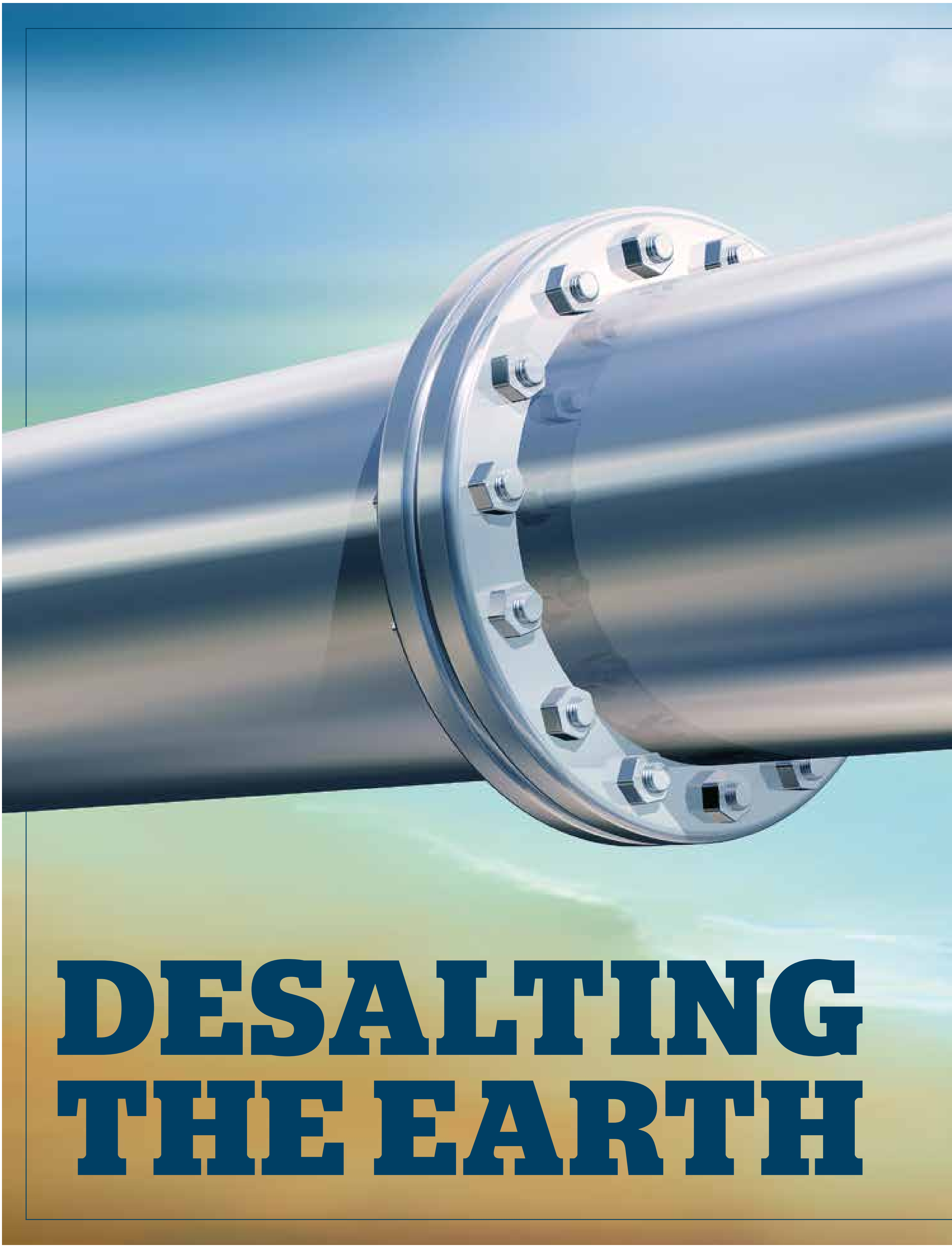


DESALTING THE EARTH

Desalination – the technology to obtain fresh drinking water from the sea and other sources – is now a successful method of quenching the thirst of many cities and countries. So could water crises become a thing of the past? Or should such prophesies be taken with a pinch of salt?

by Chris Fitch

Cape Town is hoping that desalination techniques will make the 'Day Zero' water rationing crisis a one-time problem

A year ago, Cape Town wobbled on the brink of disaster, facing a situation seemingly unthinkable in the modern world. With local reservoirs rapidly depleting, South Africa's second largest city, home to 4.4 million people, ran a serious risk of running out of water. Mayor Patricia De Lille was unrelenting in her warnings about 'Day Zero' – set for 21 April 2018 – as the critical point when emergency measures would need to be taken to prevent the city's taps from finally running dry. Once reservoir levels dropped below ten per cent, water access would be restricted, by rationing supplies from controlled public distribution points around the city. 'We can no longer ask people to stop wasting water,' she declared. 'We must force them!'

