ISBN NUMBER FOR CSE23 IS: 978-1-925627-71-8

The future of water infrastructure services in an impacted world

Marco van Winden
AECOM
marco.vanwinden@aecom.com

ABSTRACT

Our planet is changing rapidly – ecology, climate, oceans and financial systems – and humanity needs to rapidly reduce its impacts, as evidenced by the IPCC AR6 Synthesis report released March 2023. This paper looks 10 to 20 years into the future to explore what the current water engineering graduates might be doing mid-career. The paper and presentation will generate interest and excitement for the future of the water industry and help water engineers prepare for purposeful services to their local and global community.

Included is a comparison of the concepts of green growth, sustainable development, carbon net-zero, net-positive, regenerative, degrowth and postgrowth. It will demonstrate the improbability of de-coupling the demand for energy and finite resources from economic growth, and so demonstrate that GDP in the industrialised world will need to decline to assure a viable biosphere.

With references from scientific papers and publications, the author will expand upon several trends that are expected to evolve in coming decades, including:

- *The likely increase in manufactured water production (both desalinated and recycled) for people and crops.*
- *How water services will change as economic activity and affordability decrease, and as materials availability reduces. It will explore what 'sufficient' water services might look like.*
- *How socially equitable water services will improve life in underdeveloped regions in Australia and globally, and the role for our engineers in this.*
- *As arid and equatorial regions suffer sustained droughts and crop failures, millions of climate refugees may be 'allocated' by the United Nations to wealthy temperate countries*

like Australia. What water services will be required when far more immigrants than Australia has ever seen begin arriving?

The reader and audience will learn that:

- *Water production will become more industrial in nature.*
- *Water services planning for new Australian cities will be very exciting and challenging.*
- *Water engineering services will have far more purpose.*

OBJECTIVE OF THIS PAPER

This paper looks 10 to 20 years into the future – nominally 2040 – to explore what today's engineering graduates might be doing mid-career in the water services sector. Similarly, those who are already mid-career can look ahead to what we might be doing approaching retirement.

THE WORLD IN 2040

Introduction

Projected global greenhouse gas (GHG) emissions in 2030, implied by nationally determined contributions (NDCs) announced by October 2021, make it likely that warming will exceed 1.5°C during the 21st century and make it harder to limit warming below 2°C. There are gaps between projected emissions from implemented policies and those from NDCs, and finance flows fall short of the levels needed to meet climate goals across all sectors and regions (IPCC, 2023). According to the UNEP Production Gap report, global total fossil fuel production needs to decrease by at least 6% per year between 2020 and 2030 to be able to limit warming to below 1.5°C (SEI, IISD, ODI, E3G and UNEP, 2021). However, at the current 1.2°C warming (IPCC, 2022), the world is on a trajectory to produce more than twice as much coal, oil and gas by 2030 than is consistent with limiting the rise in global temperature to below 1.5°C.

In the near term, every region in the world is projected to face further increases in climate hazards, increasing multiple risks to ecosystems and humans. Hazards and associated risks expected in the near term include an increase in heat-related human mortality and morbidity, food-borne, water-borne, and vector-borne diseases, mental health challenges, flooding in coastal and other low-lying cities and regions, biodiversity loss in land, freshwater and ocean ecosystems, and a decrease in food production in some regions. Cryosphere-related changes in floods, landslides, and water availability have the potential to lead to severe consequences for people, infrastructure and the economy in most mountain regions. The projected increase in frequency and intensity of heavy precipitation will increase rain-generated local flooding (IPCC, 2023).

Figure 1 is an excerpt from part (a) of Figure 2, which presents the International Panel for Climate

Change's (IPCC) latest global warming projections. Figure 1 projects that warming will almost certainly be in the range of 1.5°C to 2.0°C by 2040, with the uncertainty band for the low emissions scenario ranging from 1.4°C to 2.0°C.

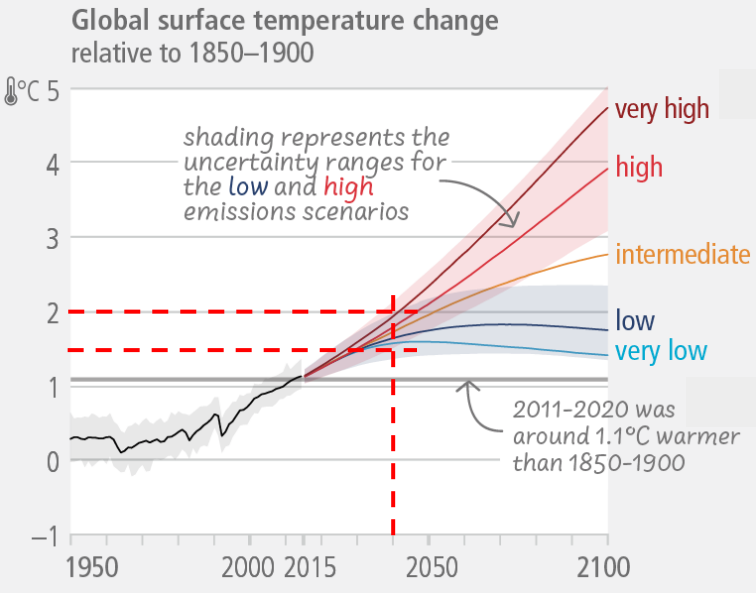

Figure 1. Excerpt from Figure 2 indicating 2040 predicted warming

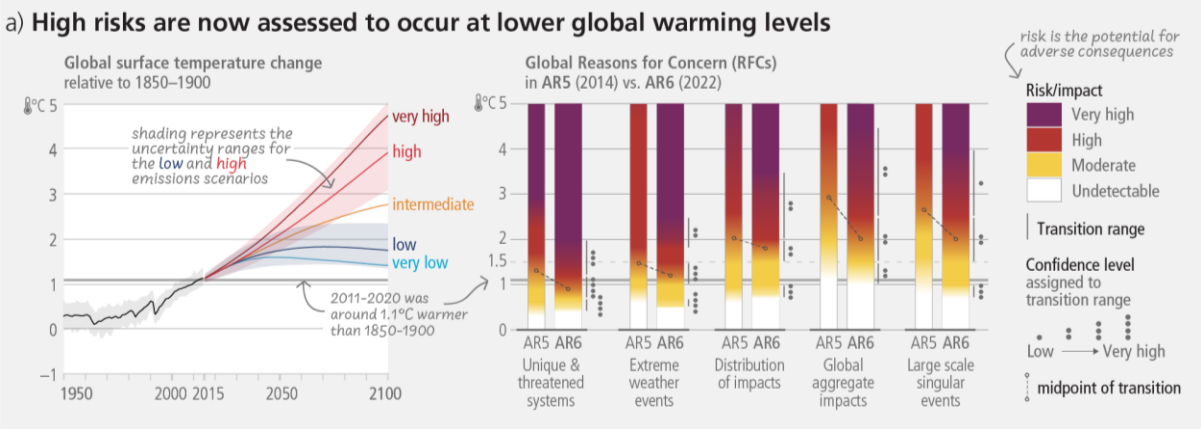

Figure 2. Risks are increasing with every increment of warming (Part (a) of Figure SPM.4 from IPCC, 2023)

