Desalination Market

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Desalination Industry (1)

In some countries, the cost of water produced in even seawater desalination plants is already lower than from any other method, (especially in cases where the natural resources are limited).

Saudi Arabia ranks first in total capacity (about 24% of the world's capacity), with most of it being made up of seawater desalting units that use the distillation process.

The United States of America (USA) ranks second in overall capacity, with about 16 %. Most of the capacity in the USA consists of plants in which the RO process is used to treat brackish water.

Desalination Industry (2)

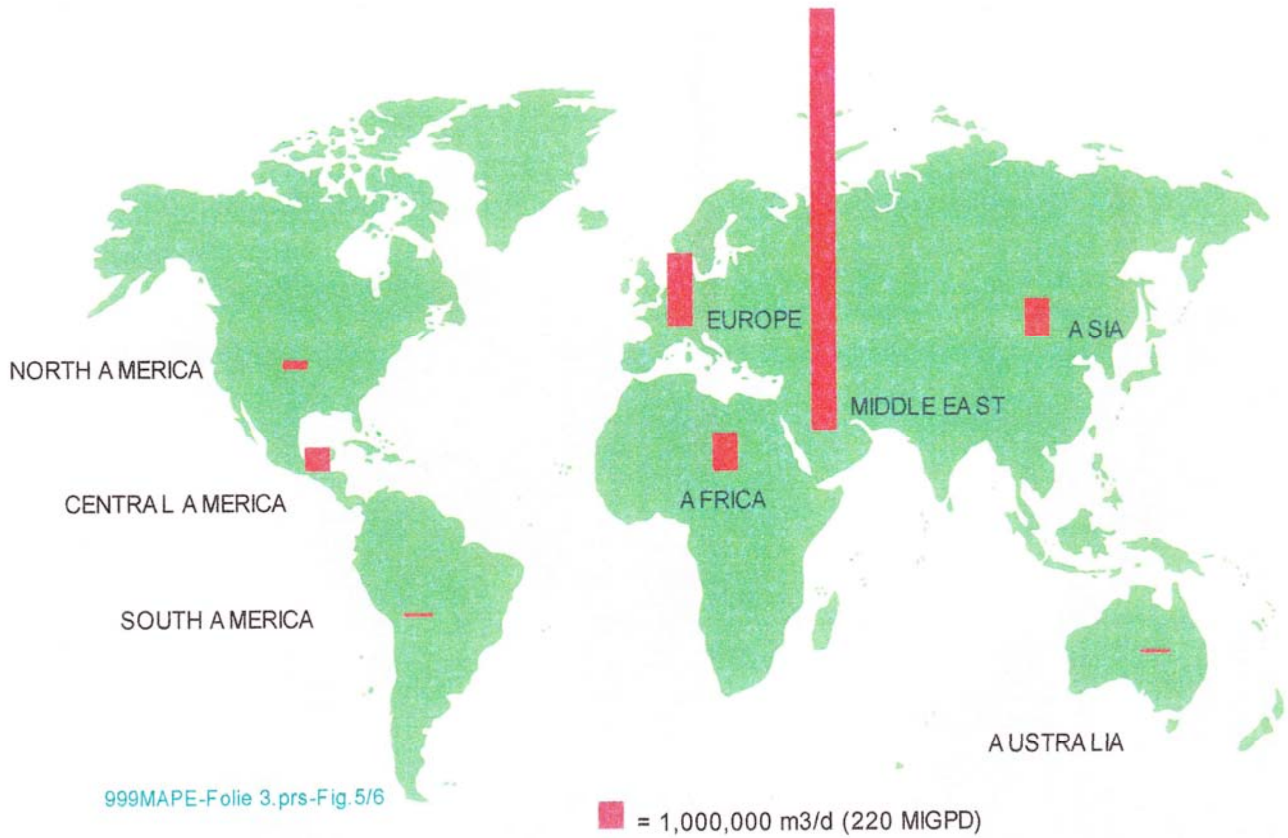
The world's installed capacity consists mainly of the MSF distillation and RO processes.

These two processes make up about 84% of the total capacity.

In recent years, the industry has achieved great advances in RO technology, and since the 1970s new membrane capacity has exceeded new distillation capacity.

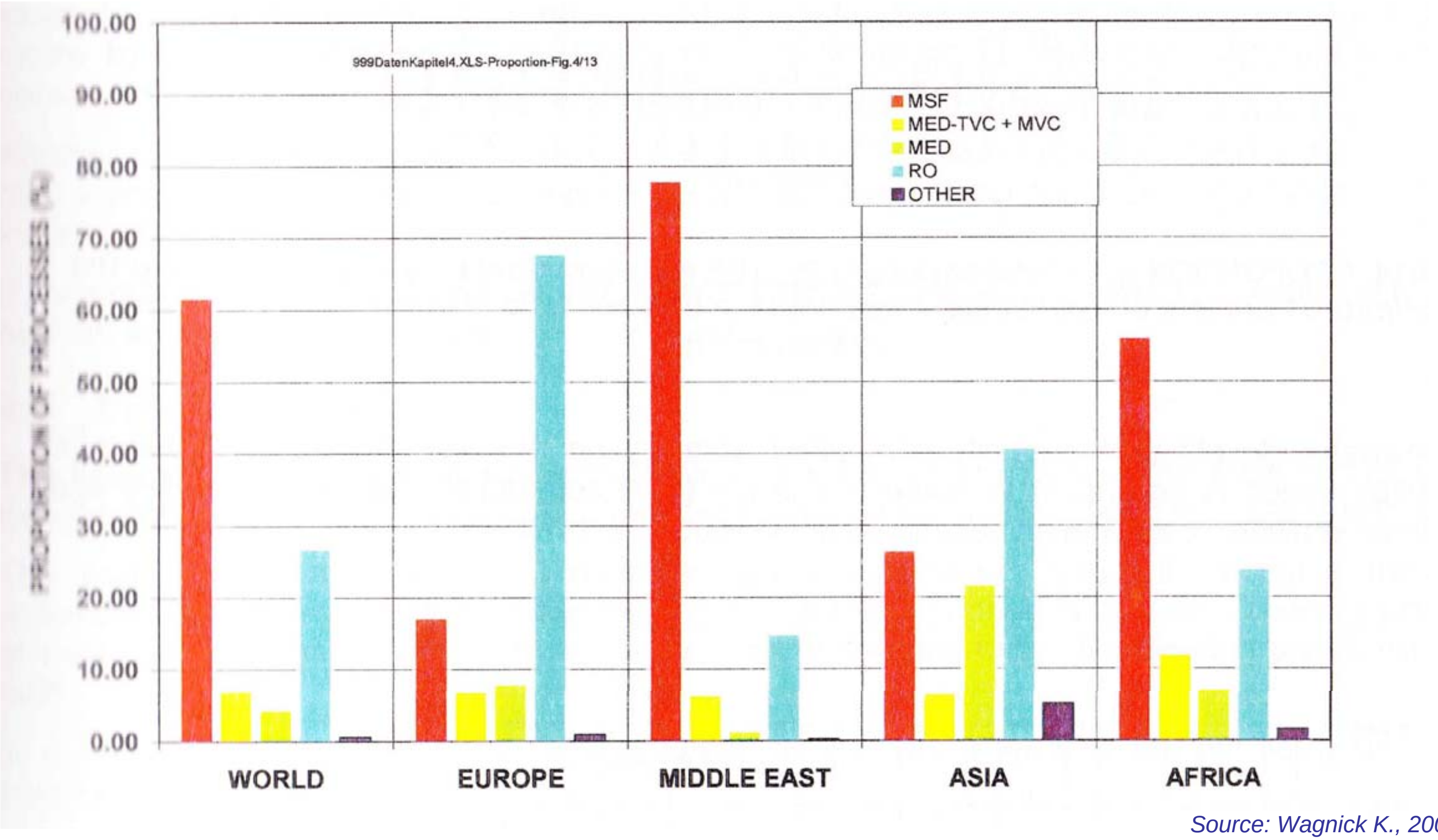
The remaining 15% is made up of the Multiple Effect, Electrodialysis, and Vapor Compression processes, while the minor processes amounted to less than 1%.