History will record that the most apocalyptic outcomes never emerged. As residents duly skimped and saved on their personal water usage, including showering with buckets, and flushing the toilet just once per day, consumption dropped. Eventually the winter rains returned allowing the reservoirs to slowly replenish. Crisis was averted. Nevertheless, it was a call close enough to shake awake city authorities, now wide-eyed to the potential threat they may again face in the future, despite their status as running one of Africa's richest and most developed cities. In an uncertain future climate, unpredictable rainfall might be the one reliable constant, meaning city officials decided they needed to prepare for such a scenario to come around again.

Therefore, the past year has seen Cape Town embarking upon the development of temporary desalination plants, to quickly inject water resources into the city's reservoirs. 'Ultimately we initiated three desalination plants, all of a temporary nature. They will only be in operation for two years,' explains councillor Xanthea Limberg, the city's Mayoral Committee Member for Water and Waste Services. 'They are small-scale, and collectively are contributing about 16 million litres of water per day.'

Despite consumption continuing to run at 525 million litres per week through most of 2018, the city now has large ambitions to ramp up production to 150 million litres of desalinated water per day. It has the potential to demonstrate the rapid and significant difference the technology can provide to a city's water security. Given Cape Town's geographical location, sandwiched at the meeting point between two great oceans, could desalination therefore be the preventative measure that removes the risk of another 'day zero' forever? Indeed, could desalination make water crises all around the world a thing of the past?

Tokyo holds the title for the most water stressed city in the world, with Shanghai, LA, Rio, Istanbul and London not far behind

WATER CRISIS

Sadly, and perhaps predictably, this experience of urban water shortages is not unique to Cape Town. Many cities around the world have had to face, or are continually fending off the threat of, extreme drought and severe water restrictions, with at least one in four major global cities deemed significantly water stressed. Large-population capitals such as Delhi, and Mexico City are famously among those urban centres diagnosed most at stress, all of which regularly face severe droughts that can cripple a fragile water supply essential for tens of millions of residents. But while 844 million people worldwide live without access to safe water, and 2.3 billion live without access to adequate sanitation, this threat isn't restricted to the developing world. Tokyo actually holds the title for the most water stressed city in the entire world, with other major cities such as Shanghai, Los Angeles, Rio de Janeiro, Istanbul and London not far behind.

The steadily dropping water line of Cape Town's reservoirs provided a visual cue to how close the city was to the edge of mayhem. But such strikingly visual evidence isn't always available. Many human areas of habitation – not just major cities – are heavily reliant on water supplies hidden naturally beneath out feet, a resource we, unfortunately, can't actually see with the naked eye. 'The vast majority of water that we use everywhere in the world for food production, for drinking water ... comes from aquifers,' explains Dr Jimmy O'Keeffe, a research associate at the Faculty of Engineering, Department of Civil and Environmental Engineering, Imperial College London. 'We don't know that water is disappearing if we can't see it, we're not going to care until it actually reaches a crisis.'

Groundwater aquifers, the largest available store of global freshwater, are relied upon by more than two billion people, according to a recent study from Cardiff University. Unfortunately, these supplies are being depleted faster than nature can replenish them. 'Our research shows that groundwater systems take a lot longer to respond to climate change than surface water, with only half of the world's groundwater flows responding fully within human time scales of 100

NUMBER OF OPERATIONAL DESALINATION PLANTS WORLDWIDE AS OF 2018, BY REGION

- Middle East and North Africa **4,826**
- East Africa and Pacific **3,505**
- North America **2,341**
- Western Europe **2,337**
- Latin America and Caribbean **1,373**
- Southern Asia **655**
- Eastern Europe and Central Asia **566**
- Sub-Saharan Africa **303**

WHERE IS ALL OUR WATER CONTAINED?

