

BENEFICIAL USE OF TREATED PRODUCED WATER



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ARE WE ONE SMALL STEP OR ONE GIANT LEAP
AWAY?

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AGENDA

- **PRODUCED WATER**
 - **AVERAGE QUANTITIES**
 - **TDS BY FORMATION / PLAY**
 - **GENERAL COMPOSITION**
- **CURRENT TREATMENT TECHNOLOGY**
 - **REVERSE OSMOSIS**
 - **VD/MVR**
 - **CRYSTALLIZATION**
- **POTENTIAL GAME CHANGERS**
 - **MEMBRANE DISTILLATION**
 - **GRAPHENE NANOMATERIALS**
- **EXCITING TIMES**



Photo copyright Patriot Environmental

AVERAGE QUANTITIES

- **2.4 BILLION GALLONS PER DAY**
 - (57.1MM BBL/D)
 - 25.6 BILLION 12oz CANS/D
 - ENOUGH TO REACH TO THE MOON AND BACK 8 TIMES – EVERY DAY

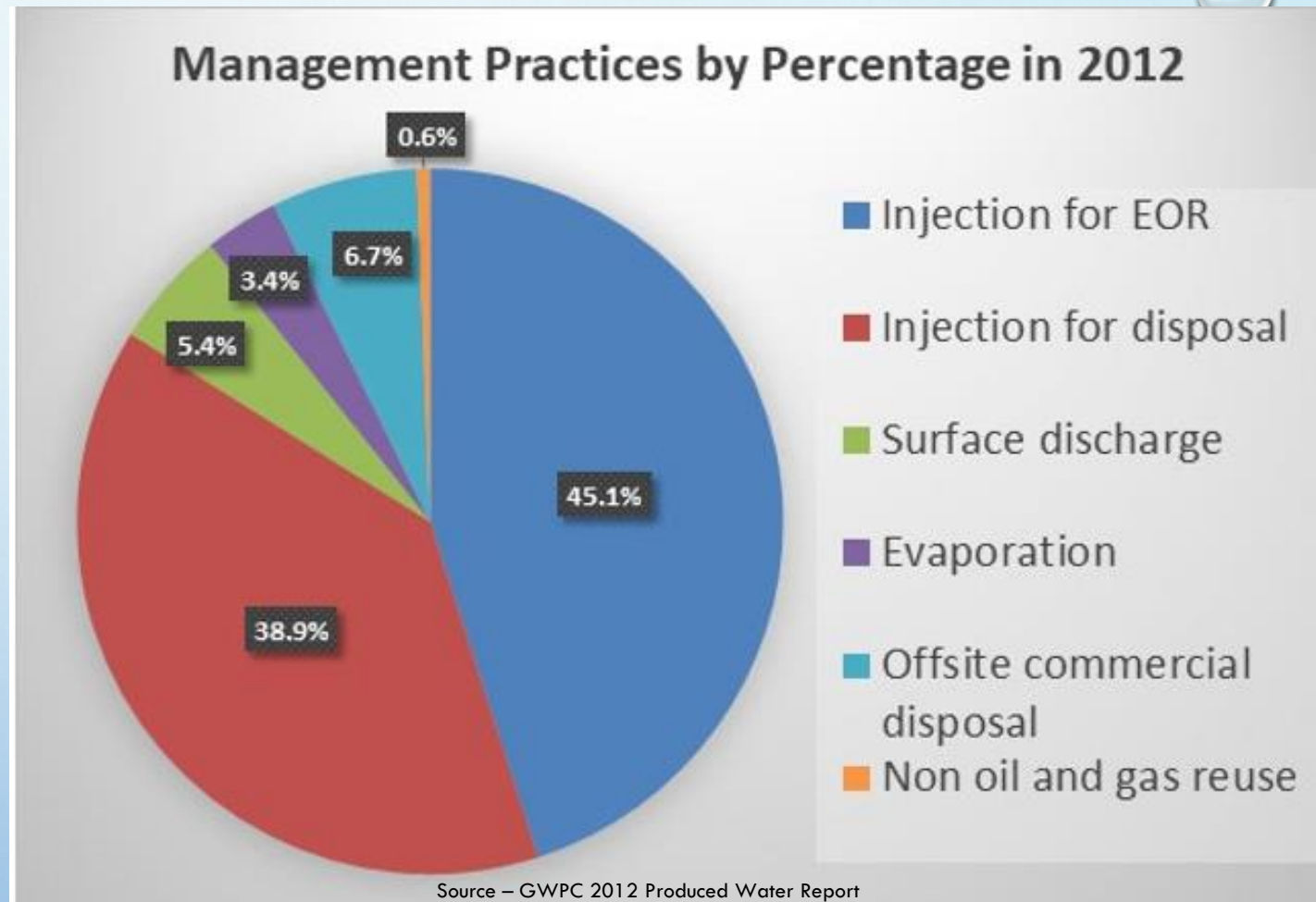
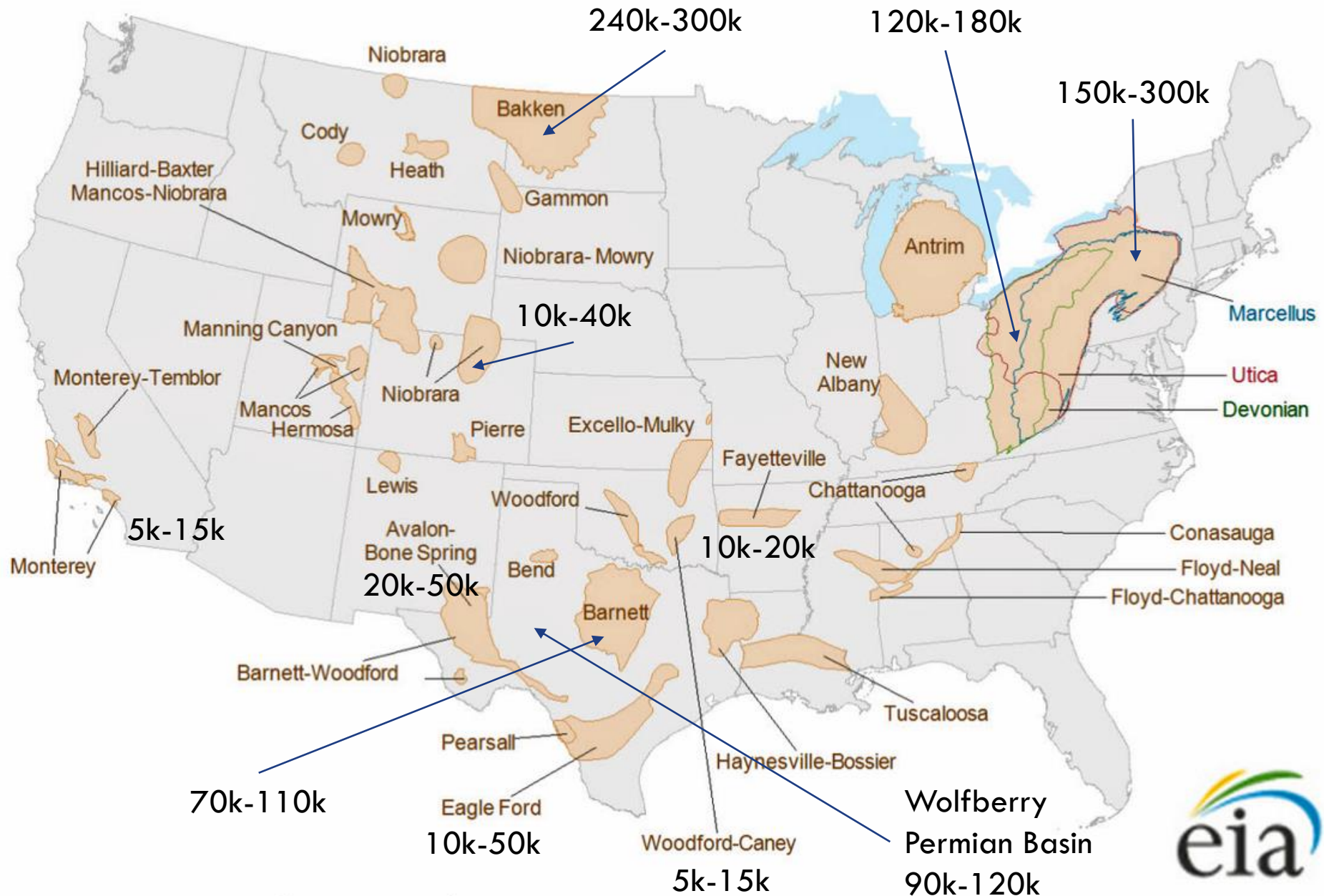


