# Hydraulic Fracturing Wastewater Treatment: Building a Framework

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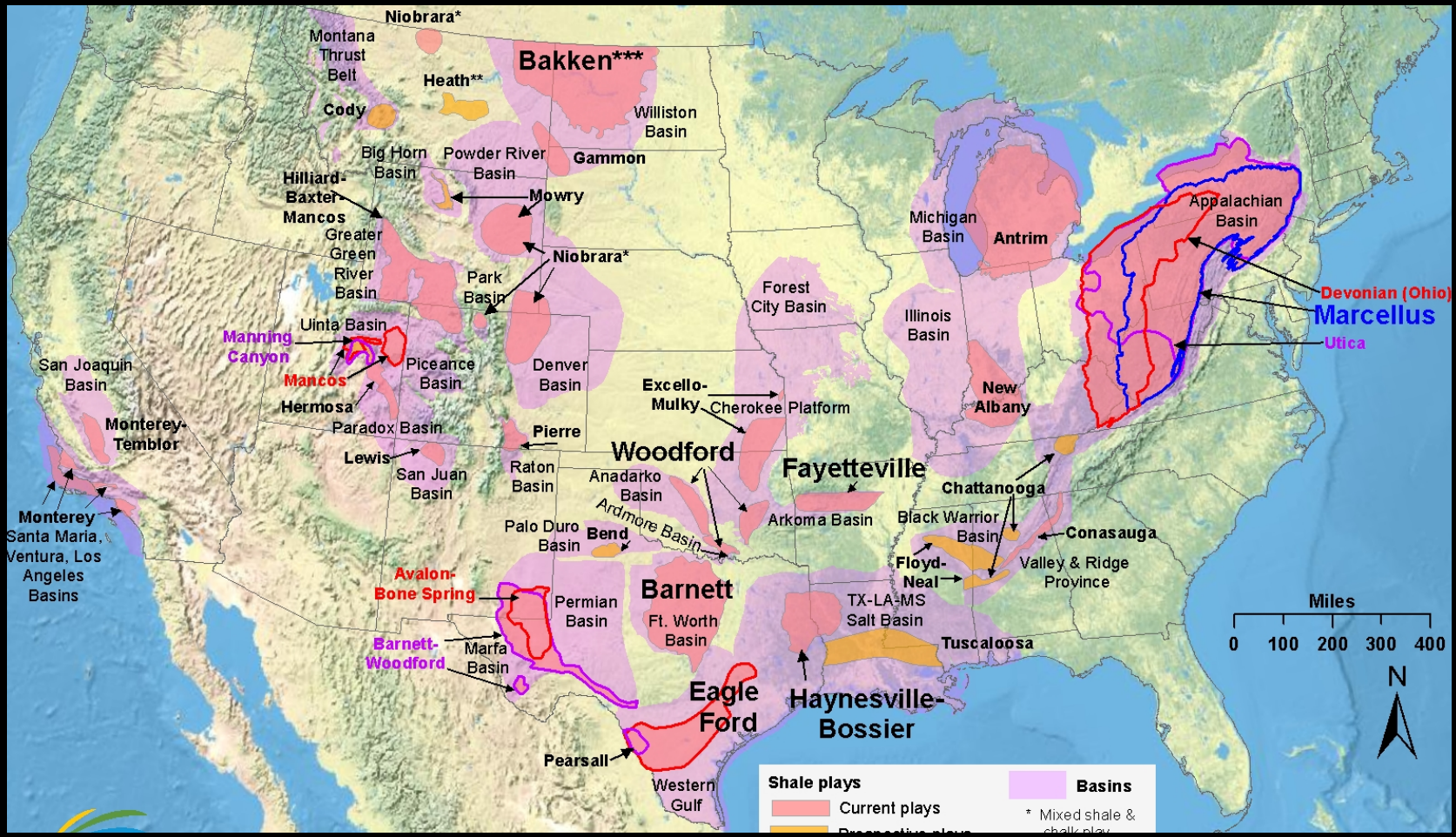
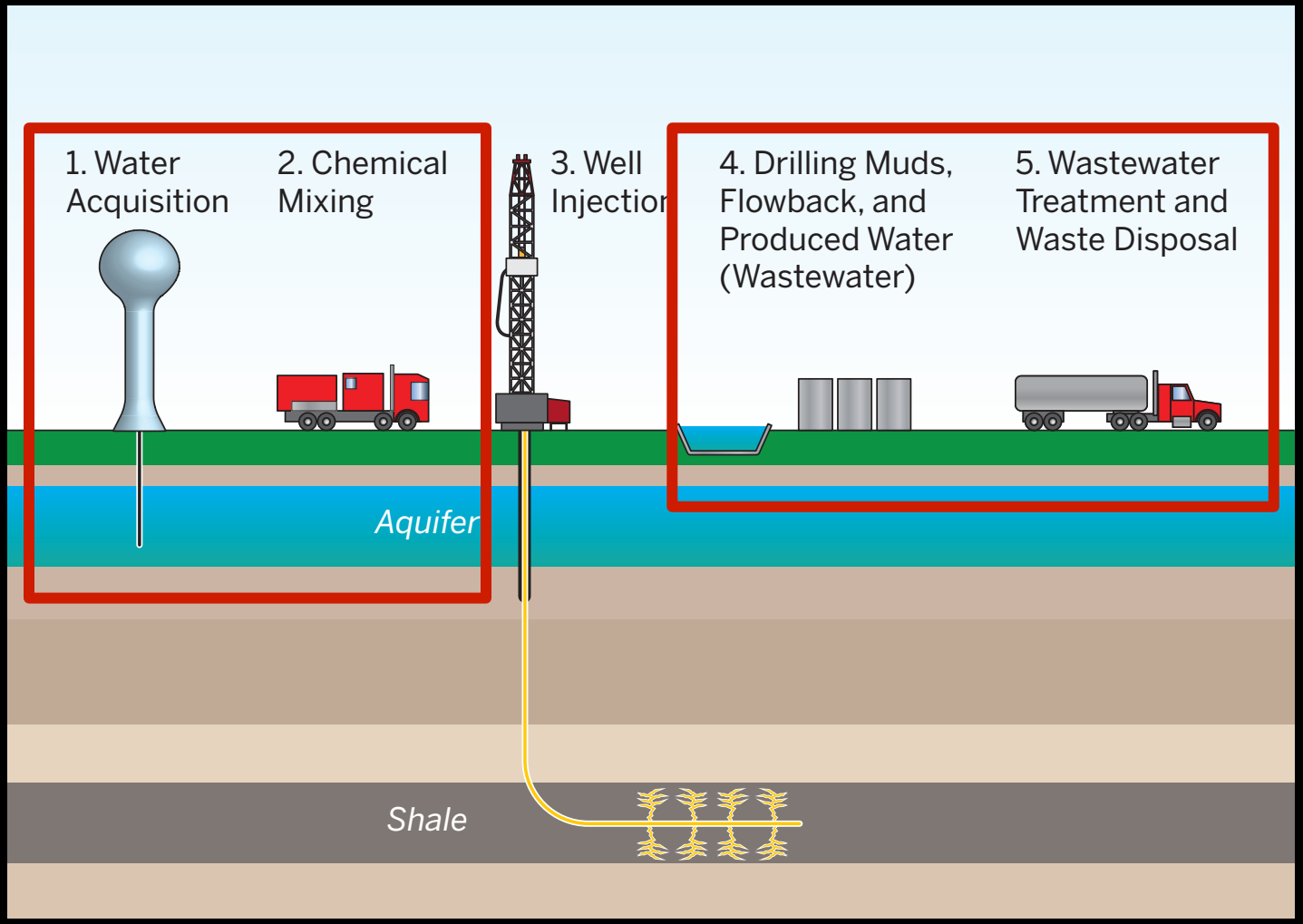
# How do we select the right treatment for wastewater from shale?

