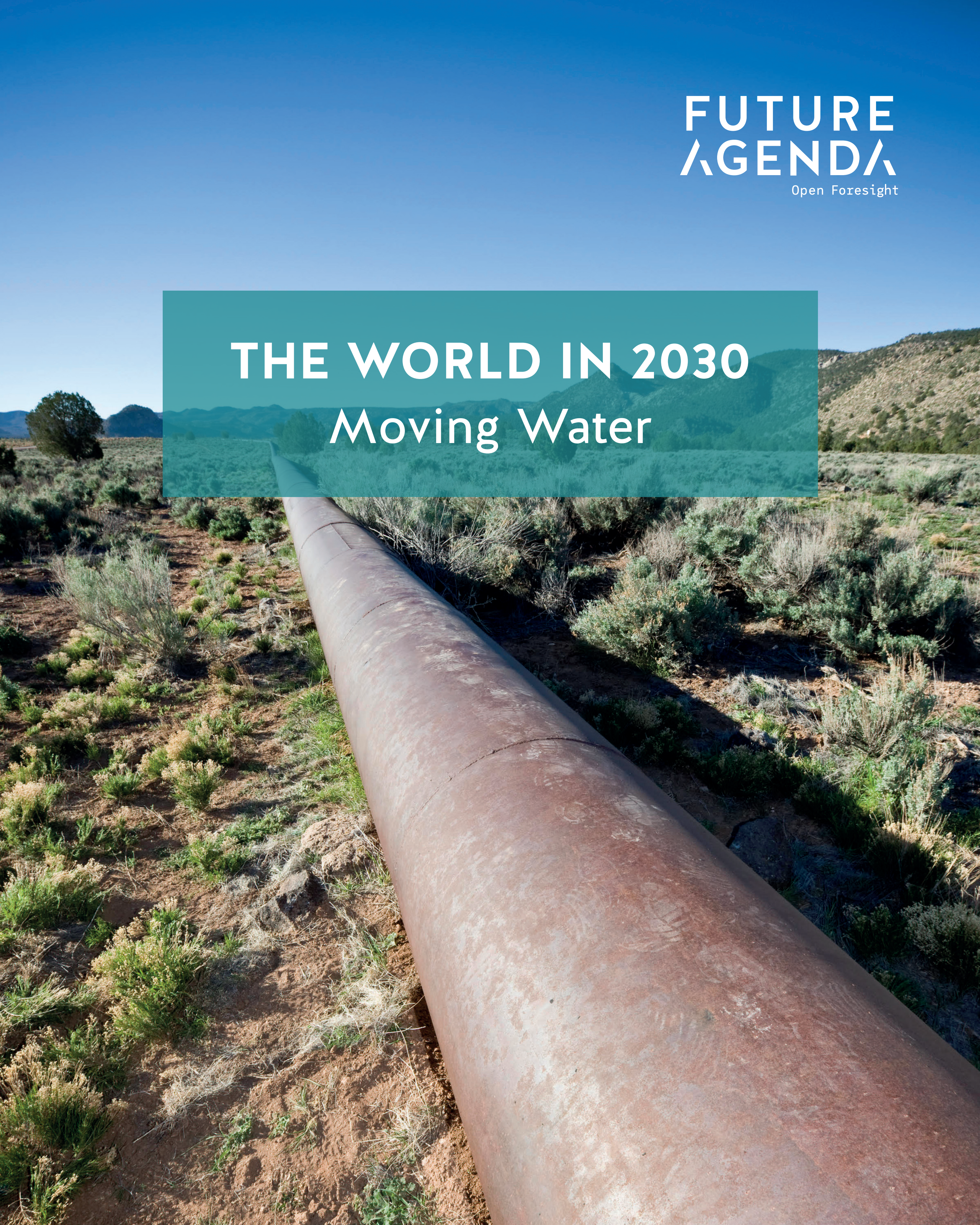
FUTURE AGENDA
Open Foresight

THE WORLD IN 2030
Moving Water



Moving Water

While some regions gain from better water management, much of the world's population increasingly depend on water moved from one river basin to another. New options are explored to achieve this economically and with reduced socio-environmental damage.

