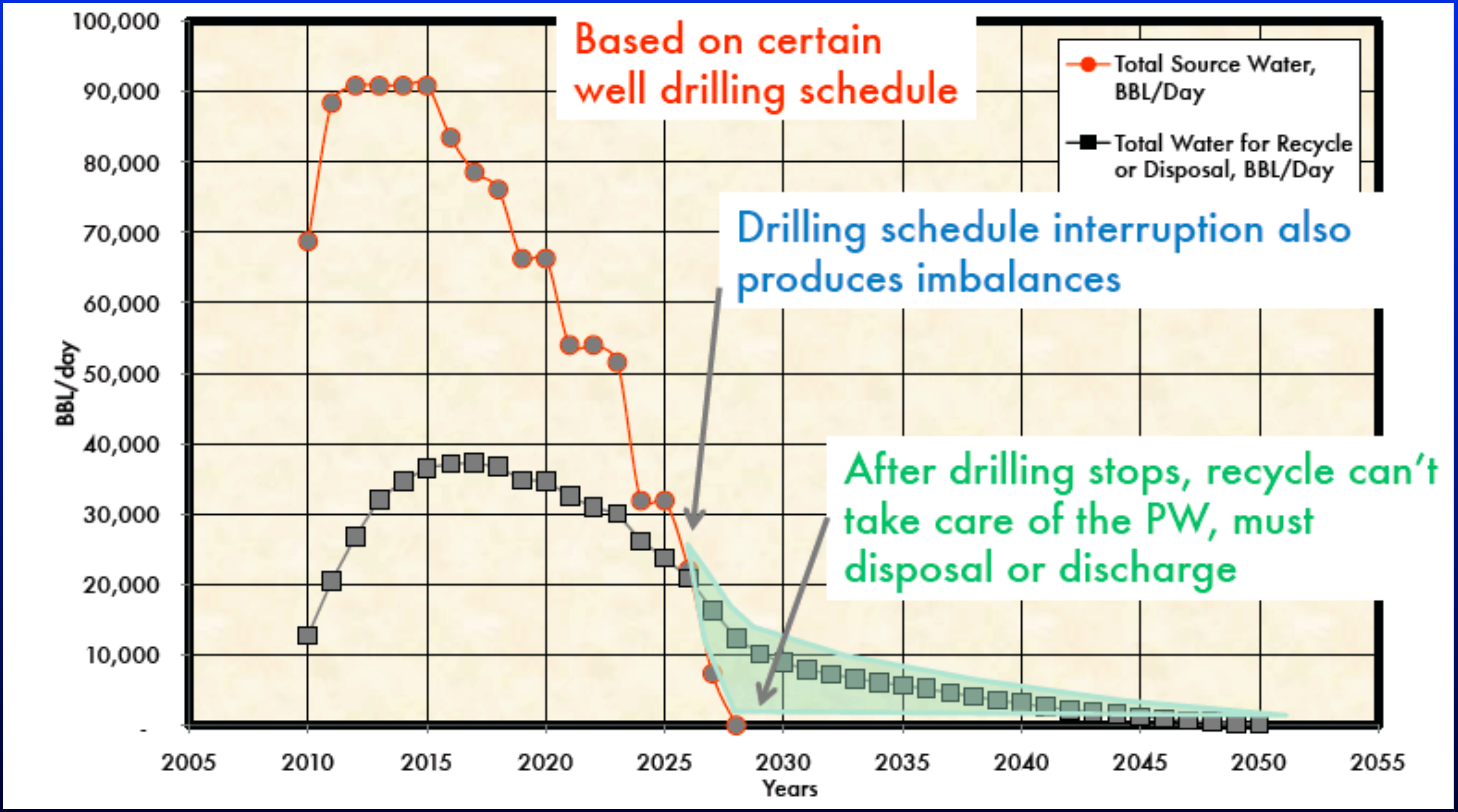


(Hart, P., 2011)

Why is there no water recycling in other shale plays?

