The Future of Urban Water:
Scenarios for Urban Water Utilities in 2040

ARUP

Arup and Sydney Water

The Future of Urban Water: Scenarios for Water Utilities in 2040 is the result of a jointly funded collaboration between Arup and Sydney Water. The programme explored trends and future scenarios for the future of urban water utilities in 2040. It was delivered and managed by Arup, in close collaboration with experts from Sydney Water. The programme has helped us gain a better understanding of possible pathways into the future, including implications for future infrastructure, governance and customer experiences.

The contents of this report are the sole responsibility of Arup and do not necessarily represent the views of Sydney Water.

Arup
13 Fitzroy Street
London W1T 4BQ
United Kingdom

Arup
1 Nicholson Street
Melbourne VIC 3000
Australia

Sydney Water
1 Smith Street
Parramatta, NSW
Australia

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Executive Summary

How can we meet the water needs of a rapidly growing urban population? Can we provide equitable water services in a world increasingly faced with water scarcity and environmental degradation? How can we achieve this without further compromising the planet's ecosystem?

The Future of Urban Water: Scenarios for Water Utilities in 2040 depicts four plausible scenarios for the future of urban water utilities in 2040. Using Sydney as a reference city, the report explores how a wide range of social, technological, economic, environmental and political trends could shape our urban water future. In times of increasing uncertainty — and with a future likely to be utterly different from the world we are experiencing today — scenarios help us better understand possible pathways into the future and enable conversations about how we can influence and shape the direction we are travelling in.

By understanding trends and planning for the future, water utilities can create more engaging customer experiences, enhance the liveability of urban areas and get more out of their current and future assets. The scenarios featured in this report can be used to explore the viability of different strategies, inspire innovation and assist in long-term planning for more sustainable and resilient urban water systems. While the scenarios are based on Sydney Water, their implications are relevant to a wide range of other utilities and organisations.

By communicating the report's outputs, Arup and Sydney Water wish to further strengthen our leading positions in delivering innovative water solutions for future cities. We believe that the challenge of delivering secure, safe and sustainable water can be met only by working collaboratively, interacting with stakeholders and being open to new ideas and innovation.

This report is aimed at the water sector, utilities, governments, cities, communities and any other individuals or organisations interested in the future of urban water.

We cannot predict the future, but we can shape it.

Implications across Scenarios

Customers	Infrastructure	Governance	
Focus on customer services that are user-centric and provide greater personal choice and control over service levels and pricing	Increased deployment of digital infrastructures and data analytics to manage, reduce or eliminate system peaks and fluctuating demand patterns	Higher levels of coopetition between water, energy and telecommunication companies with a focus on integrated planning and maintenance	Incremental Improvements
Emphasis on creating a seamless customer experience across multiple integrated utilities, including shared billing, pricing and customer services	Integration and sharing of assets and infrastructure across multiple utilities, including water, energy, waste and telecommunications	Better cooperation between urban utilities through collaborative planning, integrated asset management, shared protocols and open data	Better Together
Greater focus on services that enable customers to manage and maintain autonomous water systems at building, community or cluster level	Provision of planning and infrastructure services that enable communities to develop, run and maintain autonomous urban water systems	Governance and operation of autonomous systems and small-scale water networks through cooperatives, virtual networks and community platforms	Autonomous Communities
Development of applications to provide customers with real-time data and information about water consumption, availability and pricing	Expansion of systems to manage and minimise the impact of extreme fluctuations in water availability, including fast shifts from too much water to too little	Implementation of differential water pricing and services according to availability of supply, service plans and customer behaviour	Survival of the Fittest

Water security is one of the most tangible and fastest-growing social, political and economic challenges faced today. It is also a fast-unfolding environmental crisis. In every sector, the demand for water is expected to increase and analysis suggests that the world will face a 40% global shortfall between forecast demand and available supply by 2030.

—World Economic Forum, 2014

Global Water Situation 1

Water is a precious and increasingly critical resource. The World Economic Forum's "Global Risks 2014" report identifies water crises as one of the top five global risks posing the highest concern. Water crises were ranked as the third biggest risk in terms of impact; however, strictly speaking, four of the identified top 10 risks are water-related — water crises, climate change mitigation and adaptation, extreme weather events, and food crises.[1] Despite this, water issues are often overlooked or misunderstood, and there is a need for better awareness of their social, economic and environmental impacts.

In addition to increasing water scarcity and pollution, rapid population growth and urbanisation are major factors posing fundamental challenges to the global water cycle, with a particular pressure on the urban water supply. Since 1950, cities have increased their water usage five-fold, not only through population growth but considerably through increased per capita demand. Cities increasingly struggle to access enough water supplies to sustain their population, and currently, half of the world's cities with more than 100,000 inhabitants are situated in areas experiencing water scarcity.[2] Meanwhile, there is increased decoupling of urban and rural systems and a diminishing holistic consideration of the global water cycle, with urban areas being considered as isolated entities. For cities to succeed in a world characterised by resource issues and constraints, we must recognize that cities don't exist in isolation.

Overlaying and intensifying all of these pressures is climate change, including rising temperatures, extreme weather events, rising sea levels, and reduction in river flows and groundwater levels. The exploding global demand for "water-heavy" goods including food and technological products is another critical factor, with agriculture already responsible for around 70% of freshwater withdrawals globally.[3] The 2030 Water Resources Group predicts a global gap between safe freshwater demand

and supply of 40% by 2030 if business-as-usual water management continues, thus not supporting the predicted population.[4] With a possibility for water depletion and increasing competition through scarcity, new thinking and new ways of managing water become fundamental. Who will manage, control and be responsible for water resources in the future?

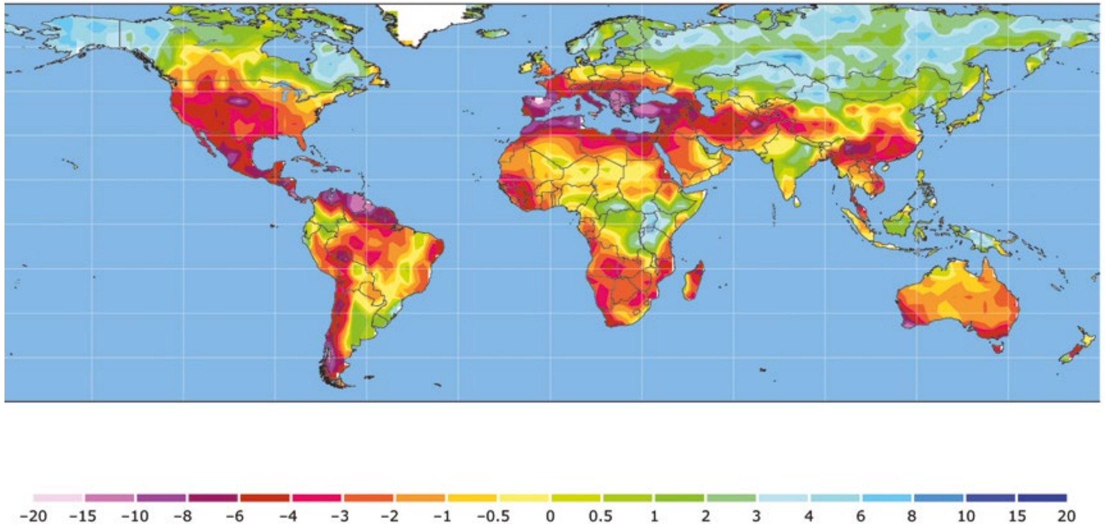
Australia: Current Situation

Challenges for water utilities in Australia include meeting future demand for water in a changing climate, managing diverse sources of supply, ensuring the health of waterways and ecological systems, maintaining the affordability of water services and reducing the carbon footprint of urban water supply and use. For urban water utilities, this means making innovation and investment decisions that maximise opportunities to provide services of value, while mitigating future risks and uncertainties.

Australia utilises over 50% of its water consumption for agricultural purposes and the remainder for household, industrial and commercial consumption. However, in urban areas, the main driver for demand remains the population, and thus population growth.[5] Despite Australia being the driest populated continent, the greatest amount of water per capita is used in global comparison.[6] Rainfall supplies most water sources in Australia, but future patterns of rainfall are likely to be highly variable and unpredictable due to the effects of climate change. Consequently, equitable access to sufficient water supply presents a key challenge.[5]

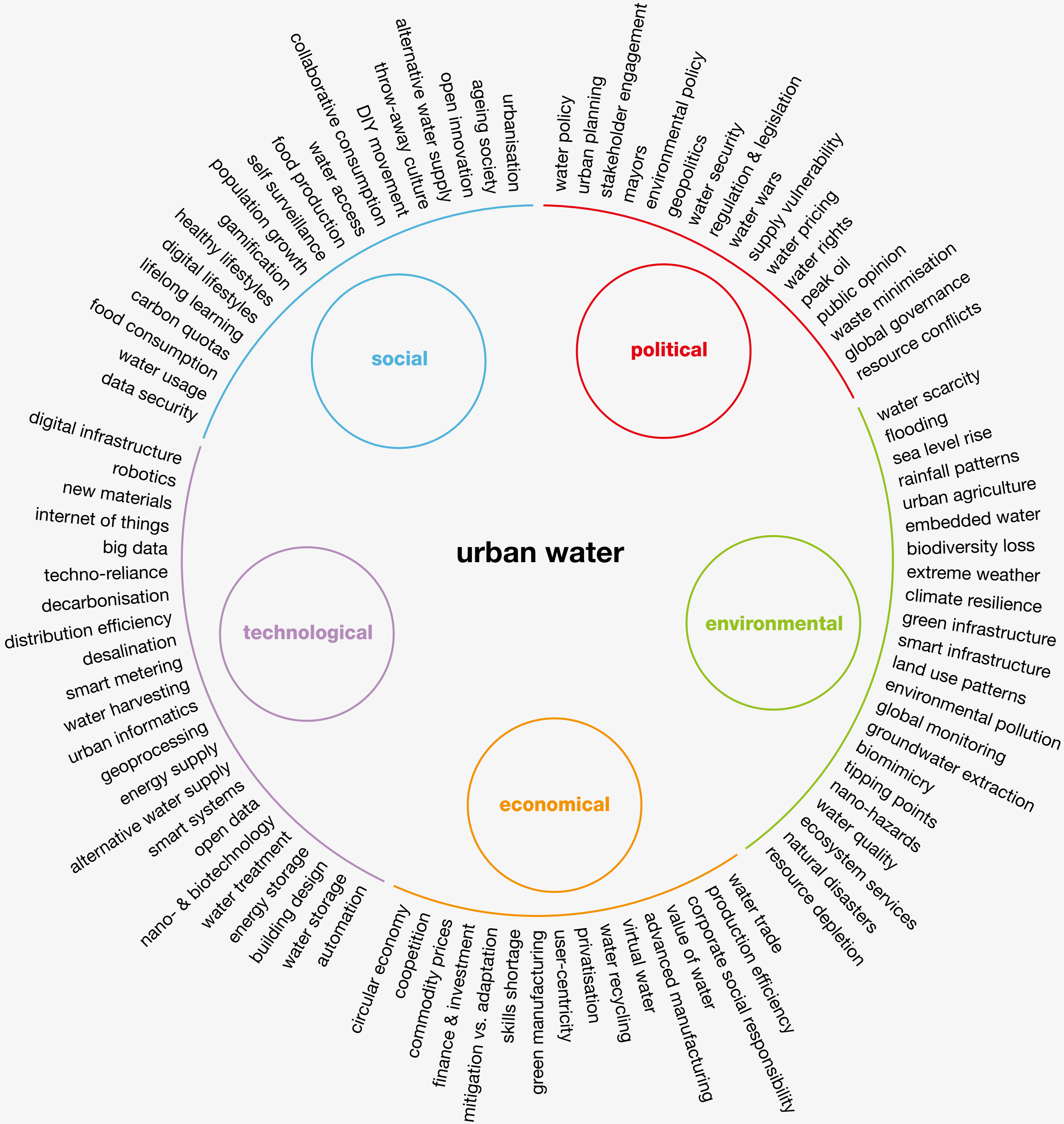
In Sydney, the reference city in the context of this report, surface water is the primary water source. Due to the irregularities in rainfall throughout the year, Sydney is highly dependent on its reservoir capacity.[7] Sydney's enormous task with regard to water supply and infrastructure is not only an issue of environmental variables but also one of a rapidly growing urban population, with an annual growth rate of 6.8% from 2007 to 2012.[8] Combined with a decade-long water crisis from 2003, insufficient dam capacity and decreasing dam levels require Sydney to access new sources and reduce demand.[9]

Global Drought Predictions 2030–2039



Potential for future drought using the Palmer Drought Severity Index. Estimates based on current projections for future greenhouse gas emissions. Actual emissions and climate variations could alter projected drought patterns. Positive numbers indicate conditions that are unusually wet. Negative numbers indicate conditions that are unusually dry. A reading of -4 or below is considered extreme drought.

