Renewable Power Generation Through Pressure Retarded Osmosis

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Introduction

Pressure Retarded Osmosis (PRO) is a means of capturing energy based on solutions of differing salinities. Water molecules from a lower salinity (feed) solution move across a semi-permeable membrane to a higher salinity (draw) solution by osmosis to reach equil-ibrium. A back pressure, which is less than the osmotic pressure, is applied on the high salinity solution causing an accumulation of pressure and volume. This pressure can then be released into a hydro-turbine, generating clean energy [1].

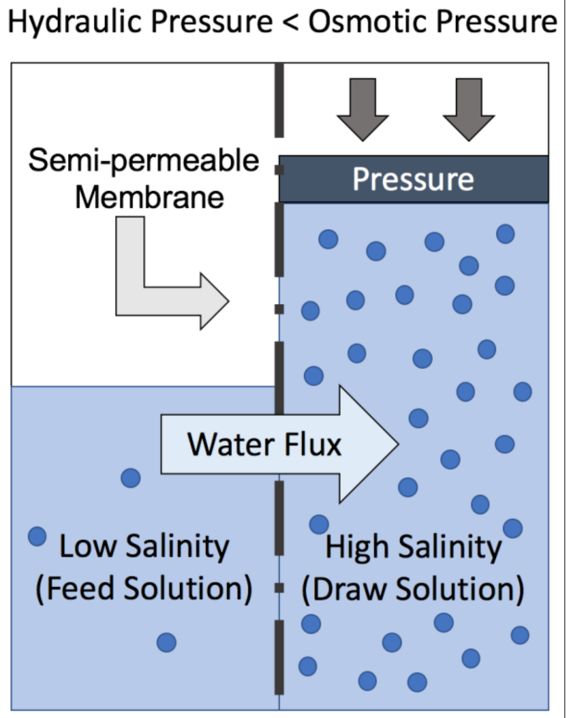

Fig. 1 Pressure Retarded Osmosis Process

Impact

Water scarcity has led to an increased demand in alternative water sources like desalination. Desalinated water is mainly produced using ocean water, which makes up over 97.2% of the planet's water resources [2]. While desalination is a valuable alternative water resource, it requires significant energy inputs and is known to cause environmental damage by returning a high salinity brine back into the ocean.

Desalination without PRO: Energy consumption of 6-8 kWh/m3 [3]

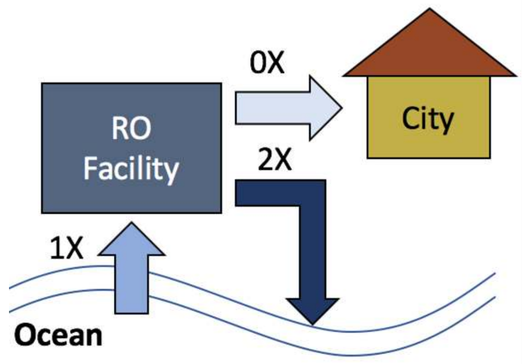

Fig. 2 Schematic of desalination without PRO

PRO has the potential to reduce these setbacks by:

- Producing clean energy to alleviate desalination costs
- Diluting the desalinated brine before it is returns to the ocean

Global energy production from mixing in estuaries: 2,000 TWh/y [4]

