SPECIAL REPORT

Purification with a pinch of salt

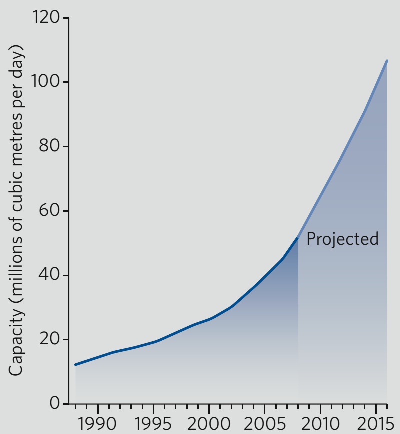
Climate change, growing populations and political concerns are prompting governments and investors from California to China to take a fresh look at desalination. **Quirin Schiermeier** wades in.

Water has always been a volatile topic in Australia, the world's driest inhabited continent, but the political row that broke out last week was perhaps surprising. Protesters are complaining that a planned desalination facility outside Melbourne, Victoria, will generate too much freshwater.

The US$3-billion government-owned plant will produce more than 300,000 cubic metres of drinkable water a day when it opens in 2011, putting it among the world's biggest. Environmental groups claim that the plant is unnecessary. Even if water consumption rose by 25%, there would be an excess of about 60% in supply over consumption by 2016, according to Neil Rankine, a spokesman for protest group Your Water Your Say. Rankine's figures are based on the state increasing other efforts such as recycling water and harvesting rainwater.

Nobody, of course, is actually worried about the possibility of having too much water — at issue is the cost to the environment. "Desalination is the most energy-intensive form of water supply," says Peter Gleick, president of the Pacific Institute, an independent environmental think-tank in Oakland, California. The Victorian plant will sit next to a six-turbine wind farm, but few believe that the small, inefficient farm will be able to power the huge facility. The highly concentrated brine discharged by the desalination processes is also of ecological concern.

GLOBAL PRODUCTION OF DESALINATED WATER



SOURCE: GLOBAL WATER INTELLIGENCE

The economic payout is steep too. Unlike the mass production of other consumer goods, there is no pronounced economy of scale at play in 'making' water — even massive plants cannot produce desalinated water at significantly lower costs than small, community-based facilities.

Increasingly, countries are willing to pay the price. Nations from Australia to Britain, the United States to China, have desalination projects in the works — 75 major plants are at various stages of development globally (see graph, below). Currently, more than 40 million cubic metres of desalinated water are produced every day by 15,000 or so production facilities worldwide. "In the next 10–20 years we will see a massive increase in capacity and production," says Bruce Durham, an independent consultant who has worked with the water industry for more than 30 years. In California alone, proposals have been put forward for at least 20 new large desalination facilities (see map), which together could ultimately supply some 6% of the state's urban water demand.

Costs have come down. Even the very energy-intensive thermal plants in the Gulf region — which purify seawater by boiling and condensing — can produce fresh water at less than US$1 per cubic metre. And the desalination plant at Ashkelon in Israel, once the world's largest, produces more than 300,000 cubic metres of freshwater per day at costs of around 50 cents per cubic metre. That's 1,000 litres of drinking water for less than half the retail price of a 1-litre bottle of Evian. But on average, the technique is 3.5 times more expensive than using other sources of freshwater such as pumping from aquifers.

Technological future

Advances in chemical engineering promise to make desalination more affordable. Polyamide membranes are the basic components of reverse-osmosis plants, which produce more than half of the world's desalinated water and are replacing less-efficient thermal distillation facilities. To remove dissolved organic matter and other impurities, brackish water or seawater is pre-filtered and then forced under pressure through bundles of these semi-permeable membranes, which separate salts from the water (see Fig. 4, page 307).

PROPOSED DESALINATION PLANTS IN CALIFORNIA

Pretreatment cannot fully prevent the membranes from fouling and degrading, so they need to be cleaned chemically and replaced frequently — a major cost factor. Every company has its own way to fight 'bio-fouling', salt deposition and other processes that reduce the flux of water through the membranes.

In a bid to tackle fouling, where geology allows it, some operators of coastal plants have begun to draw water from beach wells rather than from the open sea. The sand acts as a natural filter, pretreating the seawater. Beach wells also have the advantage of preventing fish and marine life from getting trapped and killed in the uptake pipes, a widespread problem with coastal desalination.