Source: University Corporation for Atmospheric Research 2014



urban water
social
political
environmental
economical
technological
urbanisation
ageing society
open innovation
alternative water supply
throw-away culture
DIY movement
collaborative consumption
water access
food production
self surveillance
population growth
gamification
healthy lifestyles
digital lifestyles
lifelong learning
carbon quotas
food consumption
water usage
data security
water policy
urban planning
stakeholder engagement
mayors
environmental policy
geopolitics
water security
regulation & legislation
water wars
supply vulnerability
water pricing
water rights
peak oil
public opinion
waste minimisation
global governance
resource conflicts
water scarcity
flooding
sea level rise
rainfall patterns
urban agriculture
embedded water
biodiversity loss
extreme weather
climate resilience
green infrastructure
smart infrastructure
land use patterns
environmental pollution
global monitoring
groundwater extraction
biomimicry
tipping points
nano-hazards
water quality
ecosystem services
natural disasters
resource depletion
water trade
production efficiency
corporate social responsibility
value of water
advanced manufacturing
virtual water
water recycling
privatisation
user-centricity
green manufacturing
skills shortage
mitigation vs. adaptation
finance & investment
commodity prices
coopetition
circular economy
automation
water storage
building design
energy storage
water treatment
nano- & biotechnology
open data
smart systems
alternative water supply
energy supply
geoprocessing
urban informatics
water harvesting
smart metering
desalination
distribution efficiency
decarbonisation
techno-reliance
big data
internet of things
new materials
robotics
digital infrastructure

Drivers of Change: Urban Water 2

This section identifies some of the global drivers of change linked to the future of urban water utilities, including the future of urban water access, supply and services.

We identified around 100 trends, from global megatrends to sector-specific drivers. A full list of drivers, designed as workshop cards, researched and written by Arup's Foresight + Research + Innovation team, is shown in the diagram on the left. The responses to these drivers will be critical in determining the nature of urban water supply in the future. Furthermore, businesses operating in this world of rapid social, technological, economic, environmental and political changes face a number of uncertainties and challenges. Drivers of change assist us in identifying risks and opportunities and help us better understand the long-term issues, preparing us for the world ahead.

Trends and Drivers

Social

Population growth and increasing urbanisation

The **global population** is expected to reach around 9.5 billion in 2050. At this point the population will still be growing, but the rate of growth will have slowed. An estimated 90% of population growth is expected to occur in the cities of the developing world. It is estimated that the global urban population is growing at two people per second, adding 172,800 new city-dwellers each day.[10] This rapid **urbanisation** means that by 2050 around 70% of the global population will be urban dwellers.

Australia's population is expected to rise 60% by 2050, from 23.3 million today to 37.6 million. Sydney and Melbourne's populations are projected to jump 60% to 80% to reach almost 8 million inhabitants each.[11]

Population growth and urbanisation pose great challenges to utilities — they must serve more people while facing greater scarcity of resources. Increasing demand will heighten focus on water conservation and reuse. There will be a need to manage and influence demand through behaviour change and to increase the efficiency of the system, which involves understanding its pinch points, investigating new technologies and providing incentives for behaviour change.

Another factor is an **ageing population**, due to an increase in life expectancy. As total birth rates decline, the impact of the baby-boomer generation is highlighted with an increasing proportion of the older generations. By 2050, more than 20% of the global population will be 60 years old or over. In Australia over the next 40 years, the proportion of the population over 65 years will almost double to around 25%. At the same time, growth in the population of traditional workforce-age is expected to slow to almost zero.[12]

This demographic change could lead to the need for different or shifting services, such as water for health care provision. More people at home and not working due to retirement could have an impact on services and the reporting of service interruptions. Affordability of water services could also be affected.

Sustainable behaviours and healthy lifestyles

Rising global consumption of raw materials is intensifying resource scarcity and competition for resources. With increased awareness of environmental concerns and greater global regulation, individuals and corporations are attempting to engage in more **sustainable behaviours**.

There is also a trend towards increasing self-responsibility for **health and wellbeing**. In general, people are smoking less, drinking less and exercising more. Consumers are also more interested in what goes into their food and how food is produced and processed.

Greater concern for the environment and health means that water companies will be held to account for environmental impacts and water quality. It is likely that there will be a focus on water-sensitive cities, including scrutiny of the use of water in urban landscapes and access to good quality water in public spaces. A greater emphasis will be placed on green infrastructure and a trend for companies to transition from providing utilities to providing amenities. There will also be greater scrutiny of how new technologies and new products affect water supply (eg, microplastics).

However, Australians seem to live with a contradiction. They express concern about the environment yet live **materialistic lifestyles** that result in high levels of waste. Australian households generate the second highest amount of waste per capita in the world. On average around 20 million tonnes of waste per year is thrown away, and the amount is growing. It is estimated that total **wasteful consumption** amounts to over AUD$10.5bn annually spent on goods and services that are never or hardly ever used. About AUD$5.3bn of this waste is food-related.[13] When considering the amount of water used in producing food, **food waste** is simultaneously a waste of water. This is especially true when considering the globally increasing meat demand — it takes 13,220 litres of water to produce 1kg of beef compared to 900 litres of water for 1kg of potatoes.[14] The United Nations Food and Agriculture Organisation forecasts global meat production to increase by 65% within the next 40 years.

Digital lifestyles

The digital lifestyle increasingly links consumers' lives to the internet. Smartphones are becoming the hub of our **digital lifestyles**, allowing us to constantly connect to social media, work and leisure activities. Mobile subscriptions today almost equal the earth's population, and the number of people using social media is projected to almost double by 2017, reaching 2.55 billion.[15]

This **connectivity** also means that traditional models of ownership are changing. The trend towards a **shared economy** of service provision rather than product ownership means, for example, that consumers are increasingly likely to purchase access to a car rather than buy their own car.

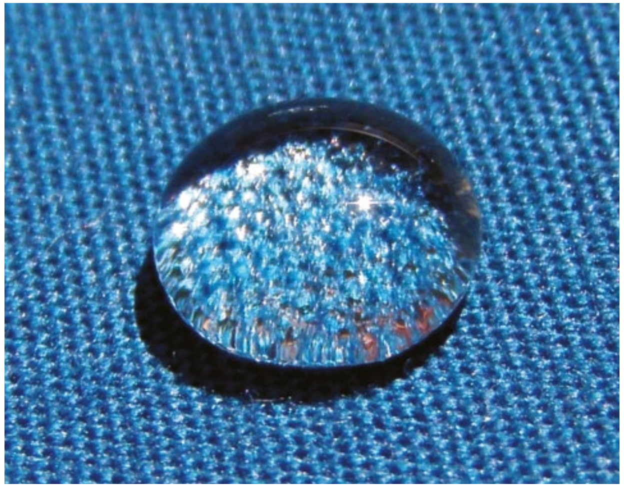
With growing connectivity and smart technology, people will be able to **monitor the consumption** and cost of water in real time. More awareness of the issues could lead to increased scrutiny of water utilities and pricing of services. The availability of data provides an opportunity to educate customers about consumption and managing resource use. The possibility of technology to allow urban water trading could result in changes to demand system characteristics.

Technological

Smart infrastructure and big data

Smart infrastructure responds intelligently to changes in its environment to improve performance. It is estimated that the market size for smart grid technologies will almost triple by 2030. **Smart water networks** could save the industry US$ 12.5bn a year. In Israel, data analytic company TaKaDu takes information supplied by **sensors and meters** dotted around a water company's supply network to build a sophisticated picture of how the network is performing. It can spot anomalies in its behaviour, from a small leak to a burst water main. Locally, smart electricity meters have already been installed in a number of states while smart water meters are increasingly being implemented, with large scale examples in Hervey Bay and Mackay, and trial programmes occurring across other Australian states.[16]

Many organisations are already using **big**



data techniques and advanced analytics to manage complex processes and supply chains. It is expected that there will be a 4,300% increase in annual data generation by 2020, and more than a third of the data produced will live in or pass through the cloud.[17] The analysis of big data can provide valuable information to help identify innovation opportunities, transform the management of assets, enhance interaction with customers and suppliers, and make sure that key risks to a business are proactively managed.

The integration of different sets of data from utilities will provide business insights. For example **customer data** will provide insights on service needs and expectations. Information such as this can be a competitive advantage for utility providers.

The rise of the Internet of Things — the connection of a huge range of devices, sensors, and machines to the internet — will enable new technologies and innovation to spread and multiply. Currently, 99% of physical objects that may one day be part of this network are still unconnected. **Digital infrastructure** is, however, growing exponentially and is an important part of a nation's strategic infrastructure. In the UK, it is estimated that digital infrastructure contributes £102bn in gross value-added and employs over 2.5 million people.[18] These technologies enable the delivery of many services by both the private sector and government.

Digital infrastructure enables big data and broadens the base of data acquisition. There is, however, a threat from techno-reliance and exposure to external control.

Advanced technologies and innovation

Nano- and biotechnology can enable breakthrough products and technologies to tackle pressing global challenges, such as reducing environmental footprints, using less and cleaner energy, and decreasing water usage and waste generation. For example, microorganisms are being used to treat water that has been contaminated by hazardous materials. The global market for nanostructured products used in water treatment was worth an estimated US$ 1.4bn in 2010 and is expected to reach a value of US$ 2.1bn in 2015.[19] This is an area that could be a game changer for the water industry, allowing use of more water sources. It could help in tackling scarcity, quality and distribution. It also raises the possibility of the utility as a **self-healing** ecosystem.

Intelligent robots will play a greater role in the inspection of infrastructure such as tunnels and bridges, and in the efficient maintenance of ageing structures. Smart robots are being used to repair and retrofit ageing water pipes, while crawling robots can test load-bearing cables and tethers of bridges, elevators and cable cars.

One important area for innovation is in the development of **new materials** that are lighter, stronger, smarter and greener. Materials like graphene, which is revolutionary in its strength, flexibility and conductivity, could have numerous applications and support completely new structures. Recently developed cellulose fibres — stronger than steel but made from natural materials and biodegradable — could revolutionise the materials industry. Maintenance costs are significant for the water sector, especially as the infrastructure ages. New materials could provide greater resilience at less energy and lower cost. Advances could lower the cost of infrastructure and new products.

New solutions for water supply

About 96% of the **earth's total water supply** is found in oceans, and there is broad agreement that extensive use of **desalination** will be required to meet the needs of a growing world population. Worldwide, desalination plants are producing over 32 million cubic metres of fresh water per day. However, energy costs are currently the principal barrier to its greater use.

As limited water supplies come under pressure, businesses are turning to **technological innovation**. New technologies are promising to transform wastewater into a resource for energy generation and humidity into a source of drinking water. For example, Israeli company Water-Gen has developed a device for extracting drinking water from air. It's already being used by the military, but its future will probably be in civilian uses. Other devices for capturing water from air are Fog Catchers, thick mesh nets that collect the water contained in fog. Fog Catchers have been successfully implemented in Lima, Peru, and other areas suffering from low rainfall levels.[20]

Nanotechnology is being used to develop solutions to three different problems in water

quality. One is the removal of industrial water pollution from groundwater. The second concerns the removal of salt or metals from water. The third involves a nanofilter to remove virus cells from water that standard filters can't eliminate. Nanotechnology will change the methods used to purify water and therefore the infrastructure required for water treatment.

New technologies are likely to broaden the source and use of water and its by-products, while new methods of treatment also enable decentralised treatment centres. However, water treatment can come at a high price. Adelaide for example, as a result of increasing uncertainty in water imports from the Murray–Darling basin, is now turning towards water recycling and desalination to supplement its water supply in coming years. The high cost of Adelaide's water supply plans is posing a serious challenge for city residents because water prices have risen more than 400% in Adelaide since 2007, in large part due to the cost of the desalination plant.[2] The high prices could also be a reflection of historically low water prices that did not reflect actual costs.

Technological innovation and data analytics capability are fundamental to the future of the water industry, and there is an opportunity for water utilities to get better at real-time monitoring and network optimisation. This also represents an opportunity area for investment by Sydney Water to become a global leader in operations and asset management.

Economic

Finance and investment

Infrastructure finance has become a global business. While most infrastructure investments are local, the sources of finance are increasingly global. The OECD has estimated that around US$50tr would be needed worldwide in the period to 2030 to satisfy the global demand for infrastructure.[21] However, accessing sources of funding is an increasing challenge. In the United States, for example, water infrastructure investment is not keeping up with demand. If current trends continue, the investment needed by 2040 will amount to US$195bn and the funding gap will be US$144bn.[22]

The cost of infrastructure could lead to the financial recycling of assets and capital, where old assets are sold or leased to fund the new. It could also lead to greater application of the **circular economy**, which will help stretch resources through end-of-life recycling and reuse. New technologies and processes are increasing our ability to recycle more and more material goods.

With growing concerns around water scarcity, environmental pollution and upgrade and infrastructure costs, users will likely have to pay the real cost of water in the future. Water prices will reflect the full cost of water services, and companies will need to integrate the true cost of water into their decision-making.

Australia is looking at superannuation funds as a key part of the solution to funding gaps in infrastructure. Over the past 20 years, Australia's superannuation funds under management have grown from $140bn to $1.3tr. Assets must meet the risk/return profile of superannuation legislation, but infrastructure can be invested in where it delivers an appropriate risk/return for the investor.[23]

User centricity and open innovation

As business strives to differentiate itself and customer expectations increase, the need to innovate around the **consumer experience** is becoming a critical factor for good design. As a result, **user-centred design practices** are becoming the de facto methodology in product design and services, including influencing the design of the built environment. Water services could become more individual and tailored to user needs. This could result in a move from an asset-based focus to a customer-centric view — for example, data is currently collected at a property level and not at an individual level. This trend highlights a need to customise service, products and prices, and to be more responsive to customer preferences.

