Global Institute for Water
Environment and Health

Leadership For Positive Change

Report on Water Technology

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Armelle de Vienne

GIWEH
10, Rue Chantepoulet
1201 Genève
E-mail: info@giweh.ch
www.giweh.ch
Tél : 022 73375 11

Introduction

Water covers roughly 70% of our planet. Of that 70%, however, only about 2.5% is freshwater and less than 1% is accessible to humans. The availability of freshwater is critical to sustaining life in this world; however, with increasing population growth and climate change, this resource is becoming scarcer than ever before. Currently, about 25% of the world's population is faced with water scarcity. Thus, we are forced to turn to alternate solutions.

With the world's oceans containing 97.2% of our world's water resources, and the majority of the world's populations residing along coastlines, technology has been focused on developing different desalination techniques. Desalination, however, requires a high amount of energy to function. The most efficient desalination reverse osmosis system consumes about 5kWh/m^3. While seawater desalination used to be viewed as extremely expensive, the new lower-cost technology has been changing the market and making desalination a more feasible solution. In the last 20 years, the cost of desalination has decreased four fold. Currently, the cost of desalination of brackish water is between $1.50 to $2.50 per 1,000 gallons of freshwater produced; and saltwater, for which large scale distillation and RO are both used cost between $4 and $6 per 1,000 gallons.[1]The market for desalination has already expanded to $5-10 billion in 2008[2] and as technology continues to develop and expand, the cost of desalination technology will only decrease.

Technology Available

There currently exists several different methods for desalination. The first is through thermal evaporation, which is predominately used in the Middle East, and the second is through membrane separation, which is dominant everywhere else. Thermal evaporation technologies include Multi-Stage Flash (MSF), Multi Effect Distillation (MED), and Vapor Compression (VC). These technologies, however, are still extremely expensive. The technologies available under Membrane separation are Reverse Osmosis (RO), Nanofiltration (NF), Ultrafiltration (UF), Microfiltration (MF), and Electrodialysis (ED). While RO dominates the market, the demand for UF is also

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[1] U.S. Congress, Office of Technology Assessment, Using Desalination ***Technologies for Water*** Treatment, OTA-BP-O-46 (Washington, DC: U.S. Government Printing Office, March 1988). P.1

[2] "Innovation in Membrane Technology." *China Water Nexus*. WordPress, 10 June 2010. Web. 23 May 2011.

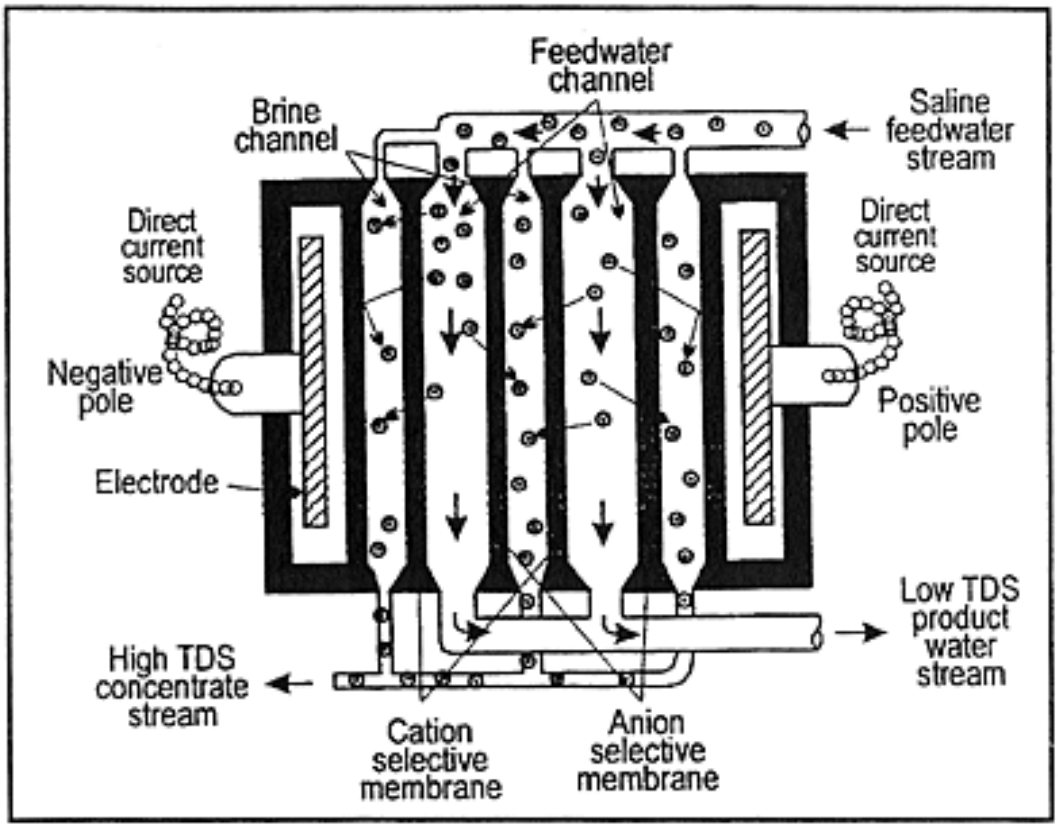
[2] "Innovation in Membrane Technology." *China Water Nexus*. WordPress, 10 June 2010. Web. 23 May 2011. <http://www.chinawaternexus.com/?p=182>.

