Sustainability Spotlight

Sustainability Research

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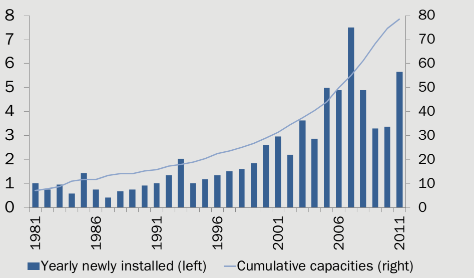
Seawater – vital source of drinking water for millions

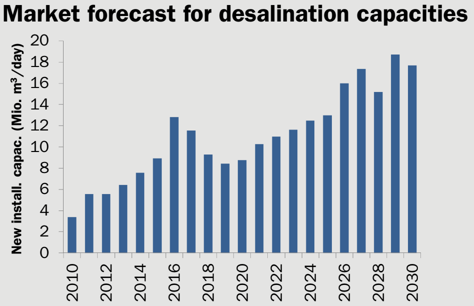
- **In many areas soaring demand for drinking water can only be satisfied by desalination of seawater. Desalination capacities have risen by 57% over the last five years.**
- **Environmental damage, high energy consumption and high costs represent major challenges for these technologies and need to be reduced.**
- **Desalination plants in the Earth's sunbelt regions will increasingly use solar energy – a combination that offers interesting investment opportunities.**

Expansion of desalination plants



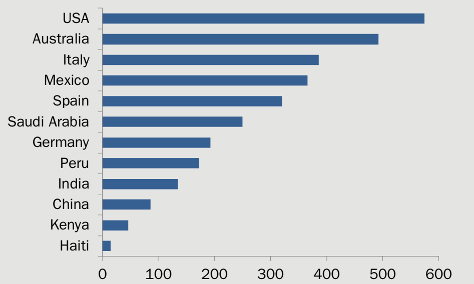
Source: Torishima Pump Mfg.

Market forecast for desalination capacities



Source: GWI, Global Water Intelligence; Hyflux

Daily water consumption per head (litres)



Source: UNDP; Human Development Report 2006

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More drinking water from desalination

Worldwide some 1.2 bn people live in areas affected by drought. Because of relentless population growth and climate change, as much as two thirds of civilisation could suffer from occasional water shortages by 2025. As a result, the desalination of seawater or brackish water is becoming increasingly important as an additional source of drinking water. Many coastal cities have to resort more to desalination facilities. In certain regions well away from the coast, groundwater is becoming increasingly salty and requires treatment. 60% of the desalination plants process seawater and 40% slightly saline groundwater. Today around 70 mn people (1% of the Earth's population) rely on desalinated water.[1] 150 countries now have desalination plants and in 2011 newly installed capacities amounted to 5.6 mn m^3/day (y/e 2011 cumulative 78.4 mn m^3/day.[2] This is 57% more than y/e 2006. Av. daily water consumption per head varies from 575 l in the USA to 14 l in Haiti.

[1] GWI, Global Water Intelligence, 2011

[2] IDA, International Desalination Association; GWI, 2012

Steady global growth

In 2012 desalination plants worth around USD 8.9 bn came on stream. In regions such as the Gulf States, Australia, Central Asia, the USA and the Mediterranean, desalination is becoming an increasingly important solution for filling the gap between dwindling reserves of potable water and soaring demand. Desalination plant capacity is therefore predicted to grow by around 19% every year in future.[3] In 2030 the annual newly installed capacities could reach 17.7 mn m^3/day. The market for desalination plants will increase to USD 18 bn by 2016 and this throws up interesting investment opportunities.

Technology comparison

The two most important technologies used for desalination are reverse osmosis (RO) and multistage flash distillation (MSF). There are also less commonly used processes such as multi-effect distillation (MED) and electro dialysis (ED).

[3] GWI, Global Water Intelligence, 2012

Reverse osmosis (RO)

With the RO process, the saline water is forced under enough force to overcome the osmotic pressure through a semi-permeable membrane made of polyamide, PTFE[4] or sulphonated copolymers with a pore diameter of between 0.5 and 5 nanometres (nm). Such a membrane acts as a filter and only lets through certain ions and molecules. This process traps 99.9% of the original salt content. Applying a pressure of between 70 and 84 bar, 40 to 60% of seawater can be converted into drinking water. The residual filtrate is returned to the sea as brine. The membrane filter is capable of trapping salts, bacteria, viruses, excess calcium, and toxins such as heavy metals. The biggest membrane producers are *Dow Chemical* (32% market share), *Nitto Denko* (28%), *Toray* (28%) and *Toyobo* (8%). In 2011 the global membrane market was worth USD 660 mn and could grow by around 9% a year in future.