- Availability of low cost disposal options
- If it's not broke, don't fix it
- Competing interest (E&P, service providers)
- Public pushback
- Regulatory incentive
- Frack fluid designed for fresh water

Total Water Balance Within a Gas Field



(Kujivenhoven et al., 2011)

Crystallization – Existing Technology for Wastewater Management

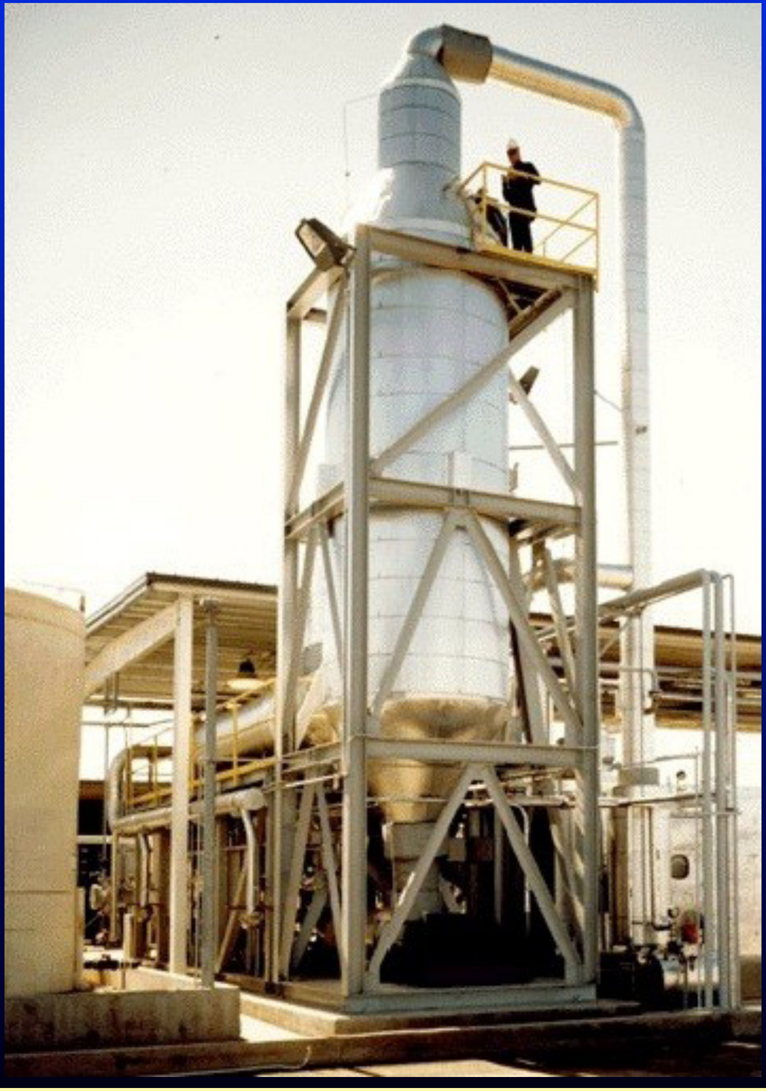
Zero Liquid Discharge