In Figure 2, the right-hand side of part (a) shows that in the eight years from IPCC's Assessment Report AR5 to AR6, global Reasons for Concern (RFC) have generally shifted towards lower temperatures with updated scientific understanding. Given that current trends show that global emissions are rising, and the world needs to achieve an average 7.6% reduction in greenhouse gas emissions every year from 2020 to 2030 to stay under 1.5°C warming (UNEP, 2020), there is a reasonable likelihood the world will have warmed by 2°C by 2040.

The following subsections summarise the science-based vision for what a world moving from 1.5°C to

2.0°C warming will look like for Australia and the parts of the world that impact Australia.

Going from 1.5°C to 2.0°C

Ice sheets and tipping points

Extreme events are occurring globally, with increased frequency and severity, with the very real danger of irreversible tipping points being breached. As warming approaches 2°C, the Arctic is expected to be free of ice every second year, adding much more radiative solar energy into the ocean and warming Earth's systems further (Wang, 2009). At the same time, an additional two million square kilometres of permafrost is expected to melt (over the 4.8 million km2 lost at 1.5°C), releasing an additional several tens of billion tonnes of CO2 and methane (Burke, 2018). These two changes alone raise the risk of advancing rapidly to 3°C or more.

Warming to 2°C also risks the irreversible loss of the West Antarctic Ice Shelf, and the point of no return for the Greenland ice sheet is understood to be 1.8°C (Pattyn, 2018). These two losses lead to much faster rates of sea-level rise. Warming to 2°C puts 136 coastal megacities at risk of flooding (Jevrejeva, 2018).

Direct human impacts of warming

In terms of direct impacts on people, one reference predicts that half a million more cases of dengue fever will be reported every year with warming of 2°C, just in Latin America (Colón-González, 2018). Dengue cases will increase in SE Asia and northern Australia also.

Half a million extra deaths from malnutrition are expected as soon as mid-century. This is because allowing two degrees of warming leads to decreases in productivity of maize, rice, wheat and other major staple crops across much of the world, seriously jeopardising our ability to feed the projected global population of 9.5 billion and raising the risk of mass starvation (Springmann, 2016).

Warming with increased moisture in the air increases the frequency and duration of extreme heat waves. Once global warming reaches 2°C, an additional 1.7 billion people will be exposed to severe heat waves, 420 million more exposed to extreme heat waves and 65 million more to exceptional – meaning deadly – heat conditions (Liu, 2018).

Australian context

In Australia specifically, a 2017 study reports that the severity of possible future temperature extremes poses serious challenges to preparedness for future climatic change. Model simulations for Victoria and New South Wales extremes indicate that major Australian cities, such as Sydney or Melbourne, could incur unprecedented maximum temperatures of 50°C under 2°C of global mean warming (Lewis, 2017). In Australia, heat extremes are expected to be at least double the average rise in a world that has warmed an average of 2°C, setting the scene for temperature highs that humanity has never experienced before on the continent. Such unprecedented temperatures would present onerous challenges to human

and natural systems (Perkins, 2015).

For the Coral Sea region, the present results of increasing high-magnitude future extremes support recent studies that demonstrate significant challenges are posed for the resilience of natural systems such as the Great Barrier Reef under 1.5°C or 2°C of warming (Hughes, 2017). The IPCC reports that by the time warming reaches 2°C, more than 99% of reefs will have been killed (IPCC, 2018).

If human activities weren't already impacting the biodiversity of the planet, warming of 2°C would double the numbers of insects, plants and vertebrates that lose more than half of their climatic range (Warren, 2018), impacting food security, weather patterns and trade.

New research in Australia and worldwide, together with the IPCC's Sixth Assessment Report, enhances the understanding of Australia's future climate. In the coming decades, Australia is projected to experience the following (CSIRO, 2022):

- Continued warming, with more extremely hot days and fewer extremely cool days.
- A further decrease in cool season rainfall across many south and east regions.
- Continued drying in the southwest of Western Australia, especially during winter and spring.
- Longer periods of drought on average in the south and east.
- A longer fire season for the south and east and an increase in the number of dangerous fire weather days.

In eastern parts of Australia, El Niño conditions are of interest. In these El Niño conditions, trade winds across the Pacific Ocean weaken (or reverse), and warmer surface water builds up in the central Pacific. Cloudiness and rainfall north of Australia are suppressed, typically leading to below-average winter-spring rainfall for eastern parts of the country and a drier start to the northern wet season (Bureau of Meteorology, 2023a). El Niño events are projected to occur more frequently in a warmer climate (Shin, 2022).

South and Central Asia

In South Asia, around 900 million people depend on waters supplied by the Indus, Ganges and Brahmaputra rivers, all three of which rise in the Karakoram–Himalayas. Despite substantial inflows from downstream rainfall in the monsoon season, meltwater in the pre-monsoon months is an important component of their overall flows. The situation is the most acute for the Indus River in Pakistan. Most of the areas through which the Indus flows are very arid, so most of the river's flow is from glacier melt all year round. Researchers estimate that 129 million people in the South Asia region are 'substantially dependent on upstream meltwater for their livelihood' and that the amount of food produced with meltwater in the plains is equivalent to the rice consumption of 52 million people and the wheat consumption of 64 million people. These numbers are 'in addition to the 48 million farmers who live in the Indus, Ganges and Brahmaputra mountains, many of whom depend directly on local glacier and

snowmelt' (Betts et al., 2018). This impact is in addition to the consequences of sea level rise on the food for the people of Bangladesh and other low-lying areas in coming decades.