Annual volume of South-North Water Transfer Project	**40bn m^3**
Typical cost of moving water by pipeline	**\$5 / m^3**

Since the Persians built the first aqueducts and the Romans then made them a mainstay of civil engineering, the task of moving water to where people choose to live has been a long-standing design challenge. As cities have become focal points and their populations have swelled, many have become increasingly water-stressed; a good number have therefore had to move water from where it is to where it is needed. Over the centuries major engineering projects around the world have sought to capture, store and move water to areas of agricultural, industrial and domestic use by adopting a wide range of solutions.

With climate change, increasing urbanisation, growing contamination, higher water consumption, more intensive farming and rising industrial use in many economies all having significant and combined impact, as the global population approaches 10 billion, but the net amount of water on the planet stays constant, concerns over water stress have been building. With 70% of water used for agriculture, a quarter of humanity is now facing a looming water crisis.[1] A broadening range of urban areas need multiple innovations to provide water to cities throughout the year.

Although better water management and the decreasing cost of desalination are having impact in some regions, in many others, and especially for fast-growing inland cities, the task of ensuring continued water access is mounting. Simply moving water from one river basin to another is not straightforward. It is fraught with technological, environmental, economic and socio-political challenge. There are however several developments underway to enable more effective long-distance movement of water – some focused on building new infrastructure at scale and others looking to imaginatively repurpose existing assets to help meet the inevitable future demand.

The Core Challenge

Global water use has increased by a factor of six over the past 100 years and continues to grow at a rate of about 1% per year as a result of increasing population, economic development and shifting consumption patterns.[2] Many are focused on the challenge of managing the supply / demand imbalance and, with the circular economy now in the mainstream of thinking, minimising transfer. However, around the world extensive systems are moving water from one location to another to satisfy need. Sometimes, they are moving fresh water, sometimes it is untreated. Alongside unsustainable use of water resources, an escalating concern, however, is that in many regions the infrastructure that is in place is not enough to meet future demand. With ever more of us living in sprawling cities, managing the mismatch between supply and demand is becoming a major challenge. The fundamental problem to be solved is in economically, environmentally and equitably addressing an increasing scarcity of water in multiple regions.

The link between population growth and water use is pivotal - urbanisation has a strong correlation with income and has often been linked to increased water consumption.[3,4,5] Thus, as many European cities became centres of industrial growth, the mid 19th century was a peak in schemes to move water into many key cities including Paris, London and Hamburg. The 1930s saw comparable development across North America and Australia. In the US, cities such as Los Angeles, Detroit, Philadelphia, New York and Chicago experienced significant population increase and associated water demand. While in Australia it was the state capitals like Sydney, Melbourne, Brisbane, Perth and Adelaide as well as mining locations, such as Whyalla, that grew as new pipelines were built to supply more water.[6]

With the geographic focus of increased urbanisation now more widespread, several see the next decade experiencing a similar growth in water demand in key regions of Asia, Africa and South America. By 2035, the population of Beijing is, for example, expected to expand from 18 to 25m; Delhi from 33 to 43m; Shenzhen from 12 to 15m; Mexico City from 21 to 25m; Bogota from 11 to 13m and Cairo from 20 to 29m.[7] Moreover there is also further growth expected in several Western conurbations – for example LA, Houston and Phoenix in the US. All these cities will experience greater water stress and so want more water, most likely from elsewhere.