Figure 2. U.S. Lower 48 tight oil and shale gas plays

TDS RANGES FOR VARIOUS OIL AND GAS PLAYS



Source: U.S. Energy Information Administration.



GENERAL CONSTITUENTS OF PRODUCED WATER

- **SALT (PREDOMINANTLY SODIUM CHLORIDE)**
- **HARDNESS (CALCIUM, MAGNESIUM, BARIUM, STRONTIUM)**
- **SULFATE**
- **METALS (IRON, MANGANESE)**
- **NATURALLY OCCURRING RADIOACTIVE MATERIALS (NORM)**
- **ORGANICS**
- **DISSOLVED GASES (CH₄, CO₂ AND POSSIBLY H₂S)**
- **COMPLETION / WORKOVER / MAINTENANCE CHEMICALS**
- **TRANSFORMATIVE CHEMICALS / COMPOUNDS**



Photo from reliableonerresources.com

WE DON'T KNOW EVERYTHING THAT MIGHT BE IN PRODUCED WATER

- 1,000+ POTENTIAL CHEMICALS USED IN HF (PER FRAC FOCUS)
- PRODUCTION / WORKOVER CHEMICALS
- TRANSFORMATIVE BY-PRODUCTS
 - $2\text{HCL} + \text{CaCO}_3 \longrightarrow \text{CaCL}_2 + \text{H}_2\text{O} + \text{CO}_2$
- LACK OF APPROVED ANALYTICAL TECHNIQUES FOR HIGH TDS MATRIX



Photo copyright Swire Company

CURRENT TREATMENT TECHNOLOGIES

- REVERSE OSMOSIS
- CONCENTRATION & CRYSTALLIZATION

REVERSE OSMOSIS

- **USES PRESSURE TO PUSH WATER MOLECULES THROUGH A PERMEABLE MEMBRANE**
- **REQUIRES EXTENSIVE PRETREATMENT, BUT REMOVES ALL MINERALS, SALTS AND METALS**
- **EASY TO FOUL MEDIA (HYDROCARBONS AND BACTERIA ARE TROUBLESOME)**
- **INEFFICIENT WITH BRINES EXCEEDING 50K TOTAL DISSOLVED SOLIDS (TDS)**