The situation is even more critical further north in Central Asia. A study reported that seasonal glacier meltwater is equivalent to the basic needs of 221 million people or most of the municipal and industrial needs of Pakistan, Afghanistan, Tajikistan, Turkmenistan, Uzbekistan and Kyrgyzstan. These countries are particularly vulnerable during drought years, when the meltwater portion from mountain glaciers can be critically important to cover the deficit from failing rain or snowfall (Pritchard, 2019). Researchers warn that 'social instability, conflict and sudden migrations' can be triggered by water scarcity, exacerbating problems in what is already a war-torn and desperately poor region of the world. Projections show that parts of this region expect to experience 'peak water' as early as this decade, with an expected sharp decline through the rest of the century as the glaciers melt. 'The days of plenty might soon be over in glacierised Central Asian catchments' is the ominous title of one recent study (Sorg, 2014).

SOME KEY CONCEPTS

Concepts

It is useful to define a few key terms and concepts to describe what the water services industry might be like in 10 to 20 years. These terms are listed in order of least effective at preserving our biosphere to most effective, in the opinion of the author.

Growth

Growth in the context of this paper refers to economic growth or growth in a nation's or the world's gross domestic product (GDP). Continuous, compounding economic growth on a finite planet is not possible and certainly not sustainable. We use energy for every good and service that contributes to GDP. Energy use and economic growth are tightly linked, and recent decades only show a small relative de-coupling of global primary energy demand from global GDP growth. Over the period from 1971 to 2010, global GDP increased by an average of 4% per year, while global primary energy consumption increased by an average of 2.1% (Huen, 2019). Continued growth in the global economy will reach limits to the world's resources or climate (Meadows, 1972 and Raworth, 2017).

A growth economy represents increasing production and consumption to grow profit for private owners by privatising the benefits and socialising the losses in the spirit of enhancing wellbeing for the selected few (Parrique, 2023a).

Green growth

Green growth is the continuing expansion of the economy in ways that protect the environment. An example of green growth is the implementation of low-cost renewable energy generation enabling the economy to continue growing, such that the added renewable energy is not sufficient to decrease the

demand for energy generated from hydrocarbons. The term 'green growth' is contradictory. Growth means more throughput, creating more impact and requiring more extraction. Endless growth – green or not – can only end up leading to no growth at all – there is no growth on a dead planet. As Greta Thunberg pointed out at the 2019 UN Climate Summit: green growth is a fairy-tale – with a very bad ending (Thunberg, 2019).

Sustainability

The 1983 UN Commission on Environment and Development (the Brundtland Commission) greatly influenced how we use the term sustainability today. The commission's 1987 Brundtland Report defines sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations General Assembly, 1987). The report helped bring **sustainability** into the mainstream of policy discussions. It also popularised the concept of sustainable development. This framework has a more recent spin-off in the form of the UN Sustainable Development Goals, an internationally agreed set of 17 goals covering education, poverty, health and wellbeing, equality and sustainability, but also including economic growth (Goal 8).

Since 1987, the population of wild species has reduced by a further 33% (Almond, 2022 and Figure 3), and the CO2 in the atmosphere has increased from 349.31 to 418.57 ppm in 2022. These are hardly sustainable outcomes.

Figure 3: The global Living Planet Index (1970 to 2018)
The average change in relative abundance of 31,821 populations, representing 5,230 species monitored across the globe, was a decline of 69%. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (95% statistical certainty, range 63% to 75%). Source: WWF/ZSL (2022)[184].

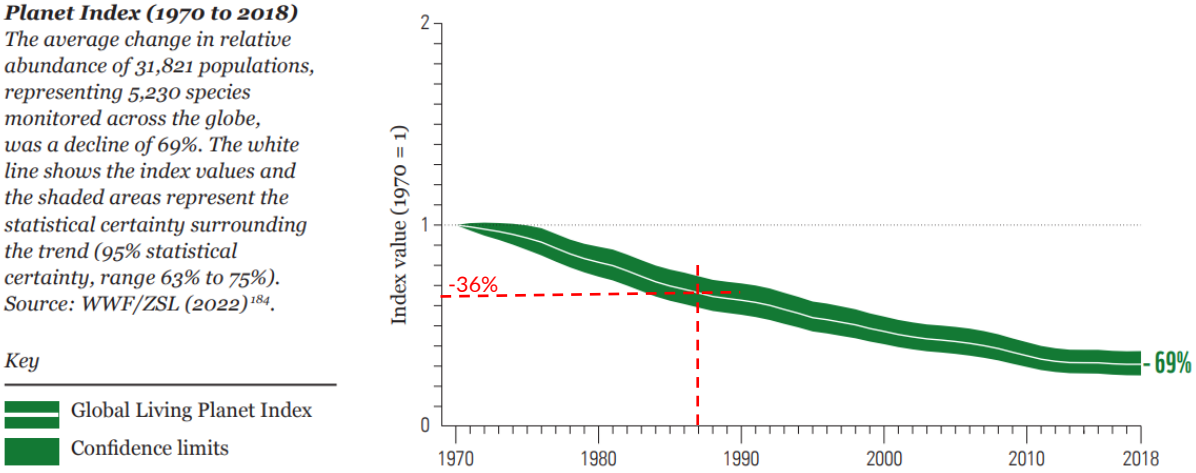

Figure 3. Global Living Planet Index (from Almond, 2022)

Net Zero carbon emissions

Simply put, net zero means cutting greenhouse gas emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere by oceans and forests, for instance.

Transitioning to a net-zero world is one of the greatest challenges humankind has faced. It calls for nothing less than a complete transformation of how we produce, consume, and move about. Commitments made by governments to date fall far short of what is required. Current national climate plans – for the 193 Parties to the Paris Agreement taken together – would lead to a sizable increase of almost 11% in global greenhouse gas emissions by 2030 compared to 2010 levels (UN, 2023).

Net-positive

Net-positive is a term best described by Paul Polman, a keynote speaker at this CSE conference in 2021. It is a business approach in which a company puts back more into society, the environment and the global economy than it takes out. The vision of net positive is a business that improves the wellbeing of everyone it impacts and at all scales—every product, every operation, every region and country, and for every stakeholder, including employees, suppliers, communities, customers, and even future generations and the planet itself. Polman acknowledges that no company can achieve all these aims at once, but it's where we should be heading if we want a viable economy and planet (Winston, 2021).