Although water itself is still seen as artificially cheap, moving it long distances is however costly, highly energy intensive, and can have significant collateral environmental, social and cultural impact. California's water system, for instance, already supports over 30 million people – with the world's largest, most productive and, in some eyes, most controversial arrangement. In particular water rights allowing large organisations to divert supplies from the poorer locations have been a key issue. Sustaining further population growth here and elsewhere is a rising political, economic and environmental test. While there are indeed some convincing alternatives to moving more water available for some, in many regions greater inter-basin transfer is increasingly seen as the only long-term option and one that will require significant new innovation to deliver.

Viable Alternatives

Given the costs and wider socio-environmental impact of moving water from one river basin to another, many ecologists, economists and, more recently, governments have been supporting alternative options. In some regions, such as California and Queensland, existing networks have, for instance, been inter-connected to become grids with bi-directional pumping so enabling full year-round movement of water to where it is most needed. However, the options of highest prominence in many eyes are the rise in the use of desalination and encouraging consumers to conserve supplies and make better use of the available water.

Cheaper Desalination

Although both causing collateral environmental impact due to the return of brine to the seas and also being highly energy intensive, and so traditionally only a rich-country solution, desalination has been undergoing a significant shift in development and investment support. With low-cost solar increasingly available as a localised renewable energy source, the affordability of desalination plants for many coastal locations is improving. As energy subsidies, more acceptable project costs and increasing competition have all taken effect, desalination is becoming a credible alternative for a broader range of cities and nations. Many envisage that, if 'low-cost desal' can be achieved at scale, then the need to move water could be significantly reduced. While a few go as far as to see a 100-year future where widespread solar energy could make energy 'free at the point of production' which could in turn lead to nearly free desalination - and so essentially free fresh water for a lucky few, managing the mid-term provision is, however, more complex.

There are two technologies both scaling: thermal desalination uses heat, often waste heat from power plants or refineries, to evaporate and condense water to purify it while reverse osmosis passes salt-water through semi-permeable membranes at high pressure to produce very high-quality water. With around 40% the world's population living on or within 100km of the coastline, it is little surprise why the progressively inexpensive production of fresh water from seawater is an attractive option.[8] Globally, thermal desalination is currently the leading technology with over 60% of the market, but reverse osmosis processing costs are gradually declining – some suggest heading for around 50 to 60 cents per m^3 by 2030 – and so growing its share.[9,10] Key regions of significant use include the US, Southern Europe, Japan and the Middle East but, with falling prices, several anticipate that India, Indonesia and several African nations will soon be building more desal plants.

Although there are numerous coastal cities with significant water supply challenges, including the likes of Chennai, Jakarta and Sao Paulo, several authorities advocate that wider use of desalination could make a major contribution. Compared to building new long-distance water transfer infrastructure, desalination also has other benefits: For politicians, it offers control of municipal water supplies without having to depending on provision from other regions; while, from an investment perspective, most projects have both the scale and financial returns necessary to attract private sector funding.

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Better Use

In addition, there are many urban areas where, either because of location or other political and environmental supply constraints, city and government bodies have supported initiatives to reduce water use. Multiple different approaches are advocated around the world including better managing stormwater and rainfall capture through to restricting daily household consumption and the recycling of used 'grey' water for groundwater replenishment or landscape irrigation. Pioneers here have included Singapore, California, Spain and Australia, but others are now improving fast. While, as nations, India, China and the US are the top 3 net water consumers globally, some of the most significant high users of water on a per capita basis include Chile, Uzbekistan, Australia, the US and Iran – all using well over 350 litres per person every day.

In recent years, several countries have better managed their water consumption to notable effect: In the US , for instance, total use has reduced by 20% while in Australia the figure is 25%. The nation has achieved this through a broad combination of adopting the Australian Reuse Water Guidelines, giving consideration to incentivised schemes, improving irrigation and rural water use (two thirds of the national consumption) as well raising household efficiency. Elsewhere, there is growing focus on reducing agricultural use through changing policy and behaviour around meat production, especially beef which consumer more water per kg than any other food. However, in other countries, where there has been less historical focus on water conservation, use per capita is rising – for example in Iran it is up by over 25% and, with more desalination but less than 5% recycling currently underway, the UAE has seen a more than doubling of water use in the past decade.[11]

More cities and countries are thus becoming aligned around the benefits of better water management with the combination of improved capture, more renewable supplies, wider reuse and, where practical, desalination all playing an important role. That said, there are still numerous locations where these are not enough.