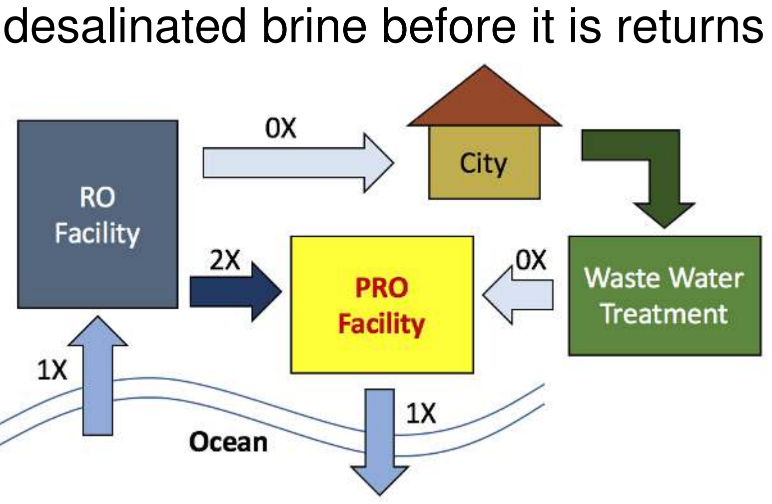

Fig. 3 Schematic of desalination with PRO

Objective and Design

Objective

The objective of this SHINE project was to quantify and visually represent the amount of energy produced from a PRO bench-scale system operating with a 70 g/L NaCl draw solution and a DI water feed solution. These solutions were representative of reverse osmosis seawater brine and highly treated wastewater, respectively. Two membranes were tested and compared under these operating conditions.