growing because of its promise to treat municipal wastewater, industrial process water, as well as other types.

Membrane Separation

The main membrane technologies, as already stated are electrodialysis (ED), reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF). Electrodialysis requires that brackish water be pumped through several hundred flat, parallel, ion-permeable membranes at low pressures. The membranes alternate between cation-permeable and anion-permeable membranes so that ions are concentrated between these alternate membranes once an electrical current is added to the stacks and pulls ions through the membranes. This leaves partially desalinated water between membrane pairs as well.

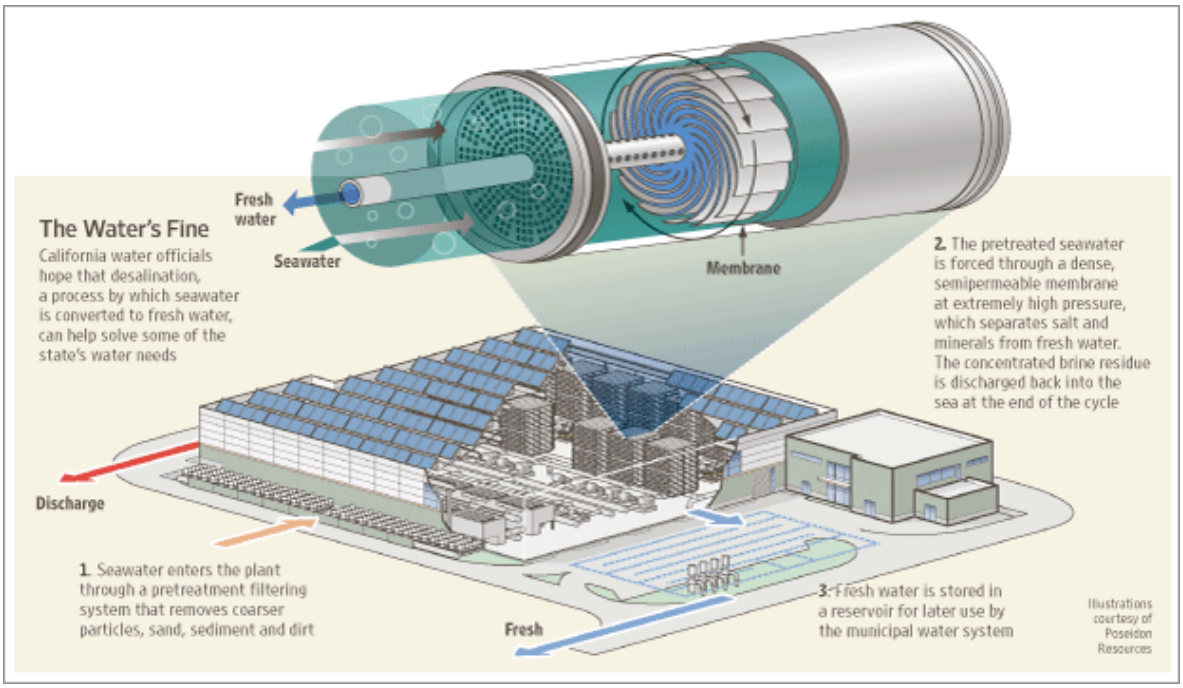
Figure 1: *Electrodialysis Technology*
Available at: http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8d/desalination.asp



Generally speaking, reverse osmosis has been used to filter and desalinate portable water, boiler feed water, process water, ultra-pure water, wastewater treatment, and beverage mix water. The ultrafiltration and microfiltration technologies are more often used for surface water treatment, RO/NF pre-treatment, membrane bioreactor, and industrial water re-use.

