Renewable Energy Powered Desalination Systems for Potable Water Production in Rural Communities

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In remote areas treatment must be low cost, reliable, and easy to operate.

Need for fresh water supplies for drinking and agriculture
Availability of solar resource

PV
Hypothesis

Solar resource: PV and/or solar concentrating

Desalination: reverse osmosis/nanofiltration or membrane distillation

Increased water supply for remote areas
Goals of this Phase of Research

1. Establish benchmark for off-grid desalination using readily available components

2. Develop methodology for comparing different types of renewable-energy powered desalination technologies
Photovoltaic-Powered Reverse Osmosis (PVRO)

**Benefits**
- Combines 2 readily-available technologies
- Inexpensive capital investment
- Allows for automation and complexity in implementation
- Allows for operational improvements

**Limitations**
- Membrane scaling/fouling
- Need for membrane replacement
- Inherent losses in converting solar energy to DC power
Simple PVRO Photos
# System Component and Installation Costs

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO system (wateranywhere.com)</td>
<td>(2) 2.5” x 40” membranes</td>
<td>2,400</td>
</tr>
<tr>
<td>PV (local hardware store)</td>
<td>400 Watt</td>
<td>1,800</td>
</tr>
<tr>
<td>Pump</td>
<td>1/5 HP, DC motor</td>
<td>1,100</td>
</tr>
<tr>
<td>Labor</td>
<td>40 hrs @ $50/hr</td>
<td>2,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>7,300</td>
</tr>
</tbody>
</table>

* Does not include the cost of well development or wellhead pumping
Operating Conditions

- Feed water: 2000 mg/L NaCl
- Membrane recovery: 30%
- Maximum feed pressure: 120 psi
- Feed pressure is a function of solar input
Data Collection

• Date, local time, latitude and longitude

• PV System
  – Panel angle (angle from the horizontal)
  – Panel bearing (from North)
  – Solar irradiance (typically horizontal indirect measurement)

• Membrane System
  – Feed: temperature, pressure, conductivity
  – Concentrate: pressure, flowrate, conductivity
  – Permeate: flowrate, conductivity
Solar Data Analysis Protocol

- Date, time
- Lat/Long
- Pyranometer reading
- Panel orientation

Solar 3D Model

Energy input to panel (W·hr/m²)
Solar 3D Model

\[ \theta = 53^\circ \]
\[ \beta = 34^\circ \]

\[ \vec{U}^{sol} = \pm \sin(Z^N) \cdot \cos(h)i - \cos(Z^N) \cdot \cos(h)j - \sin(h)k \]

Energy input = \( U \cdot I \)
PVRO Operational Data

- Permeate Flow Rate (L/min)
- Salt Rejection

Solar Energy Input to System (W/m²)
Summary of PVRO Results

- Cumulative water production: 144 L
- Solar input: 2195 W·hr/m²
- Solar panel area: 1.57 m²
- Average salt rejection: 94%
Performance Metric Allows For Comparison Between Projects

Water Production (L)

Solar Energy Input (W·hr)

Performance Metric (L/W·hr) 0.042
Extrapolation to Other Location/Conditions

Solar insolation data → Panel orientation → Solar 3D Model → Solar input W·hr × Performance metric L/W·hr → Water Production Volume
Establishing a Benchmark

Performance metric for PVRO = 0.042 L/W·hr

Metric allows for comparison of

- Systems run in different geographic locations and with different solar resource (i.e. seasonal, weather events)
- Different types of solar-desalination hybrid systems
  - Solar distillation
  - Solar-membrane distillation
  - PV-ED/EDR
- Performance metric of system improvements
  - Adding batteries
  - Energy recovery
Things to be Considered…

- Develop metric to incorporate system cost
- Incorporate energy requirement for source water pumping
- Concentrate disposal
- Develop testing/data analysis methodology for brackish groundwater source
Test Facility for Renewable Energy-Desalination Research

- Supply 4 different brackish water sources
- Abundant solar resource
- Outdoor test pads
- Laboratory facility
- 3+ years of meteorological data
Partnerships and Programs

• Reclamation programs
  – Science and Technology Program
  – Desalination and Water Purification Program (grants.gov)
  – Cooperative agreement with NMSU

• Securing Water for Food Grand Challenge – USAID
  – www.thedesalprize.net
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Solar 3D Model: Dr. Andrés Guerra (Colorado School of Mines)
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Solar Calculations
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