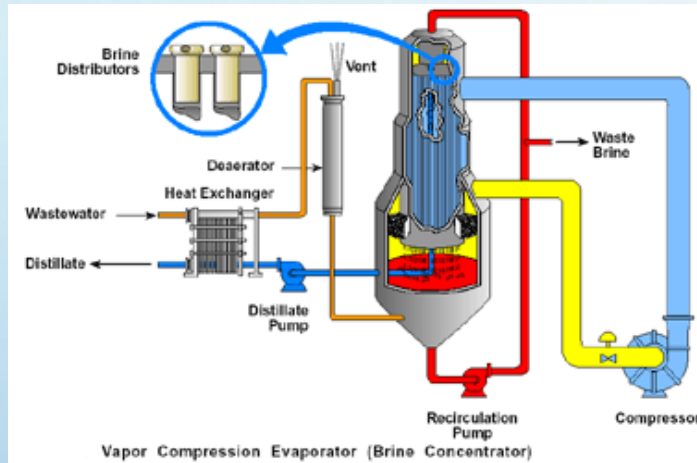
Photo courtesy of R. McCurdy



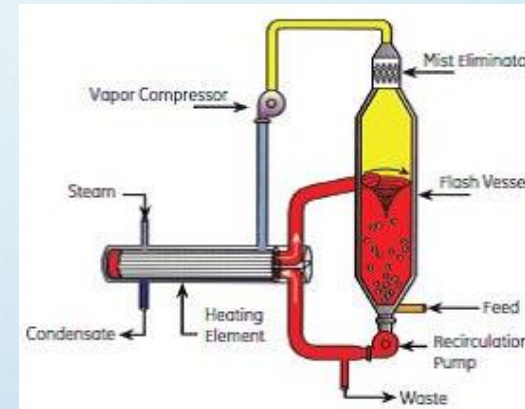
www.degremont-technologies.com

BRINE CONCENTRATOR AND CRYSTALLIZER

Brine Concentrator



Brine Crystallizer



POWER DEMAND



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- **VD/MVR & ZLD PLANTS TYPICALLY NEED 6-8 KWH / BBL WATER PROCESSED**
- **50,000 BPD PLANT WOULD USE 109.5-146.0 GWH/YEAR**
- **AVG HOUSEHOLD CONSUMPTION IS 10,932 KWH/YEAR¹**
- **AVG HOUSEHOLD IN OKLAHOMA HAS 2.55 PEOPLE²**
- **A SINGLE 50,000 BPD PLANT WILL HAVE THE ENERGY DEMAND OF A CITY WITH A POPULATION OF 25,000-34,000 PEOPLE!**

¹ – U.S Energy Information Administration (2014)