20 to 400 gpm

685 to 13570 bpd

Inlet 300,000 mg/l

Outlet Water/Salts

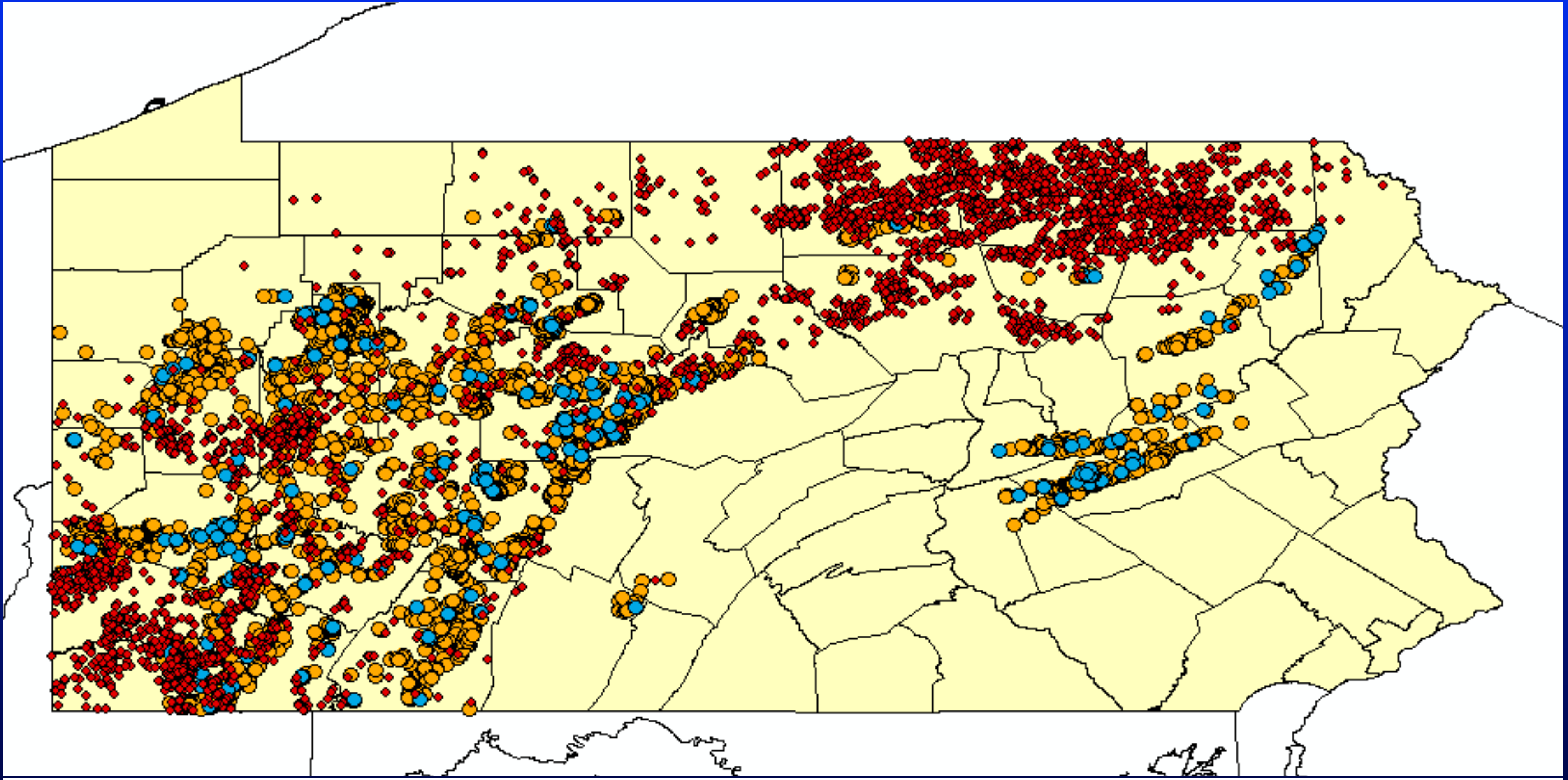


Salt production

- 100,000 wells
- 10 barrels/day/well of produced water
- 300,000 mg/L salinity of produced water
- 80% salt recovery

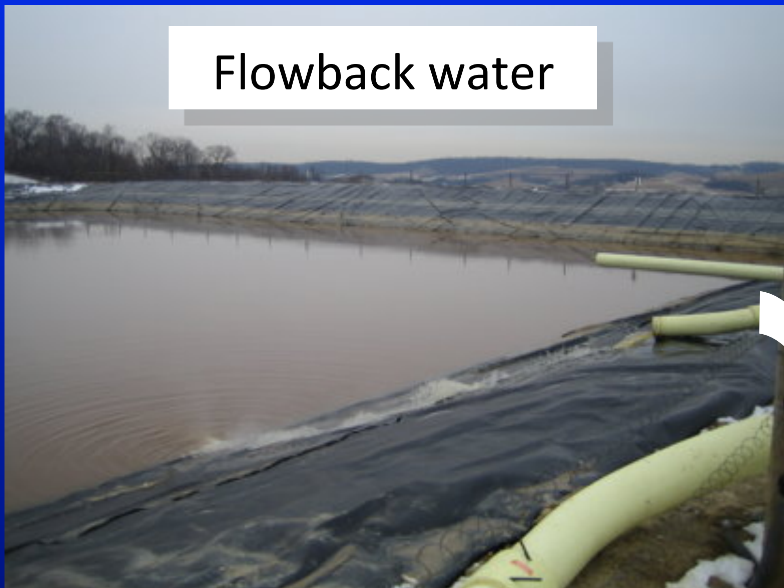
- Total NaCl produced in PA = 8 million tons
- Total salt use for deicing in the US = 12-15 million tons