Degrowth

Degrowth is a democratically planned downscaling of production and consumption to lighten ecological footprints while reducing inequality and improving wellbeing around the world. Degrowth is a macroeconomic diet to sufficiently reduce environmental pressures to stabilise the metabolism of high-income economies at a scale that can be sustainable. Degrowth as a societal transformation would lead to smaller, steady-state economies in harmony with nature that could prosper without growth (the idea of post-growth) (Holemans, 2023).

The main argument of degrowth is that an infinite expansion of the economy is fundamentally contradictory to the finiteness of the Earth. Degrowth highlights the importance of autonomy, care work, self-organisation, commons, community, open localism, work sharing, happiness and conviviality (D'Alisa, 2015). A degrowth economy is a transitionary phase, including a reduction of production and consumption to reduce the ecological footprints, planned democratically in a spirit of social justice while improving wellbeing (Parrique, 2023b).

Steady-state economy

A steady-state economy is an economy made up of a constant stock of physical wealth (capital) and a constant population size. In effect, such an economy does not grow in the course of time (Georgescu-Roegen, 1975). The term usually refers to the national economy of a particular country, but it is also applicable to the economic system of a city, a region, or the entire world. Early in the history of economic thought, classical economist Adam Smith of the 18th century developed the concept of a stationary state of an economy: Smith believed that any national economy in the world would sooner or later settle in a final state of stationarity (Smith, 2007).

Post-growth

Post-growth is a way of thinking about what might happen when the obsession with growth is over. It invites us to explore new frontiers for social progress. It points toward uncharted terrain, an unexplored territory in which plenty isn't measured in dollars and fulfilment isn't driven by the relentless accumulation of material wealth. Post-growth is the recognition that, on a planet of finite material resources, extractive economies and populations cannot grow infinitely (Jackson, 2021). Post-growth can be distinguished from similar concepts and movements (such as degrowth) in that it seeks to identify and build on what is already working rather than focusing on what is not (Hinton, 2014). Post-growth does not specify the answer to the limits-to-growth challenge, as "steady state economics" and "degrowth" attempt to do, but rather seeks to understand and address this challenge from an evolving complex systems perspective.

A post-growth economy is a steady-state economy in harmony with nature where decisions are taken together, and wealth is equitably shared to prosper without growth (Parrique, 2023c).

Doughnut economics

Another well-known framework is the increasingly popular concept of 'Doughnut Economics' (Figure 4). Seventy cities and municipalities around the world have applied doughnut economics to their planning processes to date, including Amsterdam and Copenhagen (Raworth, 2023). The 'Doughnut' is considered a compass for human prosperity in the 21st century, whose goal is to meet the needs of all people within the means of the planet. It consists of two concentric rings: a social foundation – to ensure that no one is left falling short on life's essentials, and an ecological ceiling – to ensure that humanity does not collectively overshoot planetary boundaries. Between these two boundaries lies a doughnut-shaped space that is both ecologically safe and socially just – a space where humanity can thrive (DEAL, 2023).

Discussion

Growth and green growth will lead to environmental, population and economic collapse, as set out by Meadows (1972) in 'Limits to Growth' and validated by Herrington (2022) in 'What a 50-year-old world model tells us about a way forward today'. Since the term 'sustainability' became mainstream in policy discussions in 1987, more carbon dioxide has been added to the atmosphere than in all of the years since the start of the industrial revolution (Bureau of Meteorology, 2023b).

Net zero carbon emissions commitments made in Paris in 2015 are not being met, such that carbon emissions will increase by 11% by 2030 rather than reduce by 45% (United Nations, 2023). Net-positive is voluntary and aimed at businesses, so it will have a limited global impact, notwithstanding that it is a good approach for each business and its immediate zone of influence. Steady-state economy, post-growth or degrowth could occur within nations or globally and might be prompted by multiple

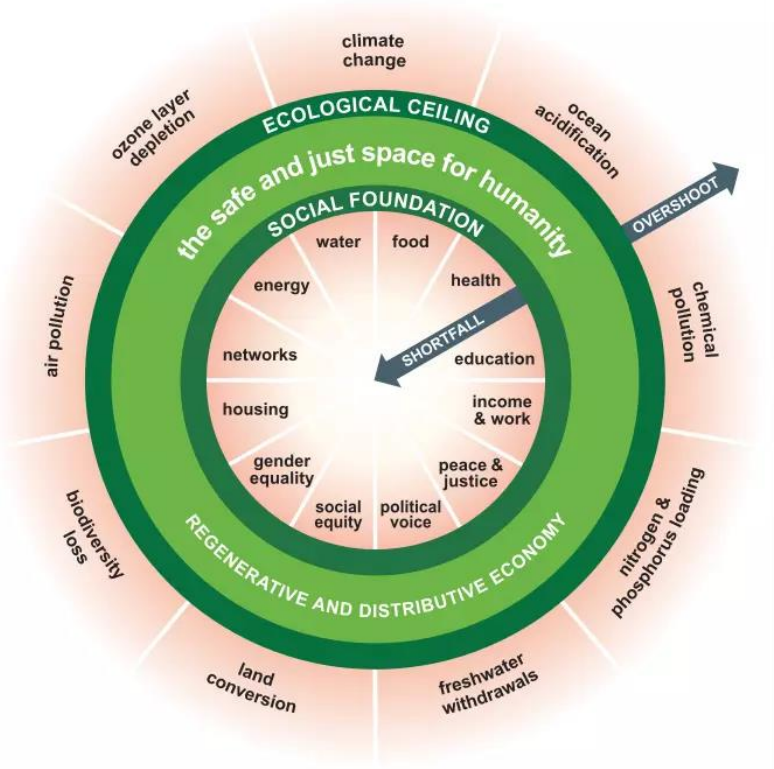

Figure 4. The Doughnut of social and planetary boundaries (from DEAL, 2023)

crises or war – i.e., out of need – or by a collective democratic choice. A steady-state economy, post-growth or degrowth, would require the rules of finance to change to prohibit fractional-reserve banking, i.e., the creation of money every time a commercial bank issues a loan or mortgage (McLeay, 2014). The concept of the doughnut economy is a practical approach allowing strategies to be planned and implemented.