² – U.S. Census 2010

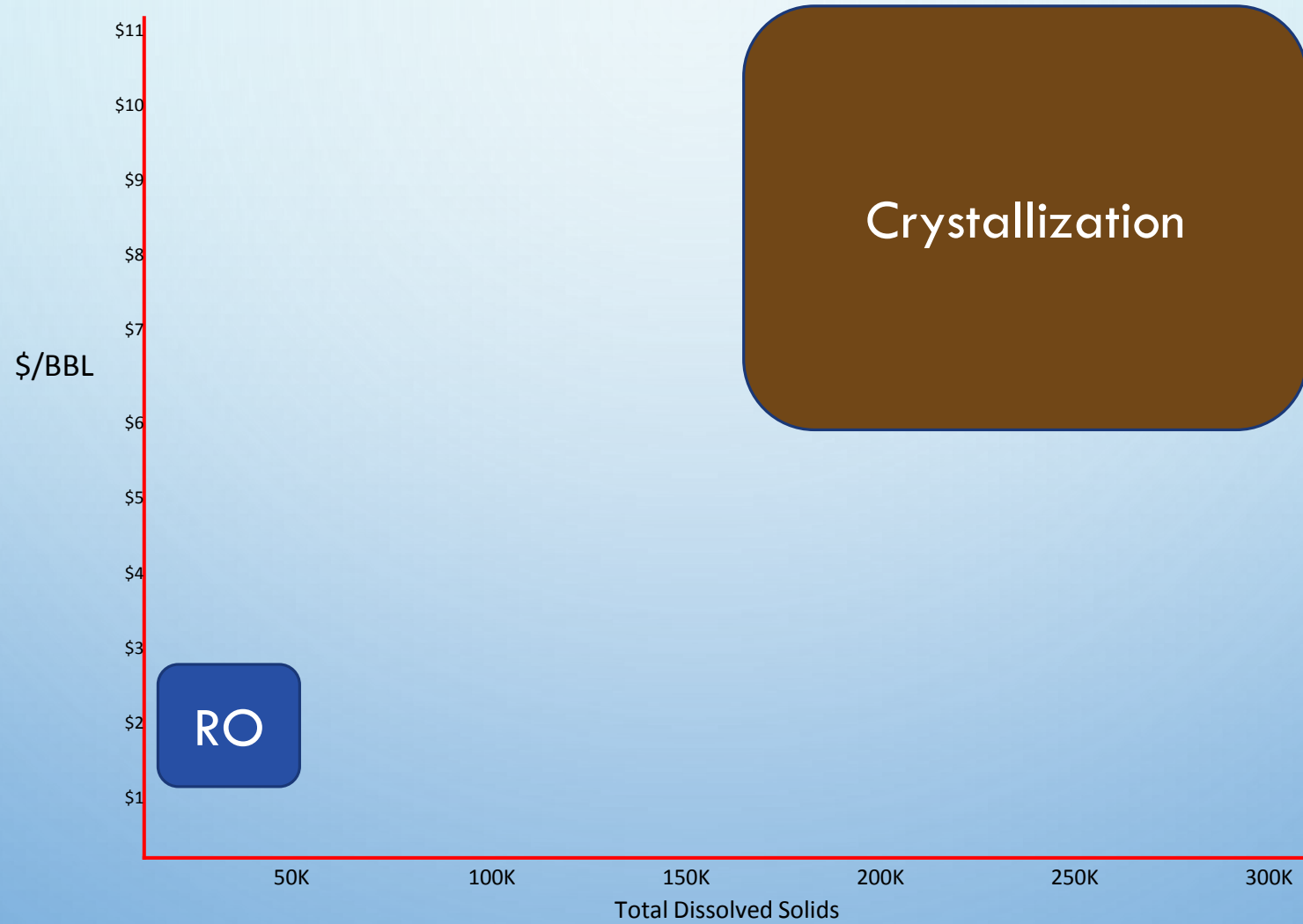
WASTE / PRODUCT GENERATION

Capacity		Products and waste			
bbl/day	MGD	Filter Cake, (tons/day)	Distillate, (bbl/day)	Salt (tons/day)	CaCl ₂ Brine (bbl/day)
5,000	0.2	53	4,000	107	1,000
50,000	2.1	533	40,000	1,066	10,000
100,000	4.2	1,066	80,000	2,132	20,000
200,000	8.4	2,132	160,000	4,264	40,000
300,000	12.5	3,198	240,000	6,396	60,000

1

Numbers based off of typical composition of a produced water that is relatively high in salinity with a moderate level of hardness.

ECONOMICS

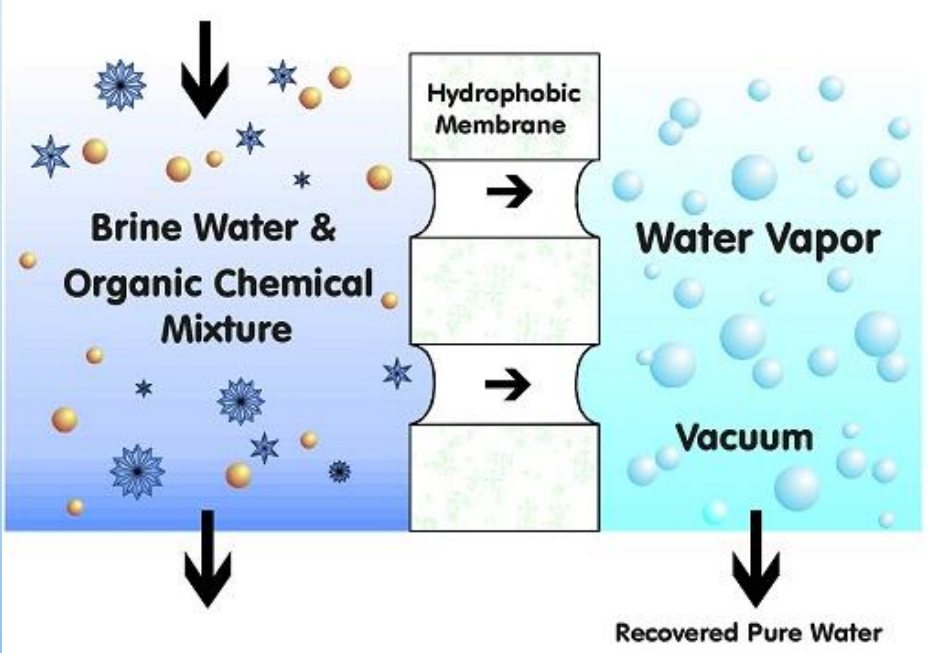


The background of the slide is a light blue gradient. It is decorated with several realistic water droplets of various sizes, some with highlights and shadows, scattered across the top and bottom edges.

