### Hydraulic Fracturing Wastewater Treatment: Building a Framework

Yael R. Glazer

Texas Desal 2016

September 29, 2016



THE UNIVERSITY OF TEXAS AT AUSTIN

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

#### THE UNIVERSITY OF TEXAS AT AUSTIN

WHAT STARTS HERE CHANGES THE WORLD

#### The U.S. shale basins are extensive



Webber Energy Group

THE UNIVERSITY OF TEXAS AT AUSTIN

Yael Glazer | HF Wastewater Treatment Framework

#### The process is water-intensive





Yael Glazer | HF Wastewater Treatment Framework

10/7/16

4

#### 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

Predominantly Oil or Gas Play	Wastewater Volume	Wastewater Quality	Average TDS* Concentration (mg/L)	Flared Gas Volumes	Sufficient Nearby Disposal
Oil	Low	Poor	250,000	Very High	Yes
Gas	Very Low	Moderate	130,000	Moderate	No
Oil & Gas	Medium	Good	40,000	High	Yes
Oil & Gas	Low	Good	25,000	Low	Yes
Gas	Low	Poor	110,000	Low	Yes
Oil & Gas	Very High	Moderate	120,000	Low/Medium	Yes
	Predominantly Oil or Gas Play Oil Gas Oil & Gas Oil & Gas Oil & Gas	Predominantly Oil Wastewater VolumeOilLowGasVery LowOil & GasMediumGasLowOil & GasLow	Predominantly Oil or Gas PlayWastewater VolumeWastewater QualityOilLowPoorGasVery LowModerateOil & GasMediumGoodGasLowGoodOil & GasLowPoorOil & GasVery HighModerate	Predominantly Oil or Gas PlayWastewater VolumeWastewater QualityAverage TDS* chychychyOilLowPoor250,000GasVery LowModerate130,000Oil & GasMediumGood40,000Oil & GasLowGood25,000GasLowPoor110,000Oil & GasVery HighModerate120,000	PredominantlyWastewaterWastewaterAverage TDS concentrationFlared GasOilLowPoor250,000Very HighGasVery LowModerate130,000ModerateOil & GasMediumGood40,000HighOil & GasLowGood25,000LowGasJenyModerate110,000LowOil & GasVery HighModerate120,000Low



THE UNIVERSITY OF TEXAS AT AUSTIN

#### 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



THE UNIVERSITY OF TEXAS AT AUSTIN

Yael Glazer | HF Wastewater Treatment Framework

10/7/16

8

# 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



Yael Glazer | HF Wastewater Treatment Framework



10

### 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



Webber Energy Group

THE UNIVERSITY OF TEXAS AT AUSTIN

Yael Glazer | HF Wastewater Treatment Framework

11

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



### **Built a down-selection tool**

Motric	Weighting	M\	/R	R	0	CGE		MD		Max.
Weurc	weighting	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



Yael Glazer | HF Wastewater Treatment Framework

10/7/16

14

Metric	Woighting	M١	/R	R	0	C	GE	Μ	D	Max.
Metho	Weighting	Factor	Grade	Factor	Grade	Factor	Grade	Factor	Grade	Value
TRL										
Mobility										
Influent Quality										
Effluent Quality										
Waste Stream										
Energy Intensity										
Cost/Service Fee										
Total										



Yael Glazer | HF Wastewater Treatment Framework

THE UNIVERSITY OF TEXAS AT AUSTIN

Motric	Woighting	MVR		RO		CGE		М	Max.	
Wellic	weighting	Factor	Grade	Factor	Grade	Factor	Grade	Factor	Grade	Value
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									



Yael Glazer | HF Wastewater Treatment Framework

THE UNIVERSITY OF TEXAS AT AUSTIN

16

Relative importance of the metric to the decision

17

10/7/16

Motric	Weighting	MVR		RO		CGE		MD		Max.
metric	Weighting	Factor	Grade	Factor	Grade	Factor	Grade	Factor	Grade	Value
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									



Yael Glazer | HF Wastewater Treatment Framework

THE UNIVERSITY OF TEXAS AT AUSTIN

Relative importance of the metric to the decision

Technology-specific rating for a specific metric

Metric	Weighting	M	<sup>(</sup> R	RO		CGE		MD		Max.
Metho	Weighting	Factor	Grade	Eactor Grade		Factor	Grade	Factor	Grade	Value
TRL	0.20	7	1.40							
Mobility	0.15	7	1.05							
Influent				Wei	ghting <sup>s</sup>	* factor				
Quality	0.20	7	1.40							
Effluent										
Quality	0.05	7	0.35							
Waste Stream	0 20	3	0.60							
Enerav	0.20									
Intensity	0.10	4	0.40							
Cost/Service										
Fee	0.10	4	0.40							
Total	1.00		5.60							



