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Author

Torabi, Elnaz, Dedekorkut-Howes, Aysin, Howes, Michael, Byrne, Jason

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Elnaz Torabi

School of Environment and Science & Cities Research Institute, Griffith University, Gold Coast
e.torabi@griffith.edu.au

Aysin Dedekorkut-Howes

School of Environment and Science & Cities Research Institute, Griffith University, Gold Coast
a.dedekorkut@griffith.edu.au

Michael Howes

School of Environment and Science & Cities Research Institute, Griffith University, Gold Coast
m.howes@griffith.edu.au

Jason Byrne

Geography and Spatial Sciences, University of Tasmania
jason.byrne@utas.edu.au

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Elnaz Torabi

School of Environment and Science & Cities Research Institute, Griffith University, Gold Coast

Aysin Dedekorkut-Howes

School of Environment and Science & Cities Research Institute, Griffith University, Gold Coast

Michael Howes

School of Environment and Science & Cities Research Institute, Griffith University, Gold Coast

Jason Byrne

Geography and Spatial Sciences, University of Tasmania

Abstract: The water sector is increasingly facing unprecedented challenges and disruptive change, as are many other sectors of the economy. Market shifts, privatisation, increasing competition, technological innovation, and changing consumer behaviour pose significant challenges for water utilities. Such factors have been disruptive to many other sectors, including energy and telecommunications, which have often been caught unprepared. The next phase of disruptions will impact the water sector, and the partial privatisation of water assets is just the beginning of this process. Climate change impacts will exacerbate all these challenges. Action needs to be taken now if threats are to be turned into opportunities. This paper examines the barriers and enablers of climate adaptation in the water sector. It uses data collected through informal meetings (short conversations), semi-structured in-depth interviews and a workshop on climate change adaptation with selected representatives from water/wastewater utilities across Australia. The results indicate that utilities face both internal and external barriers to adaptation. Barriers faced by the water sector are similar to those in other sectors and include community values and perceptions, high costs of adaptation and community's reluctance to pay, political instability and sensitivity of climate change across all Australian states, and lack of coordination and collaboration between organisations.

Key words: *Water; wastewater; adaptation; climate change; Australia*

Introduction

Water plays a key role in enhancing the integrity of the natural and built environment. Climate change impacts such as the increases in the duration, intensity, and/or frequency of extreme weather events and rising sea levels and temperatures will have detrimental impact on water (Intergovernmental Panel on Climate Change [IPCC], 2014). Globally, water/wastewater utilities are highly exposed and vulnerable to the impacts of climate change. Sewerage infrastructure, for example, can be vulnerable to sea level rise and storm surge, as they are usually located in low-lying areas to operate by gravity. Climate change affects water/wastewater utilities and their operations in different ways. For instance, increased temperature and lack of rainfall can diminish ground water sources (Evans *et al.*, 2009, Renner, 2013, Boholm and Prutzer, 2017) or lead to increased demand for water (Arnell and Delaney, 2006, Refsgaard *et al.*, 2013, Azhoni *et al.*, 2018). There are also critical impacts on water quality and public health (Rudberg *et al.*, 2012, Gasbarro *et al.*, 2016, Howard *et al.*, 2016, Ojomo and Bartram, 2016) as well as damage to infrastructure and service disruption (Arnell and Delaney, 2006, Evans *et al.*, 2009, Heath *et al.*, 2012, Renner, 2013). Through these impacts, climate change is likely to cause significant reputational damage to these organisations (Gasbarro *et al.*, 2016).

Globally, many water and wastewater utilities are at the forefront of adaptation and implement different strategies to deal with the impacts of climate change and build their resilience. However, similar to all other organisations, water utilities' adaptation journey has not always been straightforward. Several factors are important in facilitating adaptation to climate change for water/wastewater utilities. For instance, availability of appropriate scientific climate information (Rice *et al.*, 2009, Gleick, 2010, Ziervogel *et al.*, 2010, Rudberg *et al.*, 2012, Hovik *et al.*, 2015, Azhoni *et al.*, 2018) and the necessary financial and technical resources (Arnell & Delaney, 2006; Azhoni *et al.*, 2018; Brown *et al.*, 2013; Juan-García *et al.*, 2017; Neumann *et al.*, 2015; Ojomo & Bartram, 2016; Rudberg *et al.*, 2012) are two critical enablers. Effective adaptation to climate change and use of these resources is also influenced by existing policy and regulatory frameworks (Arnell and Delaney, 2006, Berkhout *et al.*, 2006, Dodman and Satterthwaite, 2008, Lopez *et al.*, 2009, Maier and Carpenter, 2015, Neumann *et al.*, 2015), community and stakeholder support (Shepherd *et al.*, 2006, Bloetscher *et al.*, 2010, Farrelly and Brown, 2011, Short *et al.*, 2012, Bettini *et al.*, 2015, Gasbarro *et al.*, 2016, Ojomo and Bartram, 2016, Boholm

and Prutzer, 2017), political factors (Shepherd *et al.*, 2006, Roncoli *et al.*, 2009, Farrelly and Brown, 2011), and strong leadership and commitment (Feldman and Ingram, 2009, Ziervogel *et al.*, 2010, Farrelly and Brown, 2011). While presence of these factors can drive climate change adaptation for water/wastewater utilities, their absence can create significant roadblocks for short and long term adaptation.