Multistage flash evaporation

Multistage flash evaporation (MSF) is a thermal process where seawater is heated up to 115 °C using recycled energy from a power station. The saltwater is heated into steam in downstream evaporation stages under a vacuum, the water vapour condenses on cooled heat exchanger pipes in a series of stages and is then collected as desalinated water. Through the evaporation process the residual water becomes increasingly saturated with salt.

Multi-effect distillation (MED)

This process preceded the MSF method and is in fact the oldest desalination technology. It was first used in the early part of the 19th century for producing sugar. The MED process comprises several "effects" or stages, each one fitted with a heat exchanger comprising a bank of tubes. The feed water is sprayed over this bank of tubes, which is heated from the inside by condensing steam. As the heat is transported over the wall of the tube, part of the condensate on the outer side of the tubes evaporates. The steam produced is used to heat the next stage, where it once again condenses on the inner side of the bank of tubes. Only the first stage or "effect" is heated by an external steam source.

[4] Polytetrafluorethylene or "Teflon"

Comparison of both common desalination technologies

	Reverse osmosis (RO)	Multistage flash evaporation (MSF)	Multi-effect distillation (MED)/others
Percentage of global capacities	60%	27%	13%
Prod. cap. per unit (1000 m^3/day)	20 - 320	70 - 500	30 - 270
Electr. energy per m^3 (kWh)	4.0 – 4.5	3.0 – 4.0	1.2 – 2.0
Thermal energy per m^3 (kWh)	-	81	74
Solar technology applicable	PV	Thermal, PV	Thermal, PV
Pre-treatment	critical	minimal	minimal
Consumption of chemicals	high	low	low
Fouling hazard	high	low	low
Capital costs	low	high	medium
Operating costs incl. amort. (USD/m^3/day)	0.76	1.07	0.83
Water/steam temperature (°C)	n/a	115	65

Source: GWI, 2011

Costs and energy consumption

Despite massive improvements over the last 50 years, desalination is still an expensive and energy-intensive process. On the plus side, the electricity consumption of a desalination plant has been reduced from 12 kWh/m^3 in the 1970s to around 3 to 4 kWh/m^3. Even so, the heat and electricity consumption is still the most important cost factor, along with the amortisation of the capital investment. Thanks to technological advances, reverse osmosis has been the most cost-effective desalination method since 2001. Compared with the MSF method, it requires less energy, incurs lower construction costs and its modular design offers better scalability for individual plants. Substantial progress has also been made in preventing the membranes from becoming dirty and clogged.

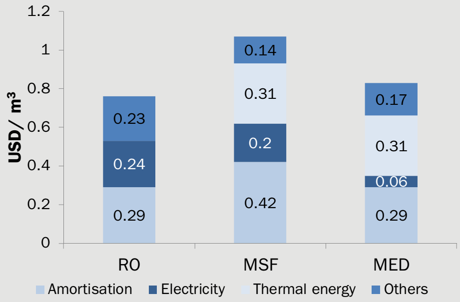
A comparison of all desalination plants either planned or under construction in the Middle East shows that 91% of all projects - equivalent to 54% of capacities – use reverse osmosis[5].

The next chart compares the relative operating costs of the most important desalination technologies for every cubic metre of drinking water produced, including the amortisation of capital costs. RO is the most cost-efficient variant, at 0.76 USD/m^3 compared with the two thermal technologies MED (0.83) and MSF (1.07).

Despite the clear cost advantages of the RO technology, thermal processes are sometimes favoured at certain locations due to the synergy effects they offer with a power station producing electricity.

[5] Desaldata.com, 2012

Total cost of individual technologies



Source: GWI 2011

In the Middle East there has been a major trend towards such dual-purpose water/energy installations. This structure allows the excess heat generated during electricity production to be recycled for use in the desalination process. In the Gulf States especially, these cogeneration plants only have to pay a fraction of the global market price for their oil and gas. This can drastically change the cost/benefit profile. Furthermore, the resulting brine can be diluted with the returned cooling water and fed back into the sea.

Environmental impact underestimated

Many decision-makers in political and industry circles tend to ignore the environmental impacts of desalination plants. Many forget that despite improved efficiency, these plants consume far more energy than traditional water treatment facilities. In cases where these plants are powered by fossil fuels, they produce substantial greenhouse gas emissions that contribute towards climate change and ultimately also towards worse drought conditions in many areas. These massive industrial facilities disfigure long stretches of the coastline and the salt removed during the process is discharged back into the sea as concentrated brine. This alters salt levels in local areas, with negative consequences for fish stocks, coral reefs and aquatic plants.