For this paper and the framing of Australia's water industry in about 2040, it is difficult to foresee that Australia or its primary defence and economic partners will have democratically chosen steady-state economy, post-growth or degrowth as their social/environmental/economic approach. The current way that our nations are organised has too great a 'momentum' to change that quickly by popular choice. The likelihood is that many businesses will be operating 'net-positive', and many local governments will be using doughnut economics for planning their communities. The economy will be under much strain due to a range of impacts on food, infrastructure, people and, therefore, the global economy, as set out in the early sections of this paper. Australia might be moving in and out of periods of economic recession. The world economy is likely to have been through a recession (World Bank, 2022). The WEF includes large-scale involuntary migration, widespread cybercrime/insecurity and geoeconomic confrontation in its top ten global risks over the next ten years (WEF, 2023). As these stresses may

increase by the year 2040 due to the increasing pressure on the environment and the severity of climatic events, it is also possible that a war more significant than the Ukraine war will have started by 2040.

RELEVANT EVOLVING TRENDS

With a specific focus on Australia's water industry, the following subsections discuss several trends that are expected to evolve over the next two decades.

Climate and conflict refugees

Over the coming decades, arid South and Central Asia will suffer sustained droughts and crop failures caused by depleting Himalayan glaciers and reduced river flows. In addition, more frequent and extreme heat waves in these areas will cause reduced productivity and increased frequency of crop failures. Extreme and catastrophic heat waves are already resulting in deaths (Hughes, 2023). The frequency, duration and severity of heatwaves will increase with the warming of the planet and continue to impact populous regions such as South Asia.

Sea level rise will progressively inundate coastal communities and their food crops, and the groundwater systems will increasingly be impacted by saline intrusion, affecting crops. A study by Chen and Mueller (2018) shows that inundation alone has negligible effects on migration and agricultural production in Bangladesh. However, gradual increases in soil salinity correspond to increasing diversification into aquaculture and migration of Bangladeshi people. Salinity was found to have direct effects on internal (domestic) and international migration, even after controlling for income losses. The study suggests that migration is driven, in part, by the adverse consequences of salinity on crop production.

Harvard Magazine interviewed Jennifer Leaning, an expert on disaster preparedness and response who has witnessed climate-induced migration firsthand. She said, "If we think the Syrian refugee crisis of one and a half million in Lebanon, and three and a half million in Turkey, and hundreds of thousands trying to get into Europe, is a problem—it is trivial compared to what's coming with the impending climate crisis. We must make every effort to make it possible for these "climate refugees" to remain at home," said Leaning, "but for some, the climate will be too forbidding, and we must welcome and accept and bring them into our lives." (Shaw, 2020)

As identified earlier, social instability, conflict and sudden migrations can be triggered by water scarcity, exacerbating problems in war-torn and/or poor regions. As has been witnessed in Ethiopia, Afghanistan, Syria and Sudan recently, drought and crop failures invariably lead to conflict and civil war, further exacerbating the movement of people within and from affected countries.

If, as above, 129 million people in the South Asia region are 'substantially dependent on upstream meltwater for their livelihood' and seasonal glacier meltwater is equivalent to the basic needs of 221 million people in the Central Asian nations of Pakistan, Afghanistan, Tajikistan, Turkmenistan,

Uzbekistan and Kyrgyzstan, then over 300 million people could be unsettled and seeking to migrate within those countries, or within those regions. A proportion of those people will attempt to leave these regions, as we presently see with migrations from Latin America, Africa and the Middle East. Of the 300 million plus, the proportion seeking to leave the Central and South Asia regions could count in the tens of millions over the coming decades and likely concentrated in the 2030s and 2040s.

The concept of accepting climate refugees will be very politically challenging for the USA, Europe and Australia. However, these include some of the wealthiest nations having benefited from the combustion or sale of fossil energy and having adequate capacity to provide for the refugees' humanitarian rights. It is entirely feasible that the United Nations will direct countries such as Australia to take many of these refugees. What water services will be required when far more immigrants than Australia has ever seen begin arriving?

Manufactured water

Western Australia is already highly dependent on manufactured water, with the Water Corporation implementing their third seawater desalination plant, and they have implemented their first indirect potable reuse plant (Water Corporation, 2023). The forecast for more frequent El Nino periods will mean more frequent and longer droughts for the eastern states. The population will continue to grow and will be amplified by (a) a general migration away from the equatorial regions due to warming, including from northern Australia, and (b) significant influxes of climate and conflict refugees, then the water demand will increase rapidly, even as the security of supply declines. The demand for municipal water will increase under this scenario.

The water needed to grow the food to sustain this increased population will also increase rapidly. Even groundwater and surface water resources will become more stressed. Further, the author hopes that by 2040 we will have a better understanding and respect for systems like the Murray-Darling system and the Great Artesian Basin, such that we are abstracting less water annually than we do at present.

It is clear from this that the need for manufactured water facilities will increase exponentially over the next two decades and will likely continue for some time. We can expect to see more seawater desalination plants and more recycled water plants. By 2040, the author believes we will have several direct potable reuse plants in operation, following leadership by Southern California.

Further, with the steadily reducing cost of harnessing renewable energy sources such as wind and solar, the ability to desalinate seawater or purify wastewater will become sufficiently economical to support intensive agriculture. This has already been shown to be effective by Sundrop Farms in Port Augusta, South Australia. Sundrop Farms' 20 hectares of greenhouse uses the sun's energy to desalinate seawater for irrigation (Sundrop, 2023). The electricity generated from solar energy powers the greenhouse to

heat and cool the crops. The inputs are sun and seawater – the outputs are tomatoes delivered all over Australia (Figure 5).