More and more companies are tapping into the public's intellectual capital by "crowd-sourcing" product ideas and solutions. In exchange they are giving creative consumers a direct say in what gets developed, designed or manufactured. **Crowdfunding** is expected to add at least 270,000 jobs and inject more than US$65bn into the global economy by the end of 2014. The industry is expected to grow 92% in 2014.[24]

The desire for greater choice and more customised services can lead to greater complexity. For water utilities this could mean a different way of doing business that challenges traditional thinking and processes to include more engagement with the public, more transparency, shared ownership/IP, responding to new ideas, forming partnerships, and engaging with customers through social media.

Resource availability and production efficiency

With increasing scarcity and cost of natural resources, **efficiency** is a driving force for manufacturing companies. Manufacturing expenditures on raw materials, energy and water can be as much as 50% of total manufacturing costs. **Green manufacturing** can improve energy productivity and operational efficiency by switching to less water-intensive equipment and minimising waste. Another way of increasing efficiency is through coopetition. **Coopetition** occurs when companies forge alliances across traditional boundaries, for example in order to share common costs. The auto industry has used coopetition to great effect as evidenced in the teamwork of Peugeot and Toyota in 2005, where shared components were created for a new city car. In the water industry coopetition manifests as knowledge sharing and contributions to joint research and development across catchment boundaries rather than competitive boundaries.

Coopetition could enable utilities to be more agile through the sharing of experiences and by not holding a monopoly on good ideas, as pooled resources can drive efficiency and innovation. Coopetition could move the idea of the smart house and smart city closer to reality.

Through using resources more efficiently, countries could become active trading partners. **Water trading** allows for the redistribution of water among users. As the amount of water used in agriculture in arid regions is two to three times higher than in rain-fed regions, water trade could help save water on a global scale. This could include a global water balance concept, similar to carbon emissions reduction strategies, where water saved in one country offsets additional water use in another. At present, physical water trading typically occurs only in connected catchments where a water balance can be calculated and maintained. Water quotas and trading could extend this beyond adjacent regions.

Commodity prices have increased sharply since 2000, erasing all the declines of the 20th century. Prices for a range of raw materials are likely to remain high and volatile as global resource markets oscillate in response to surging global demand and inelastic supplies. This could drive up the cost of living and put pressure on water utilities to reduce the cost to the customer.

In Australia, the agricultural sector is a key consumer of the country's water supplies, accounting for around 65% of total water consumption.[25] Developments in this sector have knock-on effects for the water supply industry.

Commodity prices and resource scarcity also place greater focus on virtual water and embedded water. **Virtual water** is the amount of freshwater used or polluted for the production of industrial products and food. There is growing recognition of virtual water flow, the volume of virtual water being transferred from one region to another as a result of product trade. Some experts argue that importing virtual water can be a valuable solution to water scarcity. **Embedded water** is the water used to produce food and other products. For example, it takes 13,220 litres of water to produce 1 kg of beef, 1,004 litres of water to produce 1 litre of wine and 50 litres of water to produce one orange.[14] Increasing demand for water-intensive products could lead to water security issues. Consumer education could lead to a demand for goods produced with as little impact on water resources as possible.

Urbanisation is one of the key factors affecting growth in energy demand. World **energy consumption** is projected to grow by 56% between 2010 and 2040. Renewable energy and nuclear power are the world's fastest-growing energy sources, each increasing 2.5% per year. However, fossil fuels will continue to make up nearly 80% of global energy use through 2040. Approximately 90% of global power generation is water intensive.[26] Therefore, a country's energy mix has fundamental implications for its water industry. Furthermore, **resource recycling**, such as waste-to-energy or waste-to-product, offers an opportunity for growth as well as opportunities for private sector involvement.

Environmental

Climate change and climate resilience

Climate change has led to changes in **climate extremes**, including increasing temperature variability and more heat waves with record high temperatures. It also includes increasing rainfall variability with heavier, shorter-duration events along with extended droughts. It is, for example, 90% to 100% likely that heat waves will increase in length, frequency and intensity over most land areas.[27] **Sea level rise** is also a concern as around 10% of the world's population lives in coastal areas less than 10 metres above sea level, and is therefore vulnerable to rising sea levels.

Climate change policy has developed around two themes: **mitigation and adaptation**. Mitigation is tackling the causes of climate change through the reduction of greenhouse gas emissions. Adaptation is adjusting to the impacts of climate change, by reducing vulnerability and increasing resilience. Both bear an economic cost, and both approaches will shape efforts to avoid the worst of climate change.

Due to the irreversible impacts of climate change, **climate resilience** has become critical. This is particularly vital in built-up urban areas, where challenges such as population growth, poverty, disease and pollution are exacerbated by the impacts of climate change. Water utilities need to assess their stormwater and sewer systems capacities due to intensifying storms and increased rainfall. The requirement for systems to be resilient could lead to a new lens for decision-making, looking at new risks with new measurements. Resilience includes understanding the integration of water systems with other systems. Looking beyond water systems at wider concerns will increase complexity in thinking.

Green infrastructure and ecosystem services

Sustainable urban development cannot be achieved without recognising the vital role of the natural environment and its fundamental impact on economic prosperity, health and wellbeing. According to the Millennium Ecosystem Assessment, 60% of evaluated **ecosystems** are in a state of degradation or non-sustainable usage.[28] **Green infrastructure** is the network of green and blue spaces — such as parks, agriculture, woods, rivers, ponds — in and around cities. Benefits of increased green infrastructure include the reduction of flood risk, improved health and wellbeing, as well as providing a habitat for wildlife. Extensive green networks can be formed over time to create an encompassing "city ecosystem" that can support the sustainable movement of people, rebuild biodiversity and provide substantial climate change adaptation.[29] **Ecosystem services** are benefits arising from natural ecosystems such as water purification, groundwater recharge, preservation of biodiversity, pollination and the decomposition of waste. While these services are seemingly free, the estimated economic value of ecosystem services from aquatic biomes, marine and freshwater, makes up about US$27tr per year, compared to the total economic value of ecosystem services of US$33tr per year.[30] Protecting ecosystems and achieving balance and equilibrium requires a systems approach and integration with other networks. In urban areas, solutions like urban wetlands will need to become more commonplace as essential hard-working city components to deliver storm protection, buffering and filtration, cleaning and purifying urban water through natural processes. These features can also support attractive and significant wildlife areas to increase a city's biodiversity.[29] Large-species trees also form a vital component of a green infrastructure city ecosystem, as they deliver multiple benefits, including acting as carbon sinks. They absorb huge amounts of carbon dioxide (CO_2) from the atmosphere and convert it to oxygen, helping create healthier and liveable cities for urban dwellers.[29] They also intercept rainfall and increase the capacity of underlying soils to absorb water.

Environmental pollution

Pollution is the release of chemical, physical, biological or radioactive contaminants to the environment. Pollution of surface water is a problem for over half the world's population. Each year 250 million cases of water-borne diseases are documented, with roughly 5 to 10 million deaths.[31] The King River is the most

polluted river in Australia and one of the world's most polluted rivers. About 100 million tonnes of sulfidic tailings have been deposited on the banks and bed of the King River and in a delta at the mouth of the river where it enters Macquarie Harbour.[32] Pollution is a waste of precious resources and can cause societal harm. For example, chemicals released from the textile industry into waterways around the world are broken down to form hormone-disrupting and even cancer-causing chemicals. When it rains, dense concentrations of paved surfaces channel water into storm sewers that ultimately empty into natural waterways, carrying pollutants from cities. Integrating natural systems into the built environment enables the capturing and storing of water for reuse and removing pollutants.

Australia's sea surface water is highly polluted by **tiny plastics**. It is estimated that 4,000 tiny plastic pieces per square kilometre are floating in Australia's sea. The diameter of the majority of these pieces is less than 5mm but laden with harmful pollutants to marine species. Of the 1,476,690 tonnes of plastics used in Australia from 2011 to 2012, only around 20% were recycled. A large share, around 37%, of used plastics was used for the production of single-use products and packaging such as plastic bags, bottles and cups.[33]

Political

Water security, access and pricing

Water security is the capacity of a population to access sufficient water to meet all its needs and to limit the destructive aspects of water. It involves both the productivity and destructivity of water. By 2030, almost half of the global population of 7.5 billion people is predicted to live in areas suffering from severe **water scarcity**. Compared to current figures, this reflects an increase of over 1 billion people experiencing a lack of water.[34] **Water pricing** is being recognised as an acceptable policy instrument to respond to increasing water scarcity.

Diversifying water sources helps to secure water supply systems against droughts and floods. **Alternative supply** options include recycling existing water, such as sewage and stormwater, as well as manufacturing new water through desalination.

As climate patterns in Australia are changing, water resource planning must adapt accordingly. Initiatives to secure or conserve water supply — such as water restrictions, dam expansion, water recycling or desalination — carry social consequences and costs.

While many of these measures have already been implemented in the Australian context, how they are managed in the future (with respect to decentralisation and scale) will become an important consideration.

Water policy and regulation are typically determined on a state or national rather than international level. The fixed nature of water supply infrastructure and its history as an essential government-supplied service gives rise to natural monopolies within supply areas. This led to the desire by governments to protect consumers against the abuse of this monopoly and to therefore regulate the pricing of water. Governments, however, need to ensure the pricing policy is appropriate to balance the essential need for water, the impacts on consumers (particularly those on lower incomes) and the requirement that the suppliers remain financially viable.

In Australia, state and local governments have the ability and opportunity to integrate **urban water planning** more effectively with urban development planning in order to increase efficiency and create more liveable urban environments.[35] Limitations on greenfield development can protect ecosystems and resources. Sydney, for example, currently has significant stocks of residentially zoned greenfield land and land earmarked for urban expansion, but due to population growth, by 2036 the only greenfield areas that will remain will be a long way from the centre of Sydney. This has implications for utility providers.

Waste minimisation

Humankind is producing more waste than the environment can absorb. More than 400 million tonnes of **hazardous wastes** — wastes that can cause substantial threats to our health and the environment — are produced each year (almost 60kg for every person in the world).[36] **Waste minimisation** aims to eliminate waste before it is produced in order to reduce the quantity and toxicity of waste. Prevention is the primary goal, followed by reuse, recycling,

treatment and appropriate disposal.