Inland Areas of Need

Although these alternative options have had tangible impact in many locations, they have not met the escalating water need everywhere. There are still many non-coastal fast-growing regions where the top future risks include increased water stress. Here additional approaches are needed, and relatively quickly. Some notable locations that soon expect to reach breaking point for water supply include the likes of Las Vegas, Mexico City , Moscow and Beijing.[12,13,14] Each of these cities are trying to address the challenge in different ways, but, despite the considerable energy requirements and associated high carbon footprints, all are variously now also making longer-term plans to import more water from other regions.

A core task that is progressively falling on the laps of many civil engineers is therefore how to better move significant volumes of water significant distances economically at scale: Today, to have impact, this typically means anything from 200km to 2000km. It frequently involves what is termed inter-basin transfer – the subtraction of water out of the source river system and corresponding addition at the destination. While many systems were built in the past, today environmental and development implications are often barriers to construction as much as finance and politics.

In the UK, for example, a systematic analysis of supply and demand management options is carried out for all water resources management plans prepared by different water companies. To date, assessments have shown that large-scale transfers of water to the south of England from the north or Wales would be more expensive than other options available to meet current forecast demand.

Elsewhere, a host of proposed developments are however in planning around the world. Many of these are in emerging economies and some have been the focus of ongoing debate for many years. In Africa, for instance, there has been much discussion about the Lake Chad replenishment project that would create a connection between the Ubangi and Chari rivers. The Indian Rivers Interlink includes a Himalayan component that comprises 14 main links between the main rivers such as the Ganga and the Brahmaputra.[15] These and other potential schemes are all in the midst of multiple feasibility studies and political debates about investment and potential impact.

Foremost today however the standard is being set by China. It is Beijing that is driving significant change as the Chinese capital's water shortage has been compounded by its growing population, chronic drought, pollution and massive wastefulness.[16] As a previous response, in 2003 Beijing began channelling water from its arid neighbours, Hebei and Shanxi, and sharply increased the diversion from Hebei to as much as 400 million m^3 a year as it began preparations for the 2008 Olympics. Ensuring water supply has again become a severe challenge for Beijing's current five-year plan, with municipal authorities now facing a gap of 515 million m^3 a year. The solution? The world's largest infrastructure project.

The South North Water Transfer Project

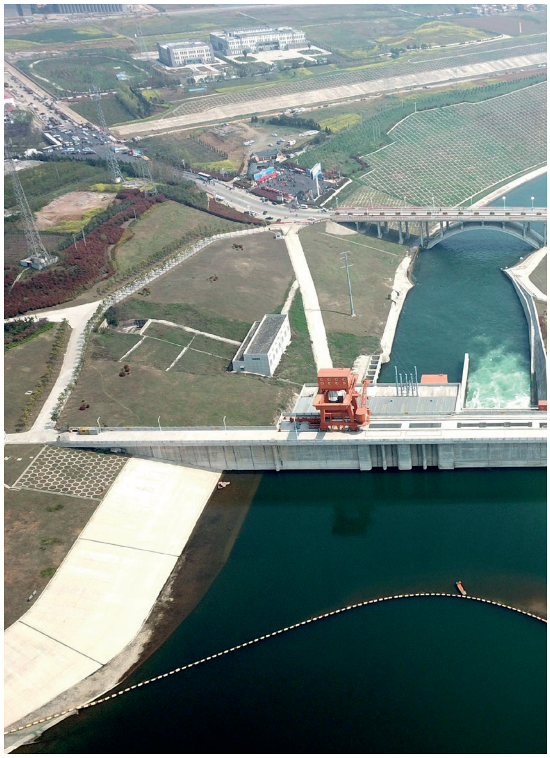
While other regions are looking at large scale movement of water between river basins, none is as ambitious as what is underway in China. The South-North Water Transfer Project is multi-decade mega-programme that aims to transfer over 40 billion m^3 each year from the Yangtze River in southern China all the way to Beijing and other parts of the industrialised north.[17] First discussed as far back as 1952, since it was finally approved in 2002 nearly $100bn has been spent on a host of dams, canals, tunnels, pipelines, reservoirs and pumping systems across three routes.