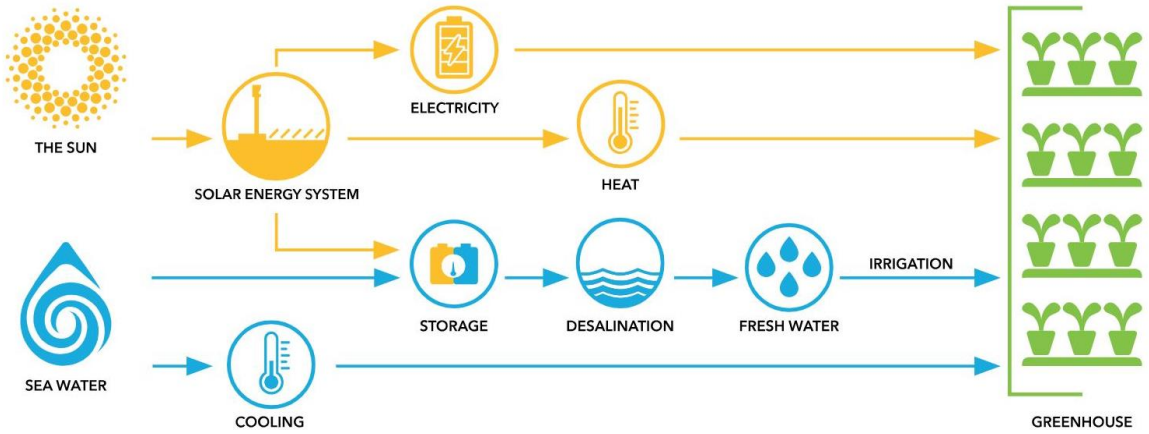

Figure 5. Sundrop Farms water and energy system (Sundrop, 2023)

Affordability and the importance of water

By 2040, the local and global economy could be severely constrained, as promulgated above. If this economic 'malaise' is unplanned and not chosen by the government or the electorate, then one would expect a significant affordability crisis. If, in that future, economic activity is reduced by planning and choice, such as with the implementation of degrowth or post-growth approaches, then there will also be reduced affordability for water services because these the implicit characteristics of these approaches are sufficiency or sobriété – the French word for moderation. The abundance of goods, services and incomes that most people in the wealthy nations enjoy today will, under degrowth or post-growth, be a thing of the past.

In such an economically constrained environment, we can expect the water services sector to challenge the relative 'abundance' in water availability and water security that our cities have experienced in recent decades. While we wouldn't expect large centres to be exposed to non-supply risk, it might be acceptable to manage more of our distribution and collection systems in a run-to-failure mode instead of pro-active monitoring, condition assessment and renewals.

We first need air to breathe under Maslow's hierarchy of needs (Maslow, 1943). Refer to Figure 6. The next thing that humans need is water, followed by food and shelter. So, by this argument, in an economically constrained future, there are several infrastructure services that would normally be funded by the state that will experience significantly less funding than the water sector. For example, one can see that private transport and subsidisation of fossil energy do not appear on Maslow's hierarchy.

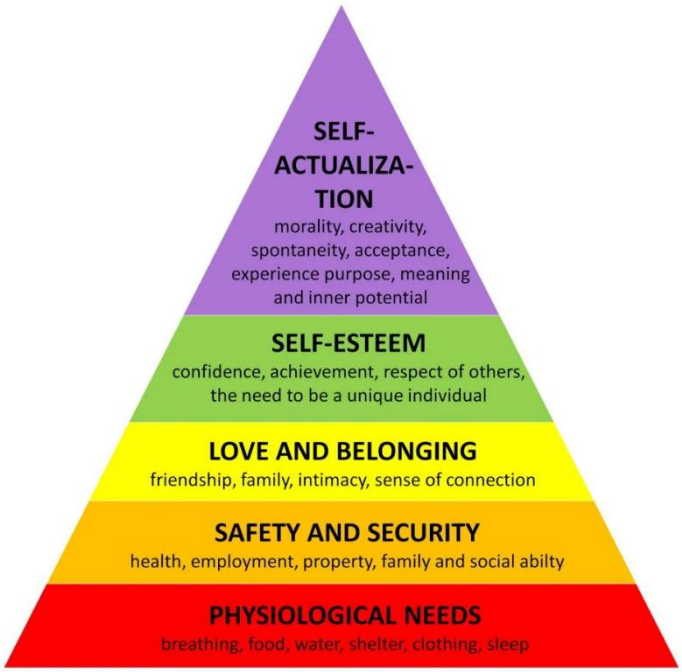

Figure 6. Maslow's Hierarchy of Needs (Maslow, 1943)

Equity in water services – locally and globally

The philosophies of degrowth and post-growth call for a reduction in economic activity in wealthy nations that is not essential to social wellbeing and ecological regeneration. Examples of activities that are not necessary and may need to reduce are marketing, fast fashion, engineered obsolescence, air travel and transport improvements to benefit private vehicles.

A key emphasis of degrowth and post-growth is on improving social equity within cities, states and nations and between nations. While the total GDP will likely decline under degrowth in wealthy nations like Australia, economic activity must increase in poorer nations to assure social wellness, health, education and ecological protection. This will be through wealth redistribution – examples we are already starting to see following COP27, where it was agreed to establish and operationalise a loss and damage fund (UN, 2023).

WATER SERVICES IN AUSTRALIA IN 2040

This paper has assessed a small number of changes to our economy or broader environment that will influence the water services we provide in Australia, including shrinking ice sheets, changes to weather patterns, reduced crop efficiencies and a weaker economy. These are all symptoms of the disproportionate impact that Western nations are having on the natural environment and finite resources, driven by exponential economic growth. But this snapshot of changes can be traced through to effects on our local water industry and therefore allows us to illustrate how the water services sector will likely change. Figure 7 illustrates these diagrammatically.

What we can see from this is that there will be rapid impacts on our communities and environments, but the opportunities for engineers in mid-career or entering choosing the water sector are incredibly exciting.

Water production will become more industrial in nature. Manufactured water in the form of seawater desalination, recycled water and industrial water reuse will become more prevalent, contribute to a larger proportion of the total supply volume and will be critical for current and future cities.

As a result of probable glacier depletion, crop failures, increased heat wave severity, and consequential conflict in Central and South Asia, Australia can expect to receive many millions of climate and conflict refugees. Given that Australia is also warming and drying, it is most likely that many of these new Australians will be accommodated in new or expanded cities in the southern half of Australia. Ideally, new communities will be close to food and other resources and away from rising sea levels. Over the long term, these new centres can also accommodate those populations that must retreat from heatwaves and the rising sea along Australia's coastline. The water services master planning, engineering, and construction required for these rapid infrastructure programmes will require thousands of water practitioners.