Capacity of land-based desalting plants capable of producing 100m³/day/unit of fresh water using sea water



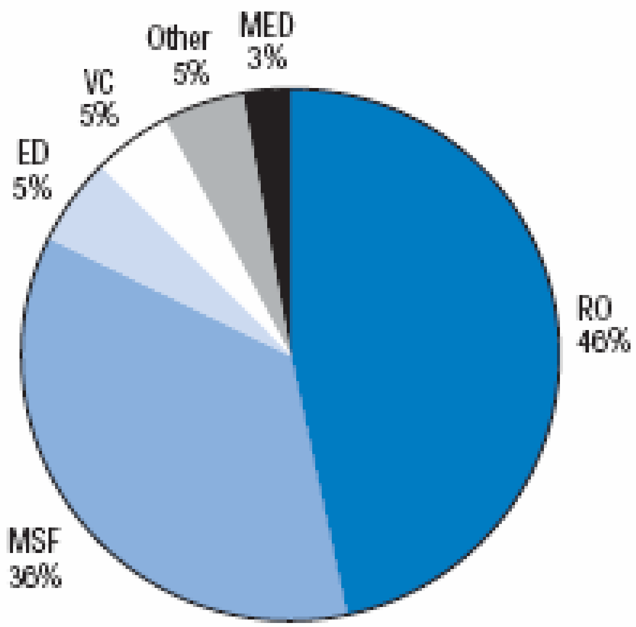
Source: Wagnick K., 2004

The majority of the desalination plants, especially in the Middle East, operate according to the MSF process, whereas in Europe, the majority operate according to the RO process.



Source: Wagnick K., 2004

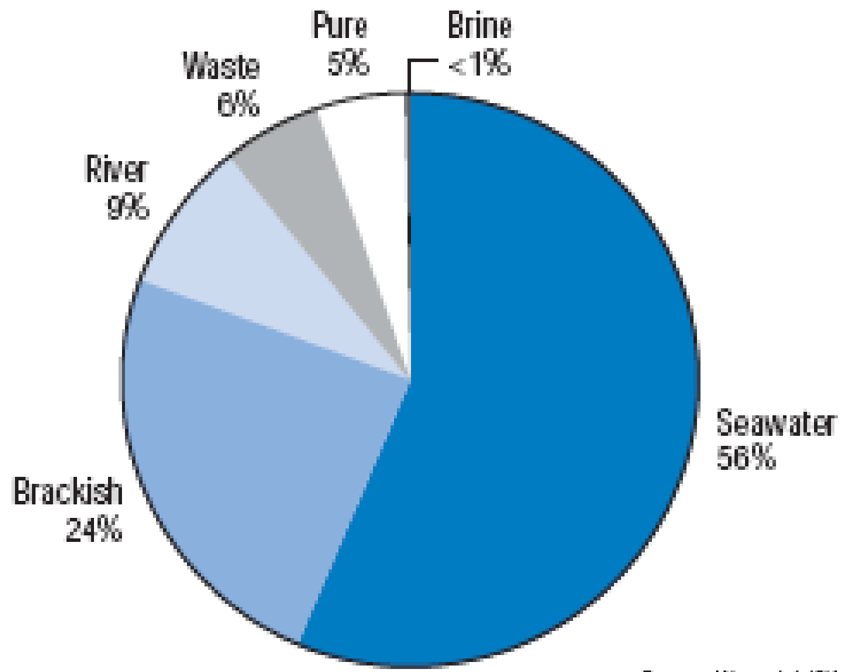
Market Share of Desalination



ED = electrodialysis
MED = multi-effect distillation
MSF = multi-stage flash
Other = freeze, hybrid, nanofiltration, thermal, and all other processes
RO = reverse osmosis
VC = vapor compression