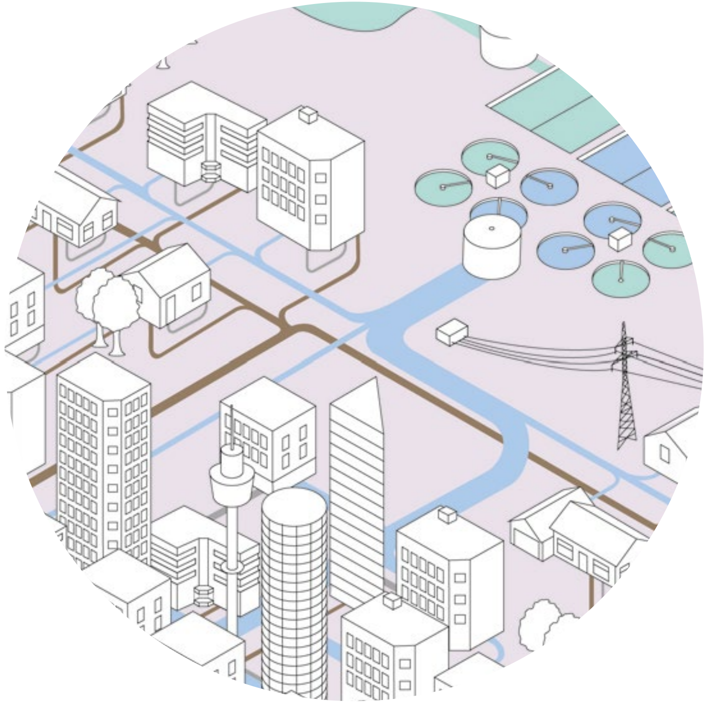
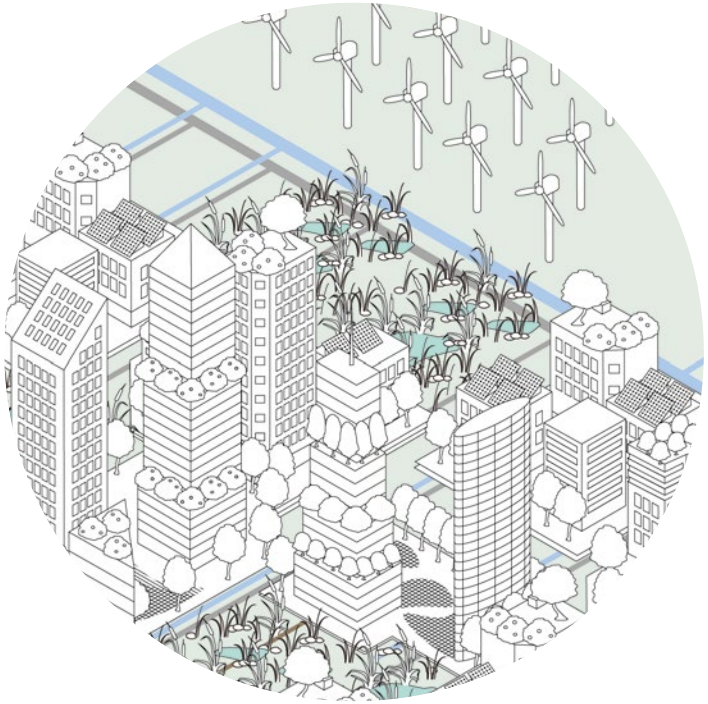
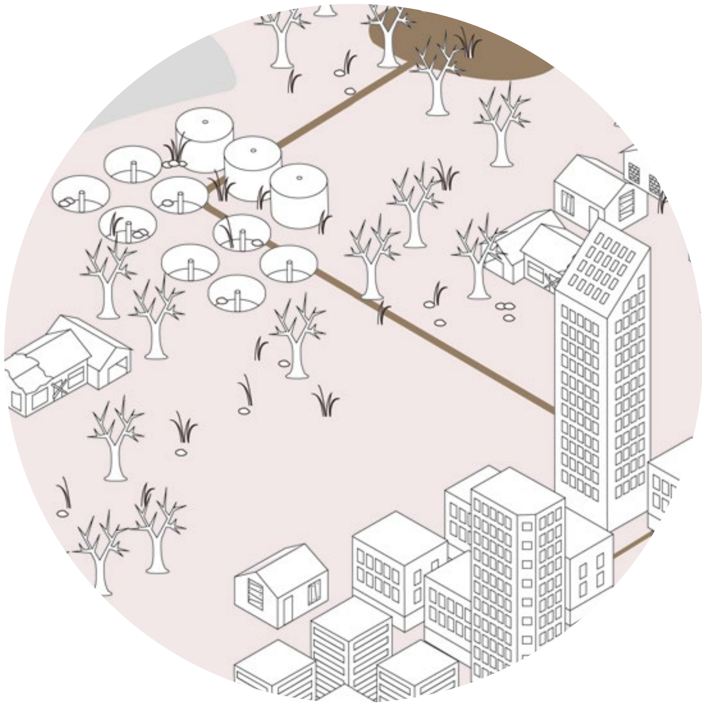
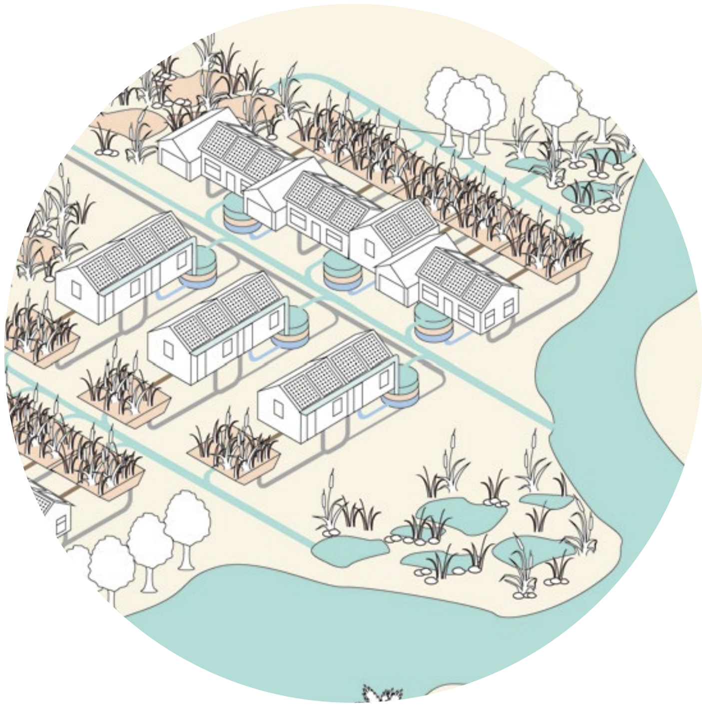
Minimising waste can increase efficiency and save resources and energy. Although waste minimisation is often the top priority for governments, in most countries the focus remains on recycling. Companies can focus on **zero waste** — a philosophy that encourages system redesign so that all products are reused or recycled. In the water sector, zero waste policy examples include no discharge or closed-loop systems.

Public opinion and engagement

A strong international consensus now exists among scientists that human-made climate change is a reality and warrants serious action. Global **public opinion** varies on the issue. If it were to shift markedly, for example in response to a major climate change event, then politicians may force through aggressive legislation to constrain emissions further. Changing customer expectations on levels of service could force a policy intervention.

Engagement with customers, education and information can have a large effect on demand management. Changes in water consumption or increasing the water efficiency of appliances can result in a large reduction of water use. Using a low-flow shower head can save 15 gallons of water during a 10-minute shower.[37] **Gamification** is a growing method of engaging with customers. It refers to the application of game-design techniques to non-game applications to make them more fun and engaging. It encourages users to engage in desired behaviours and is often used in marketing. By 2015, it is estimated that more than 50% of organisations will gamify their innovation processes.

Stakeholder engagement is another tool to help companies and organisations find out what social and environmental issues matter the most, in order to improve decision-making and accountability. Stakeholder engagement can be a powerful tool in agreeing on solutions to complex issues. It gives stakeholders a say in decision-making, rather than just being informed of the decisions.

Scenarios

3

Scenarios provide a unique opportunity to explore and compare alternative plausible futures. They are an effective engagement and communication tool that enables us to gain a better understanding of possible pathways towards the future of urban water utilities, including the role of different stakeholders and alternative system designs.

Future scenarios build upon a well-grounded understanding of current and future trends and global benchmarks. They present a tool for strategic thinking through which we are able to make sense of uncertainty and explore future options. Scenario modelling enables businesses to develop robust and resilient business strategies as well as meaningful stakeholder engagements. The scenarios in this report are intended to picture possible future worlds while describing the challenges and opportunities facing the water sector specifically, as well as the global water cycle in general. Scenarios assist in identifying and developing actions and strategies towards achieving a preferred future.

Scenario Assumptions

Informed assumptions, derived from those drivers of change that are most likely to occur, form the baseline for the future scenarios. All scenarios are based upon these overall assumptions, making it possible to explore and compare different futures under clearly defined conditions:

Developed world
Scenarios take a developed economy as a baseline

Urbanisation
Continuing growth of urban populations

Climate change
Evidence of increasing frequency and intensity of extreme weather events

Volatility
Volatility in supply of water resources and overall increasing resource scarcity

Efficiency
An efficient management of the utility is assumed, independent of who owns it

Smart utilities
A shift towards smarter utilities and technological progression is assumed

Matrix and Key Variables

To outline the future of urban water utilities, the two critical key variables representing major uncertainties were identified. They fundamentally define the future of urban water utilities, systems and experiences.

Centralised vs. decentralised system
The degree to which services and utilities are operated from a central point or from several separated locations

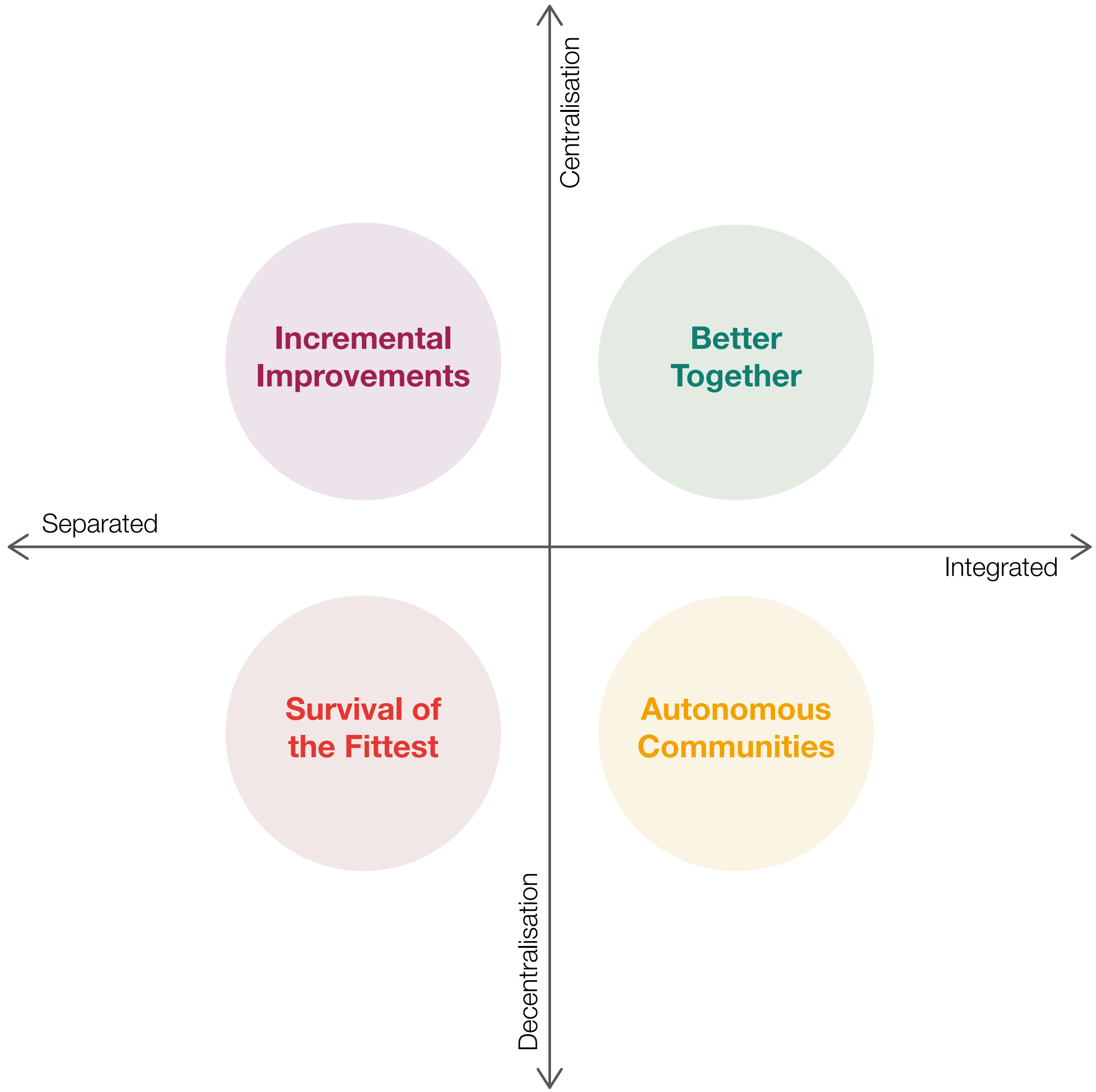
Separated vs. integrated utilities
The level to which utilities are cooperating across different types of infrastructure
Integrated — symbiosis of a variety of infrastructures, eg, water, energy, food
Separated — isolated consideration of infrastructures without acknowledging potential interrelations

Incremental Improvements describes a world with little change to existing assets and operations. A centralised water supply system with a separated provision of utilities.

Better Together pictures a scenario where industry and utilities better collaborate across a centralised system. A centralised water supply system with an integrated provision of utilities.

Autonomous Communities is a world in which households, communities and industry develop independence in water collection, processing and distribution while considering the interrelation of water, energy and food systems. A decentralised water supply system with an integrated provision of utilities.

Survival of the Fittest paints a scenario with greater competition for limited resources and restrictions to supply with high disparities in usage behaviour and access. A decentralised water supply system with a separated provision of utilities.



Incremental Improvements

Incremental Improvements describes a world with little change to existing assets and operations. A centralised water supply system with a separated provision of utilities.