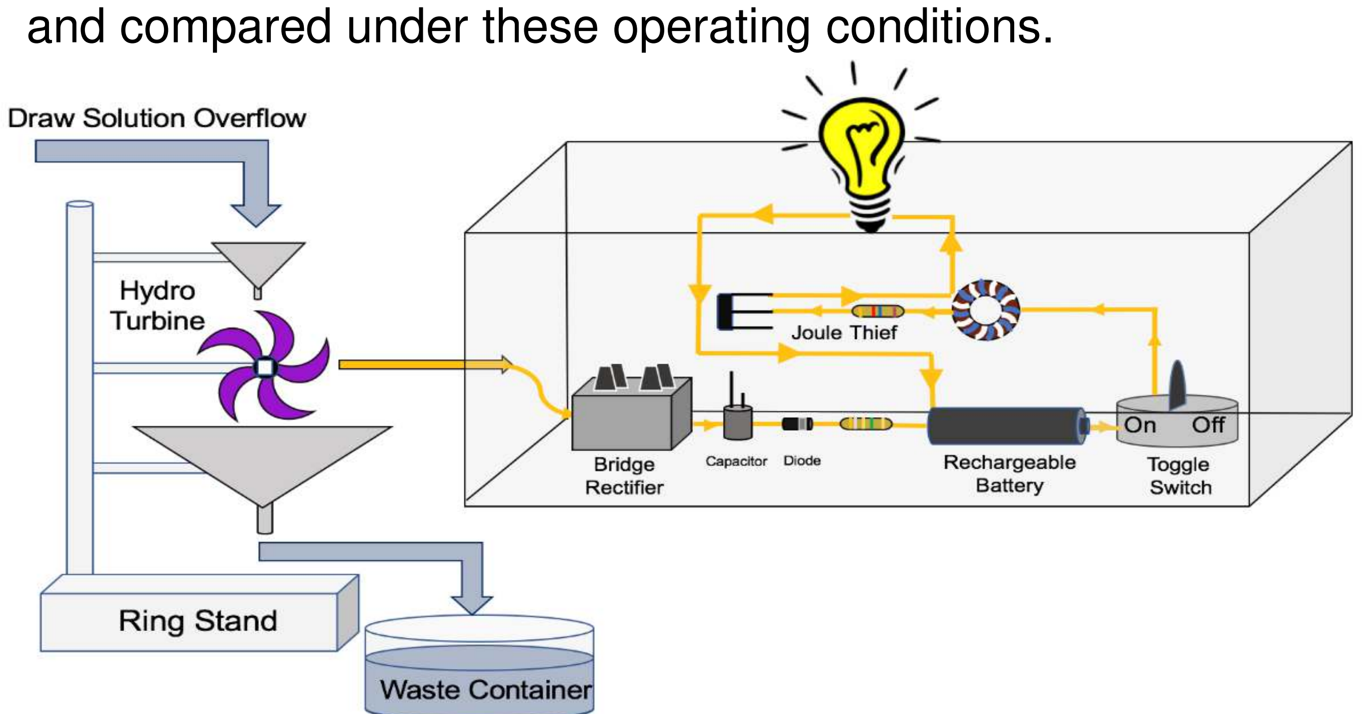

Fig. 4 Hydro-turbine and circuit schematic

Hydro Turbine Design

A hydro turbine was used to generate electricity from the draw overflow of the PRO system. Its design was developed so that the system would be able to account for intermittent flow while maximizing its number of rotations. The amount of water required to rotate the generator 90º was measured and determined to be 3.56 ml. The blades of the hydro turbine required a spoon design with high walls to store water as opposed to flat slots that let water pass.

Circuit Design

The energy that was generated from the hydro turbine was used to illuminate a 2 V red LED. Energy that was produced by the generator traveled to a bridge rectifier, which converted the AC input into DC to charge a battery. The battery was wired to a toggle switch that controlled the LED.

Results

Two membranes, Membrane A and Membrane B, were tested in PRO with a NaCl draw solution and DI water feed solution under their respective maximum operating pressures.

- Membrane A had poor water flux while operating under 300 psi of hydraulic pressure, which resulted in low power densities around 0.1 W/m². Voltage increased throughout this experiment, however, not enough to be accurately quantified.
- Membrane B had higher water fluxes operating under 100 psi of hydraulic pressure, which resulted in power densities around 4 W/m². This is 40 times the power density produced by membrane A. Based on the voltage produced from this experiment, it would take approximately 45 hours of continuous PRO bench-scale operation to fully charge a AAA rechargeable battery. This was calculated based on the measured voltage as shown in Fig. 7.