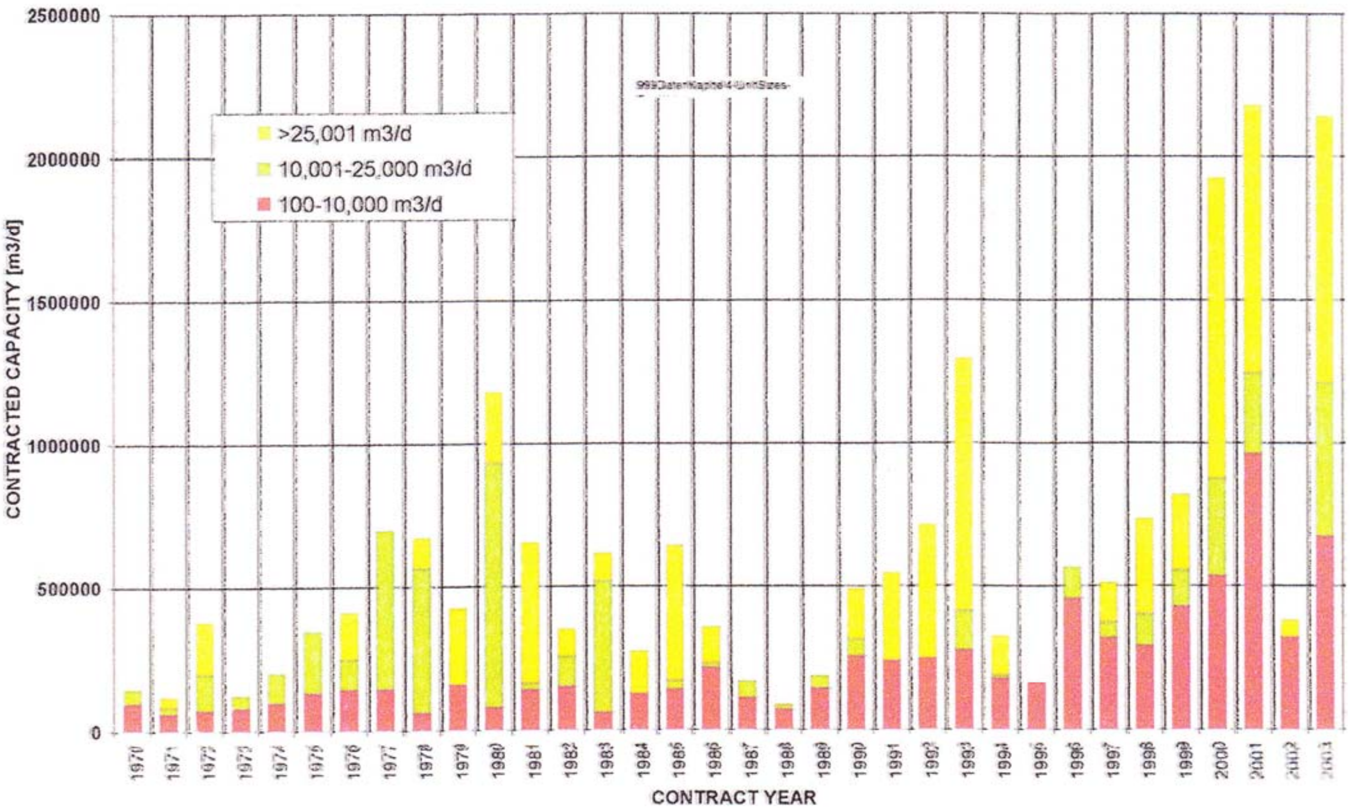
Source: Wangnick/GWI 2005

Global Desalination Capacity by Source Water



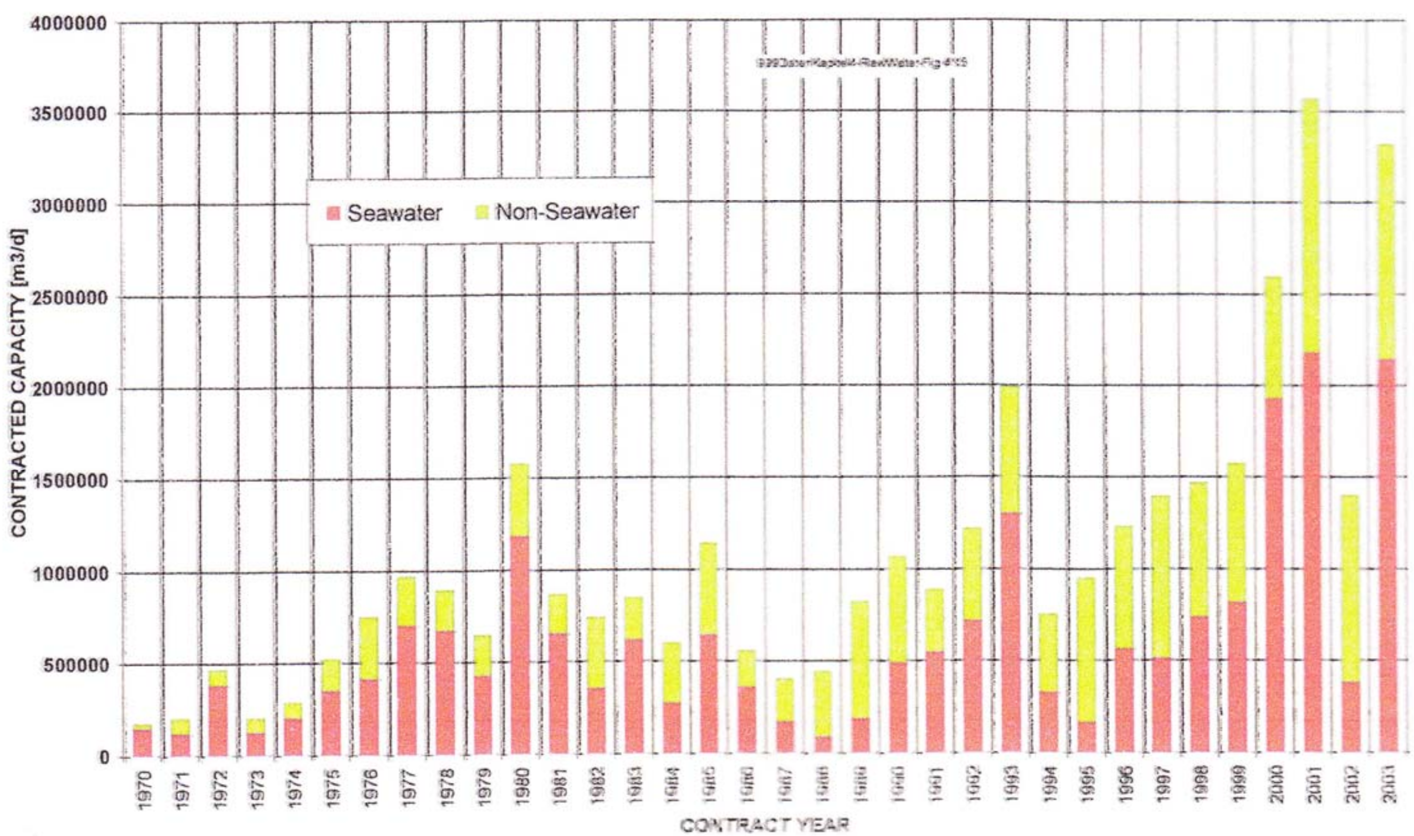
Source: Wangnick/GWI 2005

Proportion of all land-based seawater desalting plants with capacities from 100 up to 25,000 m³/day vs contract year



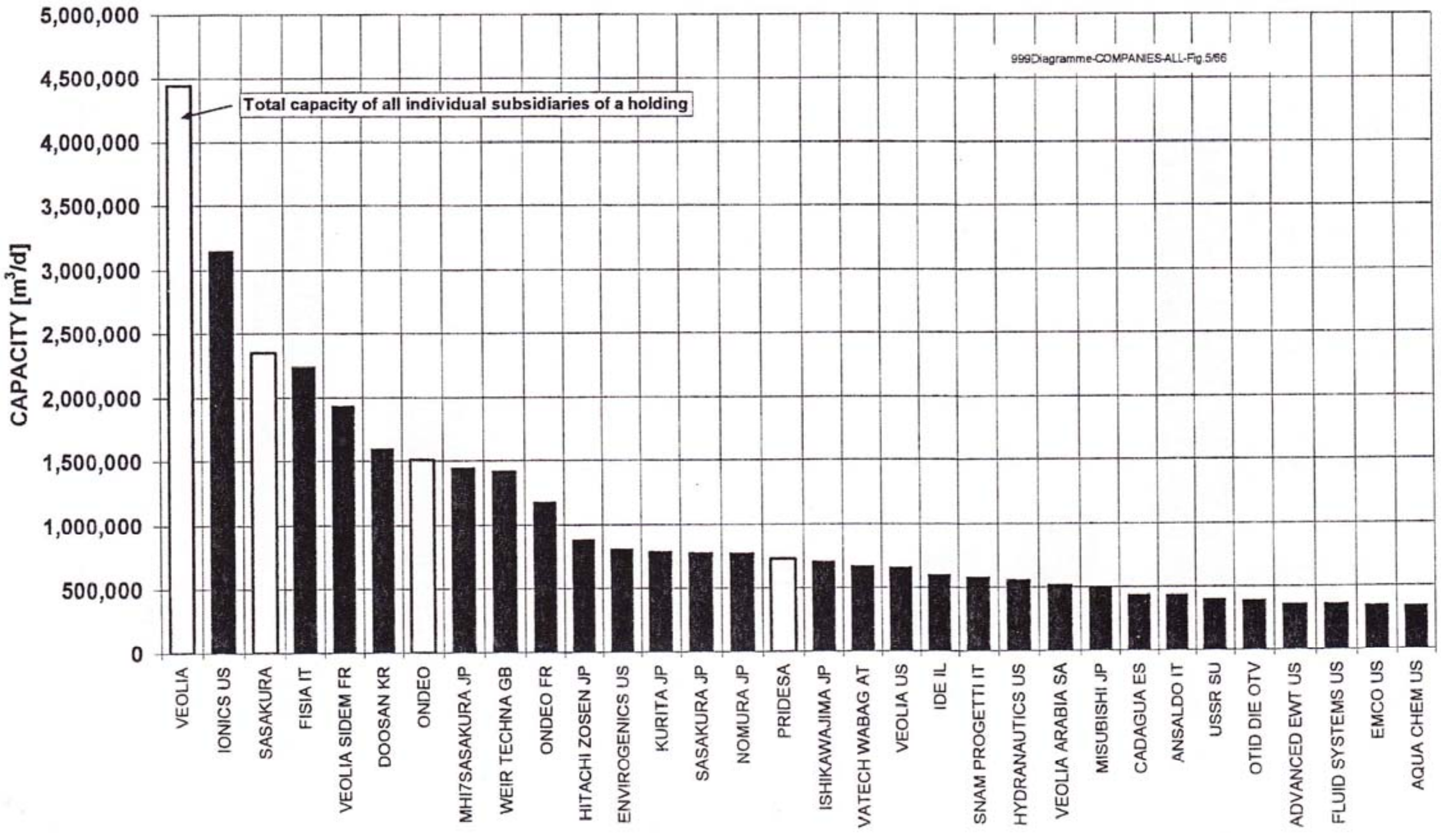
Source: Wagnick K., 2004

Capacity of land-based seawater desalting plants with capacities of 100 m³/day or more vs contract year



Source: Wagnick K., 2004

Capacity of all land-based desalting plants capable of producing 100 m³/day or more of fresh water vs manufacturer



Source: Wagnick K., 2004

Other Processes

Freezing

Membrane Distillation

Humidification - Dehumidification

Solar Stills

Dual purpose plants - Cogeneration

Hybrid

Other Desalination Processes

A number of other processes have been used to desalt saline water. These processes have not achieved the level of commercial success that RO and distillation have.