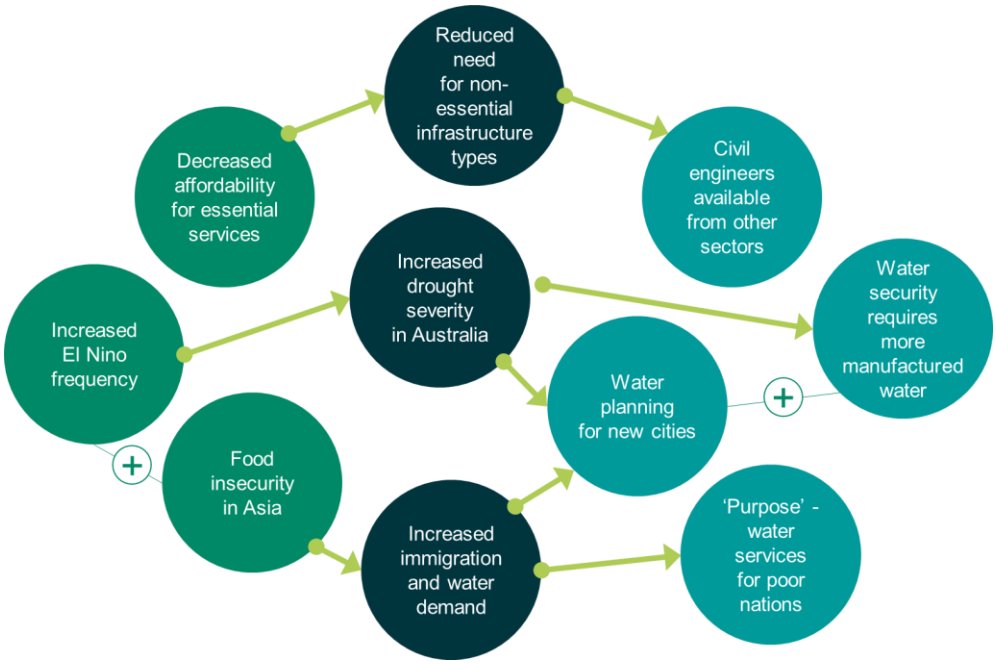

Figure 7. Causes and effects on water services in Australia

Even in a constrained economy, the provision of water services will always be necessary. Given that access to water is second only to access to air and that health – and therefore sanitation – is one of the most important human needs, several other less-essential sectors will likely have engineers and constructors with skills that can be applied to the water sector to assist with these major programmes.

As wealthy economies realise that social wellbeing and ecological regeneration are more important metrics than GDP, we can expect to see the Australian water industry support local and regional communities; and cities, communities and agriculture in poorer nations. This will not be through charity and volunteering – it will be through direct assistance in funding, planning, engineering, materials, technology and construction. These grand and humane initiatives will be volunteered by wealthy nations or directed by bodies such as the United Nations or the World Health Organisation.

In conclusion, the outlook for water services engineering in the next 10 to 20 years will be exciting and challenging for our industry and will include:

- A significant increase in demand for water services planners, engineers, constructors and operators in all facets of the sector.
- Significant and continuing increases in the need for manufactured water.
- The master planning, engineering, construction and operation of water services for new population centres to accommodate millions of new Australians.
- A significant increase in the direct uplifting of water services in poorer countries, making work in the water sector even more purposeful than it already is!

BIOGRAPHY

Marco is a talented Technical Director in the Water Infrastructure team at AECOM and has an extensive background leading critical planning studies, significant engineering projects and multi-disciplinary project teams. Marco leads planning and engineering design teams for public infrastructure projects, including water pipelines, treatment systems and transportation projects. His 30 years of professional experience has predominantly been in Australia and New Zealand, with projects in the Pacific Islands, Singapore, Papua New Guinea and China. Marco is also a Dad and a believer in the anthropogenic change this planet has experienced since the advent of the industrial age.

REFERENCES

Almond, R.E.A., Grooten, M., Juffe Bignoli, D. & Petersen, T. (Eds), 2022, "*Living Planet Report 2022 – Building a nature-positive society*", WWF, Gland, Switzerland.

Betts RA, Alfieri L, Bradshaw C, Caesar J, Feyen L, Friedlingstein P, Gohar L, Koutroulis A, Lewis K, Morfopoulos C, Papadimitriou L, Richardson KJ, Tsanis I, Wyser K, 2018, "*Changes in climate extremes, fresh water availability and vulnerability to food insecurity projected at 1.5°C and 2°C global warming with a higher-resolution global climate model*", Philos Trans A Math Phys Eng Sci.

Bureau of Meteorology, 2023a, "*El Niño Southern Oscillation (ENSO)*", http://www.bom.gov.au/climate/about/australian-climate-influences.shtml?bookmark=enso, accessed 1 July 2023

Bureau of Meteorology, 2023b, "*State of the Climate 2022 – Greenhouse Gases*", http://www.bom.gov.au/state-of-the-climate/greenhouse-gas-levels.shtml, accessed on 17 July 2023

Burke, E. et al., 2018: "*CO_2 loss by permafrost thawing implies additional emissions reductions to limit warming to 1.5 or 2°C*", Environmental Research Letters, 13, 2, 024024

Chen, J., Mueller, V., 2018, "*Coastal climate change, soil salinity and human migration in Bangladesh*", Nature Clim Change 8, 981–985

Colón-González, F. et al., 2018: "*Limiting global-mean temperature increase to 1.5–2°C could reduce the incidence and spatial spread of dengue fever in Latin America*", PNAS, 115 (24), 6243–8

CSIRO, November 2022, "*Future climate – New research in Australia and around the world, together with the IPCC's Sixth Assessment Report, enhance understanding of the state of Australia's future climate.*", https://www.csiro.au/en/research/environmental-impacts/climate-change/State-of-the-Climate/Future-climate, accessed 1 July 2023

D'Alisa, Giacomo; et al., eds., 2015, "*Degrowth: A Vocabulary for a New Era*", London: Routledge.

Doughnut Economics Action Lab (DEAL), 2023 "*What is the Doughnut?*", https://doughnuteconomics.org/tools/11#overview, accessed on 10 July 2023

Georgescu-Roegen, N., 1975, "*Energy and Economic Myths*", Southern Economic Journal. 41(3): 347–381.

Herrington, G., May 2022, "*What a 50-year-old world model tells us about a way forward today*", https://www.clubofrome.org/wp-content/uploads/2022/05/Earth4All_Deep_Dive_Herrington.pdf, accessed 10 July 2023

Heun, M.K., Brockway, P.E., 2019, "*Meeting 2030 primary energy and economic growth goals: Mission impossible?*" Appl. Energy 251 (2019) 112697.