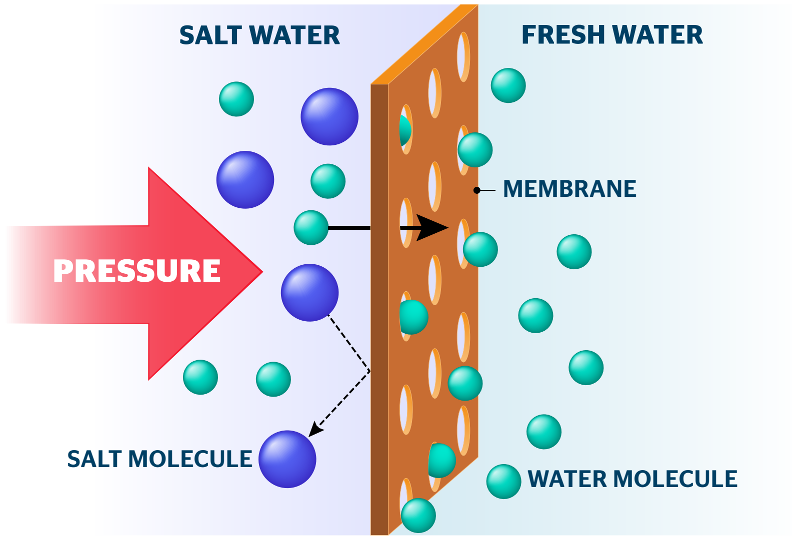
- Seawater **96.5%**
- Other salty water (on land, e.g. lakes or groundwater) **1%**
- Frozen fresh water (ice caps, glaciers, perennial snow) **1.72%**
- Underground fresh water **0.75%**
- Other fresh water (e.g. in soil, atmosphere,plants) **0.02%**
- Surface water (lakes, swamps, rivers) **0.01%**

years,' says Dr Mark Cuthbert, a research fellow and lecturer at the School of Earth and Ocean Sciences, Cardiff University. 'Groundwater systems can have a very long memory which means there are often lag times between changes in groundwater replenishment, and the downstream changes to rates of groundwater discharge to streams or wetlands.'

Another reason why an impending water crisis might be less obvious is that for most people, especially urban dwellers in developed countries, they have only an indirect relationship with the vast majority of water they consume. 'Maybe 70 or 80 per cent of water globally is used by agriculture for food production,' explains Dr O'Keeffe. 'The amount of water it takes to

A row of membranes in a reverse osmosis water desalination plant in Ashkelon, Israel

REVERSE OSMOSIS



produce a steak, or a cup of coffee, is huge. It's not just pouring water out of a tap and making a cup of tea, there's a lot of water that it takes to get that teabag or steak to you. But we don't see that.'

While the idea of 'water footprints' has sprung up around this exact phenomenon, the relative invisibility of the amount of water the average person consumes means that many cities could be on the brink of running dangerously low on supplies of potable, consumable freshwater with the city's residents none the wiser. Hence, the impending risk of major water crises, as cities, and the vital supply lines of food that fuel them, run the risk of running desperately low of this most vital of resources.

DESALINATION EFFORTS

Of course, even the briefest of glances at a world map will reveal that Earth has plenty of water. Roughly 70 per cent of the planet's surface is somewhat aqueous. But statistics make it clear how unhelpful the oceans are in meeting our hydrological needs. Only 2.5 per cent of Earth's water isn't salty, and nearly three-quarters of this is (currently) frozen, locked up as glaciers or ice caps. Only 0.75 per cent of Earth's water exists in groundwater stores, while the planet's entire surface water – all the streams, rivers, and lakes you've ever seen – make up just 0.01 per cent of the global storage of water.

Therefore, it's hardly a surprise that people have long looked to the sea – where a whopping 96.5 per cent of the water on Earth can be found – as a potential solution to ensuring every person has access to the water they need to survive. The theory of desalination dates back as far as history itself. Aristotle recorded potential methods for extracting 'sweet' potable water from the ocean using evaporation millennia ago, while, in 1791, soon-to-be US president Thomas Jefferson documented his thoughts on 'converting salt water into fresh', noting the immense value this would have particularly for ships out at sea.

But desalination is pure alchemy no more. Instead, it is a real, significant, quantifiable, and reliable means of obtaining fresh water – for drinking, growing, washing, or many other applications – from what was once raw sea water (worth noting: desalination technology is also sometimes used to desalinate salty 'brackish' groundwater, lakes and wastewater – not always on ocean water). At present there are nearly 16,000 operational desalination plants around the globe, with the most in the Middle East and North Africa (MENA), 4,826 plants, ahead of East Africa (3,505), North America (2,341) and Western Europe (2,337). MENA plants are also the most prolific, pumping out just shy of half of the 95 billion litres (roughly 38,000 Olympic swimming pools) of desalinated water produced daily.

