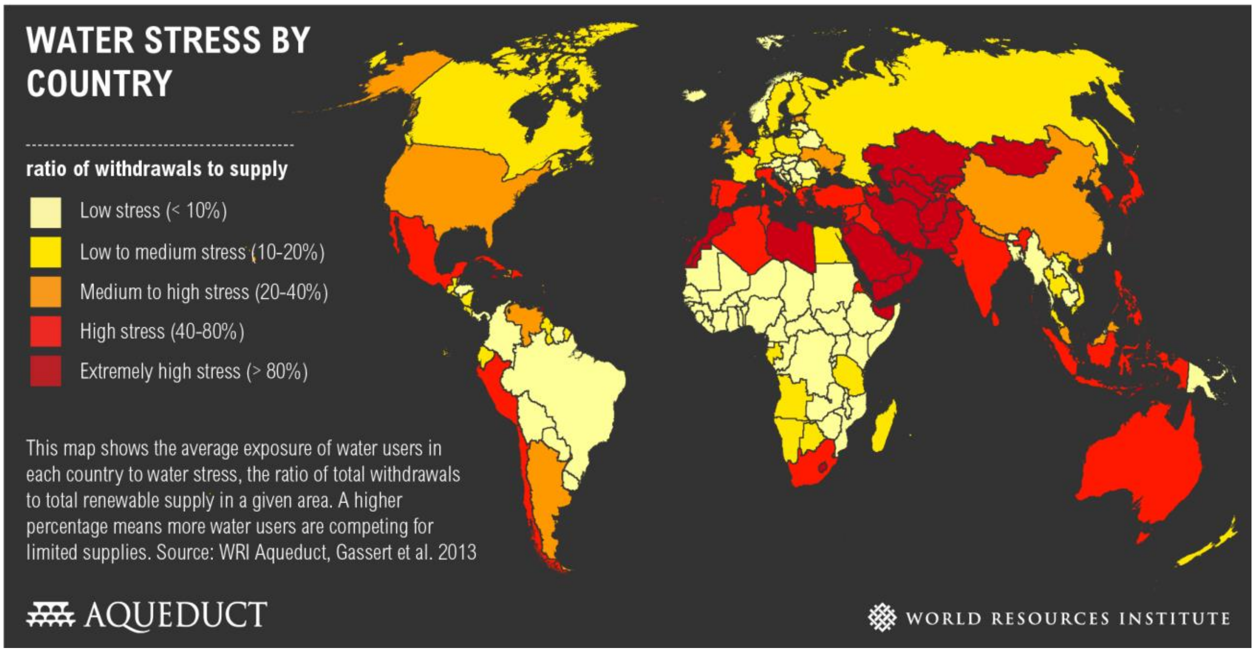
Harness the Power of the Sun for Off-the-Grid Desalination

By Dr. Payam Niknejad and Amanda Yoshino, Magna Imperio Systems Corp.

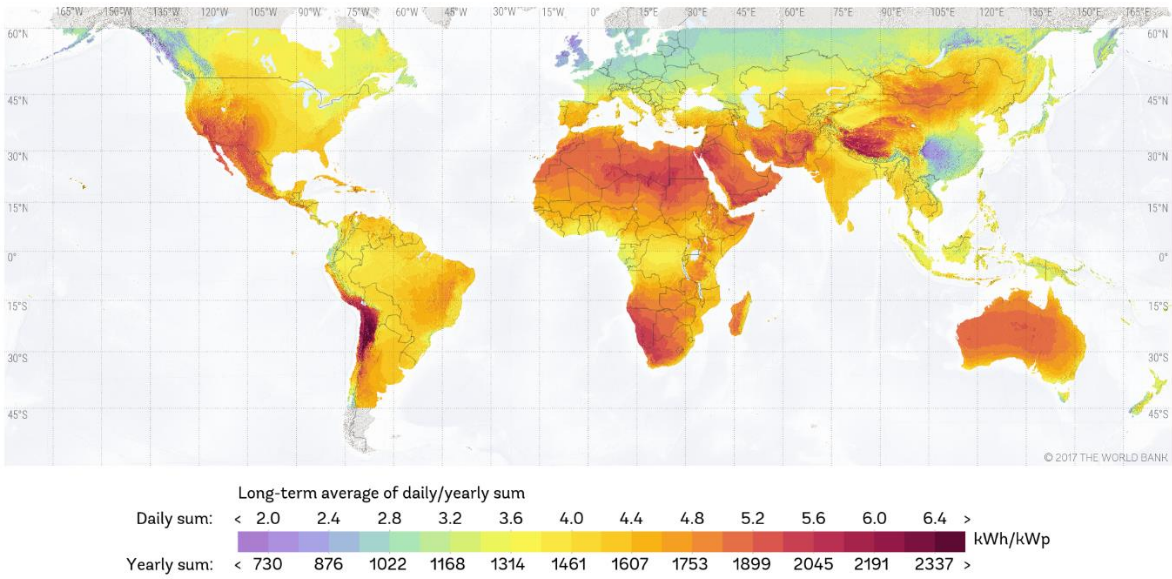


Water Stress Map (World Resources Institute, 2013).