1. The 1150km East route is an upgrade of the 7th century Grand Canal to supply Tajin and its environs;

2. The 450km West route aims to divert water from the headwaters of the Yangtze across the Tibetan plateau; and

3. The Central route, that will supply Beijing itself, crosses the North China Plain and includes two huge tunnels under the Yellow River.

Completion of the project is expected between 2040 and 2050 and, as well as the huge bill, it will necessitate the relocation of millions of people in central China as well as the destruction of substantial acres of pasture.[18] However, according to the Chinese government, once built, this project will transform the country's future development capability, enable further expansion of northern cities and will only consume a small share of water from the Yangtze, 'the majority of which flows into the Pacific'.



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Alternative Options

While socio-political and environmental concerns are clearly pivotal in decision-making for many locations, in terms of the core economics building new infrastructure, whether pipelines, tunnels or canals is hugely expensive. Moreover, as inter-basin water transfer projects often involve moving large quantities of water over long distances and significant elevations, they are also high energy-consuming assets.

Australian analysis a decade ago highlighted that, at around $5 per m^3, the average cost of moving water by new pipeline or canal is comparable to moving it by tanker –so ten times the future target price for desalination at scale.[19] While the environmental impact of using tankers is clearly much worse than a pipeline, for many it is a pragmatic option as few countries beyond the likes of China can afford the level of investment required for major infrastructure.

Some have also been looking at alternative options for moving large volumes of water. While towing icebergs from the Antarctic has, for example, been the subject of speculation since the 1970s, more recently some countries including South Africa and the UAE have seriously looked into the practicalities but concluded it is not credible - yet.[20] Others have explored the idea of using bags and flexible barges to tow fresh water around the world but have increasingly recognised the high costs as well as several significant practical concerns. However, amongst the varied proposals, there is another option that, with several parallel shifts underway, is now becoming increasingly possible and potentially extremely cost effective.

Repurposing Exsiting Assets

As the world gradually migrates from oil and gas towards more renewable energy supplies from solar and wind, energy transportation needs change from long-distance pipelines and the use of tankers to short distance power transmission lines: as well as being increasingly distributed, energy supply is becoming more localised. As such, the old oil and gas infrastructure will become gradually redundant and can, some propose, be repurposed. As was first suggested in an expert workshop back in 2004 and reiterated multiple times since, a 2040 horizon of being past 'peak oil' could open the door for more affordable water transfer as "this is just about moving a different liquid using the same infrastructure."[21]

In some parts of the world, such as Vietnam, old oil pipelines have already been dismantled, relocated and reused for water transport. Although more complex than building a new pipeline, this was nonetheless far cheaper. However, if the pipelines don't need to be relocated - but just repurposed for water use, then both complexity and investment falls significantly.

While an engaging concept in theory, the key questions for practical implementations cover three issues – cleanliness, volume and location.

- **Cleanliness:** Some advocating using old oil pipelines to move fresh water highlight the need to refurbish the infrastructure to the necessary public health standards. Others however point out that with point-of-use purification and filtering technologies becoming cheaper and more widely available, there is no need to incur the expense of pipeline refurbishment. Furthermore, over time water passing through the pipeline will clean it up and so output quality will quickly improve. For the reuse of gas pipelines this is not an issue.