These are:

- Freezing
- Membrane Distillation
- Humidification - Dehumidification
- Solar stills
- Dual purpose plants - Co-generation
- Hybrid

Freezing

Freeze separation takes advantage of the insolubility of salts in ice. When ice crystals form, dissolved salts are naturally excluded. If the resulting pure ice crystals can be separated from the brine, desalinated water can be produced.

Extensive work was done in the 1950s and 1960s on separation technology using freezing of water.

Freezing has some theoretical advantages over distillation, including a lower minimum energy requirement, minimal potential for corrosion, and little scaling or precipitation.

Among the disadvantages, however, is the difficulty of handling and processing ice and water mixtures.

A small number of demonstration plants have been built over the past 40 years but, except for the treatment of some industrial wastes, the process has never proven commercially feasible.

Membrane Distillation

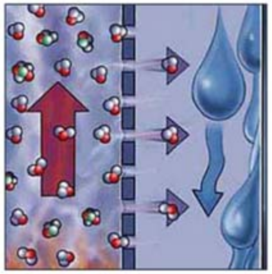
Membrane distillation (MD) combines the use of both thermal distillation and membranes and was introduced commercially on a small scale in the 1980s. The process relies primarily upon thermal evaporation and the use of membranes to pass vapor, which is then condensed to produce fresh water.

In the process, saline water is warmed to enhance vapor production, this vapor is exposed to a membrane that can pass water vapor but not liquid water. After the vapor passes through the membrane, it is condensed on a cooler surface to produce fresh water. In the liquid form, the fresh water cannot pass back through the membrane, so it is trapped and collected as the output of the plant.

Thus far, MD has been used only in a few facilities, since it requires more space, more pumping energy per unit of fresh water produced, and more money than other approaches. The main advantages of MD lie in its simplicity and the need for only small temperature differentials to operate.

MD is probably best suited for desalting saline water where inexpensive low-grade thermal energy (60-80^{o}C) is available, such as from industries or solar collectors.
Commercially it is of little significance.

Once the vapor has passed through the hydrophobic membrane, it can be extracted or directly condensed in the channel on the other side of the membrane.



MD Module

Properties of MD-modules

Source: Fraunhofer ISE, Germany

- Dimensions: diameter 30-40 cm, height 85 cm
- distillate output 10-30 l/h (80°C evaprator inlet, 300 l/h feed flow)
- thermal energy demand about 90 to 200 kWh per m³
- Wide range of operation temperatures possible (50°C to 85°C)
- favourable behaviour under dynamic operation conditions
- no pre-treatment of feed water
- high quality of water because of distillation (conductivity of distillate 5 to 50 µS/cm)
- modular set up for systems from 100 to 20000 litres per day

Humidification - Dehumidification process

In the Humidification - Dehumidification process a dry air stream is enriched in vapour in a humidification unit and then the vapour is re-condensed in a de-humidification unit where fresh water is collected.

These processes seem to be well promising, first for the high efficiency and secondly for the possibility of using renewable energies to power them, for instance the use of direct solar energy for desalting saline water.

These devices generally imitate a part of the natural hydrologic cycle in that the sun's rays heat the saline water so that the production of water vapor (humidification) increases.

The water vapor is then condensed on a cool surface, and the condensate collected as fresh water product. An example of this type of process is the greenhouse solar still, in which the saline water is heated in a basin on the floor, and the water vapor condenses on the sloping glass roof that covers the basin.

Solar Stills

Solar distillation is a process in which the energy of the sun is directly used to evaporate fresh water from sea or brackish water. The process has been used for many years, usually for small scale applications.

Well designed units can produce around 2.5 l/m^2 per day with a thermal efficiency of 50%.

Source: CRES

Kastelorizo island, Greece

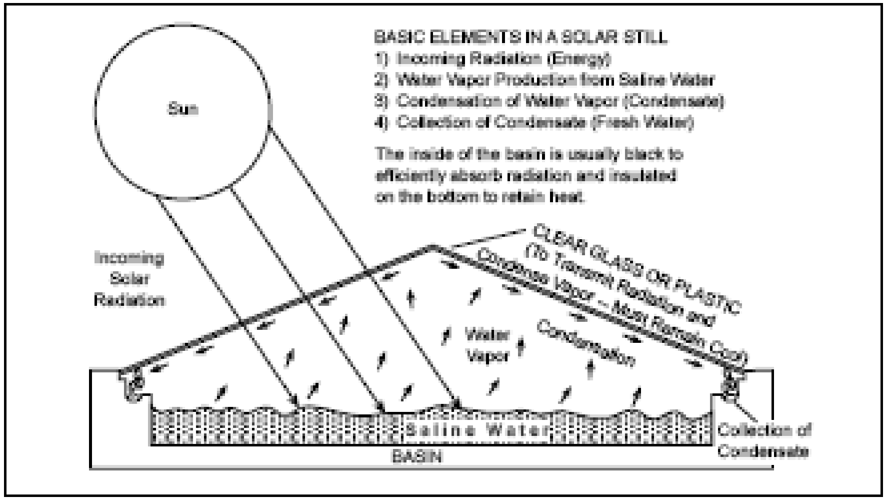


Diagram of a solar still — *USAID*

Solar stills are simple in operation and maintenance. The only maintenance required is the cleaning of the plant, especially of the glass roof.

Dual Purpose - Co-generation Plants

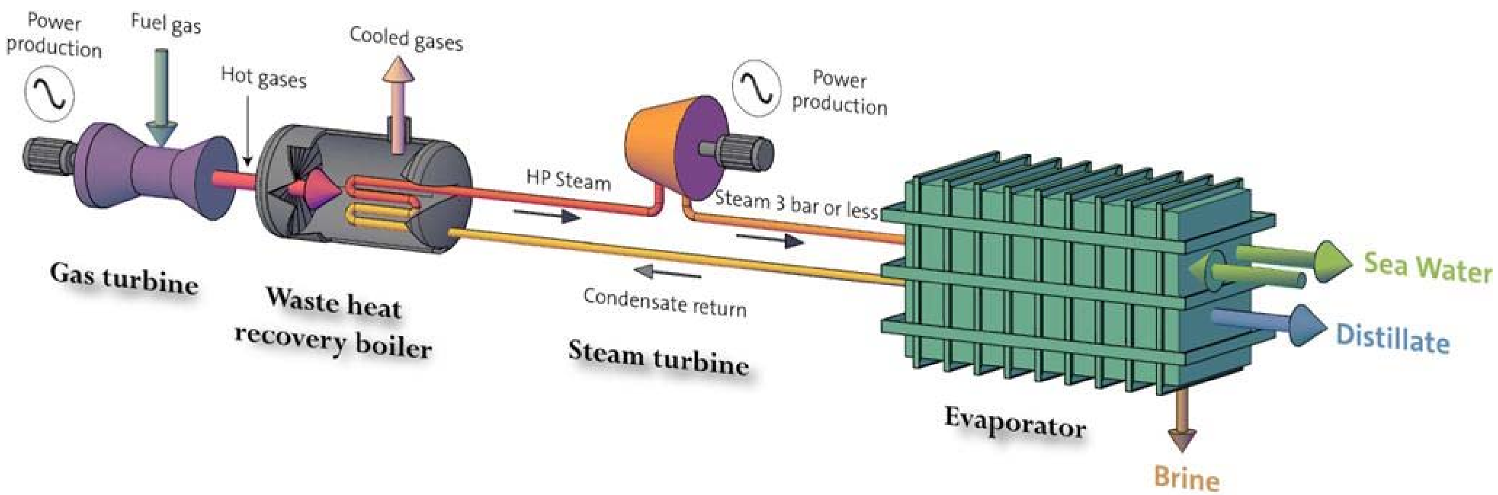
In some situations, it is possible to use energy so that more than one use can be obtained from it as the energy moves from a high level to an ambient level.
This occurs with co-generation where a single energy source can perform several different functions.