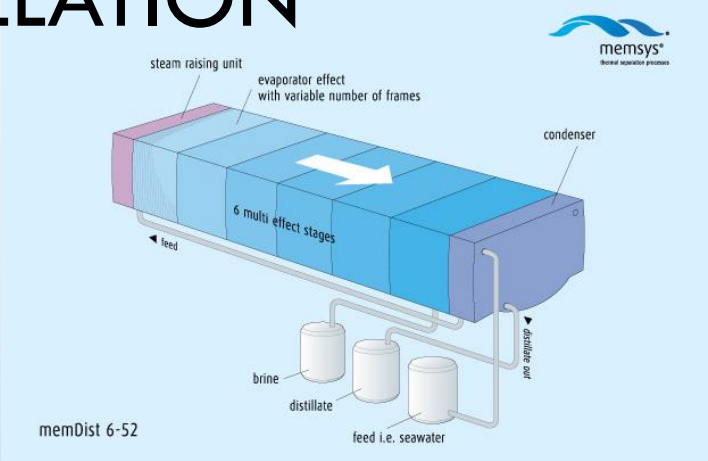
POTENTIAL GAME CHANGERS

- **MEMBRANE DISTILLATION**
- **GRAPHENE NANOMATERIALS**

MEMBRANE DISTILLATION



http://www.kmxcorp.com/water_chemical_purification.php?division=Technologies&area=Membrane%20Distillation&page=Introduction