Industrial and population growth continue to outpace the supply of freshwater resources in many regions of the world, as shown in the graph above. This need for additional freshwater resources is driving the need for desalination. When combined with concerns regarding climate change and harmful impacts associated with fossil fuels, desalination powered by renewable energy should be considered as a necessary part of the solution. Solar energy, with benefits including abundance, sustainability, and a high level of operational safety, has become a promising renewable energy source for desalination systems in regions with long sunlight hours and limited water supplies. Solar energy has the potential to be used for desalination in either solar-thermal or photovoltaic (PV) modes depending on the technology selected, plant size, and salinity of the feed water (Ghaffour et al., 2015).

Not so Fast: What are the Challenges?

A study by the International Groundwater Resources Assessment Center (2009), shows that over 24 million km^2 of the world's surface has significant saline and brackish groundwater resources at shallow and intermediate depths, with approximately 1.1 billion people inhabiting these regions. Many of these regions have an abundance of sunlight, as shown in the figure below – so why are solar-powered desalination solutions not more widespread?



Photovoltaic Power Potential ([World Bank Group](), 2017).

To answer this question, an analysis of how solar power can be used in desalination is necessary. As mentioned above, the two main approaches are to convert sunlight for desalination are solar-thermal and photovoltaic. The main drawback of using PV panels in water treatment is capital cost, which is directly proportional to the power requirement of the desalination technology. The low conversion efficiency of sunlight to electrical energy also drives high capital costs. Thus, the techno-economic challenges of PV powered desalination are non-trivial.

Solar-thermal energy has been utilized directly in distillation or phase change processes such as multi-effect distillation (MED) or multi-stage flash (MSF); however, as discussed by Darwish & Al-Najem (1987), these distillation processes are energy-intensive (1.5-4 kWh/m^3). Their low gain output ratios (GOR), a measure of thermal energy consumption in desalination, necessitate more collection area and limit their application in areas with space constraints. Case studies also demonstrate that a solar-thermal approach is not efficient in small scale desalination process due to significant heat losses.

Designing a Sun-Powered Solution

Desalination technologies powered by solar energy have the capability of providing freshwater for industry and communities in regions where infrastructure for high-capacity, centralized water treatment systems is not established. Due to the cost of renewable energy relative to more traditional energy sources, an important design consideration is the choice of desalination technology: thermal-, pressure-, or electrically-driven. Common thermal processes include MSF evaporators and MED while the most common pressure-driven system is reverse osmosis. Electrodialysis is an example of an electrically-driven process. A comparison of the energy consumption of these technologies is shown in the table below.

Energy consumption of various desalination processes (Ghaffour et al., 2013, Younos & Tulou, 2005)

Process	Thermal Energy kWh/m^3	Electrical Energy kWh/m^3	Total Energy kWh/m^3
MSF	7.5-12	2.5-4	10-16
MED	4-7	1.5-2	5.5-9
SWRO	-	3-4	3-4
BWRO	-	0.5-2.5	0.5-2.5
Conventional EDR	-	1.7	1.7
END®	-	0.3-0.5	0.3-0.5

