Energy Consumption and Desalination

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AGENDA

1. Introduction
2. Desalination
3. SWRO – Seawater Reverse Osmosis
4. Energy consumption
5. Renewable energy
6. Conclusion
INTRODUCTION

Source: https://www.wri.org/aqueduct
INTRODUCTION

The Impact of Water Scarcity on GDP

Today’s Path

[Map showing regions with varying water scarcity impacts, color-coded from +6% to -6%]

A Better Path

[Map showing regions with improved water scarcity conditions]

Desalination
DESALINATION

1970  Multistage Flash

1982  Membrane Technology

2002  Membrane Technology Improvements

2005  Renewable Energies

Source: Multistage picture - Environmental XPRT. Membrane technology - James Grellier / Wikimedia Commons
Seawater Reverse Osmosis Cost Trend

Source: Wateruse association – Seawater Desalination Costs 2020 – Estimated cost breakdown. Jubail SWRO – 0.41 USD/m³ and Yanbu 4 – 0.47 USD/m³
Membrane Feed Pressure for Feedwater and Membrane Technology

- **RO** (Sea Water) 80 Bar
- **RO** (Brackish water) 40 Bar
- **RO** (Low pressure) 20 Bar
- **NF** (Nano-filtration) 10 Bar
- **UF** (Ultra-filtration) 5 Bar
- **MF** (Micro-filtration) 5 Bar
Annual Contracted Capacity by Feedwater Type, 2000-2019

Seawater is feedwater with higher contracted capacity

Dotted line indicates values through June 2019; Source: GWI
Annual Contracted Capacity by Region, 2000-2019

Persian Gulf has the largest demand of SWRO desalination

Dotted line indicates values through June 2019; Source: GWI
Additional Contracted Desalination Capacity by Technology, 2000-2019

Reverse Osmosis as preferred technology for SWRO desalination

Dotted line indicates values through June 2019; Source: GWI
SWRO – Seawater Reverse Osmosis
SWRO DESALINATION PROCESS OVERVIEW

Source: www.Sciencedirect.com
Energy Consumption
Energy Consumption Over Time

Specific energy consumption (kWh/m³)

- Multistage Flash Evaporation
- Reverse Osmosis

ENERGY CONSUMPTION FOR SWRO

- Pre-Filtration: 0.24 kWh/m³
- Permeate treatment: 0.4 kWh/m³
- RO process: 2 kWh/m³
- Intake: 0.45 kWh/m³
- Permeate distribution: 0.22 kWh/m³

**2.98 kWh/m³**

Energy consumption in SWRO

- RO Process 2 kWh/m³
- Intake 0.45 kWh/m³
- Pre-Filtration 0.24 kWh/m³
- Permeate Treatment 0.4 kWh/m³
- Permeate Distribution 0.22 kWh/m³

- RO Process is the most energy intensive process within the SWRO treatment plant
- ERD can reduce energy consumption of RO process up to 60%; therefore, it is a critical component to achieving 2 kWh/m³
- ERD CAPEX only represents 1% of overall plant CAPEX

Source: [www.Sciencedirect.com](http://www.Sciencedirect.com)
**ENERGY CONSUMPTION FOR SWRO**

**Problem Statements:**
- Energy consumption and costs made SWRO uneconomical historically
- Approx. 60% of energy wasted during SWRO prior to implementation of ERDs

**HP Pump Provides Full Feed Flow and Pressure to SWRO Membranes**

**SEC: 8 kwh/m³**

**How it Works**

A full-size main high-pressure pump is used to supply the membranes with 100% of the feed flow + pressure in order to overcome the osmotic pressure of the membranes. Potential energy is “wasted” across the discharge valve.
The Pelton Wheel converts hydraulic energy into mechanical energy to offload the work done by the high-pressure pump’s motor. The Pelton Wheel’s shaft is directly connected to a dual-shafted motor and must rotate at the pump’s design speed. The high-pressure pump must be sized for the full flow and head required by the membranes.

SEC: 4 kwh/m³
Turbochargers convert hydraulic energy in the brine stream into mechanical energy reducing the amount of head required by the main high-pressure pump. The turbine drives the pump section “boosting” the discharge of the high-pressure pump to membrane feed pressure. The Turbocharger “decouples” the ERD from the pump and motor, allowing it to run at higher speeds and higher efficiency than the Pelton Wheel.
The PX Pressure Exchanger converts hydraulic energy in the concentrated brine stream into hydraulic energy that supplements the flow from the main high-pressure feed pump which feeds the membranes. This is done via direct contact between the concentrated brine and filtered seawater feed stream.

**SEC: 2.98 kwh/m³**
Isobaric energy recovery systems have high efficiency regardless of system size.
ENERGY CONSUMPTION FOR SWRO

- **Carlsbad SWRO**
  - **Location**: California
  - **Capacity**: 189,250 m$^3$/day (50 MGD)
  - **Energy recovery device**: Isobaric – PX devices
    - 116 million kWh (kilowatt-hours)
    - Equivalent to 82,107 metrics tons per year of CO$_2$
    - Equivalent to 12 million dollar in electricity cost

[Image of infographic showing greenhouse gas emissions and energy consumption]

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

*Photo courtesy of Poseidon Water*
Renewable Energy
RENEWABLE ENERGY POWERED DESALINATION

- The energy consumption of seawater desalination is higher than traditional water supply solutions (groundwater, rain catchment, rivers, lakes, etc.)
- This is a sustainable and cost effective solution thanks to decreasing cost of renewable energy systems

Estimated CO₂ Emissions of Global Water Desalination Plants

- Baseline scenario assumes compounded growth rate of water desalination of 10% per year
- Target scenario assumes gradual introduction of fully renewable powered desalination until 2040

Source: Global Clean Water Desalination Alliance
Suitable option for remote locations and small islands where the reliable and safe provision of drinking water is a constraint and expensive.