# The U.S. shale basins are extensive




Source: EIA

# The process is water-intensive



# HF wastewater is often very dirty

Wastewater constituents include: hydrocarbons, salts, minerals, metals, naturally occurring radio active material (NORM)…

…and many more!

# Shale plays differ in water characteristics and availability

| Shale Region | Predominantly Oil or Gas Play | Wastewater Volume | Wastewater Quality | Average TDS* Concentration (mg/L) | Flared Gas Volumes | Sufficient Nearby Disposal |
|---|---|---|---|---|---|---|
| Bakken | Oil | Low | Poor | 250,000 | Very High | Yes |
| Marcellus/Utica | Gas | Very Low | Moderate | 130,000 | Moderate | No |
| Eagle Ford | Oil & Gas | Medium | Good | 40,000 | High | Yes |
| Niobrara | Oil & Gas | Low | Good | 25,000 | Low | Yes |
| Haynesville | Gas | Low | Poor | 110,000 | Low | Yes |
| Permian Basin | Oil & Gas | Very High | Moderate | 120,000 | Low/Medium | Yes |

# Many ways to deal with wastewater

Deep well injection

Evaporation pit

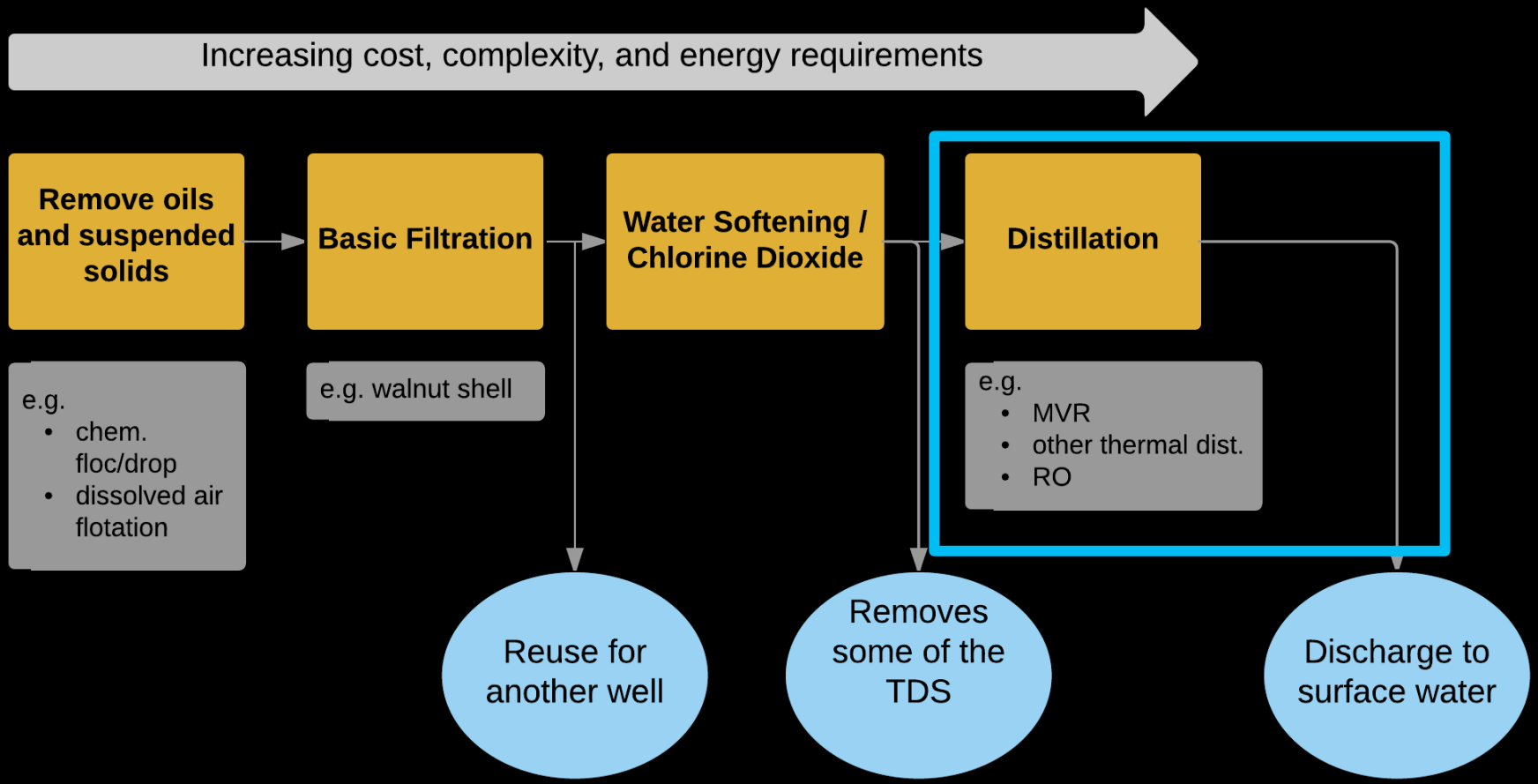
Treatment facility

Reuse for subsequent well

Land applications

Discharge to surface water

# The level of treatment depends on the end use for the wastewater



# We developed a tool to determine the optimal treatment technology

- Step 1: Build a water treatment technology database
- Step 2: Build a down-selection tool
- Step 3: Use the down-selection tool to determine the optimal treatment technology

# Evaluated over 70 products for treating wastewater

# Many metrics were used to compare the different treatment technologies

TECHNOLOGY CONSIDERATIONS:

- Technology Readiness Level (“maturity”)
- Mobility
- Recovery Rate
- Energy Requirements
  - Energy source & amount
- Constituents Removed
- Maximum Throughput Per Day
- Waste stream (requiring disposal)
- Service Cost or CAPEX & OPEX
- Personnel Requirements

# Seven technologies were chosen

- Multistage Flash Distillation (MSF)
- Multi Effect Distillation (MED)
- Forward Osmosis (FO)
- Mechanical Vapor Recompression (MVR)
- Carrier Gas Extraction (CGE)
- Reverse Osmosis (RO)