Certain types of desalination processes, especially the distillation process, can be structured to take advantage of a co-generation situation. Most of the distillation plants installed in the Middle East and North Africa have operated under this principle since 1960s and are known in the field as dual purpose plants (water plus power).
These units are built as part of a facility that produce both electric power and desalted seawater for use in a particular country.

The main advantage of a co-generation system is that it can significantly reduce the consumption of fuel when compared to the fuel needed for two separate plants. Since energy is a major operating cost in any desalination process, this can be an important economic benefit.

Dual purpose (power-water) facility in Saudi Arabia
Photo — SWCC

One of the disadvantages is that the units are permanently connected together and, for the desalination plant to operate efficiently, the steam turbine must be operating.
This permanent coupling can create a problem with water production when the demand for electricity is reduced or when the turbine or generator is down for repairs.



Source: SIDEM, France

Example of a Cogeneration plant

The electricity is produced with high-pressure steam to run turbines that in turn power electric generators.

In a typical case, boilers produce high-pressure steam at about 540^{o}C. As this steam expands in the turbine, its temperature and energy level is reduced.

Distillation plants need steam whose temperature is below 115^{o}C, and this can be obtained by extracting the lower temperature steam at the low pressure end of the turbine after much of its energy has been used to generate electricity.

This steam is then run through the distillation plant's brine heater, thereby increasing the temperature of the incoming seawater.

The condensate from the steam is then returned to the boiler to be reheated for use in the turbine.

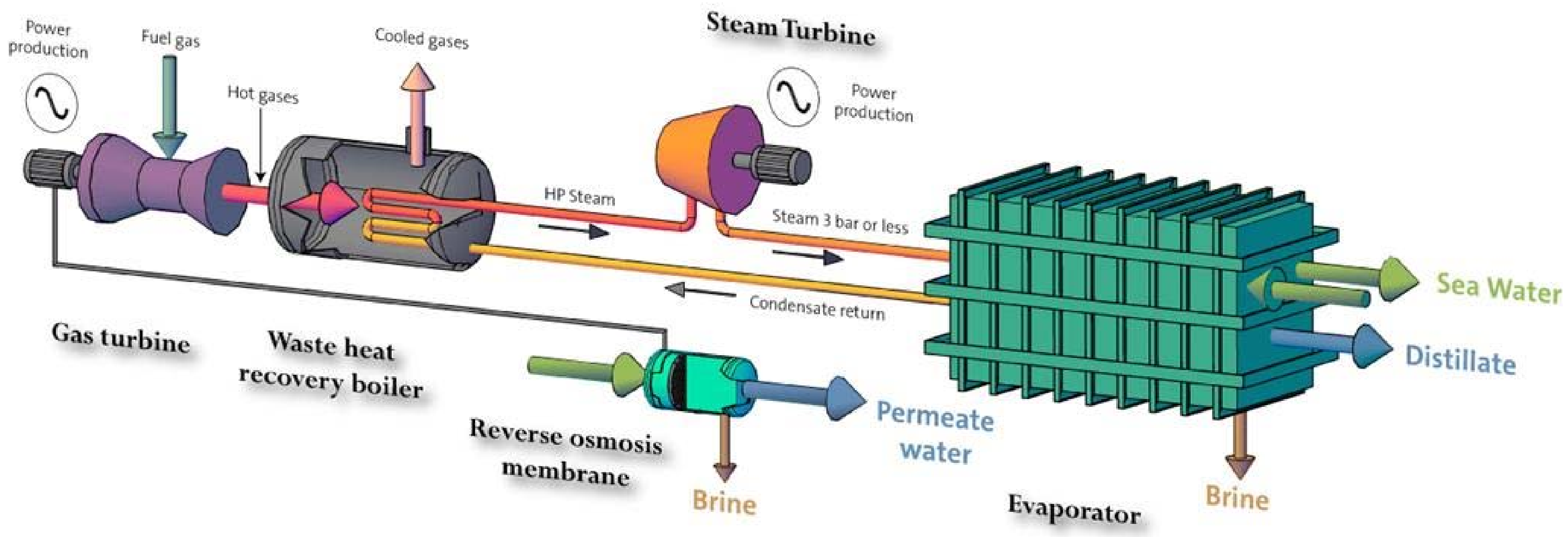
Hybrid Plants

Another method of reducing the overall costs of desalting can be the use of hybrid systems. Such hybrid systems are not applicable to most desalination installations, but can prove to be an economic benefit in some cases.

A hybrid system is a treatment configuration made up of two or more desalination processes. An example is using both distillation and RO processes to desalt seawater at one facility and to combine the different characteristics of each process productively.

Hybrid systems provide a better match between power and water development needs.

An example of a hybrid system could be the use of steam in a dual-purpose plant (electricity and water). The steam is used in a distillation plant to desalt seawater. The product water from the distillation unit has a low level of total dissolved solids, perhaps 20 mg/L. Alongside the distillation plant could be a seawater RO plant that would be run only in off-peak power periods. This would help to stabilize the load on the generator and therefore use lower cost electricity. The RO plant could be designed to produce water with a higher level of total dissolved solids and, thus, also lower its production costs.



Source: SIDEM, France

Desalination Economics
Water Cost

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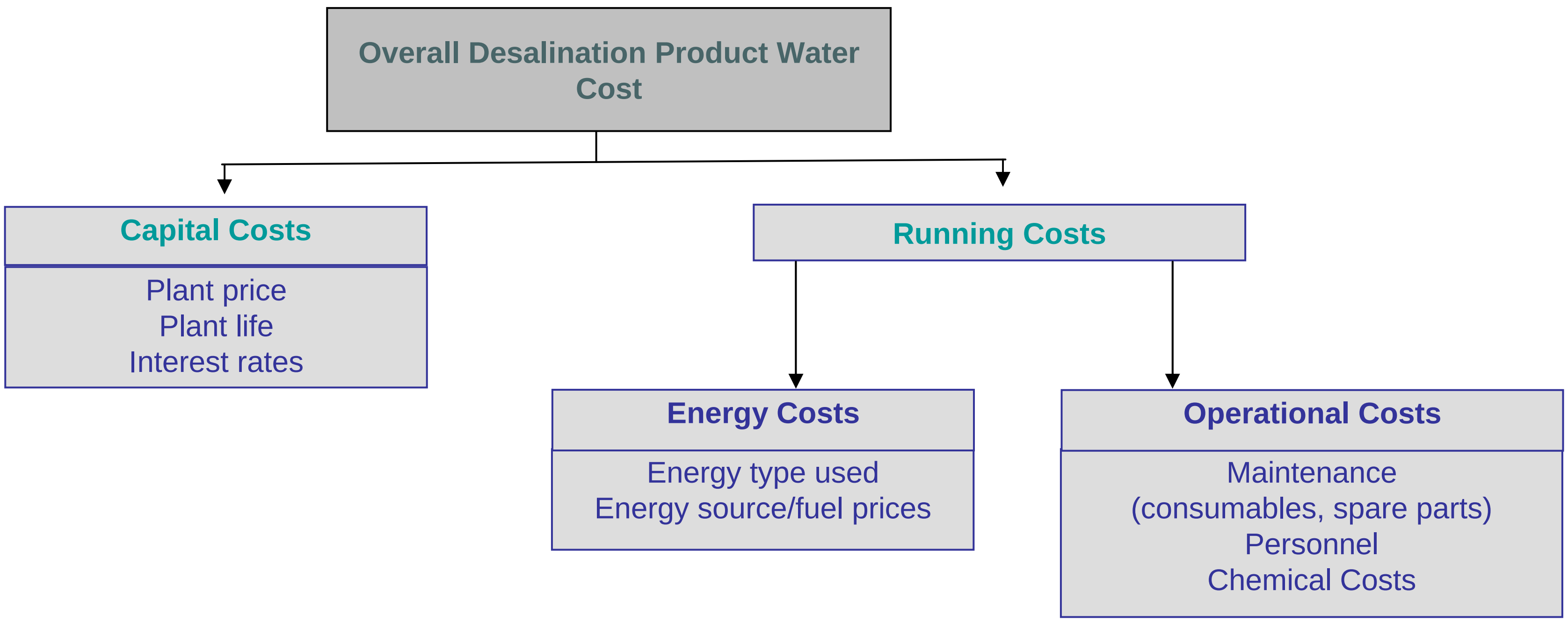
Desalination Water Cost

