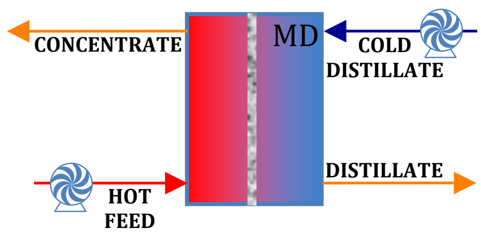
Membrane Distillation

Membrane distillation (MD) is an emerging, thermally driven membrane separation process that utilizes a low-grade heat source (i.e., waste heat) to facilitate mass transport through a hydrophobic, microporous membrane. The driving force for mass transfer is a vapor pressure gradient between a warm/hot feed solution and a colder distillate; making MD one of the only desalination membrane processes that can maintain productivity almost independent of solution concentration. MD is capable of producing ultra-pure water; most likely at lower cost compared to conventional distillation processes. MD can be operated in four unique configurations: direct contact MD (DCMD), vacuum MD (VMD), air gap MD (AGMD), and sweeping gas MD (SGMD). Of these four configurations, DCMD and AGMD are the most likely to be deployed as either pretreatment or post-treatment for CBM produced water. MD can achieve high removal of most non-volatile compounds from water (e.g., sodium, potassium, sulfate, magnesium, and calcium); however, compounds that are more volatile than water (i.e., have a higher vapor pressure than water) will preferentially diffuse through the membrane (e.g., ammonia or BTEX compounds). Membrane distillation processes have been applied for the treatment of saline waters with high scaling propensity including brackish water, seawater, and evaporative cooling tower blowdown water. An illustration of the DCMD process is shown below.



Summary of technical assessment of MD

Criteria	Description/Rationale
Status of technology	Emerging thermally driven membrane technology, not previously employed for CBM produced water treatment.
Feed water quality bins	TDS application range is controlled by the presence of sparingly soluble salts that might scale the membrane and organic matter that might foul the membrane. MD can treat feed streams having TDS levels of up to 200,000 mg/L. MD has 100% theoretical rejection of all non-volatile solutes.
Product water quality	MD distillate/condensate quality is equal to that of distilled water from thermally driven processes (TDS 2 to 10 mg/L). All solutes with higher volatility than water (such as ammonia and VOCs) will preferentially diffuse into the product water.
Recovery	Product water recovery can reach more than 90%
Energy use	MD is a thermally driven process and therefore it requires some energy input. However, the process only requires a moderate temperature gradient to achieve high water flux. This allows for the system to function by utilizing waste heat from other processes or onsite compressors, pumps, etc.

Summary of technical assessment of MD

Criteria	Description/Rationale
Chemical use	Scale inhibitor and caustic may be required for process control to prevent scaling or fouling. Chemical cleaning frequency depends on feed water quality. Membrane cleaning is triggered when certain operating conditions are exceeded, and may require the use of NaOH, Na_4EDTA, or HCl.
Expected lifetime of critical components	Depending on operating conditions, MD membranes are likely to require replacement within 3 to 7 years.
Infrastructure considerations	MD processes have not enjoyed the same level of development as pressure driven membrane processes; as such, the membrane modules are not yet optimized. This may result in a larger footprint than an equivalent capacity RO or NF system. Heat exchangers are needed to deliver or extract heat from the various streams. Because of its larger footprint, MD systems have reduced mobility compared to pressure driven membrane processes.
O&M considerations	Monitoring and control required for fluid temperature, flow rates, pressures, and membrane integrity. System automation lessens demands on skilled labor, however a skilled technician is required to perform routine system maintenance. Level of flexibility: high sensitivity to surfactants, hydrophobic organic compounds may be difficult to remove from the membrane. Level of robustness: MD membranes, especially PTFE based, are highly resistant to pH, oxidants, and irreversible flux decline Level of reliability: MD systems operate semi-continuously with short duration chemical cleaning. Types of energy required: electrical (if no source of waste heat is available) and low-grade waste heat from various sources.
Capital and O&M costs	Capital costs were estimated for a 1 MGD (24,000 bpd) DCMD plant to be $3.34/gpd (or $0.15/bpd), with operating costs estimated to be $1.40/kgal (or $0.06/bbl).
Pretreatment of feed water	Removal of any constituents that may wet the hydrophobic, micro-porous pores of the MD membrane is required for efficient process performance.
Post-treatment of product water	Product water may require remineralization and pH adjustment. This may be achieved by lime bed contacting or by blending small amounts of filtered and sterilized feed water with distillate.
Concentrate management or waste disposal	No special concentrate treatment is required. Moderate water recovery rates approaching 85% generate a moderate amount of concentrated brine.
Applicability for produced water treatment	Moderate to good - Appropriate pretreatment is required to remove surfactants and VOCs from the feed stream, and membrane modules are not yet optimized for water treatment in any sector.
Note: 1 barrel = 42 US gallon	