Economy
Slow economic growth coupled with economic uncertainty

Energy
Continued overreliance on fossil fuels, but some expansion in renewable power generation

Consumers
Price driven consumption with little customer engagement and little concern for sustainability

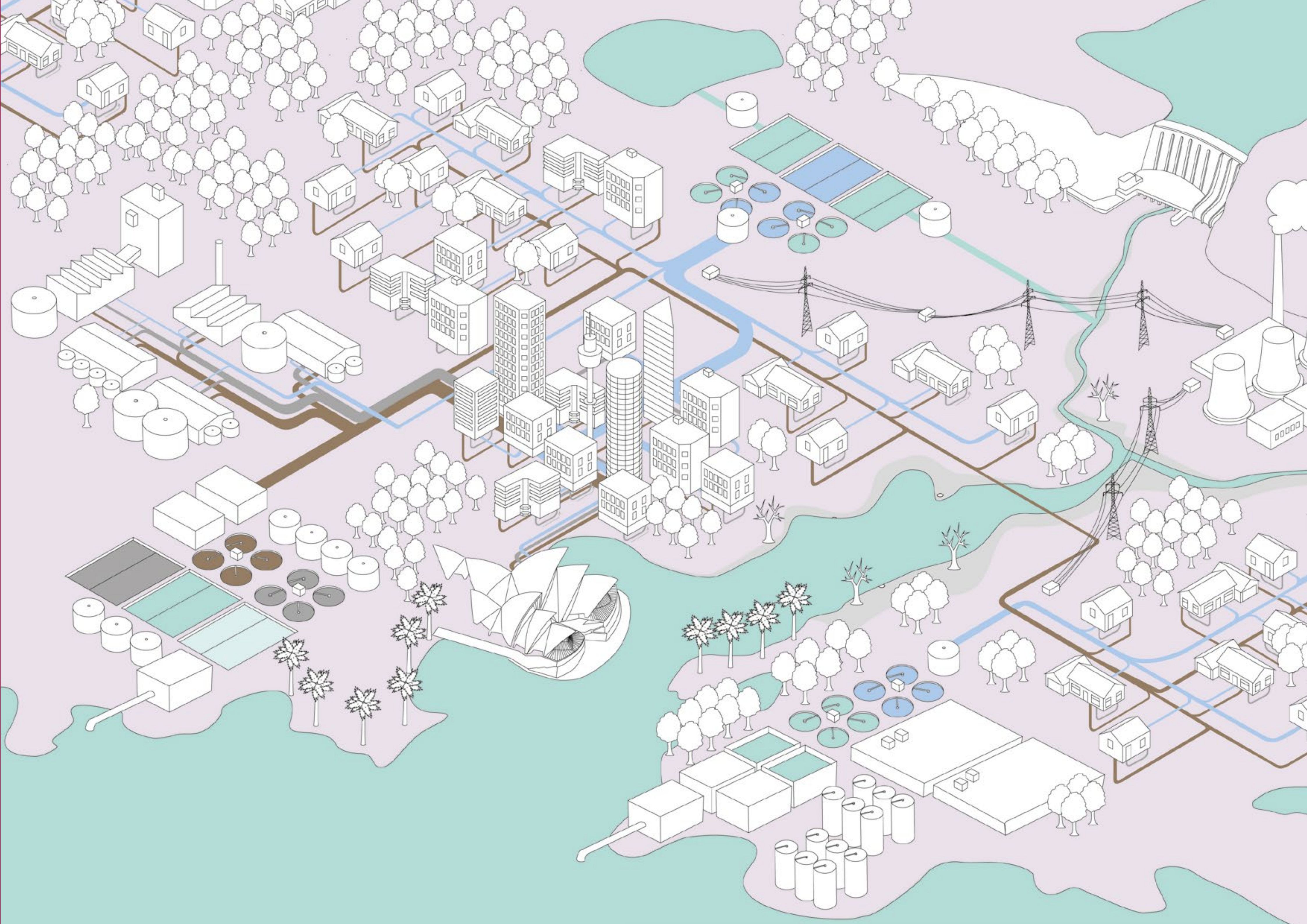
Resources
Focus on efficiency, driven by price and scarcity, but little behaviour change at the consumption level

Industry
Focus on profit maximisation and conforming to regulation

Environment
Unpredictable and extreme weather conditions continuously challenge the resilience of urban systems in need for upgrade

Technology
Focus on resource efficiency through limited deployment of smart solutions and utilisation of advanced technologies to deal with the consequences of climate change

Governance
Regulatory environment focuses on facilitating economic growth and reactive climate change related measures



Incremental Improvements

The global economy is growing, albeit slowly. Governments and businesses have not done enough to curb greenhouse gas emissions and the effects of climate change are becoming increasingly severe. We continue to break temperature records and extreme weather events are increasingly common. Cities are facing problems to source adequate food for their growing population. Australia is experiencing an increase in droughts with more frequent hot days and nights. Sydney is faced with reduced precipitation and increased summer heat waves. Climate change adaptation measures are local and reactive. Through not recognising macro-trends, an opportunity has been lost to address broader outcomes. Energy is expensive and there is still an over-reliance on fossil fuels, both at the global and national level. A failure in reducing greenhouse gas emissions has led to a higher than expected sea level rise, posing huge challenges to Sydney. However, due to the implementation of new and advanced technologies, it became possible to adapt to the consequences of climate change.

Sydney has kept its infrastructure investments to a minimum to retain profits under restrictive pricing, resulting in deteriorating systems and rising operational costs. Australia's relatively tight regulatory environment has created barriers to new entrants across the utilities sector, exacerbated by expensive energy while transporting and treating water and wastewater still requires large amounts of energy. Almost no collaboration between utilities is happening and customers are disengaged. Those investments happening in regard to water use efficiency and security of supply are mainly driven by resource constraints and regulatory pressures. However, as utilities are still operating in isolation, an effective overarching strategy of reducing resource consumption wasn't implemented as of yet. Businesses are still only reacting to financial incentives and legislation.

The water sector has used demand management through usage restrictions to manage capacity and performance during supply constraints. As to support this management, smart technologies are implemented in small parts. Furthermore, some parts of Sydney have installed energy and water efficient infrastructure, together with incremental developments in green infrastructure. Sydney has installed smart metering in households, which helped in reducing domestic water consumption. Because of climate change a handle on customers' behaviour is kept and some disposal targets and grades have been implemented. This has brought about incremental improvements to the performance of existing assets and systems despite disengaged customers not caring enough about water issues and still embracing in an established throw-away culture. Water planning is heavily compromised by a lack of agreed and clear objectives for utilities and by political intervention in planning options and decisions. Infrastructure considerations are still left behind in the urban planning sphere. This results in Sydney's water system still operating in a more linear, rather than a circular way. Utilities are still primarily focusing on water supply and cost control without fundamentally rethinking consumption patterns.

Implications for Urban Water Utilities

Customers

Focus on customer services that are user-centric and that provide greater personal choice and control over service levels and pricing

Expansion of water services that focus on meeting the requirements of individual customers and that engage people at the community level

Demand for higher levels of transparency and information in relation to metering, billing and customer satisfaction

Infrastructure

Increased deployment of digital infrastructures and data analytics to manage, reduce or eliminate system peaks and fluctuating demand patterns

Deployment of sensing technologies and metering to increase the quantity and quality of system information and enable real-time applications for asset management and customer service

Greater focus on existing assets, energy performance, and integrated infrastructure as part of maintenance and operating plans

Governance

Higher levels of coopetition and integration between water, energy and telecommunication companies with a focus on integrated planning and maintenance

Focus on deregulation and greater competition, both within the water sector and across complimentary utilities

Strategic focus on upgrading, improving and digitising existing assets in order to achieve better customer engagement and service feedback

Better Together

Better Together pictures a scenario where industry and utilities better collaborate across a centralised system. A centralised water supply system with an integrated provision of utilities.

Economy
Moderate to high economic growth driven by investment in clean technologies

Energy
Maximised use of renewable energy, fully integrated with water and food supply

Consumers
Engagement between consumer and utilities enabled by smart systems to reduce consumption

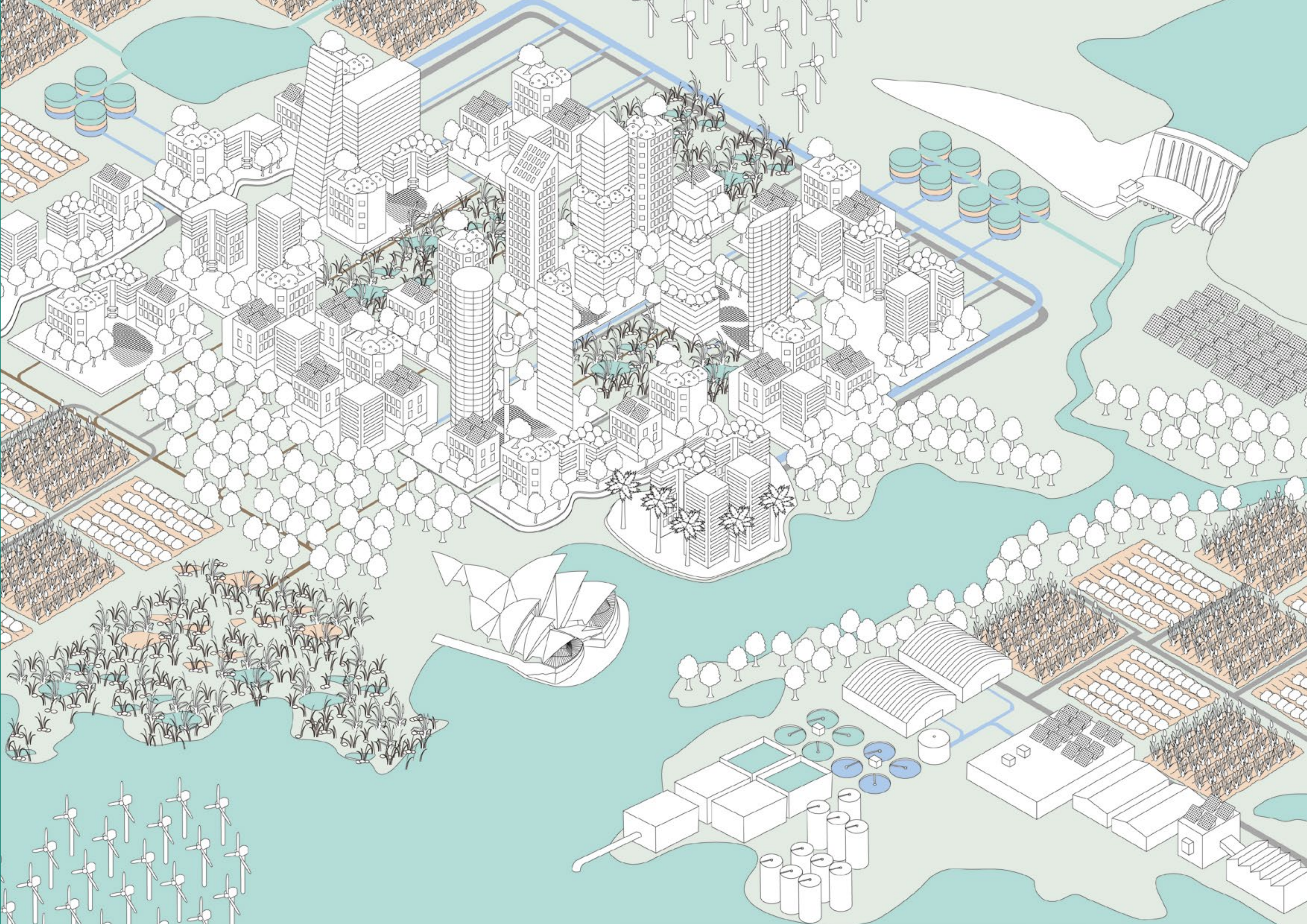
Resources
Use of resources is monitored and there is a drive for reuse, recycling and avoidance

Industry
Focus on resource efficiency, circular economy, coopetition, and coordinated investments

Environment
Green infrastructure increases the resilience of urban systems while still having to deal with consequences of climate change

Technology
Application of smart systems to enable efficiency and effective integration across utilities and customers

Governance
Regulatory environment focuses on facilitating effective cooperation across utilities and efficiency measures



Better Together

Continued globalisation and investment in new energy technologies have boosted the global economy. There have been a series of coordinated and binding efforts, globally and regionally, to curb carbon emissions and limit environmental impacts. However, Australia is still experiencing reductions in precipitation long after greenhouse gas emissions have ceased.

Sydney's planning system is driven by a commitment to integrated planning as well as strict regulations to ensure compliance with global targets. Resource use is monitored and there is a drive for reuse and recycling. Sustainable, renewable resources have been identified and exploited and there has been a concerted drive towards zero waste and the circular economy. Australia became a strong player in wind and solar energy and strong local governance ensured that Sydney has become a low-carbon city. The city has minimised its energy and water use and its waste generation and thus halved its greenhouse gas emissions. Recycled water, stormwater harvesting and reuse became a standard. Seawater desalination is being increasingly used as a reliable source of water. Due to the implementation of new techniques as well as early actions on infrastructure improvements, Sydney is now able to meet a considerable amount of its water demand through local sources and its infrastructure and dam capacity is able to keep up with population and demand. Green infrastructure is increasingly favoured over man-made, engineered solutions with a focus on liveable urban habitats, achieving a better infrastructure resilience and stormwater management, linking urban and rural areas.

Infrastructure hubs were implemented across the city and as a result there has been greater industry collaboration, especially within the water, food, energy and waste sectors. Significant strategic and coordinated investments have been made to network utilities, in order to maximise synergies by integrating assets and sharing information and protocols more effectively. Small-scale water reuse is also happening on the household scale, but the majority of services are still provided through central suppliers and their resources.

Complex and integrated water supplies are managed by smart grids and systems. Advanced technologies for water capture, storage and monitoring are widely deployed. Smart metering is implemented across Sydney, resulting in growing use of real-time data. Customers, households, industries and the landscape are integrated, resulting in Sydney operating as a big living organism. The customer experience is focused on improved transparency and efficiency, and, as a result there has been a reduction in demand, as people are engaged with the utility providers and the system and are careful about their resource usage. Events and campaigns around behaviour change are held and people are briefed on how to live green. However, governments still rely heavily on policy to change how businesses work and how people live their lives. Individuals were forced to scale down consumption. The cost for infrastructure has shifted to the consumer, which meant rising energy and water prices.