Over the years, the cost of water produced in seawater desalination has dropped considerably, but the cost of water produced from the “conventional ”treatment plants has risen, due to the over – exploitation of aquifers and the intrusion of saline water, and also to the generally increasing contamination of ground water.



Capital Cost

Many factors enter into the capital and operating costs for desalination: capacity and type of plants, plant location, feed water, labor, energy, financing, concentrate disposal, and plant reliability. In general, the cost of desalted seawater is about 3 to 5 times the cost of desalting brackish water from the same size plant.

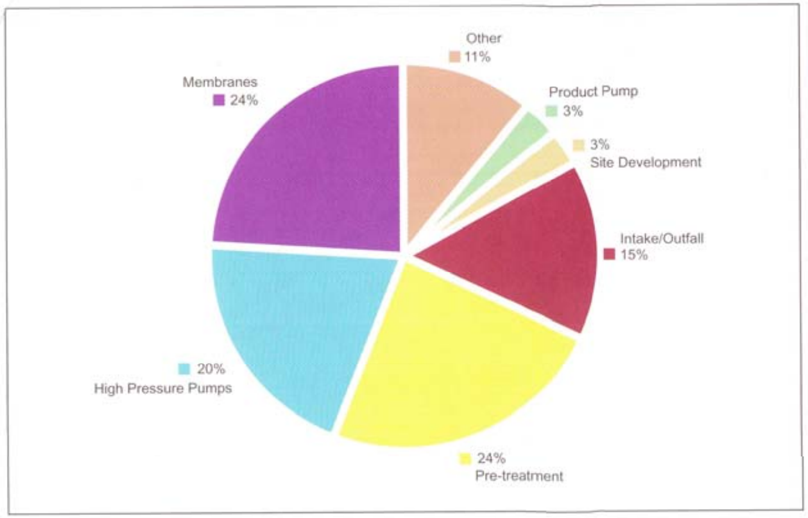


Figure 5.6 RO plant turnkey cost breakdown

RO Plant

Source: Sommariva C., 2004

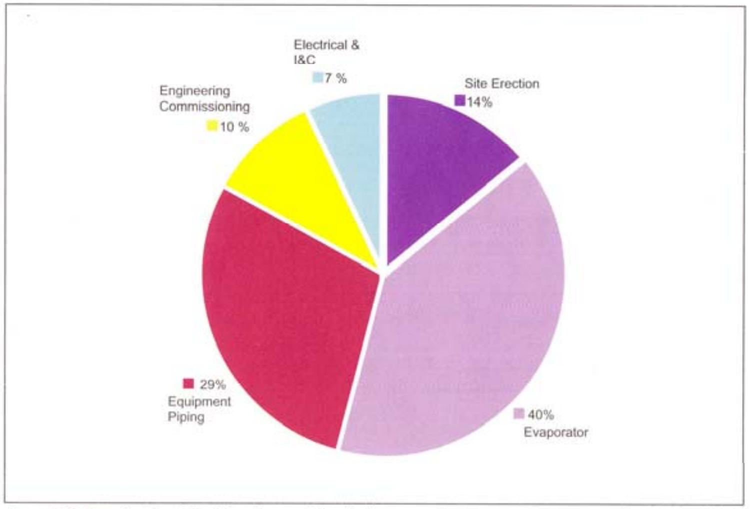


Figure 5.1 Desalination island turnkey cost breakdown

Thermal Distillation Plant

Source: Sommariva C., 2004

O&M Costs

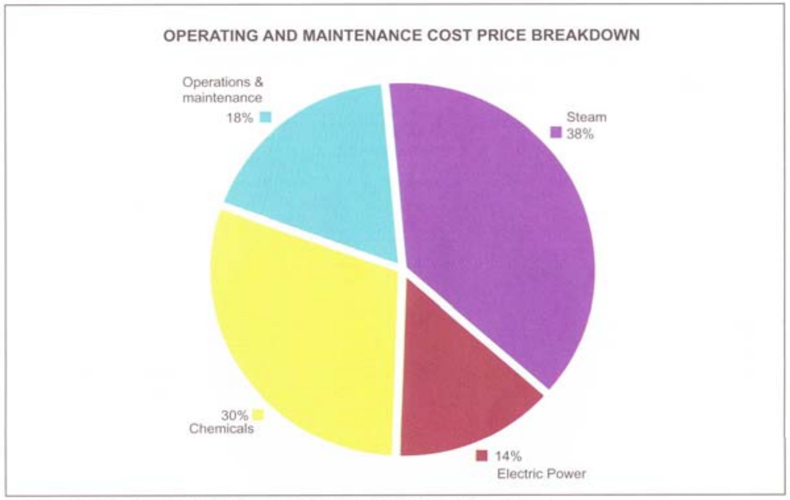


Figure 5.8 Thermal desalination plant operating cost typical breakdown

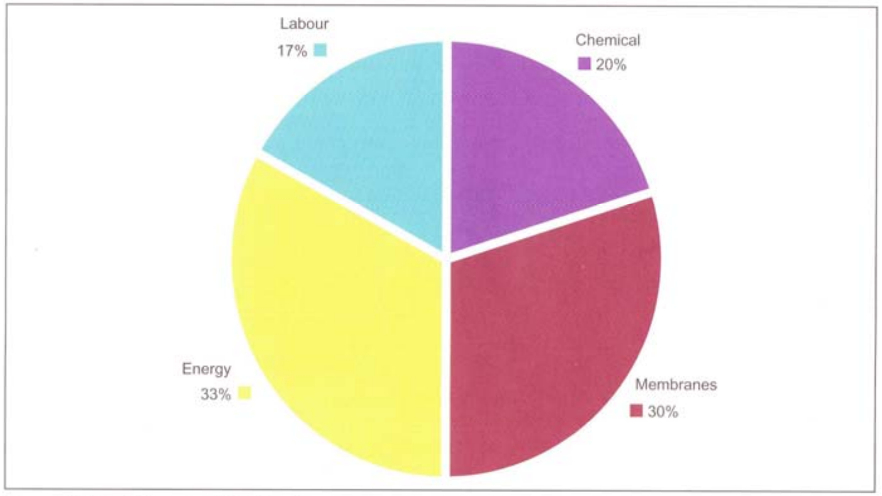
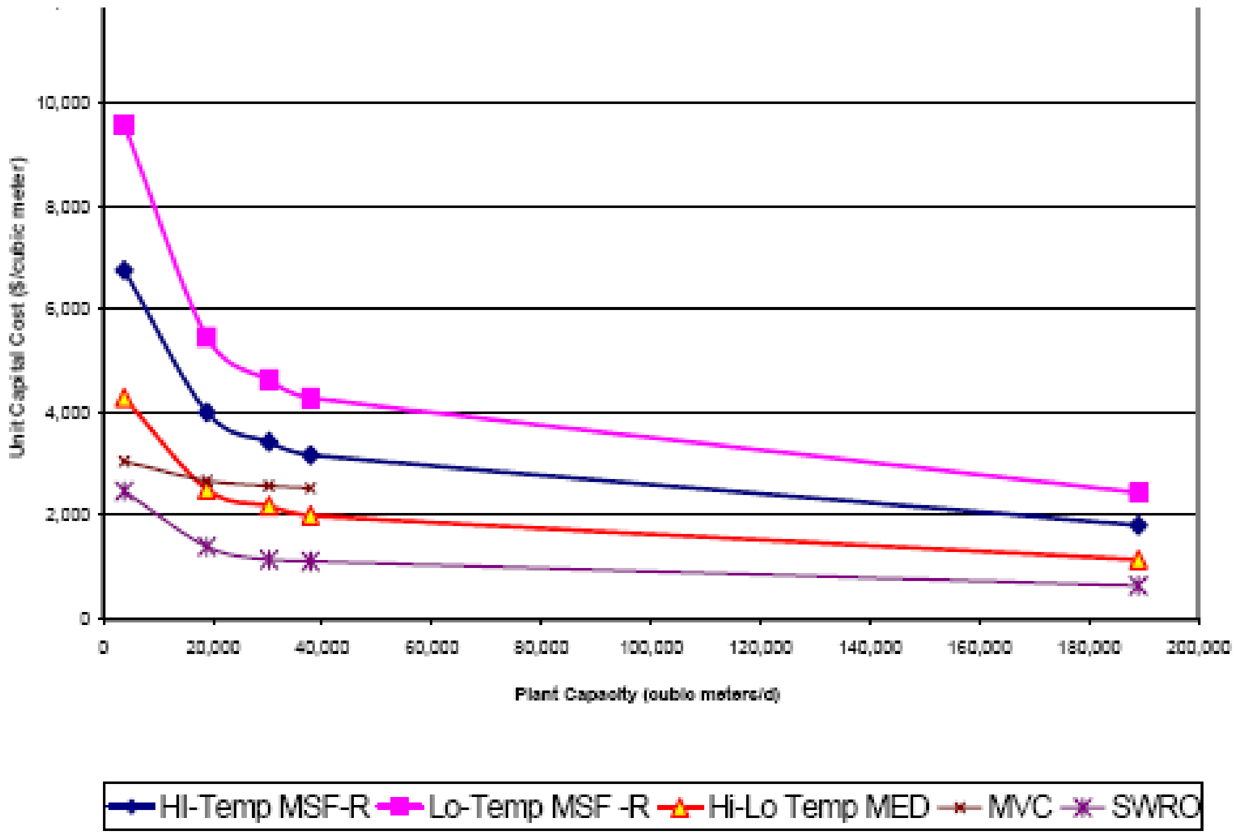