Yael Glazer | HF Wastewater Treatment Framework

THE UNIVERSITY OF TEXAS AT AUSTIN

Relative importance of the metric to the decision

Technology-specific rating for a specific metric

Metric	Weighting	M	'R	R	0	C	GE	Μ	ID	Max.
metric	Weighting	Factor	Grade	Factor	Grade	Factor	Grade	Factor	Grade	Value
TRL	0.20	7	1.40							1.40
Mobility	0.15	7	1.05							1.05
Influent Quality	0.20	7	1.40	wei	gnting ?	* Tactor				1.40
Effluent Quality	0.05	7	0.35				Highes grade	t possi for a m	ble etric	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



Yael Glazer| HF Wastewater Treatment Framework

THE UNIVERSITY OF TEXAS AT AUSTIN

Relative importance of the metric to the decision

Technology-specific rating for a specific metric

Motric	Weighting	M	<sup>(</sup> R	R	0	C	GE	Μ	D	Max.
Wethe	Weighting	Factor	Grade	Factor	Grade	Factor	Grade	Factor	Grade	Value
TRL	0.20	7	1.40							1.40
Mobility	0.15	7	1.05							1.05
Influent				Wei	ghting ?	* factor				
Quality	0.20	7	1.40							1.40
Effluent							Highes	t possil	ble	
Quality	0.05	7	0.35				grade	for a me	etric	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





Yael Glazer | HF Wastewater Treatment Framework

THE UNIVERSITY OF TEXAS AT AUSTIN

Webber Energy Group

# MVR was identified as the best technology

Motric	Weighting	M\	/R	R	0	CGE		MD		Max.
Weurc	weighting	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	040	0.70
Total	1.00		5.60		4.25		4.55		4.10	7.00



Yael Glazer | HF Wastewater Treatment Framework

10/7/16

21

# MVR was identified as the best technology

MetricWeightingFactorGradeFactorGradeFactorGradeFactorGradeValueTRL0.2071.4040.8040.8010.201.40Mobility0.1571.0540.6040.6071.051.05Influent Quality0.2071.4040.8071.4071.401.40Effluent Quality0.0570.3570.3570.3570.350.35	Motric	Woighting	N	MVR	R	RO		CGE		MD	
TRL0.2071.4040.8040.8010.201.40Mobility0.1571.0540.6040.6071.051.05Influent Quality0.2071.4040.8071.4071.401.40Effluent Quality0.0570.3570.3570.3570.350.35	Weurc	weighting	Factor	Grade	Factor	Grade	Factor	Grade	Factor	Grade	Value
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	TRL	0.20	7	1.40	4	0.80	4	0.80	1	0.20	1.40
Influent Quality0.2071.4040.8071.4071.401.40Effluent Quality0.0570.3570.3570.3570.350.35	Mobility	0.15	7	1.05	4	0.60	4	0.60	7	1.05	1.05
Effluent Quality     0.05     7     0.35     7     0.35     7     0.35     7     0.35 <th< th=""><th>Influent Quality</th><th>0.20</th><th>7</th><th>1.40</th><th>4</th><th>0.80</th><th>7</th><th>1.40</th><th>7</th><th>1.40</th><th>1.40</th></th<>	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	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	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 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	Total	1.00		5.60		4.25		4.55		4.10	7.00



Yael Glazer | HF Wastewater Treatment Framework

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

Metric Weighti		iahtina	M	/R	R	0	C	GE	MD		Max.
meane		gnang	гасил	Graue	Гастог	Graue	гасцог	Graue	гастог	Graue	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



Yael Glazer | HF Wastewater Treatment Framework

### 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



Yael Glazer | HF Wastewater Treatment Framework

10/7/16

 $\mathcal{D}4$ 

### **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



Yael Glazer | HF Wastewater Treatment Framework

<u>10/7/16</u>

#### Thank you!

#### Co-authors: Jamie J. Lee | F. Todd Davidson, Ph.D. | Margaret Cook | Michael E. Webber, Ph.D.

#### Sponsors:











#### Questions?

Yael R. Glazer Ph.D. Candidate The University of Texas at Austin yael@utexas.edu www.webberenergygroup.com



THE UNIVERSITY OF TEXAS AT AUSTIN