One of the world leaders in desalination technology in the MENA region is Israel. While the country might not quite have the vast surplus of water that rumours have suggested, water shortages have certainly plummeted over the past 15 years. Desalination was first embraced in Israel in the 1980s, to make the brackish water underground consumable. But as even that began to run low, it began looking towards the sea. In 1997, desalinated seawater began supplying the southern city of Eilat, in the Gulf of Aqaba. It wasn't long before authorities began hatching plans to expand operations across the country, as a way to try and meet demand in a country with a booming population, high consumption rates, depleting aquifers, and decreasing rainfall.

'It began to become clear that our climate was beginning to change, and it was beginning to get drier,' recalls Dr Jack Gilron, head of the Department of Desalination and Water Treatment at Ben Gurion University. 'Also because of increased population demand, there was more and more demand on water. It wasn't enough to go around. Large scale seawater desalination would be the way to bridge the gap between our resources and our needs.'

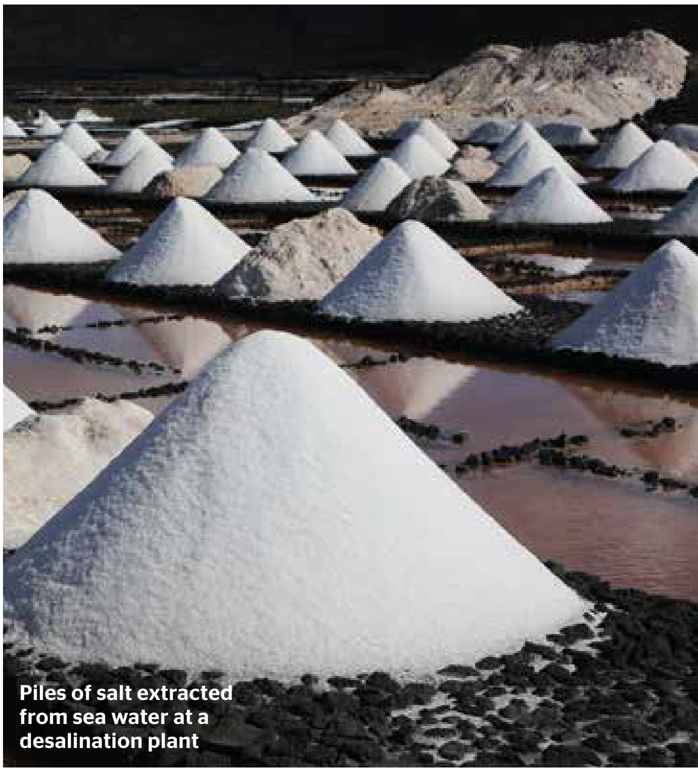
Since the turn of the millennium there have been five large-scale desalination plants constructed along Israel's Mediterranean coastline, distributing water across the landscape using the remnants of a 1960s infrastructure project called the National Water Carrier. 'That set of pipelines and channels then became available for distributing water both north and south, once desalinated seawater became available,' explains Gilron. 'We're a long narrow country. We had the geography and existing infrastructure provided. and we're taking it up to do large scale desalination.' From absolutely nothing just 15 years ago, Israel now pumps out nearly 600 billion litres of desalinated water annually, with the hope of tripling this production by 2050.

Another role model for desalination technology making a radical difference to water security in recent years has in many ways something of an affinity with South Africa's Mother City. 'Cape Town and Perth are climatically, and resource-wise extremely similar,' says Wendell Ela, Professor of Desalination and Water Treatment at Murdoch University, Western Australia. 'It's just that they're starting at a point where they're already under the gun, whereas Perth started when you can see the gun out there, but it wasn't quite pointed at your head yet. But there's nothing magical about Perth.'

Unlike in Cape Town, the residents of Perth began experimenting with desalination around the turn of the century, in response to the so-called 'millennium drought' that affected much of southern Australia between the late 1990s and 2010. Crucially, city officials recognised that a drop in rainfall of 20 per cent over 35 years was a warning of much future hardship, and set in motion plans to prepare residents for such an outcome. Now the city gets as much as 50 per cent of its water from desalination. 'It was in a lot of ways a no-brainer for Perth,' continues Ela. 'The timeline was not determined by economics, there wasn't a rush to get these first plants up and running to compliment the groundwater that had historically supplied the city's water. But if they hadn't acted when they did, Perth might now be just like Cape Town.'

