More Affordable Seawater Desalination

Technological advances are expected to drive down the costs of seawater desalination.

By Nikolay Voutchkov

The world's oceans contain over 97.2 percent of the planet's water resources. Because of the high salinity of ocean water and the significant costs associated with seawater desalination, most of the world population's water supply has traditionally come from fresh water sources—groundwater aquifers, rivers, and lakes. However, changing climate patterns combined with population growth pressures and limited availability of new and inexpensive fresh water supplies are shifting the water industry's attention to an emerging trend—the world is reaching to the ocean for fresh water.

The ocean has two unique and distinctive features as a water supply source: it is drought proof and it is practically limitless. Over 50 percent of the world's population lives in urban centers bordering an ocean or sea. Usually coastal zones are the highest population growth hot spots as well. Therefore, seawater desalination provides the logical solution for a sustainable, long-term management of the growing water demand pressures in coastal areas.

Until recently, seawater desalination has been limited to the desert-climate dominated regions of the world. New technological advances and associated decreases in water production costs over the past decade have expanded its use into coastal areas traditionally supplied with fresh water resources. Recent examples are the 86-mgd Ashkelon Seawater Desalination Plant in Israel, and the 36-mgd Tuas Plant in Singapore. Both plants began operation in the second half of 2005 and currently produce high quality water for potable, agricultural, and industrial uses at a price of $1.99/1,000 gal and $1.82/1,000 gal, respectively.

Reverse osmosis membranes-the work horses of today's desalination plants.

Membrane seawater desalination is becoming more affordable in the U. S. as well. The cost of desalinated water produced at the Tampa Bay seawater desalination plant in Florida is estimated at $2.45/1,000 gal. The cost of desalinated water offered to the City of Carlsbad and neighboring communities in San Diego County is in a range of $2.70 to $2.80/1,000 gal. With a credit of $0.77/1,000 gal, which will be awarded to local utilities by the Municipal Water District of Southern California, the cost of desalinated water will match that currently paid by most utilities for alternative drinking water supplies.

Today, desalination plants provide about one percent of the world's drinking water and this percentage is increasing annually. Over $10 billion of investment in the next five years would yield an additional 1,500 mgd of new desalinated water production capacity. This capacity is expected to double by 2015.

Two basic types of technologies have been widely used to separate salts from ocean water: thermal evaporation and membrane separation. In the last ten years, seawater desalination using semipermeable seawater reverse osmosis (SWRO) membranes have gained momentum and they currently dominate desalination markets, outside of the Middle Eastern region where thermal evaporation is still the desalination technology of choice mainly due to access to lower-cost fuel and traditional use of facilities co-generating power and water.

Membrane Technology and Cost Trends

Developments in SWRO desalination technology during the past two decades, combined with transition to construction of large capacity plants, colocation with power plant generation facilities, and enhanced competition by using the Build-Own-Operate-Transfer method of project delivery, have resulted in a dramatic decrease in the cost of desalinated water.

One of the key factors that contributed to the dramatic decrease of cost of seawater desalination is the advancement of SWRO membrane technology. Today's high-productivity membrane elements are designed with features to yield more fresh water per membrane element. These features are: 1) higher surface area and 2) denser membrane packing. Increasing active membrane leaf surface area allows significant productivity gains using the same size (diameter) membrane element. Active surface area of the membrane leaf is typically increased by improving and automating the membrane production process.

The total active surface area in a membrane element can also be increased by increasing membrane size/diameter. Although eight-in. SWRO membrane elements are still a standard size for most large full-scale applications, larger 16-in. and 18-in. membrane elements are currently commercially available. In the second half of the 1990s the typical eight-in. SWRO membrane element had a standard productivity of 5,000 to 6,000 gpd at salt rejection of 99.6 percent. In 2003, several membrane manufacturers introduced high-productivity seawater membrane elements that can produce 7,500 gpd at salt rejection of 99.75 percent. Just one year later, even higher productivity (9,000 gpd at 99.7 percent rejection) seawater membrane elements were released. Membrane elements combining productivity of 12,000 gpd and high-salinity rejection are expected in the not-so-distant future.

The newest membrane elements provide flexibility and choice and allow a tradeoff in pressure/power costs. The same water product quality goals can be achieved either by 1) reducing the system footprint/construction costs by designing the system for higher productivity or 2) by reducing the system's overall power demand by using more membrane elements, designing the system at lower flux and recovery, and taking advantage of the newest energy recovery technologies, which further minimize energy use if the system is operated at lower (40 to 45 percent) recoveries.

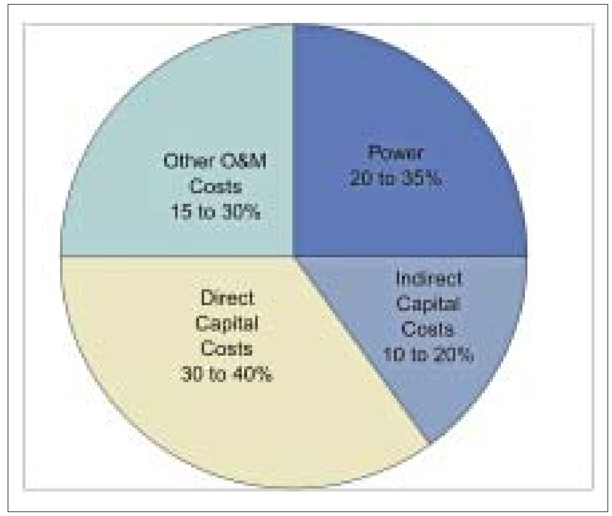

Figure 1. Desalination Cost Breakdown.