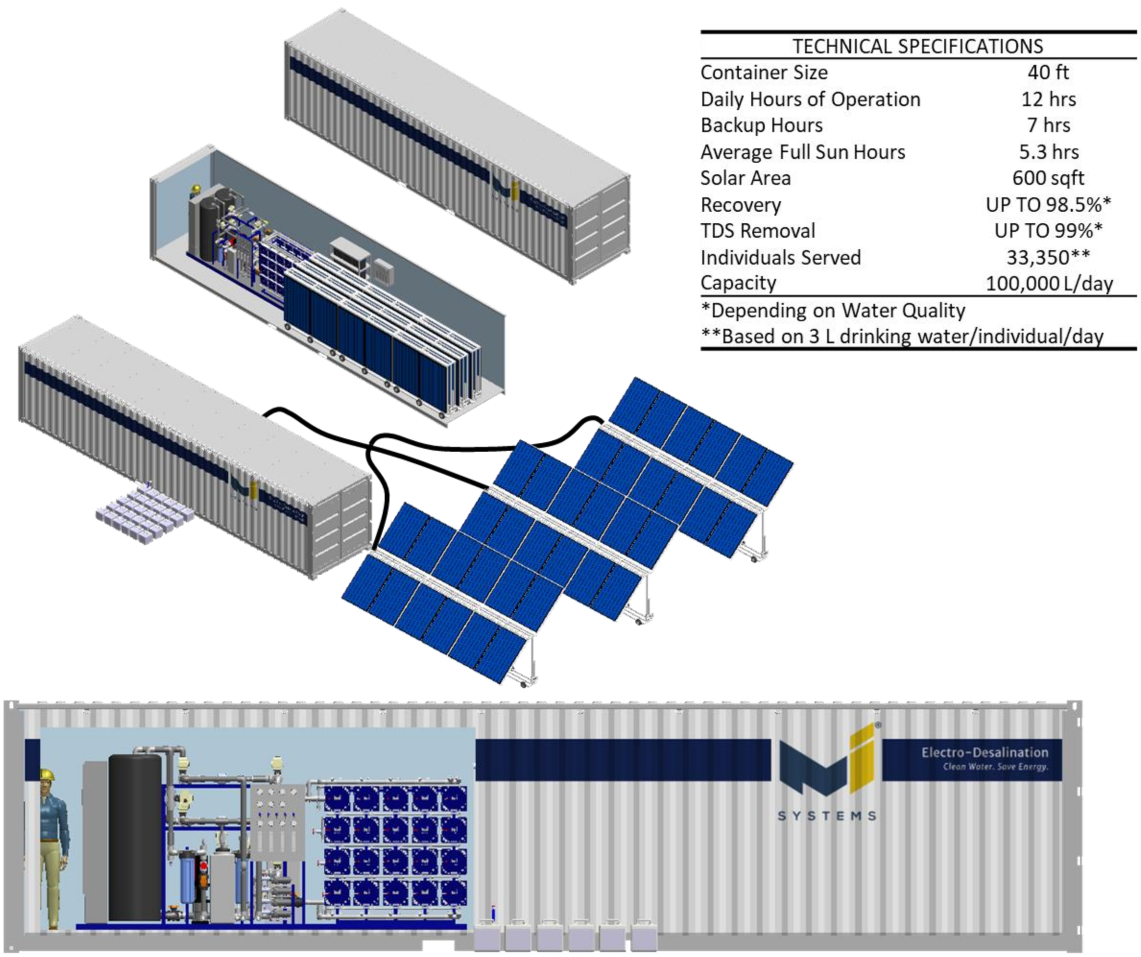
Thermal energy processes avoid the conversion to electrical energy which can reduce capital cost; however, their GOR is relatively low and heat losses are a significant issue in small systems. Pressure-driven processes such as reverse osmosis require the conversion of DC current from the PV panels to AC current for the pumps, which translates to energy conversion inefficiencies. Electrically-driven processes such as EDR allow for direct usage of the DC current from the panels. This represents the potential for a low energy loss solution when the EDR system is designed to minimize energy consumption while maintaining reliable, high water recovery operation. High recovery is often important for solar-powered desal since regions where sunlight is abundant, water is often scarce.

PV-Powered Electric Desalination – Maximum Recovery, Minimum Energy™

To overcome water scarcity, efforts must be dedicated to developing desalination technologies that target high water recovery and minimum energy consumption to reduce capital expenses and water losses. MI Systems provides a solution to resolve the traditional challenges of using solar-powered water treatment by coupling PV with the low-energy demand END® desalination system based on electrodialysis technology.

MI Systems' solar-based containerized water treatment unit, designed and fabricated by a dedicated team of engineers and scientists, is a combination of low energy consumption, electrically-driven END® technology and high-efficiency PV panels (over 20% efficiency compared to typical 12% to 18% efficiency of commercial solar panels) delivered at 0.3-0.5 kWh/m^3. Systems are designed for industrial or community use. As an example of community use, the PV-END® system is designed to operate at any location with an average of 5.5 hours of daily sunlight, and is capable of treating 30 gallons of water per minute with 12 hours of daily operating schedule and 7 hours of backup. With this capacity, the PV-END® system can serve the drinking water needs of a community of over 33,000 people (based on the average water consumption data provided by World Health Organization, 2003). The total power demand of the PV-END® system is approximately 4 kW and is fully provided by PV panels and includes the power required for pumping, ventilation, and water treatment. Systems are modular for easy scale up from 30 gpm to over 1 MGD.

The PV-END® mobile desalination unit is contained within a 40-foot container to accommodate simplified shipping and transport. The container includes a high recovery water treatment system, folded mobile solar array modules, power/control panel and battery compartment. The solar array modules fold out to 600 ft^2 when deployed. The PV-END® unit is an example of MI Systems' response to the world's water crisis, providing environmentally responsible solutions through innovative technology and services.



TECHNICAL SPECIFICATIONS	
Container Size	40 ft
Daily Hours of Operation	12 hrs
Backup Hours	7 hrs
Average Full Sun Hours	5.3 hrs
Solar Area	600 sqft
Recovery	UP TO 98.5%*
TDS Removal	UP TO 99%*
Individuals Served	33,350**
Capacity	100,000 L/day

*Depending on Water Quality
**Based on 3 L drinking water/individual/day

Mobile, fully-containerized PV-END® desalination unit capable of serving the drinking water needs for a community of over 33,000 people.