Reverse osmosis desalinates salty or brackish water by subjecting it to high amounts of pressure (200 to 500 lb/sq in. for brackish water and 800 to 1,200 lb/sq in. for seawater) [3]that pushes the pure water through a set of semi-permeable membranes and leaves the concentrated brine behind.

Figure 2: *Seawater Reverse Osmosis System*
Available at:
http://www.alexanderhamiltoninstitute.org/lp/BuildingGreenUSA/Solar%20Power%20Desalination.htm

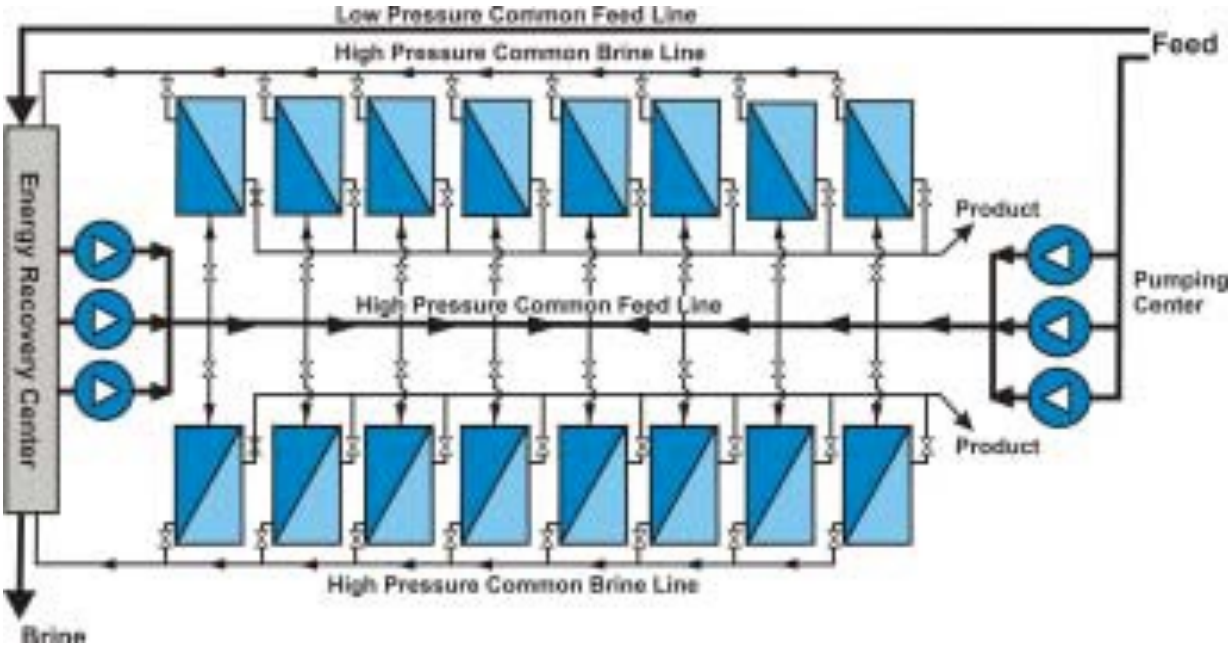


One of the largest RO plants in the world is the Ashkelon Seawater Reverse Osmosis Plant in Israel. This plant has been proven to be extremely successful. The Ashkelon SWRO plant was built in 2001 and in 2006 it was voted the 'Desalination Plant of the

[3] U.S. Congress, Office of Technology Assessment, Using Desalination ***Technologies for Water*** Treatment, OTA-BP-O-46 (Washington, DC: U.S. Government Printing Office, March 1988).

Year.' Part of what has made this plant so successful is its three center reverse osmosis configuration. This means that the RO membrane vessels, the high pressure pumps, and energy recovery equipment are not separated but rather combined in three functional centers. There are several aspects that make this type of a system so effective. Firstly, the SWRO feed pumping center only has a few large-capacity high pressure pumps, which is more efficient that many small-capacity pumps. Whereas small capacity pumps are about 80-83% efficient, large capacity pumps are roughly 85-88% efficient.[4] Secondly, the membrane center configuration contains two to four times more RO vessel groups and a smaller number of membrane vessels per bank. This allows for individual membrane banks to directly connect to high pressure pump feed lines, allowing them to be easily taken out during maintenance. Lastly, the third component to this system, is that the centralized energy recovery system has a high-efficiency, pressure exchanger-based energy recovery technology, which is energy efficient, reduces system power and equipment/construction cost.