Energy is among the largest expenditures associated with seawater desalination. Figure 1 shows a typical breakdown of seawater desalination costs. Advances in the technology and equipment that allow recovery and reuse of the energy applied for seawater desalination have resulted in an 80-percent reduction of the energy used for water production over the last 20 years. Today, the energy needed to produce fresh water from seawater for one household per year (~2,000 kW/yr) is less than that used by the household's refrigerator.

At present, the majority of the existing seawater desalination plants use Pelton Wheel-based technology to recover energy from the SWRO concentrate. The largest Pelton Wheel system in the world is installed at the 36-mgd Point Lisas seawater desalination plant in Trinidad. This power plant uses about 14.4 kWh/1,000 gal of produced fresh water. Pelton Wheel systems allow recovery of 25 to 35 percent of the power initially applied by the SWRO system's feed pumps.

Over the past few years, Pelton Wheel energy recovery systems have begun to give way to a newer, pressure-exchanger based technology. The key feature of this technology is that the energy of the SWRO system concentrate is directly applied to pistons that pump intake seawater into the system. Pressure-exchanger technology typically yields five to 15 percent higher energy recovery savings than Pelton Wheel-based systems. Therefore, pressure exchangers have been installed on most large desalination plants built in the last three years and are planned for some of the largest projects under implementation, such as the 53-mgd Hamma, Algeria, plant and the 37-mgd desalination plant for the City of Perth, Australia. Pressure exchangers are used for practically all large seawater desalination projects built in the last two years.


Largest Pelton Wheel energy recovery system in the world in Trinidad.

In 2005, a group of U. S. federal and state agencies, public utilities, and private desalination industry leaders formed the Affordable Desalination Collaboration (ADC, www.affordabledesal.com) team, which is designing a SWRO plant aimed to achieve the lowest possible power demand using state-of-the-art pumping and energy

The pressure exchanger system of the Ashkelon seawater desalination plant, which currently is the largest system of this type in the world. This plant has broken the energy use barrier of 13.2 kWh/m^3 established by previous projects for intake salinity in the range of 38 to 41 ppt.

recovery equipment and the latest membrane technology. The ADC team has installed a pilot SWRO plant at the U. S. Navy's test facility in Pt Hueneme, CA, and operated it for over nine months. The results of this study show that potable water with salinity of less than 500 mg/L can be produced from Pacific Ocean water (salinity concentration of 33,500 mg/L) using less than 10.0 kWh/1,000 gal of energy. The main constraints associated with achieving such low energy use in large-scale desalination plants are the quality of the product water in terms of boron, chlorides, and bromides, and the efficiency of available off-the-shelf pumps and motors used for source water collection, transfer, and feed to the SWRO system. Often, the aforementioned product water quality targets are driven by other more stringent uses, such as irrigation of boron- or chloride-sensitive crops and ornamental plants, rather than by water quality requirements for human consumption. Achieving these goals requires addition of one or more water quality polishing facilities after then main SWRO desalination process, which in turn increases the overall energy consumption for water production.

While the quest to lower energy use is continuing, there are physical limitations to how low the energy demand can go when using reverse osmosis desalination. The main limiting factors are 1) the osmotic pressure that must be overcome to separate the salts from the seawater and 2) the amount of water that could be recovered from a cubic meter of seawater before membrane separation process is hindered by salt scaling on the membrane surface and the service systems. The practical limit for the entire seawater desalination plant and Pacific Ocean seawater is about 6.0 kWh/1,000 gal.

ADC seawater desalination facility in Pt Hueneme, CA.

The Future

Future improvements of SWRO membrane technology are forecast to encompass:

- Development of membranes with higher salt and pathogen rejection and productivity.
- Improvement of membrane resistance to oxidants, elevated temperature, and compaction.
- Extension of membrane useful life beyond ten years.
- Integration of membrane pretreatment, advanced energy recovery, and SWRO systems.
- Integration of brackish and seawater desalination systems.
- Development of new generation of high-efficiency pumps and energy recovery systems for SWRO applications.
- Replacement of key stainless steel desalination plant components with plastic components to increase plant longevity and decrease overall cost of water production.
- Reduction of membrane element costs by complete automation of the entire production and testing process.
- Development of methods for low-cost continuous membrane cleaning to reduce downtime and chemical cleaning costs.
- Development of methods for low-cost membrane concentrate treatment, in-plant and off-site reuse, and disposal.

These technological advances are expected to ascertain the position of SWRO treatment as viable and cost–competitive processes for potable water production and to reduce the cost of desalinated water by 20 percent in the next five years and by up to 50 percent by 2020 GE

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