- Membrane Distillation (MD)

# And narrowed down to four

- Multistage Flash Distillation (MSF) ✗
- Multi Effect Distillation (MED) ✗
- Forward Osmosis (FO) ✗
- Mechanical Vapor Recompression (MVR)
- Carrier Gas Extraction (CGE)
- Reverse Osmosis (RO)
- Membrane Distillation (MD)

# Built a down-selection tool

| *Metric* | *Weighting* | MVR | | RO | | CGE | | MD | | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | |
| **TRL** | 0.20 | 7 | 1.40 | 4 | 0.80 | 4 | 0.80 | 1 | 0.20 | 1.40 |
| **Mobility** | 0.15 | 7 | 1.05 | 4 | 0.60 | 4 | 0.60 | 7 | 1.05 | 1.05 |
| **Influent Quality** | 0.20 | 7 | 1.40 | 4 | 0.80 | 7 | 1.40 | 7 | 1.40 | 1.40 |
| **Effluent Quality** | 0.05 | 7 | 0.35 | 7 | 0.35 | 7 | 0.35 | 7 | 0.35 | 0.35 |
| **Waste Stream** | 0.20 | 3 | 0.60 | 3 | 0.60 | 3 | 0.60 | 3 | 0.60 | 1.40 |
| **Energy Intensity** | 0.10 | 4 | 0.40 | 7 | 0.70 | 4 | 0.40 | 1 | 0.10 | 0.70 |
| **Cost/Service Fee** | 0.10 | 4 | 0.40 | 4 | 0.40 | 4 | 0.40 | 4 | 0.40 | 0.70 |
| **Total** | **1.00** | | **5.60** | | **4.25** | | **4.55** | | **4.10** | **7.00** |

Parameters used to evaluate technologies

| Metric | Weighting | MVR | | RO | | CGE | | MD | | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Factor | Grade | Factor | Grade | Factor | Grade | Factor | Grade | |
| TRL | | | | | | | | | | |
| Mobility | | | | | | | | | | |
| Influent Quality | | | | | | | | | | |
| Effluent Quality | | | | | | | | | | |
| Waste Stream | | | | | | | | | | |
| Energy Intensity | | | | | | | | | | |
| Cost/Service Fee | | | | | | | | | | |
| Total | | | | | | | | | | |

Parameters used to evaluate technologies

Relative importance of the metric to the decision

| *Metric* | *Weighting* | MVR | | RO | | CGE | | MD | | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | |
| TRL | 0.20 | | | | | | | | | |
| Mobility | 0.15 | | | | | | | | | |
| Influent Quality | 0.20 | | | | | | | | | |
| Effluent Quality | 0.05 | | | | | | | | | |
| Waste Stream | 0.20 | | | | | | | | | |
| Energy Intensity | 0.10 | | | | | | | | | |
| Cost/Service Fee | 0.10 | | | | | | | | | |
| Total | 1.00 | | | | | | | | | |