- **Volume:** The question is whether existing steel oil and gas pipelines could transfer enough water to solve the problem at hand. While pipeline size and throughputs vary, many oil and gas pipelines are 1.2m in diameter. Oil is clearly thicker than gas but still it is pumped at speeds of up to 10km/h – this is very much driven by liquid viscosity and density. Under pressure, water can reach higher speeds and many of the plastic pipelines typically used are also around 1m in diameter so, overall, engineers see that comparable volumes of water can be pumped through oil pipelines as through those specifically designed for water transfer.

- **Location:** Many of the countries most threatened by increased water stress already have significant oil and gas pipeline infrastructure in place.[22,23] THE US, especially states such as California, Arizona and New Mexico, has several regions with significant water-supply challenges. With the world's largest pipeline infrastructure of over 2 million miles, over 70% of US crude oil and petroleum products are currently shipped by pipeline. China equally has an extensive oil pipeline infrastructure and, as highlighted above, notable water challenges.[24]

Elsewhere, the Middle East and North Africa is a primary region of focus for many concerning potential pipeline re-use. Here the extensive oil infrastructure aligns well with locations with high levels of water scarcity from Morocco to Oman. Even in countries such as the UK, where water stress in the SE of England is increasingly evident, there is a sizeable oil pipeline network – the 7th largest in the world – that could be repurposed. Similar synergies exist in France, Germany, Spain and Italy.

Moreover, much of India's 35,000 miles of oil infrastructure cuts across Rajasthan, Haryana and Uttar Pradesh – states with the highest levels of water stress.[25] While in Australia a significant share of the nation's oil and gas infrastructure connects the north and south pretty close to where much of the future water transportation needs lie. Although not a 100% match everywhere, in a good number of locations there is significant alignment of potentially reductant oil and gas supply lines with future water transfer needs.

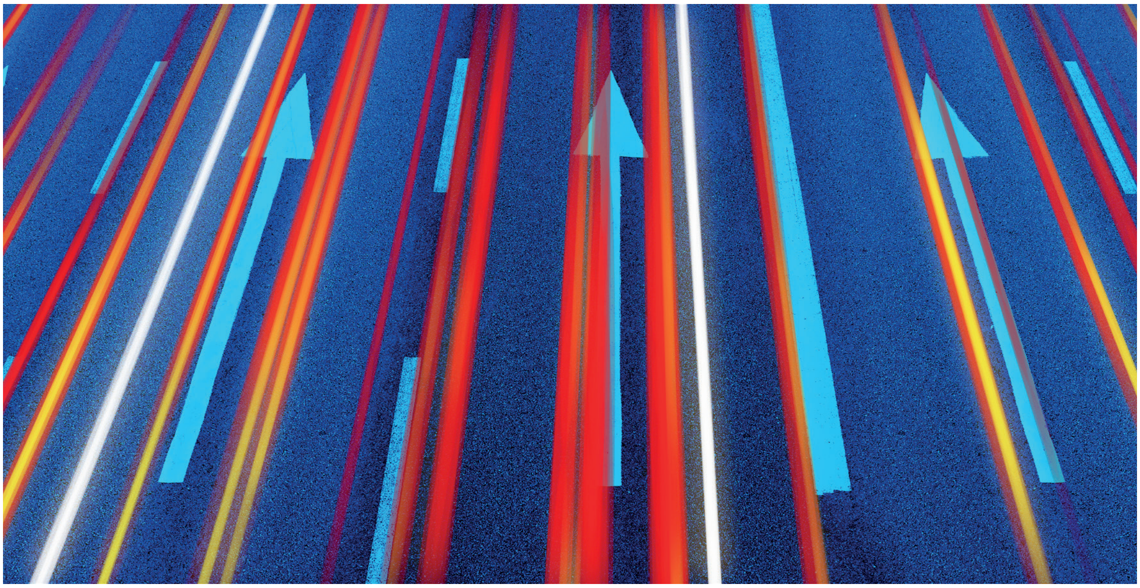
So, although still on the drawing board of several engineering firms, the repurposing of oil and gas pipelines is indeed looking increasingly plausible. Given that energy still costs so much more than water, the timing of any switchover will clearly be driven by the market. But, given that a viable infrastructure has largely already been built, and all the capital costs repaid, the benefit of reusing rather than dismantling these assets is becoming increasingly attractive to many organisations involved. Not only can water be supplied at a fraction of the cost of many alternatives, including solar powered desalination, but there is little negative environmental impact. The question is who will go first and so set a new standard for others to follow. Eyes are, unsurprisingly, on California and Australia but maybe the Middle East could also be an early mover.