ENERGY DRAIN

With so many case studies showing that the technology works, any logical thinker might wonder how it is that these haven't been scaled up and instigated on a global scale to ensure a clean fresh water supply to anyone who wishes for it. Conveniently, around 1.9 billion people – over a quarter of the world's population – are located less than 100km from the coast, as are just over half of the world's largest cities. Given the great oceans have always been vital to trade and prosperity for most of human history, not to mention an essential source



Piles of salt extracted from sea water at a desalination plant

of food, this relative proximity of most of the world's population to the sea would, it might seem, be extremely helpful in allowing this new technology to quickly, cheaply and effectively fulfil the water needs of the majority of the planet's 7.5 billion human population.

But there's one key problem: energy. Desalination uses an immense amount of energy, especially when pushing water molecules through tiny holes in a membrane (in a process known as 'reverse osmosis'). Separating water molecules from the salts that make seawater undrinkable seemingly just isn't something that can be attempted without a large, reliable energy source to power the process.

So if the key inhibitor of desalination is energy demands, does that mean that truly renewable energy could also create infinite freshwater? Certainly, renewable solar power continues to forge ahead, helping create low-carbon energy on a global scale. 'There are two solar options for providing electricity: photovoltaic (PV) and concentrated solar power (CSP),' explains professor Chris Sansom, from the School of Aerospace, Transport and Manufacturing, Cranfield

From absolutely nothing just 15 years ago, Israel now pumps out nearly 600 billion litres of desalinated water annually

A concentrated solar power array is one of the easiest ways to power a desalination plant, but it requires a vast amount of land

University. Both of these systems have their pros and cons depending on where they are located (PV being cheaper but also more intermittent, a problem when powering temperamental reverse osmosis plants, while CSP is easier to provide a regular supply of energy, but it demands a huge amount of land).

With regards to desalination, there is the intriguing possibility of a third way: thermal. 'That could be direct heat from the sun, it could be biomass, or anything else that provides renewable heat,' explains Sansom. 'Just to simply evaporate sea water, and then – usually in a separate chamber – distil it into pure water.' While this process is energy-intensive in its own way ('There's just no way round the amount of energy it takes to do desalination') it does provide an alternative methodology for potentially obtaining fresh water without exhausting the national grid.

Furthermore, it might be one of a wide diversification of options that makes this future for renewable desalination a reality. Researchers at the University of Illinois have successfully shown how sodium-ion rechargable batteries can purify salty water, while a team at Rice University in Houston is developing a new system of membrane distillation using revolutionary solar-powered nanotechnology.

The idea of directly using 'dry rock' geothermal power to heat and evaporate brackish water is being tested by experts at Florida Gulf Coast University, while, inspired by their observations of Hurricane Katrina in 2005, researchers at the Sandia National Laboratories in New Mexico are working on a way to harness wave energy to desalinate ocean water without the need for external intervention. The hope is that such a wide diversity of experimentation will ultimately yield a significant breakthrough.

Nevertheless, in the right parts of the world, traditional technology is proving itself capable of solving these energy problems. While the prospect of being stranded on the west side of Australia without a reliable water supply means that most Perth residents are content to pay an extra 20 to 30 per cent on their energy bills to keep the plants pumping away, the relaxed construction timeline meant the installation of the plants was accompanied by solar and wind farms capable of matching the excess energy consumed by the desalination process. Even the leading pioneers of desalination find it hard to avoid the immense energy demands, but with careful, well-planned growth, keeping a lid on the costs to consumers can be achieved.

WATER SOLUTIONS

In Cape Town, councillor Limberg is insistent that a diversity of new back-up water sources is necessary to ensure the city's future water security, with the drilling of new aquifers and recycling of wastewater accompanying its new desalination plants. It's an approach that mirrors the efforts by Israel, Perth, and most other desalination role models. 'The technology by itself doesn't do it,' says Ben Gurian University's Dr Gilron. 'It's the technology, integrated into an overall policy vision and policy approach.'

Instead, as authorities in Cape Town discovered, reducing water consumption itself could actually be key to solving the problem. 'Engineers want to build desalination plants,' says Imperial's Dr O'Keeffe. 'They want to build canals, they want to build pipelines, these are really clear-cut, obvious solutions to solve a problem. While in reality, it might be easier if people just change their behaviour.' So while desalination technology is making a major difference in parts of the world that have heavily invested in it over a long period of time, it's not quite the silver bullet that it might appear. ●