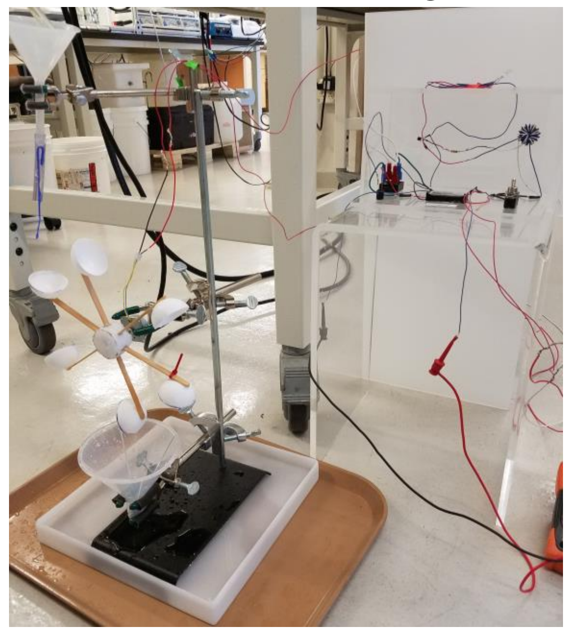

Fig. 5 Bench-scale hydro turbine for PRO bench-scale system

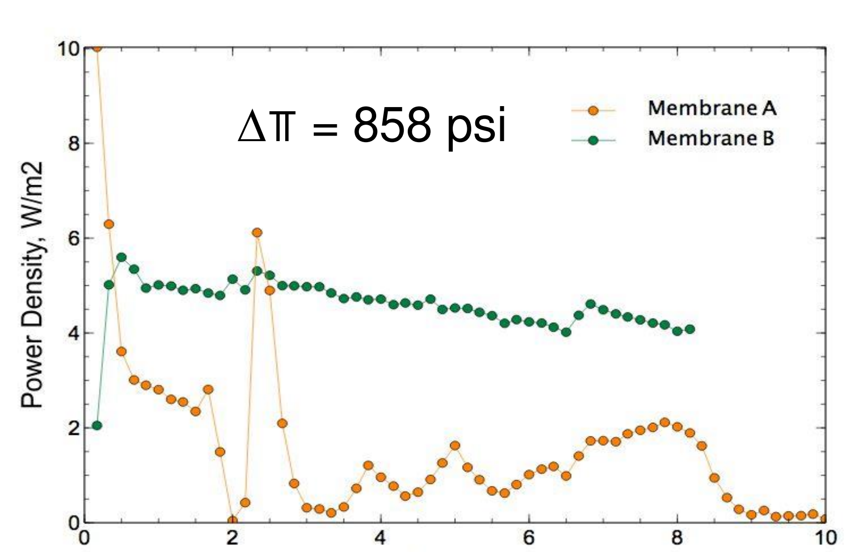

Fig. 6 Power density values from Membrane A and Membrane B

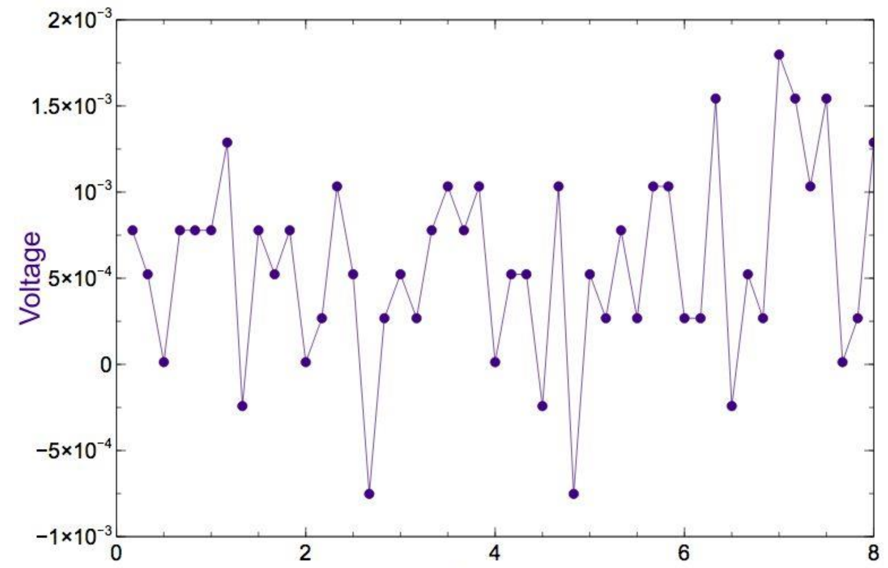

Fig. 7 Voltage produced from Membrane B

Childress Research Group field trip to Carlsbad's 50 MGD Seawater Desalination Facility on 07/11/17.

Conclusions

- Neither membrane was able to achieve a power density of 5 W/m², which is necessary for power generation on a commercial basis [5].
- In order to reach the target 5 W/m², higher water fluxes are necessary.
- Higher water fluxes can be achieved through improvements in membrane technology and operating conditions.
- PRO is a promising technology that has the potential to generate clean energy for water treatment. A continued investment in PRO and membrane research can contribute to a solution for our increased demand for potable water.

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References

[1] A. Achilli and A. E. Childress, "Pressure retarded osmosis: From the vision of Sidney Loeb to the first prototype installation — Review," Desalination, vol. 261, no. 3, pp. 205–211, Oct. 2010.

[2] Voutchkov, N., Vette, K., Sridhar, C. and Mcdonald, R. (2017). Desalination – Past, Present and Future. [online] International Water Association.

[3] Raluy, R. G., et al. (2005). "Life cycle assessment of desalination technologies integrated with renewable energies." Desalination **183**(1): 81-93.

[4] Aaberg, R. J. (2003). "Osmotic power." Refocus **4**(6): 48-50.

[5] Skilhagen, S. E. (2010). "Osmotic power — a new, renewable energy source." Desalination and Water Treatment **15**(1-3): 271-278.