Figure 3: *Three Center Seawater Reverse Osmosis Configuration*
Available at: http://www.wcponline.com/pdf/0709Voutchkov.pdf



[4] Voutchkov, Nikolay. "Advances in Seawater Desalination Technology." *Water Conditioning and Purification* 49.9 (2007): 1-7. Web. 23 May 2011. p. 4: available at: http://www.wcponline.com/pdf/0709Voutchkov.pdf

Thermal Evaporation

Distillation has been another method used to desalinate salt water. Distillation allows for the separation of salt and minerals from freshwater by vaporizing the water and then re-condensing it again on a cooler surface. The four major processes used in commercial distillation include multiple effect (ME), multi-stage flash (MSF), and vapor compression (VP). Whereas ME and MSF processes requires the boiling of the concentrated brine in adjacent chambers at lower vapor pressures without adding heat, VC collects the water vapor from salty feed water and condenses the vapor.

Rapid Spray Evaporation is a patented technology, licensed by US AquaSonics Corporation, that has proven to desalinate water effectively and at a low cost. The water efficiency is estimated at 95% and it costs under $2 per 1,000 gallons of water produced.[5] This technology needs heat to function, which can come from geothermal, gas-turbine, heat pump, electrical heating element, power generation, or solar sources. RSE can also separate solids cost-effectively. It has been proven to effectively filter wastewater that includes up to 25% dissolved solids, which makes it a good potential alternative with regards to wastewater treatment. Another positive feature to this technology is that it is environmentally friendly. Where many reverse osmosis systems return brine into the ocean, raising salinity concentrations along coasts, the RSE system does not return concentrated brine to the saltwater source.

Renewable Energy

As these desalination plants require a lot of energy to function, renewable technology has increasingly become incorporated into the technology. One of these examples is the Pelton-Wheel Based technology, which allows for 25-35% of recovery of power initially applied by SWRO system's feed pumps. From this technology, emerged also the pressure-exchanger technology, which can recover 5-15% more energy than even the Pelton-Wheel.[6] What makes this technology so effective is that it takes the energy from the SWRO system's concentrate and reapplies it to the pistons that pump seawater into the system. This is only one example though of technology used make sustainable use of energy in order to help generate these systems that require large amounts of energy.

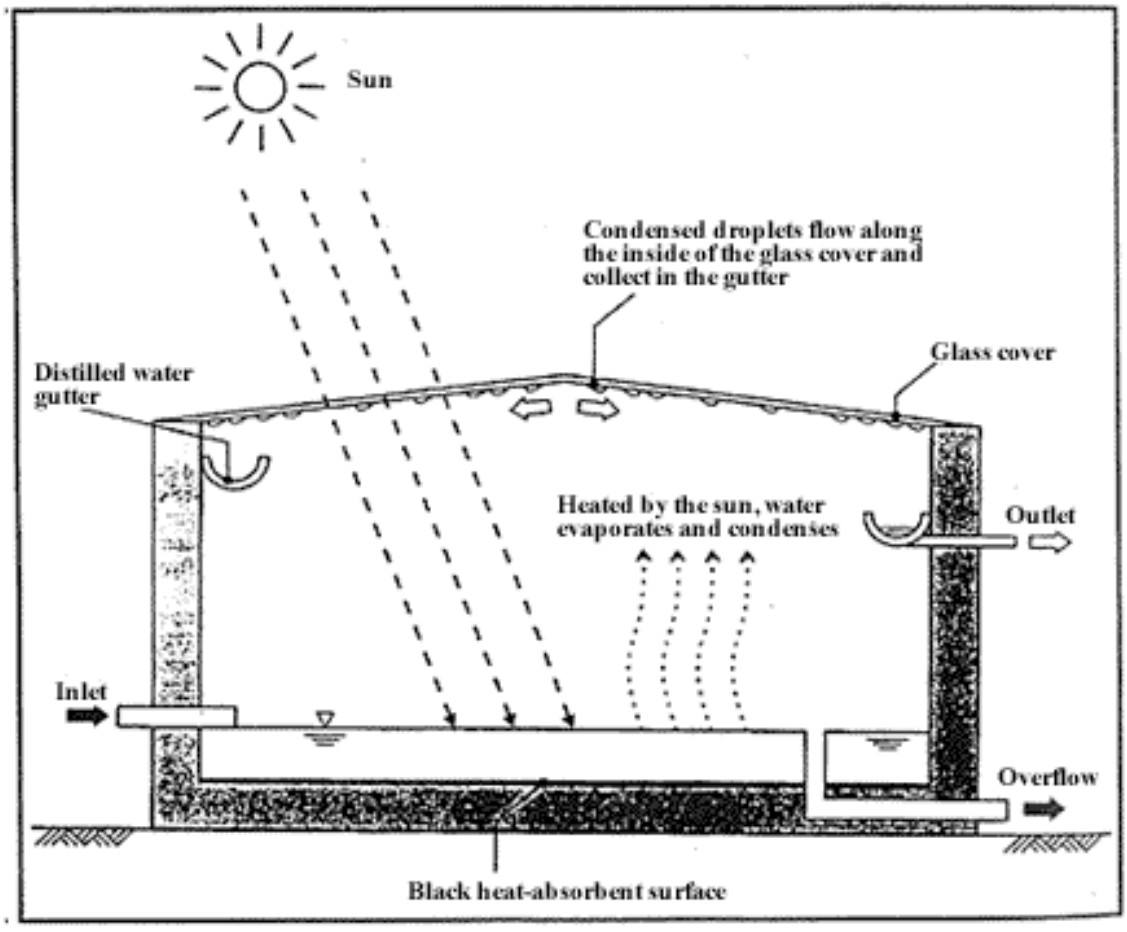
Solar desalination, which can be used by humidification, distillation, and photovoltaic separation, is another type of technology that is becoming increasingly used,