Electric grid and water networks are often inadequate.

Small-scale renewable energy powered desalination can be the optimal solution to address the water constraints.

Source: Global Clean Water Desalination Alliance
This configuration is ideally suited for very remote locations with limited access to a reliable electricity grid and service personnel. The configuration avoids using batteries and uses water storage instead to allow a water supply during day and night.

Source: Global Clean Water Desalination Alliance
TECHNOLOGY BRIEF: SMALL SCALE SOLAR SEAWATER DESALINATION – DIRECT COUPLING (OFF-GRID) WITH STORAGE OR BACKUP GENERATION

- Good option for locations with inadequate grid supply but access to service personnel for batteries or back-up generators
- Distributed solution obviating the need for costly water transmission and distribution systems

**Energy supply system**
- Photovoltaic modules/Wind turbine
- Batteries storage
- Back-up diesel

*Source: Global Clean Water Desalination Alliance*
TECHNOLOGY BRIEF: SMALL SCALE SOLAR SEAWATER DESALINATION – GRID CONNECTED

- Good option for locations with access to a reliable electric grid
- The renewable energy supply system can be sized to completely offset the CO₂ emissions of the desalination plant
- Reduced maintenance requirements due to absence of storage and backup generators

*Source: Global Clean Water Desalination Alliance*
The Desalination Plant and the Renewable Power Plant are connected to the grid and don’t need to be co-located.

The Renewable Power Plant is sized to completely offset the CO₂ emissions of the Desalination Plant (over the lifetime of the plant).

- **Desalination Plant**
  - Operates 24h per day
  - Connected to the grid, using existing infrastructure to supply electricity 24h per day

- **Electricity Grid**

- **Renewable Power Plant**
  - Operates only during certain hours of the day producing electricity from sunlight or wind
  - Connected to the grid, using existing infrastructure

*Source: Global Clean Water Desalination Alliance*
## General Information

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
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<tbody>
<tr>
<td>Owner/promoter</td>
<td>Elemental Water Makers</td>
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<tr>
<td>Location of SWRO Plant</td>
<td>La Union, Luzon, Philippines</td>
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<tr>
<td>Year of construction</td>
<td>2018</td>
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<tr>
<td>Capacity of SWRO Plant</td>
<td>11 m³/d</td>
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<tr>
<td>Type of RE Plant</td>
<td>PV plant</td>
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<tr>
<td>Capacity of RE Plant</td>
<td>4 kWp</td>
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*Source: [https://www.elementalwatermakers.com/project-philippines/](https://www.elementalwatermakers.com/project-philippines/)*

11 m³/d PV powered RO system from Elemental Water Makers, Philippines
REFERENCES: MEDIUM-SCALE WIND AND SOLAR-POWERED DESALINATION – CHINA

An independent grid was designed to support the desalination of 10,000 m³/day of sea water a day. The current production line has a capacity of 5,000 m³/day.

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<tbody>
<tr>
<td>Owner/promoter</td>
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<td>Location of SWRO Plant</td>
<td>Jiangsu province, China</td>
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<td>Year of construction</td>
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<td>Capacity of SWRO Plant</td>
<td>5,000 m³/d</td>
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<tr>
<td>Type of RE Plant</td>
<td>Wind power</td>
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<td>Capacity of RE Plant</td>
<td>2.5 MW turbine</td>
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Containerized system
It is the first large-scale seawater RO plant in the world powered by renewable energy using green electricity procured from an Australian wind farm.

**Kwinana SWRO Plant – Perth**

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<td>Owner/promoter</td>
<td>Water Corporation</td>
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<tr>
<td>Location of SWRO Plant</td>
<td>Kwinana, Perth Western Australia</td>
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<td>Year of construction</td>
<td>2006</td>
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<td>Capacity of SWRO Plant</td>
<td>144,000 m³/d</td>
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<td>TDS (design)</td>
<td>35,000 – 37,000 mg/l</td>
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<td>Specific Energy Consumption</td>
<td>4 - 6 kWh/m³</td>
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<td>Power requirement of SWRO Plant</td>
<td>24 MW</td>
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<tr>
<td>D&amp;C Joint Venture</td>
<td>Suez-Degrémont/Multiplex/Worley Parsons/Water Corporation</td>
</tr>
</tbody>
</table>

- The green electricity consumed by the desalination plant is provided by the 80 MW Emu Downs Wind Farm.
- The wind farm comprises 48 wind turbines and is located in a distance of 200 km from the desalination plant.

*Source: Global Clean Water Desalination Alliance*
Conclusion
CONCLUSION

- Seawater Reverse Osmosis (SWRO) is a feasible option to increase water availability for isolate locations, cities, industrial applications or others
- Reverse Osmosis is the preferred technology for desalination
- If the SWRO plant uses the correct technology, the SWRO design will reduce energy consumption and operational cost

- Energy renewable + SWRO are a good match to reduce water cost, and environmental impact
  - Wind power
  - Wave power
    - DOE Announces Prize Competition for Wave Energy Water Desalination
  - Solar Power
  - Other options
CONCLUSION

SWRO energy consumption to produce water for a family of four for one day is equivalent to:

- 1 m³ of desalinated water requires 2.98 kWh
- 1 family of 4 persons – 100 gallons per person per day [1] – 400 gallons (1.5 m³) per family
  - Equivalent to 4.5 kWh to produce desalinated water + 1.5 kWh for distribution
- 6 kWh is the same energy consumption for the following appliances [2]:
  - Equivalent to 3 tons of air conditioning capacity running for 1.3 hour (covers 1,200-1,500 sf) [3]

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Thank You