Implications for Urban Water Utilities

Customer

Emphasis on creating a seamless customer experience across multiple integrated utilities, including shared billing, pricing and customer services

Focus on maximising customer satisfaction and engagement through digital experiences, gamification and community-based water systems

Exploitation of synergies between multiple utilities and service offerings, with a focus on finding more efficient ways to meet customer requirements

Infrastructure

Integration and sharing of assets and infrastructure across multiple utilities, including water, energy, waste and telecommunications

Creation of smart and self-learning water distribution networks that is enabled by sensors and automation across water collection, processing, distribution and consumption

Implementation of green infrastructure solutions on a city and regional scale, with a focus on minimising the impacts of droughts, flooding and storm water

Governance

Better cooperation between urban utilities through collaborative planning, integrated asset management, shared protocols and open data

Emergence of third-party service providers that focus on integration and cooperation between customers, systems components and utility providers

Increase in prices for service provision in order to enable investment in infrastructure improvements, coupled with a higher number of investments that are shared by multiple utilities

Autonomous Communities

Autonomous Communities is a world in which households, communities and industry developed independence in water collection, processing and distribution while considering the interrelation of water, energy and food systems. A decentralised water supply system with an integrated provision of utilities.

Economy
Moderate to high economic growth and an increase in independently operating businesses

Consumers
Customer experience focused on independence, sharing, open networks and resource efficiency

Industry
Clusters, autonomous systems and resource trading across industries with a focus on circular systems

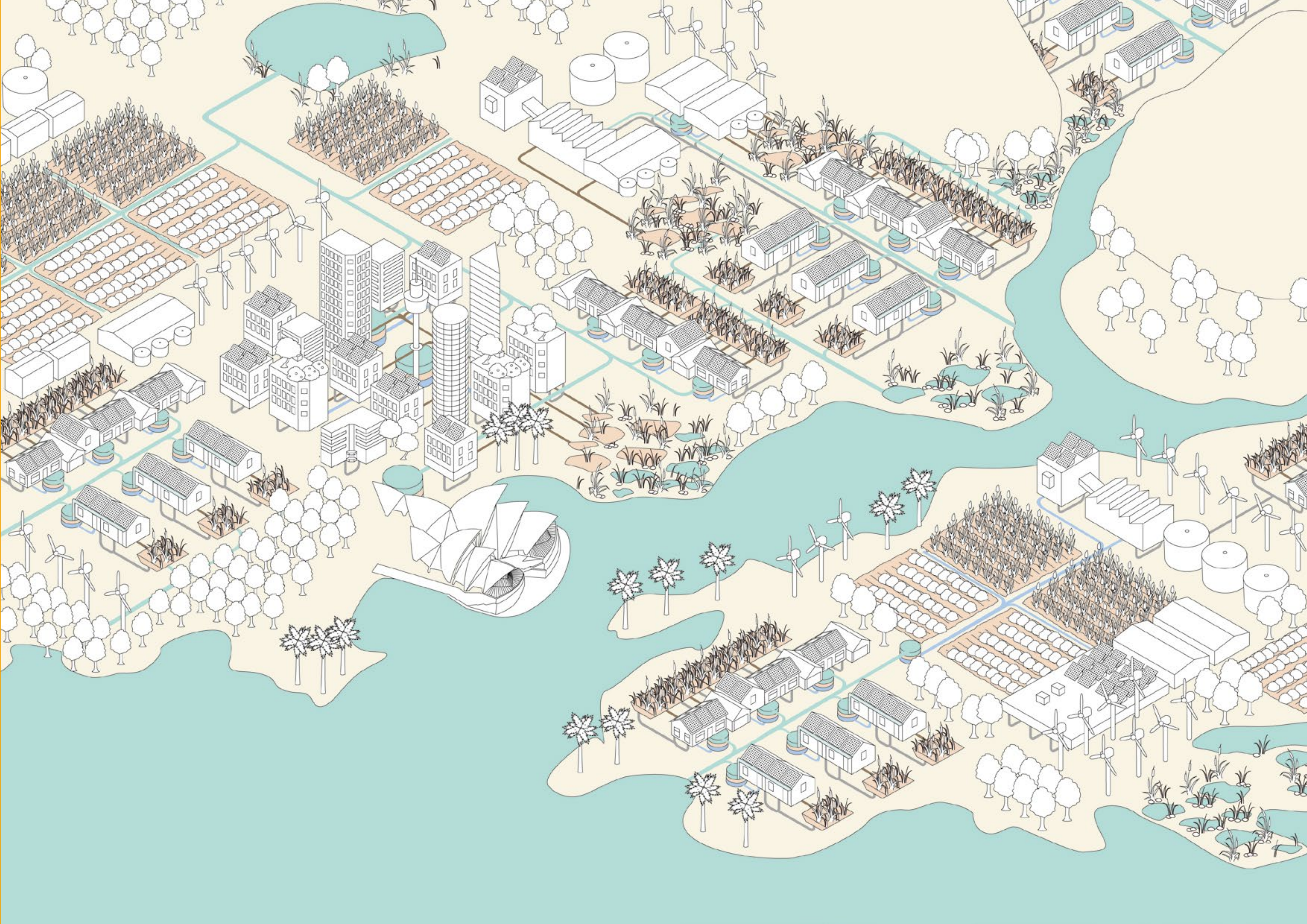
Technology
Virtual management of a decentralised network and increased use of data and advanced technologies on the community scale

Energy
Dominated by small-scale and decentralised renewables operated by virtual power plants

Resources
High resource prices and increasing scarcity foster local systems, including collection and supply

Environment
Unpredictable weather conditions with green infrastructure measures implemented on the local scale dealing with weather events

Governance
Focus on local and regional governance and a collaborative model



Autonomous Communities

The international community has coordinated efforts to combat advanced climate change. While weather patterns remain unpredictable, it is widely thought that the worst of climate change has been avoided. Despite the fact that a global agreement on the necessity to combat climate change was reached early in time, no binding global deal was achieved. Thus, communities started to look for solutions on the local scale and customers realised that a disconnection from the system might be beneficial for them. This has led to a focus on alternative energy and autonomous systems.

Although greenhouse gas emissions have been halted and the economy has shifted to a green economy, Sydney still has to deal with the impact of global warming, due to the huge amounts of emissions that have been put into the air in earlier times. High prices and constrained supply forces individuals to maximise efficiency and decrease their dependence on national utilities. As a result, urbanisation has been stabilised in favour of a more sprawled way of living. More focus is put on existing assets, with resettling taking place and people being closer to where their commodities are produced along with commodities being increasingly produced closer to existing settlements.

These new systems are often at the scale of households, communities, and industry clusters. Production and consumption are driven by the desire to be autonomous and operate on the local scale. A spirit of a circular economy is driving all decision-making. People are better harnessing linked systems, with food production, water and waste treatment and energy production being operated in a closed circle. Local renewable energy generation and decentralised grids have superseded coal, gas and oil.

Sydney has become a more resilient city with individuals adjusting creatively to the unavoidable consequences of climate change. Communities increasingly embrace urban agriculture, growing food on and between buildings. Houses and apartment blocks have their own water harvesting, recycling and purification, and recycled water became a standard. Through treating and sourcing water locally, Sydney was able to significantly reduce the amount of energy and infrastructure needed to perform these tasks.

Power resides at the community level, utilising computer-based collaborative tools. Independent customers are operating connected or disconnected small water networks. Communities engage with the water industry for trading, information, system design, and maintenance. There is, however, no supplier of last resort. Sydney has become more informal. Individual customer relationships are facilitated through open data, crowdsourcing and the sharing economy, benefiting from favourable attitudes towards data sharing. DIY and collaborative consumption is prospering and users are more acquainted and willing to use resources according to availability. Sydney's communities managed to achieve a closed system with little water going to waste. They are focusing on conserving, efficiency and reuse of water. Monitoring, sensing and metering is deployed and people's skills and talent is harnessed to its full extend. A strong focus is put on alternative means of water treatment such as reed beds and wetlands, aeration and solar water disinfection.

Implications for Urban Water Utilities

Customer

Greater focus on services that enable customers to manage and maintain autonomous water systems at building, community or cluster level

Shift from customers that pay for the delivery of services to those that pay for the cost of installing and maintaining local infrastructure, either individually or collaboratively

Utility services focus on assisting with end-user system design, installation, information, maintenance and emergency response

Infrastructure

Provision of planning and infrastructure services that enable communities to develop, run and maintain autonomous urban water systems

Shift to clusters of autonomous and self-regulated water networks that operate at a building or community level, independent of the wider grid

Increased deployment of digital infrastructure to facilitate resource trading and information sharing across a large number of autonomous urban water networks

Governance

Governance and operation of autonomous systems and small-scale water networks through cooperatives, virtual networks and community platforms

Change in legislation and building regulations to enable greater autonomy and smaller-scale applications in water collection, storage, treatment and distribution

Increase in small- and medium-sized utilities that focus on providing information, system design, installation, and maintenance services to autonomous communities

Survival of the Fittest

Survival of the Fittest paints a scenario with greater competition for limited resources and restrictions to supply with high disparities in usage behaviour and access. A decentralised water supply system with a separated provision of utilities.

Economy
Prolonged period of recession and a lack of investment increases competition for capital and resources

Consumers
Accessibility and price-driven consumer behaviour increases inequality

Industry
Lack of reliable water supply forces extreme efficiency measures and some private water networks

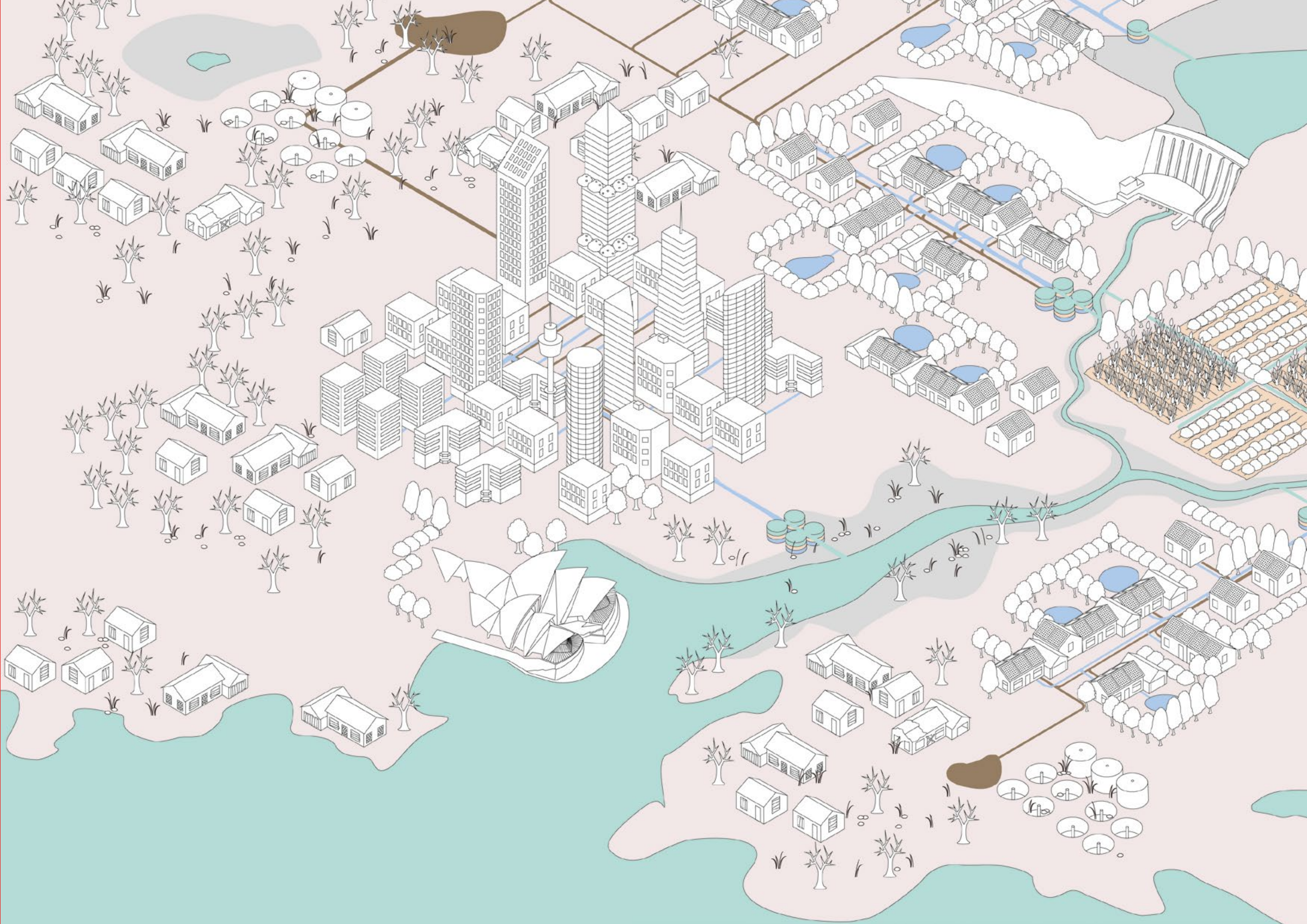
Technology
Smart technologies are deployed to monitor and control the restricted water consumption

Energy
High energy prices and a failed shift to renewables

Resources
Utilities fail to manage supply constraints effectively forcing restrictions on resource usage

Environment
Continued environmental degradation and frequent extreme weather events, including an increase in droughts

Governance
Strong restrictions on consumption and supply with access rights at the city scale



Survival of the Fittest

The global economy is in a prolonged period of recession. We are experiencing a world that woke up late to climate change, a world with greater water stress and resources only available for those who can pay for it. Many countries have already overpumped and depleted their aquifers and have reached or gone past peak water. Australia is faced with insecure water supply and an increasing amount of droughts. As a global agreement failed, tough measures have been adopted regionally to combat climate change. Resource use is strictly regulated in a world short of food and land.