[5] "AquaSonics Technology." *AquaSonics-Water Desalination Technology*. US AquaSonics Corporation, 2001. Web. 23 May 2011. <http://www.aquasonics.com/tech.html>.

[6] Voutchkov (2007) p. 3

especially in areas that have access to excess sunlight. Solar Humidification is similar to vapor compression technology except that the system gets its energy from solar rays and heats up the salty water. As the water evaporates, it is then condensed on a cooler surface and collected. This type of system, however, is expensive and best used on a small scale, as for individual homes or small villages. While it does not require high maintenance expertise, simple adjustments do need to be made occasionally.

Figure 4: *Solar Humidification*
Available at: http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8d/desalination.asp



Solar distillation is another process that uses concentrated solar energy to heat the feedwater so that it can be used in the heating section of the thermal desalination process. As this kind of system is most efficient on a large scale, requires heavy maintenance, and a lot of energy input, this technology is best used in large and well developed plants.

Desalination through the use of photovoltaic cells is another type of technology that can be used in reverse osmosis or electrodialysis systems, however, there are several difficulties with such use. RO and electrodialysis processes need batteries and inverters to supply alternating currents to the membranes. Solar energy can help support these batteries, however, solar energy is only available for a portion of the day; thus, a commercial unit must be oversized in order to produce adequate supply of water during that portion of the day.

Some people have suggested that desalination technologies will also see a push towards using nuclear power as it would be much more cost efficient considering the amount of energy needed to generate the desalination systems. The amount of energy needed to generate desalination plants depends on the process used. While reverse osmosis requires roughly 5kWh/m^3, multi-stage flash requires 4-6 kWh/m^3, multi-effect distillation 1.5-2.5 kWh/m^3, and vapor compression uses 7-12 kWh/m^3.[7] Considering these figures and that most desalination is driven almost entirely by the combustion of fossil fuels, it is vital to look towards more energy efficient processes that can make desalination a feasible and sustainable solution to the increasing problem of water scarcity.

The Market

It's been predicted that the desalination market will generate roughly $95 billion in the ten-year span from 2005-2015. This expenditure will mostly be concentrated in the Gulf region, although the market will also expand along the Mediterranean Rim, China, India, the United States, and several European countries.[8]

Mediterranean Rim/ Middle East:

The main countries along the Mediterranean Rim that will be seeing large growth in its desalination market are Spain, Algeria, Libya, and Israel. It's expected that the market in these areas will increase roughly 300%. Spain alone is expected to increase its desalination capacity by 179%. Spain is expected to become a large player because of its recent drought and water shortage problems. In 2004-2005, Spain suffered the worst drought on record and Libya is also expected to invest in the desalination market, with an estimated value of 2 million m3/d of capacity by 2016.

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[7] Energy Requirements Of Desalination Processes, Encyclopedia of Desalination and Water Resources (DESWARE), UNESCO Encyclopedia of Life Support Systems (EOLSS) http://www.desware.net/desa4.aspx

[8] http://www.idswater.com/Common/exhib_6/Desalination%20Markets%20Contents.pdf

The North African countries also will experience water shortage problems in the near future. Due to increasing populations and climate change, which will result in rising sea levels and consequently coastal flooding, the African countries are at risk of water contamination resulting in greater shortage. A prediction has been made that "water shortages will be experienced by 80-100 million people before 2025."[9] In order to avoid such tragic outcomes, the region has and will continue to invest heavily in desalination technology. The World Bank has even heavily funded the region's water development and are encouraging greater private sector participation.