Parameters used to evaluate technologies

Relative importance of the metric to the decision

Technology-specific rating for a specific metric

| *Metric* | *Weighting* | MVR | | RO | | CGE | | MD | | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | |
| TRL | 0.20 | 7 | | | | | | | | |
| Mobility | 0.15 | 7 | | | | | | | | |
| Influent Quality | 0.20 | 7 | | | | | | | | |
| Effluent Quality | 0.05 | 7 | | | | | | | | |
| Waste Stream | 0.20 | 3 | | | | | | | | |
| Energy Intensity | 0.10 | 4 | | | | | | | | |
| Cost/Service Fee | 0.10 | 4 | | | | | | | | |
| Total | 1.00 | | | | | | | | | |

Parameters used to evaluate technologies

Relative importance of the metric to the decision

Technology-specific rating for a specific metric

| *Metric* | *Weighting* | MVR | | RO | | CGE | | MD | | Max. Value |
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| TRL | 0.20 | 7 | **1.40** | | | | | | | |
| Mobility | 0.15 | 7 | **1.05** | | | | | | | |
| Influent Quality | 0.20 | 7 | **1.40** | | | | | | | |
| Effluent Quality | 0.05 | 7 | **0.35** | | | | | | | |
| Waste Stream | 0.20 | 3 | **0.60** | | | | | | | |
| Energy Intensity | 0.10 | 4 | **0.40** | | | | | | | |
| Cost/Service Fee | 0.10 | 4 | **0.40** | | | | | | | |
| Total | 1.00 | | **5.60** | | | | | | | |

Weighting * factor

Parameters used to evaluate technologies

Relative importance of the metric to the decision

Technology-specific rating for a specific metric

| Metric | Weighting | MVR | | RO | | CGE | | MD | | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Factor | Grade | Factor | Grade | Factor | Grade | Factor | Grade | |
| TRL | 0.20 | 7 | 1.40 | | | | | | | 1.40 |
| Mobility | 0.15 | 7 | 1.05 | | | | | | | 1.05 |
| Influent Quality | 0.20 | 7 | 1.40 | | | | | | | 1.40 |
| Effluent Quality | 0.05 | 7 | 0.35 | | | | | | | 0.35 |
| Waste Stream | 0.20 | 3 | 0.60 | | | | | | | 1.40 |
| Energy Intensity | 0.10 | 4 | 0.40 | | | | | | | 0.70 |
| Cost/Service Fee | 0.10 | 4 | 0.40 | | | | | | | 0.70 |
| Total | 1.00 | | 5.60 | | | | | | | 7.00 |

Weighting * factor

Highest possible grade for a metric

Parameters used to evaluate technologies

Relative importance of the metric to the decision

Technology-specific rating for a specific metric

| *Metric* | *Weighting* | MVR | | RO | | CGE | | MD | | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | |
| TRL | 0.20 | 7 | **1.40** | | | | | | | **1.40** |
| Mobility | 0.15 | 7 | **1.05** | | | | | | | **1.05** |
| Influent Quality | 0.20 | 7 | **1.40** | | | | | | | **1.40** |
| Effluent Quality | 0.05 | 7 | **0.35** | | | | | | | **0.35** |
| Waste Stream | 0.20 | 3 | **0.60** | | | | | | | **1.40** |
| Energy Intensity | 0.10 | 4 | **0.40** | | | | | | | **0.70** |
| Cost/Service Fee | 0.10 | 4 | **0.40** | | | | | | | **0.70** |
| Total | 1.00 | | **5.60** | | | | | | | **7.00** |