But although polymer membranes have become more permeable and durable since they were first developed, neither the basic technology used in reverse osmosis nor the membrane materials used in the desalination process have changed much. Scientists in Singapore — which has recently earmarked US$250 million for developing desalination technologies — are testing alternative techniques such as membrane distillation, which combines both membrane technology and evaporation processing in one unit. This can

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Desalination plants in coastal Spain use sand as a natural filter to pretreat the seawater.

F. GIERTH/DPA/CORBIS

then be coupled with solar energy, geothermal energy or waste heat.

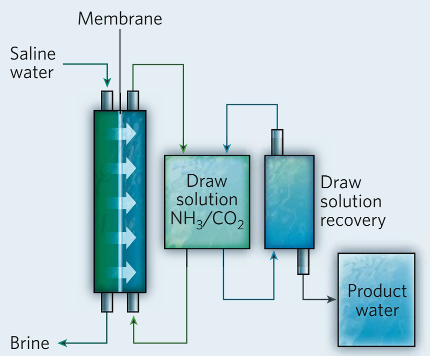
Another promising method is the use of aligned carbon nanotubes — molecular-scale pipettes through which water can be forced frictionless 1,000 times faster than through polymeric membranes. However, no one has as yet demonstrated the desalination ability of nanotubes, or suggested how to get around the fouling problem. Moreover, this technology, which requires hydraulic pressure, would reduce energy consumption by just 20% according to experts.

Prototypes now exist for a desalination technology based on 'forward osmosis', which works at very low pressure. Menachem Elimelech, an environmental engineer at Yale University in New Haven, Connecticut, leads a team that has constructed a pilot desalination plant that uses osmotic, rather than hydraulic, pressure (see graphic, above). The researchers position a concentrated solution of dissolved ammonia and carbon dioxide gases behind a membrane, creating osmotic pressure. This draws the saltwater on the other side through the membrane. Freshwater can then be recovered from the draw solution by heating it to 58 °C so that ammonia and carbon dioxide bubble out of solution and are captured.

"In absolute terms the process is not quite as efficient as reverse osmosis, but the nice thing is that you can use waste heat to decompose salts from solution," says Elimelech.

Besides being less energy-intensive, forward osmosis would greatly reduce brine discharge. Residual brine from existing desalination processes must be watered down to concentrations that are harmless to marine life.

DESALINATION BY FORWARD OSMOSIS



SOURCE: MEMBRANE TECHNOLOGY

However, forward osmosis requires membranes that must be extremely thin and porous, and tolerant to strongly basic water, and such devices are not yet commercially available, Elimelech says.

Energy will always remain the crucial constraint. Twenty years ago, 5–10 kilowatt hours of electricity was needed to produce one cubic metre of desalinated water. Modern reverse-osmosis plants, such as that at Ashkelon, now need around 2 kilowatt hours to produce the same volume. The world record, achieved in a pilot plant in California, is 1.58 kilowatt hours. The laws of thermodynamics impose a theoretical limit of around 0.7 kilowatt hours on the energy-efficiency of desalination. And because the desired high flux rates require extra energy, plants such as Ashkelon are already close to what is realistically feasible.

"You can further improve membrane materials and you can optimize energy-recovery devices," says Gary Amy, a desalination expert at the United Nations Educational, Scientific and Cultural Organization's Institute for Water Education in Delft in the Netherlands. "But no matter what you try, the energy-efficiency of desalination will soon reach a plateau."

Despite these limitations, well-designed desalination plants can still be more efficient and environmentally sound than large dams, pipelines or canals. "Desalination is one technology that can mitigate the problem of water shortages. The solution it is not," says Mark Shannon, a mechanical engineer at the University of Illinois at Urbana-Champaign, who oversees a science and technology centre for water purification funded by the US National Science Foundation.

As Rankine and his supporters gear up for a new round of protests, Melbourne could do worse than look west to the city of Perth. Its US$329-million desalination plant, which opened in 2006, has won grudging approval. In fact, a second, US$811-million plant is now planned. The secret: renewable energy — the power comes mainly from a wind farm, and up to 90% of it can be recycled by energy-recovery devices. ■