Previous studies explored climate change adaptation for the water sector in general including the key barriers and drivers, particularly in the context of impacts on water and integrated water resource management (Ludwig *et al.*, 2014, Giupponi and Gain, 2017, Azhoni *et al.*, 2018). However, climate change adaptation and its implications at the water/wastewater utility scale has largely been neglected in Australia. This paper addresses this gap by exploring the main drivers for adaptation and barriers to effective action by these organisations. The next sections provide an overview of the water sector in Australia and outline the methodology of this research. The discussion of the findings is presented next and the paper concludes by outlining the key findings and areas of future research.

Australian Water Sector and Climate Adaptation

Australia is the driest inhabited continent on Earth, with 70 percent of its landmass defined as arid (with average annual rainfall below 250 mm) or semi-arid (receiving annual average rainfall between 250-350 mm per year) (Climate Council of Australia, 2018). Around 85% of Australia's population lives along the coast, often in low-lying areas (Department of Climate Change, 2009). As a result, the existing water/wastewater infrastructure supporting this population is extremely exposed and vulnerable to the impacts of climate change. Significant climate change impacts and risks to Australia's water security (including health, water supply, energy, bushfires, and flooding issues) are already evident and will continue to increase (Climate Council of Australia, 2018).

The water sector is one of the key pillars of the Australian economy. Urban water sector directly accounts for 0.75 per cent of Australia's annual Gross Domestic Product, with assets worth of A\$160 billion (Infrastructure Partnerships Australia and Water Services Association of Australia, 2015). Australia's urban water sector delivers services across around 220 urban water utility businesses that are owned by state and/or local governments. The supply chain of the urban water sector in Australia stretches from management of water resources to bulk water supply and treatment to the delivery to households as well as collection and treatment of wastewater. Accordingly, the structure and governance of urban water/wastewater utilities vary widely across jurisdictions. For example, while water/wastewater utilities in South Australia and Western Australia are vertically integrated (from dam to tap), in other states such as in Queensland, New South Wales, and Victoria bulk water supply, distribution, and wastewater services are separated and managed by different organisations (Infrastructure Partnerships Australia and Water Services Association of Australia, 2015). Some of these utilities are state owned corporations, while others are departments within local governments or separate statutory bodies with local government shareholders.

Australian water/wastewater utilities have already started to adapt to the impacts of climate change, particularly in the area of water security and augmentation of water supplies through desalination and alternative water sources (Water Services Association of Australia, 2012). Recognising the importance of addressing climate change risks and building resilience in the water industry, 17 utilities across Australia collaborated through the Water Services Association of Australia (WSAA) in 2016 to produce the first *Climate Change Adaptation Guidelines* for the water industry (WSAA 2016). The work of WSAA on climate adaptation has attracted national and international attention for several years (Barsugli *et al.*, 2012, Short *et al.*, 2012). In a study of the urban water sector in Australia, Farrelly and Brown (2011) found that overall, demonstrating leadership in the sector and building reputation have been important drivers for transition to more sustainable urban water practices and adaptation to climate change. Their findings were echoed in a later study that found the generation of strategic support and policy network for a change agenda around alternative water sources by water practitioners in Adelaide, as the key driver to the development of decentralised water supply schemes and new water services (Bettini *et al.*, 2015).

Methodology

This research uses a case study approach to explore the barriers and drivers to climate adaptation in the context of Australian water/wastewater utilities. A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within a real life context, especially when the boundaries between the phenomenon and the context are not clearly evident or when there is a lack of relevant information (Yin, 2009). The study triangulates data from multiple sources including informal short conversations, semi-structured in-depth interviews with selected individuals from water/wastewater