Use of AMD in Marcellus Shale



◆ Well permits ● Abandoned discharge ● Reclaimed discharge

Co-treatment of flowback water and AMD



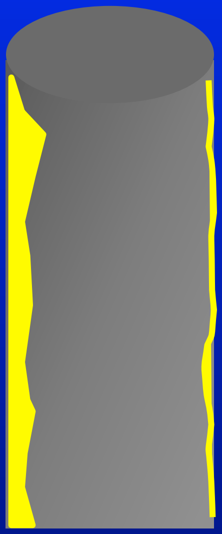
Barium, Strontium, Calcium

Sulfate

Hydraulic fracturing

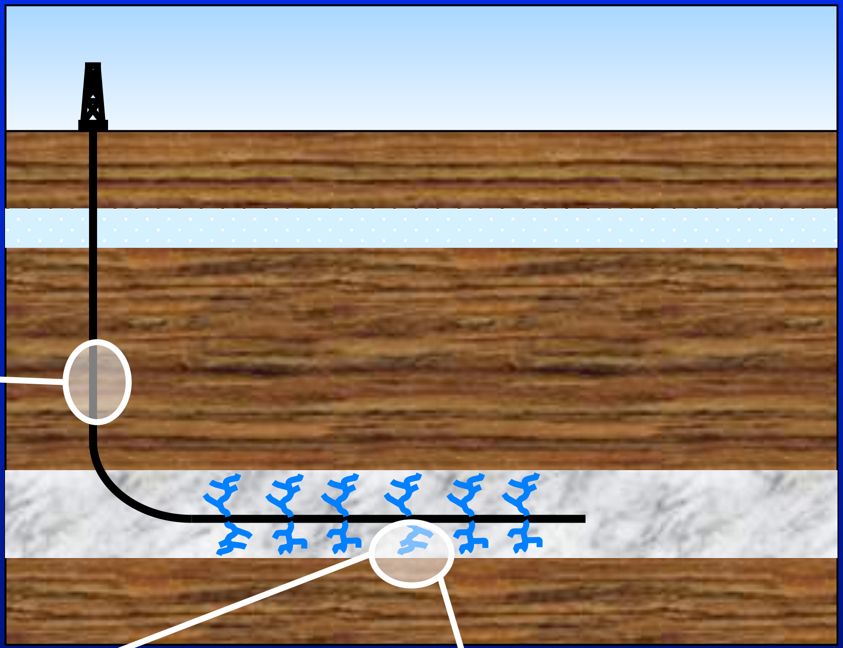
Enables the reuse of flowback water for hydraulic fracturing with limited treatment => decreases the treatment and transport cost of flowback water

Potential impact of sulfate downhole



Scaling in production casing

Microbial sulfate reduction?



"Homogeneous " scaling

Formation of plugs

Sulfate precipitation downhole

Calculations performed using:

- Fracturing fluid volume = 3 million gal
- 9%$_w$ proppant
- Proppant density = 1200 kg/m^3

SO_4 (mg/L)	$BaSO_4$ volume (m^3)	Volume percentage compared with proppant
200	0.98	0.1%
800	4.9	0.4%
2000	9.8	1.3%

Negligible volume compared with the volume of proppant injected

Summary

- Key to innovation
  - Technical performance
  - Cost
  - Ease of implementation
  - Incentives and pressures (regulatory, public)
- Competing interests (customers vs. service providers)
- Other benefits
  - Social
  - Environmental

Thank You for Your Attention