Hickel, J., March 2020, "*Less is More: How Degrowth Will Save the World*", London: Penguin

Hinton, J, Maclurcan, D., September 2014, "*A Post-growth Event: Free Money Day – What is the difference between post-growth and degrowth?*", https://degrowth.info/en/blog/a-post-growth-event-free-money-day, Accessed 10 July 2023.

Holemans, D., et al, May 2023, "*Imagining Europe Beyond Growth*", published by European Environmental Bureau (EEB), Oikos vzw and Green European Journal

Hughes, R.A., 20 June 2023, "*Morgues full and hospitals overwhelmed as India's heatwave death toll hits 170*", Euronews, https://www.euronews.com/green/2023/06/20/morgues-full-and-hospitals-overwhelmed-as-indias-heatwave-death-toll-hits-170, accessed 2 July 2023

Hughes, Terry P et al., 2017, "*Global warming and recurrent mass bleaching of corals.*" Nature vol. 543,7645 (2017): 373-377.

IPCC, 2018, "*Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*", Cambridge University Press, Cambridge, UK and New York, NY, USA.

IPCC, 2022, "*Summary for Policymakers, in IPCC. Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.*" Cambridge University Press, Cambridge and New York.

IPCC, 2023, "*Summary for Policymakers. In: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*" [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 36 pages. (in press).

Jackson, T., March 2021, "*Post-growth: Life after Capitalism*", Polity Press

Jevrejeva, S. et al., 2018, "*Flood damage costs under the sea level rise with warming of 1.5°C and 2°C*", Environmental Research Letters, 13 (7), 074014

Lewis, S. et al., 2017 "*Australia's unprecedented future temperature extremes under Paris limits to warming*", Geophysical Research Letters, 44, 9947–56

Liu, W. et al., 2018, "*Global drought and severe drought-affected populations in 1.5 and 2C warmer worlds*", Earth Systems Dynamics, 9, 267–83

Maslow, A. H., 1943, "*A theory of human motivation*", Psychological Review, 50 (4), 370-96

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W., 1972, "*The limits to growth: A report for the Club of Rome's project on the predicament of mankind*", Universe Books

Michael McLeay, Amar Radia and Ryland Thomas, 2014, "*Money creation in the modern economy*", Bank of England's Bank's Monetary Analysis Directorate, Bank of England Quarterly Bulletin 2014 Q1, https://www.bankofengland.co.uk/-/media/boe/files/quarterly-bulletin/2014/money-creation-in-the-modern-economy.pdf, accessed 1 July 2023.

Parrique, Tomothée, 2023a, 14 March, https://twitter.com/timparrique/status/1635573168101261313, accessed 6 July 2023

Parrique, Tomothée, 2023b, 14 March, https://twitter.com/timparrique/status/1635573170768945154, accessed 6 July 2023

Pattyn, F. et al., 2018, "*The Greenland and Antarctic ice sheets under 1.5°C global warming*", Nature Climate Change, 8, 1053–61

Perkins, S. E., 2015, "*A review on the scientific understanding of heatwaves—Their measurement, driving global scale*" Atmospheric Research, 164-165, 242–267

Pritchard, H., 2019, "*Asia's shrinking glaciers protect large populations from drought stress*", Nature, 569, 649–54

Raworth, K. and Hagens, N., 28 June 2023, "*Kate Raworth: The Superorganism V. The Doughnut*", The Great Simplification podcast, https://www.thegreatsimplification.com/episode/77-kate-raworth, accessed 10 July 2023

Raworth, K., 2017, "*Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist*", Random House Business

SEI, IISD, ODI, E3G and UNEP, 2021, "*The Production Gap Report 2021*", https://productiongap.org/wp-content/uploads/2021/11/PGR2021_web_rev.pdf, accessed 10 July 2023

Shaw, Jonathan, 2020, "*A Climate Refugee Crisis in the Offing*", Harvard Magazine, https://www.harvardmagazine.com/2020/11/features-climate-refugee-crisis, accessed 2 July 2023

Shin, NY., Kug, JS., Stuecker, M.F. et al., 2022, "*More frequent central Pacific El Niño and stronger eastern pacific El Niño in a warmer climate*", npj Climate and Atmospheric Science. 5. 10.1038/s41612-022-00324-9.

Smith, Adam, 2007 [1776], "*An Inquiry into the Nature and Causes of the Wealth of Nations*", Amsterdam: MetaLibri.

Sorg, A. et al., 2014, "*The days of plenty might soon be over in glacierised Central Asian catchments*", Environmental Research Letters, 9, 104018

Springmann, M. et al., 2016: "*Global and regional health effects of future food production under climate change: a modelling study*", The Lancet, 387 (10031), 1937–46

Sundrop Farms, 2023, "*Our Technology*", https://www.sundropfarms.com/our-technology/, accessed 5 July 2023

Thunberg, G., 23 September 2019, "*Transcript: Greta Thunberg's Speech At The UN Climate Action Summit*", https://www.npr.org/2019/09/23/763452863/transcript-greta-thunbergs-speech-at-the-u-n-climate-action-summit, accessed 10 July 2023

United Nations Environment Programme, 2019, "*Emissions Gap Report 2019*", UNEP, Nairobi

United Nations General Assembly, 20 March 1987, "*Report of the World Commission on Environment and Development: Our Common Future; Transmitted to the General Assembly as an Annex to document A/42/427 – Development and International Co-operation: Environment; Our Common Future, Chapter 2: Towards Sustainable Development; Paragraph 1*", United Nations General Assembly, https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf, accessed 10 July 2023.

United Nations, 2022, "*Delivering for people and the planet*", https://www.un.org/en/climatechange/cop27, accessed 5 July 2023

United Nations, 2023, "*For a liveable climate: Net-zero commitments must be backed by credible action*", https://www.un.org/en/climatechange/net-zero-coalition, accessed 10 July 2023

Wang, M. & Overland, J., 2009, "*A sea ice free summer Arctic within 30 years?*", Geophysical Research Letters, 36 (7), L07502

Warren, R. et al., 2018, "*The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5°C rather than 2°C*", Science, 360 (6390), 791–5.

Water Corporation, 2023, "*Climate and Water*", https://www.watercorporation.com.au/, accessed 10 July 2023

Winston, Andrew S., October 2021, "*Net Positive: How Courageous Companies Thrive by Giving More Than They Take*", Harvard Business Review Press, Boston MA

World Economic Forum, January 2023, "*Global Risk Report 2023*" https://www.weforum.org/reports/global-risks-report-2023, accessed 17 July 2023