Weighting * factor

Highest possible grade for a metric

Overall score for the technology

# MVR was identified as the best technology

| *Metric* | *Weighting* | MVR | | RO | | CGE | | MD | | Max. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | **Value** |
| **TRL** | 0.20 | 7 | 1.40 | 4 | 0.80 | 4 | 0.80 | 1 | 0.20 | 1.40 |
| **Mobility** | 0.15 | 7 | 1.05 | 4 | 0.60 | 4 | 0.60 | 7 | 1.05 | 1.05 |
| **Influent Quality** | 0.20 | 7 | 1.40 | 4 | 0.80 | 7 | 1.40 | 7 | 1.40 | 1.40 |
| **Effluent Quality** | 0.05 | 7 | 0.35 | 7 | 0.35 | 7 | 0.35 | 7 | 0.35 | 0.35 |
| **Waste Stream** | 0.20 | 3 | 0.60 | 3 | 0.60 | 3 | 0.60 | 3 | 0.60 | 1.40 |
| **Energy Intensity** | 0.10 | 4 | 0.40 | 7 | 0.70 | 4 | 0.40 | 1 | 0.10 | 0.70 |
| **Cost/Service Fee** | 0.10 | 4 | 0.40 | 4 | 0.40 | 4 | 0.40 | 4 | 0.40 | 0.70 |
| **Total** | **1.00** | | **5.60** | | **4.25** | | **4.55** | | **4.10** | **7.00** |

# MVR was identified as the best technology

| *Metric* | *Weighting* | MVR | | RO | | CGE | | MD | | Max. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | **Value** |
| **TRL** | 0.20 | 7 | 1.40 | 4 | 0.80 | 4 | 0.80 | 1 | 0.20 | 1.40 |
| **Mobility** | 0.15 | 7 | 1.05 | 4 | 0.60 | 4 | 0.60 | 7 | 1.05 | 1.05 |
| **Influent Quality** | 0.20 | 7 | 1.40 | 4 | 0.80 | 7 | 1.40 | 7 | 1.40 | 1.40 |
| **Effluent Quality** | 0.05 | 7 | 0.35 | 7 | 0.35 | 7 | 0.35 | 7 | 0.35 | 0.35 |
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| **Energy Intensity** | 0.10 | 4 | 0.40 | 7 | 0.70 | 4 | 0.40 | 1 | 0.10 | 0.70 |
| **Cost/Service Fee** | 0.10 | 4 | 0.40 | 4 | 0.40 | 4 | 0.40 | 4 | 0.40 | 0.70 |
| **Total** | **1.00** | | **5.60** | | **4.25** | | **4.55** | | **4.10** | **7.00** |

# The tool can be modified for different shale regions and treatment technologies

| *Metric* | *Weighting* | MVR | | RO | | CGE | | MD | | Max. Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | *Factor* | *Grade* | |
| **TRL** | 0.20 | 7 | 1.40 | 4 | 0.80 | 4 | 0.80 | 1 | 0.20 | 1.40 |
| **Mobility** | 0.15 | 7 | 1.05 | 4 | 0.60 | 4 | 0.60 | 7 | 1.05 | 1.05 |
| **Influent Quality** | 0.20 | 7 | 1.40 | 4 | 0.80 | 7 | 1.40 | 7 | 1.40 | 1.40 |
| **Effluent Quality** | 0.05 | 7 | 0.35 | 7 | 0.35 | 7 | 0.35 | 7 | 0.35 | 0.35 |
| **Waste Stream** | 0.20 | 3 | 0.60 | 3 | 0.60 | 3 | 0.60 | 3 | 0.60 | 1.40 |
| **Energy Intensity** | 0.10 | 4 | 0.40 | 7 | 0.70 | 4 | 0.40 | 1 | 0.10 | 0.70 |
| **Cost/Service Fee** | 0.10 | 4 | 0.40 | 4 | 0.40 | 4 | 0.40 | 4 | 0.40 | 0.70 |
| **Total** | **1.00** | | **5.60** | | **4.25** | | **4.55** | | **4.10** | **7.00** |

# Choosing optimal treatment depends on several factors

- Regulations vary state to state
  - Often not aligned with the potential beneficial uses for wastewater
- Treatment level and type differs based on desired use
- Shale plays have varying characteristics
  - Quality and quantity of wastewater

# Future considerations

- Incorporate economic and market constraints
- Evaluate other technologies (beyond distillation) using the down-selection tool
- Use the tool to inform industry, policy makers, and the general public on beneficially treating wastewater

# Thank you!

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# Questions?

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