<http://www.memsys.eu/products.html>



MEMBRANE DISTILLATION

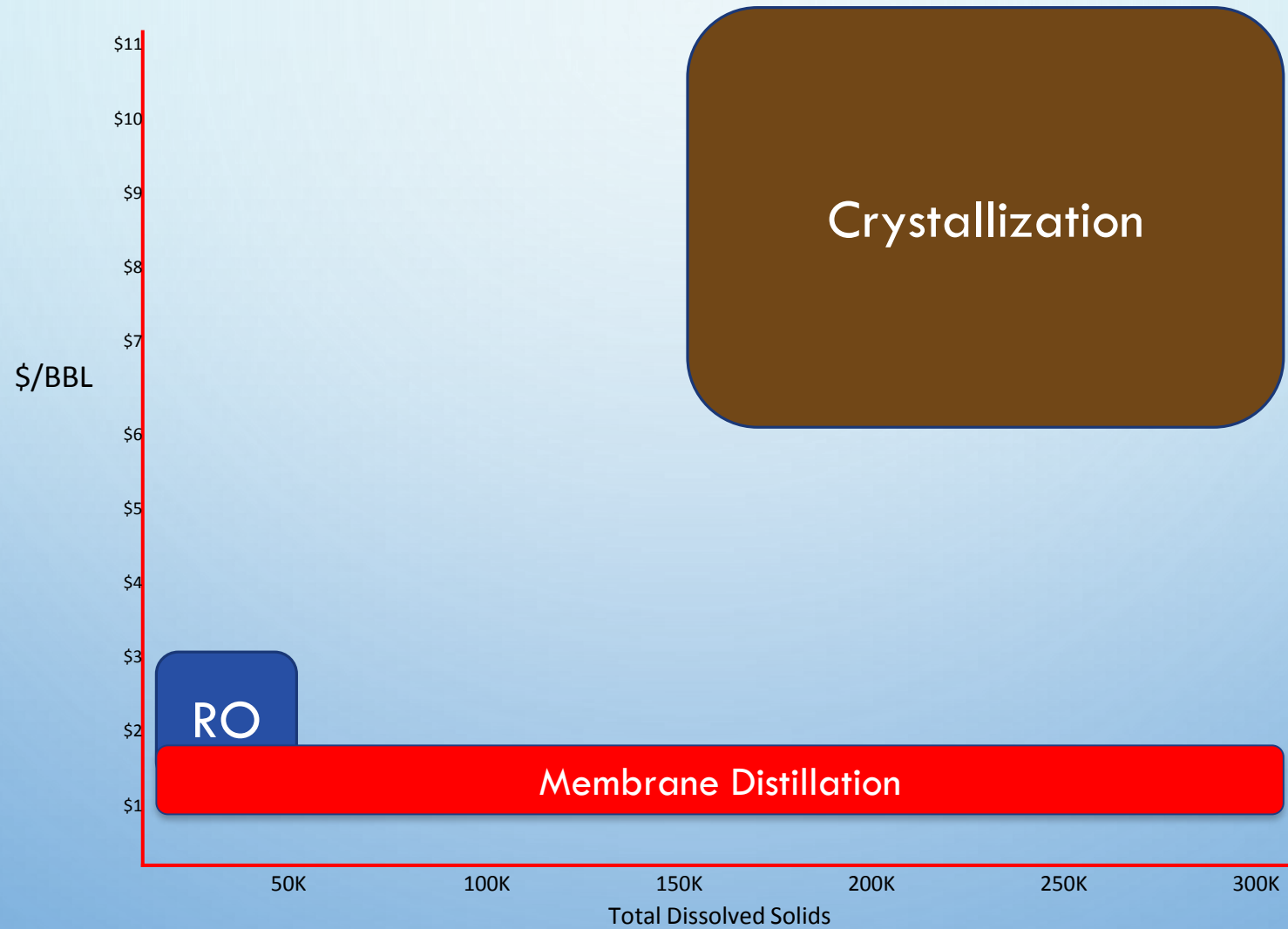
- PROS

- MEMBRANE IS RESISTANT TO FOULING
 - ONLY PRETREATMENT IS OIL REMOVAL
 - HARDNESS AND BACTERIA HAVE NOT SHOWN TO BE TROUBLESOME
- LOW ENERGY DEMAND
- CAN HANDLE HIGH TDS BRINES
- CAN UTILIZE WASTE HEAT SOURCES
- POTENTIAL TO PROVIDE RECOVERY OF A DISTILLATION UNIT AT THE COST OF AN RO

- CONS

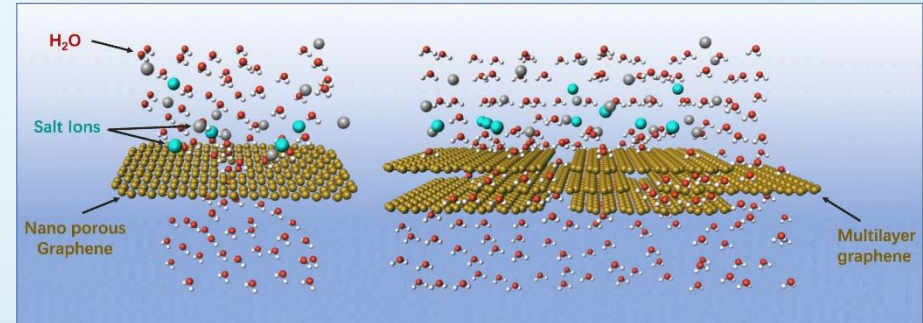
- OIL CAN FOUL MEMBRANES
- WHILE MORE ECONOMICAL THAN A VD/MVR PROCESS AND MUCH LESS ENERGY INTENSIVE – STILL CANNOT COMPETE COST WISE WITH MAJORITY OF CLASS II SWD OPTIONS; HOWEVER, WASTE HEAT CAN SWING THE PENDULUM

ECONOMICS



GRAPHENE NANOMATERIALS

- EXTRAORDINARY HIGH SURFACE AREAS
- DURABLE
- ATOMIC THICKNESS
- NANO-SIZED PORES
- CAN BE CONSTRUCTED TO BE REACTIVE TO BOTH POLAR AND NON-POLAR CONTAMINANTS



https://ars.els-cdn.com/content/image/1-s2.0-S0011916417310974-fx1_lrg.jpg



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EXCITING TIMES IN THE PRODUCED WATER SPACE

- NEW MEXICO STATE UNIVERSITY AND NEW MEXICO ENVIRONMENT DEPARTMENT – MOU – PRODUCED WATER RESEARCH CONSORTIUM
- FOCUS WILL BE ON ECONOMICAL TREATMENT OF PRODUCED WATER FOR BENEFICIAL USE OUTSIDE OF THE OILFIELD

DOE NATIONAL DESAL HUB

- \$20 MILLION PER YEAR
- 5 YEARS
- FOCUS ON IMPROVED
DESALINIZATION FOR
 - BRACKISH GROUNDWATER
 - GEOTHERMAL WATER
 - PRODUCED WATER



National Association for Water Innovation

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