Sydney is experiencing severe water shortages with periodic supply disruptions and population growth has been restricted by availability of water and land. The environmental system considerably suffered from environmental degradation and depletion. During this time competition for capital and investment has been acute. Poor economic and environmental conditions have created clusters of haves and have-nots within the Australian society. As a result of water scarcity, Sydney has implemented strong restrictions on consumption and supply, forcing conflicts for water and resources at the local scale. The government thus enforces more decision on people's lifestyles. Life in Sydney is tough and major parts of the formerly flourishing city centre of Sydney have been abandoned in people's search for available resources. Thus, large-scale resettling is happening which resulted in the urban population being lower than estimations predicted. The black market for water is a reality and informal economies are prospering. For those who weren't fortunate enough to build-up their own system, with no regards to planning or legal rights, water rationing and a constant fight for water and resources are daily fare.

The lack of cooperation has limited opportunities for the efficient management of networks, while simultaneously suffering from a lack of skills and talent. Government planning and policy has proved woefully short-termist with just enough of the basic infrastructure being maintained. However, the major part of an ageing water infrastructure is in need for upgrade, putting increasing pressure on capital needs. Local water supply and treatment companies compete for control over critical infrastructure and sources of supply. At the community level, no one is willing to share resources anymore. Groundwater is used with little concern for others, people use as much as they can once they have access. All available sources are identified and exploited and consumer behaviour is driven through accessibility. Despite increasing resource scarcity, consumption hasn't been cut down, it is just distributed unequally and all resource usage is driven by who is the fastest and who can pay for it.

Implications for Urban Water Utilities

Customer

Development of applications to provide customers with real-time data and information about water consumption, availability and pricing

Increased disparity in the type of water services delivered to urban customers as service models are increasingly influenced by variable pricing and service packages

Usage of smart technologies within households, industry and networks to enforce, monitor and control efficient use, distribution and recycling of water

Infrastructure

Expansion of technology and systems to manage and minimise the impact of extreme fluctuations in water availability, including fast shifts from too much water to too little

Focus on advances in decentralised and centralised water storage solutions, coupled with intelligent demand management and higher water recycling and reuse rates

Increased focus on monitoring and reducing illegal water trade and theft, coupled with a reduction in leakages and wastage across the existing network

Governance

Implementation of differential water pricing and services according to availability of supply, service plans, and customer behaviour

Greater focus on autonomous and community-based water systems, where service and infrastructure levels are determined by private investors and income power

Resettlement of communities and industries into areas where resources are available and risks associated with urban water scarcity are reduced

Case Studies 4

Case studies of emerging projects and ideas from across the globe serve as inspiration in tackling future challenges and in preparing for possible future worlds. The following case studies encompass large, city-wide as well as small-scale, more technology-based examples and illustrate the state-of-the-art, the possible and the surprising. They are intended to assist us in shaping future pathways and in developing forward-looking solutions. Case studies are intended to showcase possible reactions to future scenarios and inspire in developing concepts for working towards a preferred future.

THE CITY OF ZARAGOZA'S WATER CONSERVATION INITIATIVE

The Zaragoza Water Commission has successfully implemented a water-saving culture within the city that has led to an almost 30% reduction in water consumption over 15 years. It includes water-saving technology as well as a reduction in wasteful water usage.

As a response to severe water shortages and growing demands in water supply, Spain's 5th largest city developed a programme with a number of initiatives that aimed for long-term, sustainable change in water use behaviour. Instead of increasing supply and reach and thereby exploiting already limited resources, the city introduced a solution that significantly reduced demand. Residents and key stakeholders were mobilised through engagement programmes, reformed billing systems and the rehabilitation of distribution infrastructure. The Zaragoza Water Saving City Programme was implemented through 4 phases: Small steps, big solution; 50 good practices; School for efficient water use; and 100,000 commitments.

Water tariff reforms and leakage control brought further incentives to change water use behaviour on a broad scale.

Zaragoza is a demo city of the European Union and UNESCO-IHE's SWITCH project that promotes efficient use and management of water among citizens towards sustainable urban development.

Source: www.switchtraining.eu/fileadmin/template/projects/switch_training/files/Case_studies/Zaragoza_Case_study_preview.pdf


TOKYO'S ADVANCED WATER SYSTEM AND LEAKAGE PREVENTION

With one of the most efficient leakage prevention and maintenance systems in the world Tokyo has managed to more than halve its water loss within 10 years and minimised its leakage rate from 20% to 3.6%.

Tokyo's 12 million inhabitants' daily water consumption of 5 million m^3 is met with a water supply system that feeds from four rivers that flow through the city's metropolitan area. A three step process of coagulation, sedimentation and filtration purifies the rivers' initially untreated water before feeding it into an over 25.000km long distribution pipe system. With leakage prevention and resource management at the core of their mission the Bureau of Waterworks has developed a programme that sees actions such as same day repairs, early detection, pipe material developments in order to reduce possible resulting damage including subsidence of roads and muddying of water.

Most leakage (97%) is caused by corroded or cracked service pipes and ageing distribution pipes (3%); through pipe replacement and improvement of pipe materials Tokyo's leakage rate could be reduced from 20% to 3.6% and leakage repair cases minimised from 58,000 in 1985 to 21,000 in 2005.

Other measures of leakage prevention implemented are: monitoring of service pipes for early detection of leakages (account for 97% of repairs), large investments into research and development and tracking all details of repair work in a computerised system. Additionally, measures such as a computerised energy saving system, water saving equipment, and advanced water treatment have helped the city benefit financially, ecologically and technically.

The second stage of the programme aims to extend its efforts into a global and cross national scale while continuing to further reduce its leakage rate. Tokyo's model can be applied to other cities, helping to reduce CO_2 emissions, gain financial savings through increased energy efficiency, and simultaneously tackle consequences of climate change.

Source: www.c40.org/case_studies/tokyo-world-leader-in-stopping-water-leakage

SELF-SUFFICIENT WATER MANAGEMENT IN SINGAPORE

As a result of lacking freshwater resources and the resulting dependence on external providers, the city-state has developed a strategy to become fully self-sufficient by 2061, utilising alternatives such as rainwater collection, recycled water and desalination.

Already sourcing half of its water supply from sustainable sources (rainwater collection 20%, recycled water 30%, desalination 10%) Singapore is well under way of achieving its goals of becoming entirely self-sufficient. Already a prime example for water management, it plans to ultimately meet its demand with 40% recycled water, 30% desalinated water and 20% rainwater. Its ABC Waters plan (Active, Beautiful, Clean) for sustainable water management aims for an integrated and holistic approach towards urban environments, with over 100 projects under way for the next decade.

Singapore's actions include the large-scale collection of rainwater. Two-thirds of Singapore's land surface is protected in order to act as drainage basins and land-use is regulated as to facilitate rainwater collection. Secondly, Singapore implemented a branding campaign, NEWater which successfully promotes the use of recycled water. Through an integrated water management system, Singapore is now able to meet 30% of its water demand through recycled water. NEWater is treated to drinking quality through a new wastewater recycling technique operating in four stages: first, wastewater is treated conventionally, then it is going through a micro-filtration process, followed by reverse osmosis, and finally UV treatment is utilised. Thirdly, Singapore is investing heavily in desalination processes and continuously develops new technologies, with the goal to triple its desalinated water supply. Finally, behaviour campaigns and incentives have been developed by Singapore's water utility provider, resulting in a reduction of per capita water consumption to 155 litres per day. And, water spillage rates have been brought down to 5%, one of the lowest worldwide.

Source: http://wwf.panda.org/what_we_do/footprint/cities/urban_solutions/themes/water/?204587

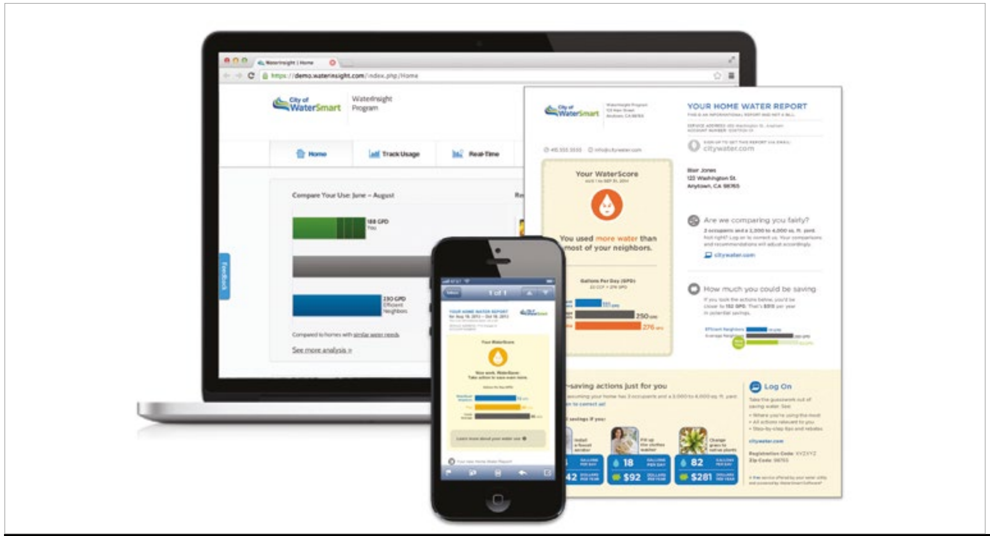
STOCKHOLM'S WASTEWATER TREATMENT AND UTILISATION STRATEGY

The city of Stockholm has developed a plan that sees the transformation of wastewater into useful products such as biogas, fertilizer and heat that hold various ecological and economic benefits.

Through anaerobic digestion of biological waste multiple types of energy are generated such as electricity, heat, fuel and gas. The strategy addresses a range of environmental problems and could in the long-term make water treatment economically more sustainable. It looks to utilise resources originating from water and sewage treatment. Low operating costs of the technology and the potential of its further development make this wastewater treatment approach more sustainable and economically viable.

Ecological benefits include the reduction of greenhouse gas emission by replacing fuels with biogas, which in itself produces no net CO_2. The use of biogas would also reduce air pollution and the overall demand of energy of sewage plants when replacing currently used conventional energy. Sludge with its high percentage of nutrients can be used to fertilise agricultural land and the use of bio-gas would diminish the fight over land between food and crop cultivation for bio-gas production. Additional benefits arise from the reduction of landfill flows, a general transition to renewable energy sources and district heating within the city.

Source: http://wwf.panda.org/what_we_do/footprint/cities/urban_solutions/themes/waste/?204458



WATERSMART SOFTWARE

A smart software to be deployed by water utilities that nudges customers towards a change in their water consumption habits.

WaterSmart Software aims to guide customers towards changing their water consumption behaviour on their own, without deploying any force or legislation. Developed by Peter Yolles and Rob Steiner, WaterSmart utilises a system of regularly issued customer-specific home water records, which compare one's water usage to that of one's neighbours. Additionally, incentives, such as the expected money savings through specific water saving actions, are utilised. This project successfully applies the principle that people's awareness of a topic is raised when compared to others. The WaterSmart Software has already been implemented by several water utilities. And, according to the developer, a 5% reduction in residential water usage can be achieved within 6 months.

If implemented on a larger scale not only could active personal water management be promoted and in the long-term behaviour change be achieved, but water utility providers could also use the data to better monitor and estimate water use.

Source: www.watersmartsoftware.com/index.html

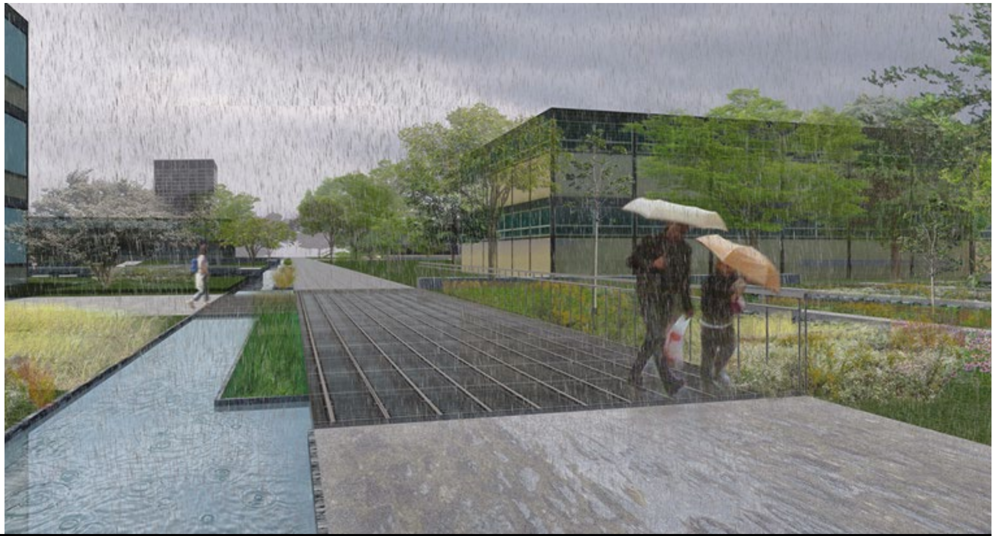
CHRISTCHURCH'S "LITTLE WATER SENSOR" LARGE-SCALE WATER MONITORING

The first of three Sensing City projects allows Christchurch's residents to test their own water quality with the use of sensor kits developed by MIT.