The repurposing of oil and gas pipelines is indeed looking increasingly plausible.

Leading in 2030

Water demand is exceeding supply in many regions and is set to increase substantially over the next decades. Global water use for agriculture alone will increase by 60% by 2025 and the UN World Water Development Report predicts that nearly 6 billion people will suffer from clean water scarcity by 2050.[26] It suggests that “Urban water resilience goes way beyond the traditional city boundaries. In cases where water supplies rely on distant watersheds, planning needs to look well beyond the city’s boundaries and consider the long-term impacts of urban expansion on distant freshwater ecosystems and the local communities that also rely on them.” With rising awareness of the need for better water management, more conservation and reducing demands from agriculture as well as energy needs all increasingly part of the debate, many are hopeful that the need for water transfer can, in the long term, be reduced. But, for some, this transformation may not happen quick enough.

Moving water will increasingly be a pivotal mechanism in helping to rebalance supply and demand but more efficient solutions need to be adopted. High cost infrastructure projects are an option for the few nations that can afford them, and also bypass social and environmental concerns, but elsewhere more imaginative solutions will be needed. The repurposing of old oil and gas pipeline assets seems to be a viable alternative in some of the major locations, and so may see broadening support, but other options will also need to be explored. As occurred with the Romans 2000 years ago, in Europe in the 1850s and in the US and Australia in the first half of the last century, innovation in moving water is set to again take centre stage in many significant locations of escalating need.



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FUTURE AGENDA
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The World in 2030

This is one of 50 global foresights from Future Agenda's World in 2030 Open Foresight programme, an initiative which gains and shares views on some of the major issues facing society over the next decade. It is based on multiple expert discussions across all continents and covers a wide range of topics. We do not presume to cover every change that will take place over the next decade however we hope to have identified the key areas of significance. Each foresight provides a comprehensive 10-year view drawn from in-depth expert discussions. All foresights are on https://www.futureagenda.org/the-world-in-2030/

Previous Global Programmes

The World in 2020 was published in 2010 and based on conversations from 50 workshops with experts from 1500 organisations undertaken in 25 countries as part of the first Future Agenda Open Foresight programme. This ground-breaking project has proven to be highly accurate in anticipating future change and the results have been used by multiple companies, universities, NGOs and governments globally. Rising obesity, access not ownership, self-driving cars, drone wars, low cost solar energy, more powerful cities and growing concerns over trust were just some of the 50 foresights generated. For more details: https://www.futureagenda.org/the-world-in-2020/

Five years on, the World in 2025 programme explored 25 topics in 120 workshops hosted by 50 different organisations across 45 locations globally. Engaging the views of over 5000 informed people, the resulting foresights have again proven to be very reliable. Declining air quality, the growing impact of Africa, the changing nature of privacy, the increasing value of data and the consequence of plastics in our oceans are some of the foresights that have already grown in prominence. For more details: https://www.futureagenda.org/the-world-in-2025/

About Future Agenda

Future Agenda is an open source think tank and advisory firm. It runs the world's leading Open Foresight programme, helping organisations to identify emerging opportunities, and make more informed decisions. Future Agenda also supports leading organisations on strategy, growth and innovation.

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