Figure 5.11 O&M cost subdivision for reverse osmosis

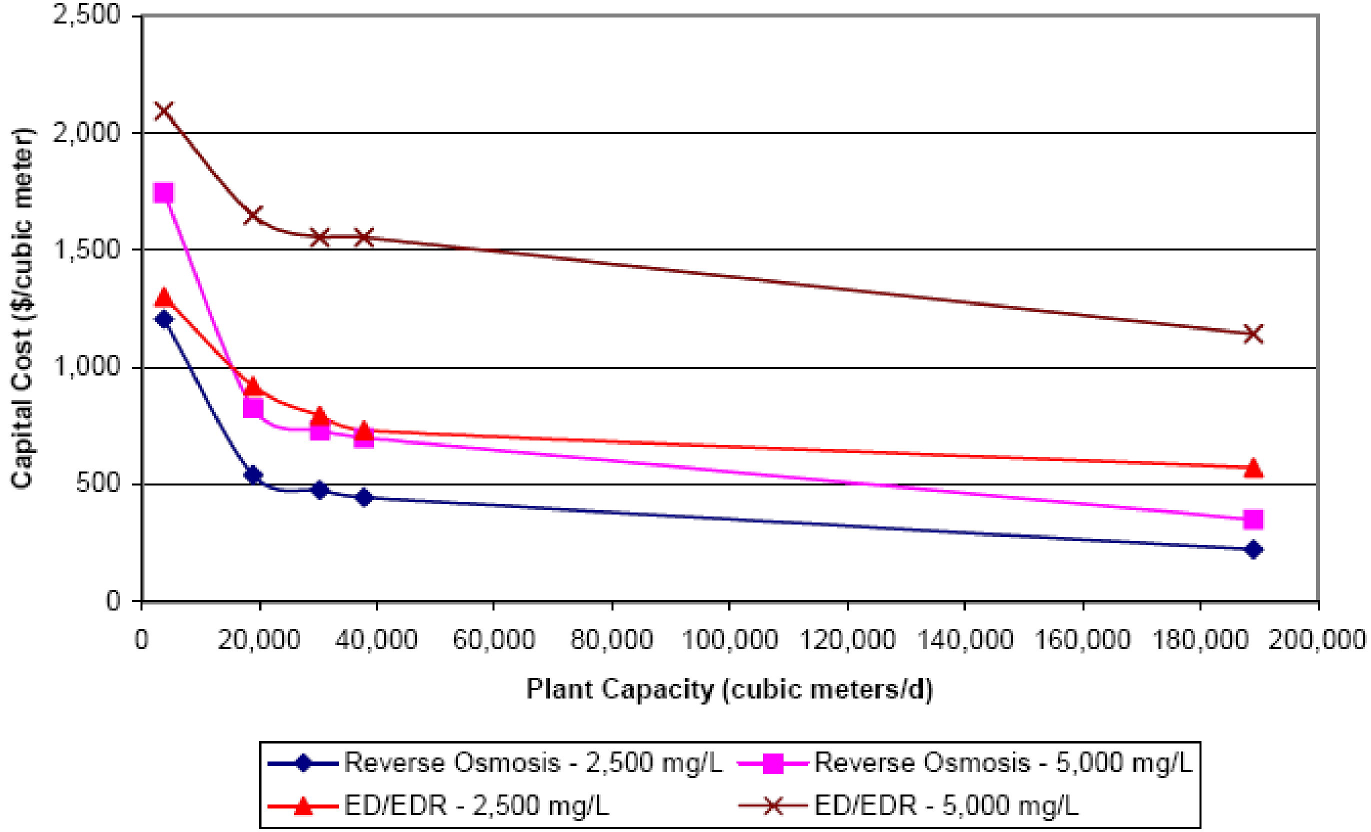
Source: Sommariva C., 2004

Relative Seawater Desalting Capital Costs



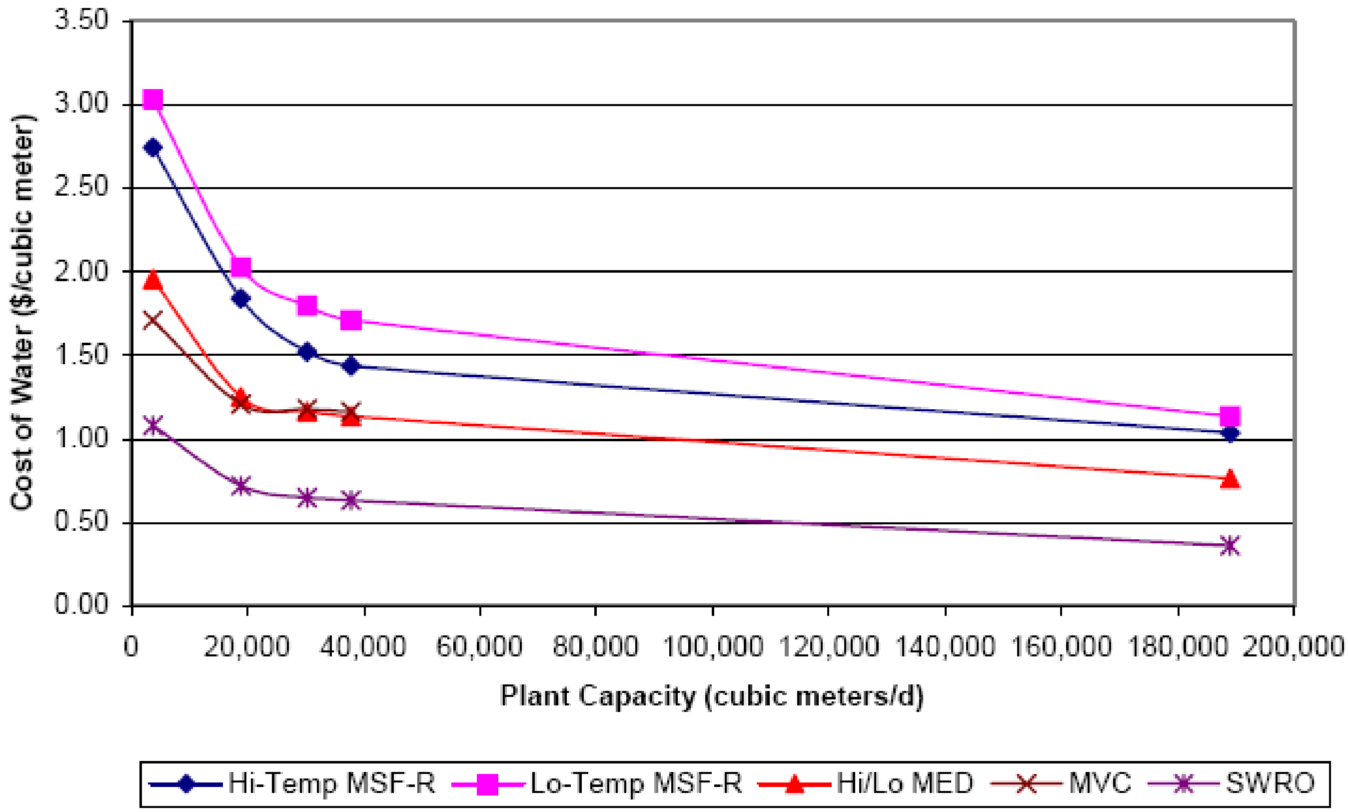
Source: Bureau of Reclamation

Relative Brackish Water Desalting Capital Costs



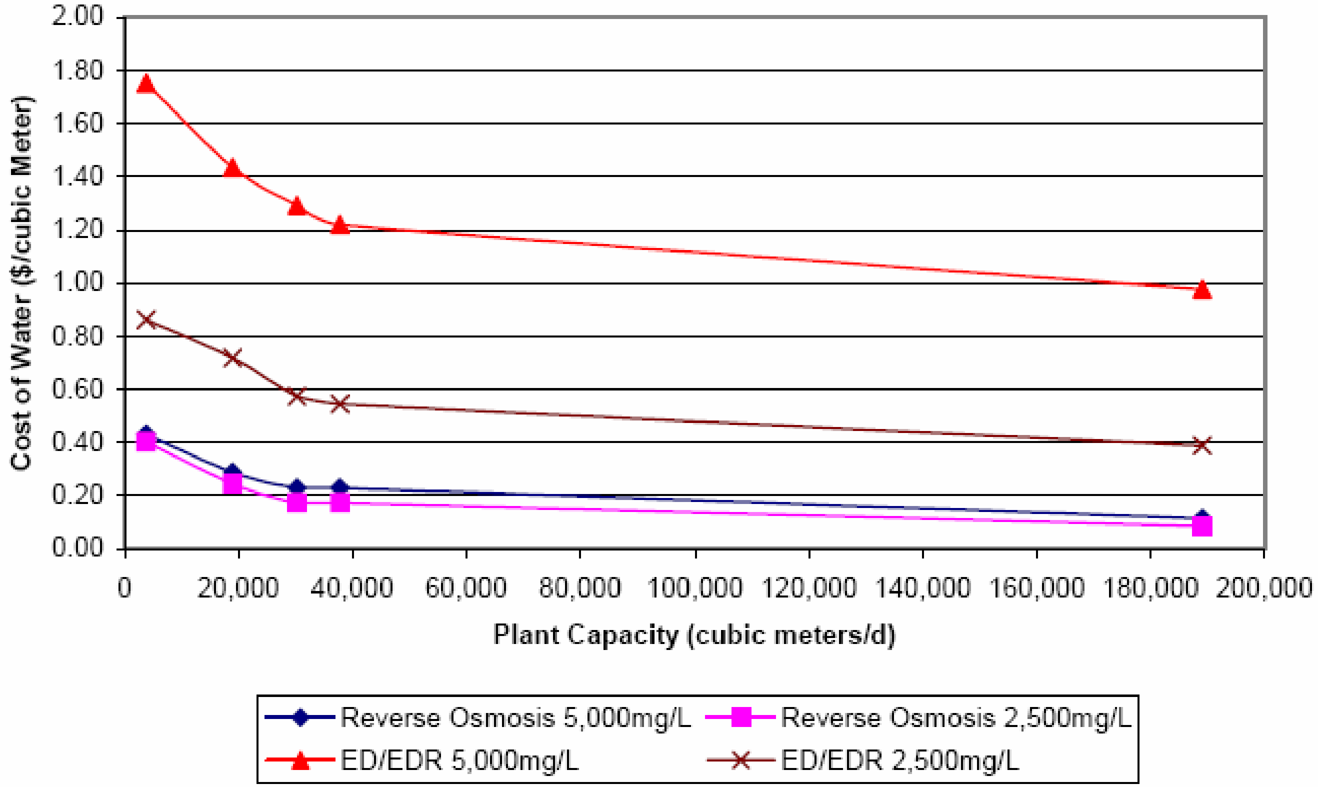
Source: Bureau of Reclamation

Cost of Water Seawater Desalting



Source: Bureau of Reclamation

Cost of Water - Brackish Water Desalting



Source: Bureau of Reclamation

The Water Price

The price of water is increasing—sometimes dramatically—throughout the world. Over the past five years, municipal water rates have increased by an average of 27% to around 60%, For instance 27% in the United States, 45% in Australia, 50% in South Africa, and 58% in Canada, (www.earth-policy.org).

- Water costs = cost of exploitation and extraction +
  cost of treatment (cleaning, desalination) +
  cost of distribution (transportation, pipeline, losses) +
  cost of sewerage

- Water price = Water costs - *Subsidies*

Typical real costs (worldwide):

Exploitation and extraction:	0.05 … 0.8 €/m³	0.5 … 20 €/m³
Desalination (large installations):	0.43 … 2.0 €/m³	
Distribution:	0.2 … 15.0 €/m³	
Sewerage:	0.3 … 2.0 €/m³	

Water prices and consumptions in Europe

Country	Consumption (liter/ day / person)	Mean water price per m³ Water + sewerage + taxes (€/m³)
Spain	130	1,0
Ireland	135	0
Luxembourg	150	0,90
UK	150	1,6
Italy	160	0,8
Sweden	180	1,15
Portugal	190	1,0
Greece	200	1,1
France	113	2,6
Finland	116	2,5
Germany	118	3,6
Belgium	120	1,9
Netherlands	126	2,7
Danmark	138	4,3
Austria	150	2,6

Source: IWA Statistic 2005