The data collected through phone applications forms part of an extensive data analysis with far-reaching benefits. In collaboration with Arup the Sensing City Initiative seeks to be one of the catalysts to create a step change in New Zealand's economy. By integrating and making openly available the data from a variety of sources, Sensing City will encourage the development of information-based solutions by the city and its constituents, improving quality of life in Christchurch. It allows members of the public to test river water quality in the city through easy to use Little Water Sensor kits created by the Massachusetts Institute of Technology. As a first instance 200 sensor kits have been distributed to students who will be measuring water quality along Christchurch's waterways. The kits test for levels of potassium hydride, nitrite, hydrogen and general hardness in the rivers that flow through the city.

The aim is to encourage citizens of Christchurch to understand the current state of water quality in the city's rivers and ultimately take ownership of the resource. Its educational benefit will in the long term contribute to raised awareness amongst citizens and behaviour change around water and its use. The collected data will play a key role in understanding city-wide water quality levels that hold the opportunity to develop timely and location-specific solutions.

Source: www.sensingcity.org/



ILLINOIS INSTITUTE OF TECHNOLOGY CAMPUS STORMWATER INFILTRATION AND CONSERVATION

By utilising its campuses green infrastructure this proposal predicts a 70% to 80% reduction of stormwater runoff in Chicago's sewer system, while making the collected non-potable water available for irrigation.

As a reaction to the region's increasing difficulties to deal with damage caused by stormwater and heavy rain, IIT launched a competition amongst its students to develop campus-based, sustainable solutions. The winning proposal used green infrastructure and a combination of environmental and social elements to enhance underused outdoor spaces: rain gardens can be reutilised as communal meeting spaces, throughways are turned into permeable walkways, and three acres of new native plant communities with underground cisterns collect rainwater for future non-potable reuse. The project's main benefits are seen to be the reduction of flooding caused by heavy rain, the decrease of stormwater runoff into the city's sewer system (with an estimated complete reduction by 2020), stormwater management that integrates its conservation for reuse, and the improvement of water quality. On an educational level the competition brought attention to the increasingly important topic of stormwater management (one of the most widespread challenges to water quality in the US) and enabled the collaboration between disciplines to inspire holistic solutions.

Source: www.sustainable-chicago.com/2013/06/13/iit-takes-first-prize-in-water-saving-competition/

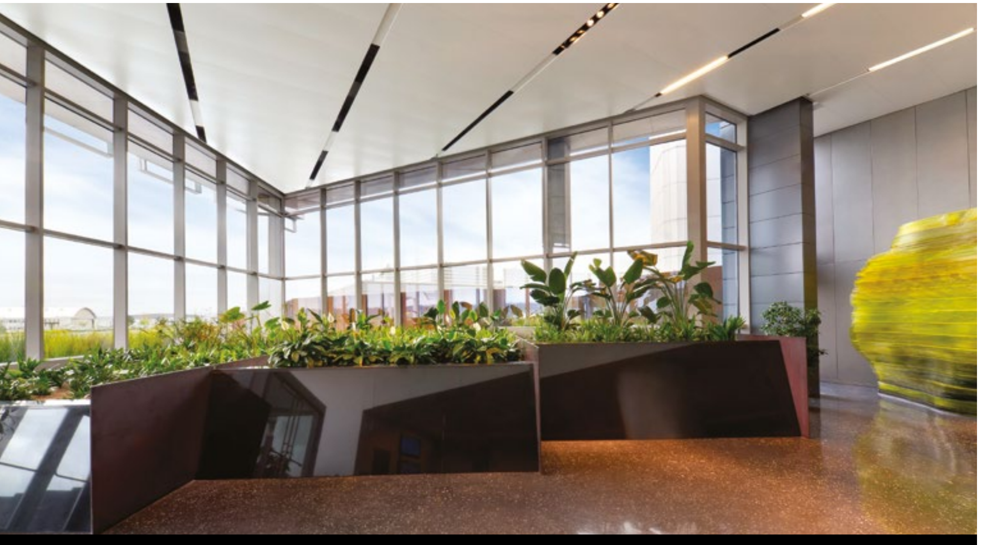
H_2O FILTERING RAINHOUSE

A revolutionary rainwater management system in the shape of a building made from bio-concrete that collects and turns rainwater into high-quality drinking water.

The complex rainwater harvesting system builds on a pH-neutral bio-concrete that is bio-compatible with water — a material innovation by IVANKA, concrete designers and manufacturers. The concept was demonstrated during the Milan Design Week where visitors had the chance to experience the scheme in action: water was dispensed from a fake cloud installation onto a rooftop tiled with concrete. From there it flowed seamlessly into a storage tank with interior walls fitted with bio-concrete.

The project plays with the idea of a home that can produce and conserve drinking water by utilising rainwater as a source. It holds the potential to provide a variety of users with affordable and clean water without impacting the environment and eco-system. If used in large-scale urban developments, rainwater purification has the potential to become an integral part of a city's water system.

Source: http://drinkrain.com/



'THE LIVING MACHINE' CRADLE-TO-CRADLE WASTEWATER TREATMENT

The A. J. Lewis Centre for Environmental Studies has developed a technology that ecologically treats and recycles wastewater within a building, integrating processes of wetland ecosystems with conventional procedures.

Designed to recycle wastewater into reusable greywater, the system holds potential to recycle 90% of a building's internal water. While conventionally supplied water is used for drinking and hand-washing, the recycled, non-potable water can be used in the Centre's toilets and for landscape irrigation and recharging the wetland pond.

The treatment process comprises three elements: wastewater enters a primary tank where solids settle and start to degrade. In Tidal Flow Wetland Cells® the water goes through a repeated filling and draining process that supports a diverse, productive micro-ecosystem below the surface where microscopic plants and animals grow on gravel filling the tanks and consume the waste in the water. After final filtration and disinfection, clean, non-potable water leaves the tanks. Additionally, a unique set of valves and pumps that maximises the use of gravity is employed to minimise energy consumption.

Currently designed to cater for single buildings (7,500 litres of wastewater) the system could see application in small communities where it would provide a renewable source of water that would lead to a large reduction in water use with significant financial and ecological benefits.

Source: www.climate-kic.org/blog/the-living-machine-cradle-to-cradle-wastewater-treatment/

Conclusion

5

The future of urban water is influenced by a broad range of factors, with water scarcity, urban population growth and the resulting necessity for efficient systems being the most influential ones. This report assists water utilities worldwide in exploring future options, in making sense of uncertainty and in identifying risks and challenges. We must plan ahead.

The explored drivers of change, future scenarios and case studies reflect the necessity for water utilities to be prepared to operate and succeed in a world that will likely be utterly different than the world we are experiencing today. Cities across the globe will increasingly have to focus on local water sourcing, reuse and recycling in order to sustain their population. Consequently, they have to move away from their reliance on external sources while considering the global water cycle. Water utilities need to be prepared to serve more people in the future while simultaneously dealing with an increasing scarcity and competition for resources.

An early response to increasing energy and resource prices, through the development of efficient processes and smart systems, could leverage off Sydney Water's market position. Not least through consequences of climate change, more resilient systems are needed. This offers the chance for water utilities to increasingly act as service providers for the development of autonomous systems. Furthermore, increasing investment in green infrastructure, primarily for stormwater management, would offer the opportunity to access and directly treat a new, currently underutilised water source. Water utility providers increasingly need to look at solutions through a different lens. Additionally, green infrastructure offers the possibility to turn waterways into parks and to provide natural capital and amenities to citizens rather than seeing water treatment as a technological process, separated from nature. Urban water utilities worldwide could thus shift away from water provision as hidden services towards a more visible service, a key contribution to public life.

Another opportunity area to tap into represents the engagement in behaviour change interventions in order to better influence and manage demand. More and more data availability through increasing digitisation offers opportunities for investments in real-time monitoring of network utilisation in order to enhance operations and asset management. To better deal with future challenges, water utility providers will have to favour integrated solutions over siloed interventions. This provides the chance for water utilities to play a fundamental role in the shaping of healthy and water-sensitive cities.

technological
environmental
economic
political
WHAT?
SO WHAT?
ARUP

Appendix

6

About Arup

Arup has 90 offices in over 40 countries around the world, giving us access to local markets and expertise. Arup is an independent firm of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services to clients around the world. Through our work, we aim to make a positive difference to different communities. Arup brings together broad-minded individuals from a wide range of disciplines. The firm provides expertise in all aspects of water engineering, management and technology, covering the entire water cycle in temperate, arid and tropical environments.

www.arup.com

About Arup Foresight

Arup Foresight specialises in the future of the built environment. We collaborate with our clients to help them understand trends, explore new ideas, and identify future markets. We developed the concept of “foresight by design”, combining corporate foresight with Arup’s global engineering and consulting expertise to provide clients with unique insights and strategies for the future of the built environment.

www.driversofchange.com

About Sydney Water

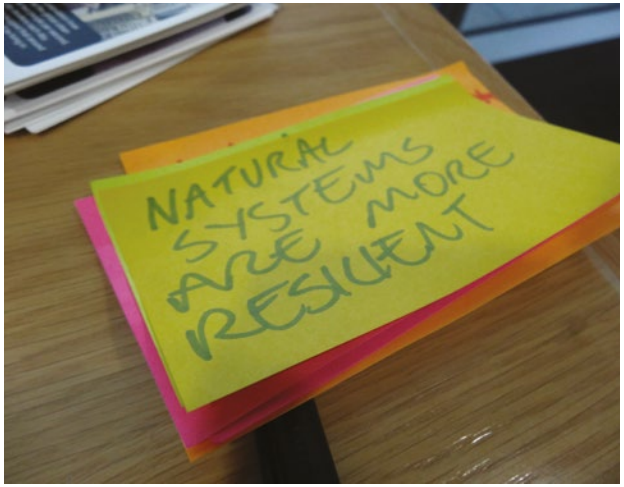
Sydney Water is Australia’s largest water utility. It is a statutory State Owned Corporation, owned by the New South Wales Government, providing potable drinking water, recycled water, wastewater and some stormwater services to more than 4.6 million people in Greater Metropolitan Sydney, the Illawara and the Blue Mountains regions. With the aim to provide valued water solutions to their customers, Sydney Water has a customer focus in all they do, they strive for business excellence and are forward-thinkers. Sydney Water’s business structure is built on three equal principles — protect public health; protect the environment; be a successful business.

www.sydneywater.com.au

Methodology

While conducting this project, resources and insights were drawn through desk research, expert consultation and a collaborative workshop. The project programme was made up of four distinct phases — baseline and context, trends and benchmarks, future scenarios, strategy and implications. Firstly, the status quo of the current system was analysed, including stakeholders and components. Simultaneously, future trends and current benchmarks were identified. The drivers of change and key trends affecting the future of urban water utilities were compiled into a workshop card set on Urban Water. Following the analysis and identification of key drivers, a set of plausible baseline scenarios on urban water utilities in 2040 was developed. The identified drivers, context and developed scenarios formed the basis for a workshop, delivered by Arup Foresight with a variety of expert participants from Arup and Sydney Water. During the workshop the Urban Water card set was consolidated and scenarios were collaboratively developed further into a set of plausible futures. Their viability and possible future implications were examined, including the risks, challenges and opportunities of each scenario and future urban water supply in general. In support of the process, global case studies were identified. These highlight the art of the possible as well as emerging solutions.

Workshop Impressions



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Contacts

Arup Global

Mark Fletcher
Water Business Leader
mark.fletcher@arup.com

Chris Luebkeman
Global Director
Foresight + Research + Innovation
chris.luebkeman@arup.com

Josef Hargrave
Associate
Foresight + Research + Innovation
josef.hargrave@arup.com

Arup Australia

Mark Vassarotti
Economics and Policy Leader
Australasia
mark.vassarotti@arup.com

Daniel Lambert
Water Business Leader
Australasia
daniel.lambert@arup.com

Andrew Maher
Arup University Leader
Australasia
andrew.maher@arup.com

Sydney Water

Greg Kane
Manager
Servicing and Asset Strategy
Liveable City Solutions
greg.kane@sydneywater.com.au

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Arup
13 Fitzroy Street
London, W1T 4BQ
United Kingdom

Arup
1 Nicholson Street
Melbourne, VIC 3000
Australia

Sydney Water
1 Smith Street
Parramatta, NSW 2150
Australia