Renewable energy is also a sector that will be seen in the North African countries as well as in the Middle East. Egypt has already committed itself to using 20% renewable energy by 2020, Algeria hopes to reach 6% by 2015, and the UAE hopes to generate 7% from renewable sources by 2020. In addition, the Egyptian National Renewable Energy Authority has planed to construct a wind farm that would contribute to their goal of generating 12% of their total energy capacity from wind.

The MENA region could potentially be the biggest renewable energy supplier in the world. It would be especially conducive to solar energy, as it's been suggested that the region holds roughly 45% of the world's total solar energy and it could generate three times the world's current demand.[10] Results from small pilot projects suggest, however, that desalination plants generated by solar energy is best suited for small, off the grid communities. However, despite this, Saudi Arabia is currently in the process of constructing the first solar powered desalination plant. The plant would be powered by photovoltaic technology and would provide up to 30,000 m3 of water to 100,000 people. [11]

While the African countries will see an emerging growth with regards to desalination technology, the Gulf region will continue to be prominent members in the desalination market, especially Saudi Arabia and the United Arab Emirates. The UAE has already invested about $50 billion in power and desalination over the past 10 years and Saudi Arabia is currently the world's largest producer of desalinated water.

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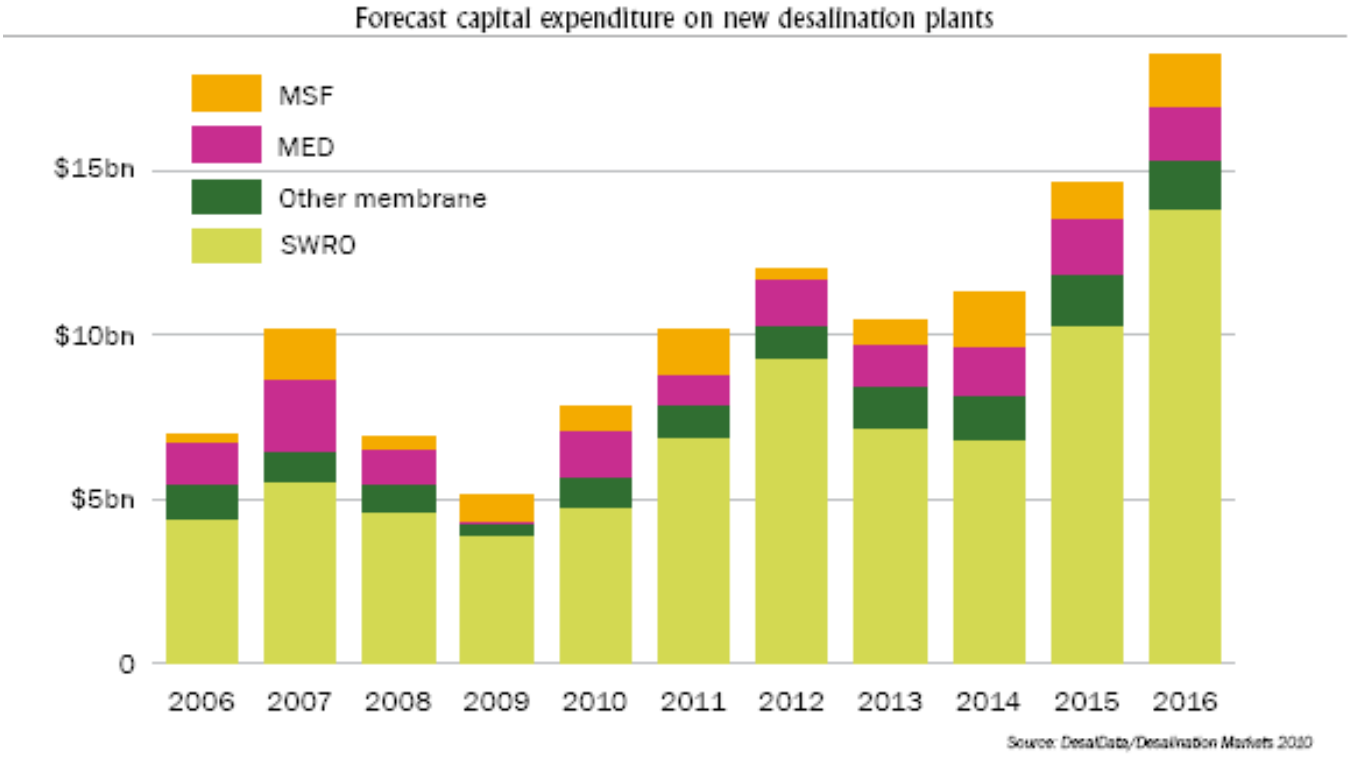
[9] http://www.sdwtc.org/Resources/WEMI/Segment%20Report/Water%20Industry%20Segment%20Report%20-%20Desalinization%202011.pdf