In rich but arid regions such as the Mediterranean, Australia and the Gulf States, as well as the USA, very little attention is paid to water conservation. The dilapidated infrastructure means that a substantial proportion of the drinking water is lost through leaking pipes. Before simply investing in yet another desalination plant, wherever possible all the available options for saving water, modernising supply networks and recycling grey water need to be investigated first. In certain cases a desalination plant could well make sense. Beforehand, however, careful management of water resources is a cheaper and more effective option for society and nature.

10 leading companies in the desalination business

Company (Country)	Pretreatment	EPC-Contract	RO	MSF	MED/Other	% of sales from water*	Water sales 2011 in mn EUR	Sustainable company
Abengoa (Spain)		✓	✓	✓	✓	< 1%	21	Y
Acciona (Spain)	✓	✓	✓			< 10%	412	Y
Consolidated Water (Cayman)		✓	✓			100%	55	N
Degrémont/Suez Environn. (France)	✓	✓	✓	✓	✓	33%	1 584	Y
Doosan Heavy Industries (Korea)	✓	✓	✓	✓	✓	10%	5 760	N
GE Water (USA)		✓	✓	✓	✓	< 20%	31 000	N
Hyflux (Singapore)	✓	✓	✓			100%	289	Y
IDE Technologies (Israel)**		✓	✓		✓	100%	112	Y
Keppel (Singapore)	✓	✓	✓	✓	✓	< 20%	2 860	Y
Veolia Environnement (France)	✓	✓	✓	✓	✓	> 40%	12 600	Y

Source: Bank Sarasin, 2013; *as a % of company's total sales; **unlisted

Solar-powered desalination offers enormous potential

The combination of solar energy and desalination enables greenhouse gas emissions to be reduced and fossil resources to be used more prudently.

Of the 78.4 mn m^3/day total global desalination capacities installed at the end of 2011, less than 0.5 mn m^3 were powered by solar energy. The biggest facility is located in Australia and uses a combination of solar power and natural gas. Unlike electricity, drinking water is easy to store. This makes it possible to decouple production and consumption. Desalination is therefore an ideal technology when used in combination with solar and wind power, where the output fluctuates.

<u>The new dream team: PV and RO</u>

In recent years both photovoltaics (PV) and reverse osmosis (RO) have made enormous technological advances which have resulted in significant efficiency improvements and cost savings. Both systems are easily scalable and can be used in combination to serve either remote villages or large conurbations. As highlighted in the solar report published by Bank Sarasin in November 2011, electricity generation costs have fallen much quicker for PV than for concentrating solar power (CSP). Because of this ideal fit, we expect to see more desalination plants in future based on the technological "dream team" of PV and RO.

<u>Saudi Arabia as an important test market</u>

This hot and arid kingdom current requires 1.5 mn barrels of crude oil a day to cover its demand for water, with more than 70% produced by desalination plants (10 mn m^3/day). Of the 15,000 desalination plants installed, only 1% use renewable energy, mainly solar power. The quantity of oil needed to operate the rest of the desalination plants is equivalent to half the kingdom's entire domestic oil consumption, or around 15% of the daily oil output of approximately 10 mn barrels. In future we expect to see far more RO desalination plants powered by PV technology across the entire Middle East.

New technology: Forward Osmosis (FO)

With the forward osmosis (FO) process, the drinking water is "drawn" from the salt water through a membrane by employing the osmosis technique. No hydraulic pressure is applied, but instead a more highly concentrated salt solution than the seawater (e.g. using ammonium bicarbonate, NH_3CO_2) is used to create high osmotic pressure. This encourages the freshwater to be "sucked" through the semipermeable membrane without requiring significant pump pressure. This technique means that the membrane does not become as clogged as it does in the RO process. Raising the temperature to 50° C separates the NH_3CO_2 into ammonium and carbon dioxide, which can then be recycled. This process requires only about 20% of the energy used in the RO process, while costs can be cut by up to 30%. Several companies are continuing to develop this technology. *Oasys* (USA) has started with the sale of its polyamide thin-film membrane for the FO process. *Modern Water* (UK) has already built two FO pilot plants in Gibraltar and Oman. *HTI* (USA) launched its "OsMem FO Membrane" in 2010. Two years ago it signed a distribution agreement with *Tri-Tech Holding* (China) to sell its FO technology in China. Initial experiences with the FO technology have been very promising and it should be able to win market share in future.

Conclusions

Most global industrial companies are active in the water or desalination industry. Water accounts for between 1% and 40% of sales. The following companies are rated as sustainable: *Abengoa, Acciona, Dégremont/Suez, Keppel* and *Veolia*. The only "pure play" water stock is the company *Hyflux*.

Other pure players such as *Modern Water* (market cap. GBP 32 mn) and the unlisted companies *HTI* and *Oasys* are active in forward osmosis. The FO technology offers dramatic reductions in energy consumption and has substantial growth potential.

By using renewable energies, the energy consumption required for the desalination process can also be produced in a sustainable way.

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