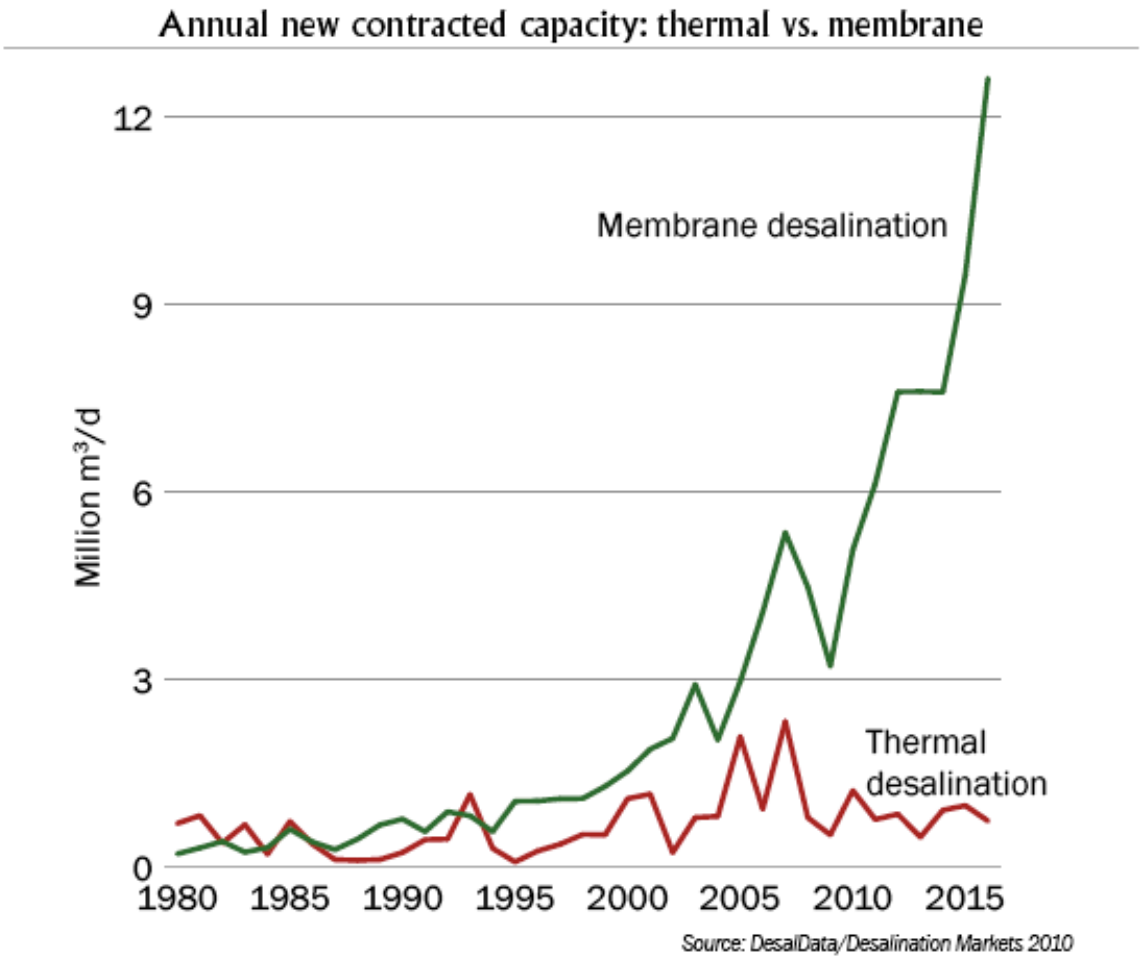
[10] A New Source of Power; The Potential for Renewable Energy in the MENA Region by Ibrahim El-Husseini, Dr. Walid Fayad, Tarek El Sayed and Daniel Zywietz (March 2010, Booz & Co.)

[11] Arabian Business (Apr 2010) Saudi eyes solar powered desalinatin plant, http://www.arabianbusiness.com/585567-saudi-eyes-solar-powered-desalination-plant

A projection for the future of the Gulf Region, however, is that it will notice a shift in an increase in reverse osmosis systems rather than the tradition MSF system:



In general, a trend away from thermal desalination is likely to occur. In a report conducted by Global Water Intelligence it was estimated that thermal desalination will amount to only around 9% of the market in the 2010-2016 period. This is not only because the Gulf region will invest more in membrane desalination but also because the market growth will increase more outside of the Gulf region, which predominantly uses membrane desalination, rather than within it.



China and India:

Both China and India will increasingly be looking towards desalination technologies as they are becoming progressively pressured by rapid urbanization especially in water stressed areas. Both China and India are suffering from freshwater scarcity and as their populations continue to expand, they are seeking alternate opportunities to enhance their water supply. Thus, a dramatic increase in new technologies is expected to appear in both of these counties. China's desalination market is expected to reach about $600-860 million in 2012-2015.[12] While currently equipment suppliers for desalination technology come from all over the world, including the US, South Korea, France, Italy, Singapore, Japan, and Israel, China is expected to become a growing supplier as well. Large Chinese suppliers

[12] Chunfeng. "Overview of Seawater Desalination Industry in Asia." Global Warming Debate. Www.warmdebate.com, 19 Dec. 2010. Web. 29 May 2011. <http://www.warmdebate.com/business/clean-tech/overview-seawater-desalination-industry-asia>.

already include Tianjin MOTIMO Membrane Technology Ltd and Harbin ROPV Industry Development Center.

References:

Arabian Business (Apr 2010) Saudi eyes solar powered desalinatin plant, http://www.arabianbusiness.com/585567-saudi-eyes-solar-powered-desalination-plant

A New Source of Power; The Potential for Renewable Energy in the MENA Region by Ibrahim El-Husseini, Dr.
Walid Fayad, Tarek El Sayed and Daniel Zywietz (March 2010, Booz & Co.)

"AquaSonics Technology." AquaSonics-Water Desalination Technology. US AquaSonics Corporation, 2001. Web.
23 May 2011. http://www.aquasonics.com/tech.html

Chunfeng. "Overview of Seawater Desalination Industry in Asia." Global Warming Debate. Www.warmdebate.com, 19 Dec. 2010. Web. 29 May 2011. <http://www.warmdebate.com/business/clean-tech/overview-seawater-desalination-industry-asia>.

Energy Requirements Of Desalination Processes, Encyclopedia of Desalination and Water Resources
(DESWARE), UNESCO Encyclopedia of Life Support Systems (EOLSS)
http://www.desware.net/desa4.aspx

"GE Doubles Capacity of Water Technology Manufacturing Facility to Support China's Growing Demand for
Cleaner Energy and Water: Press Releases: News: GE." GE News. General Electric Company, 2011. Web. 23 May 2011. http://www.genewscenter.com/Press-Releases/GE-Doubles-Capacity-of-Water-Technology-Manufacturing-Facility-to-Support-China-s-Growing-Demand-for-Cleaner-Energy-and-Water-2fd3.aspx

Hodge, Nick. "Investing in the Future: Desalination Companies." Green Chip Stocks. Angel Publishing LLC., 8 Jan.
2008. Web. 23 May 2011. http://www.greenchipstocks.com/articles/desalination-companies-stocks/195

"Innovation in Membrane Technology." China Water Nexus. WordPress, 10 June 2010. Web. 23 May 2011.
http://www.chinawaternexus.com/?p=182

UNEP: Division of Technology, Industry and Economics. "Alternative Technologies." Part B. United Nations

Environment Programme:Division of Technology, Industry and Economics. United Nations Environment Programme. Web. 23 May 2011. http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8d/desalination.asp

U.S. Congress, Office of Technology Assessment, Using Desalination **Technologies for Water**
Treatment, OTA-BP-O-46 (Washington, DC: U.S. Government Printing Office, March 1988).

Voutchkov, Nikolay. "Advances in Seawater Desalination Technology." Water Conditioning and Purification 49.9
(2007): 1-7. Web. 23 May 2011. p. 4: available at: http://www.wcponline.com/pdf/0709Voutchkov.pdf

Wangnick/GWI. 2005. 2004 Worldwide desalting plants inventory. Global Water Intelligence. Oxford, England. (Data provided to the Pacific Institute and used with permission.)

"Worldwide Seawater Desalination Capabilities." Seawater Desalination: Huntington Beach Facility. Poseidon
Resources Corporation, 2010. Web. 23 May 2011. http://hbdesal.com/desalination-101/desalination-worldwide