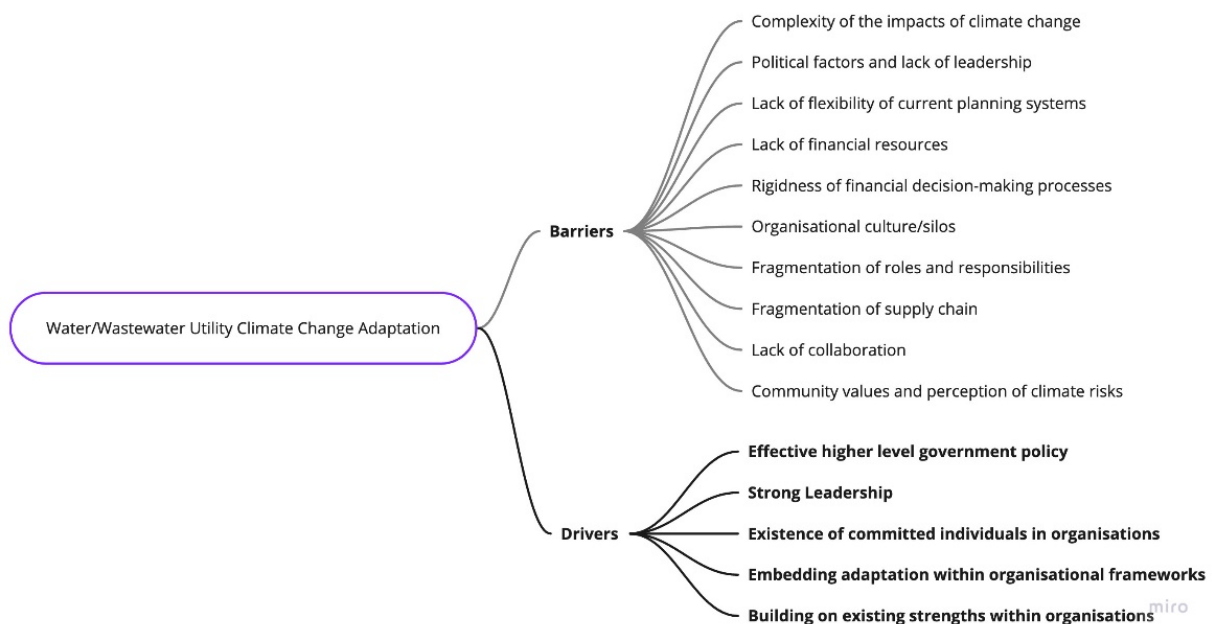
utilities across Australia, and a half day workshop with water/wastewater utility representatives in Queensland.

Participants were selected based on their expertise and interest in strategic planning and climate change. Informal meetings and a first set of ten interviews were focused on water utilities in Queensland. More participants (including from other states) were recruited for a second round of interviews later via purposive sampling technique (Patton, 2002) from a list of Australian utilities. This was followed by sequential sampling to identify more participants based on recommendations. Overall, 20 semi-structured interviews with water professionals from utilities in Queensland, New South Wales, Australian Capital Territory, Victoria, Western Australia and a representative from a water sector national body were conducted between June and October 2018. A half day workshop was also organised in Brisbane in October 2018, during which discussions were recorded. We analysed and coded the collected data thematically (Kvale and Brinkmann, 2009) using NVivo software. A list of the interview participants is presented in the Appendix.

Water/Wastewater Utilities’ Adaptation to Climate Change

Overall, the data points to several internal and external factors that constrain or enable adaptation for water/wastewater utilities in Australia. These factors are presented in Figure 1 below.

Figure 1. Barriers and Drivers for Water/Wastewater Utility Adaptation to Climate Change in Australia



Source: Authors

Barriers to Water/Wastewater Utility Adaptation

Our research found that the key constraints in adapting to climate change for the Australian water/wastewater utilities are both internal and external such as the complexity of the impacts of climate change, political factors and lack of leadership, lack of flexibility of current planning systems, lack of financial resources, rigidness of financial decision making processes, organisational culture/silos and fragmentation of roles and responsibilities, fragmentation of water supply chain, lack of collaboration, and community values and perception.

While in the past decades our understating of the scientific impacts of climate change has improved and the importance of adaptation is increasingly being recognised globally and (somewhat) nationally, the *complexity of the impacts of climate change* on water and wastewater systems is still an important barrier to action for utilities. Interviewee 14 framed this shift as “a few years ago there was a lot of climate change sceptics [...] climate change was a dirty word for some. I think that has gone now. I think it's something that is generally expected that it is going to be happening, we just don't know the level of how it is going to happen, how quickly”. This lack of clarity of the climate impacts limits effective action, as noted by Interviewee 3:

In the absence of a clear, defined event or challenge, I think the organisation can struggle to frame its response. So, you have a flood, it is very clear. You need to get the treatment plant out of the water. You need electricity reconnected, you need customers with service. It is a very clear remit of what needs to happen. Whereas if we think that sometime over the next 10 - 20 year plus horizon, that the majority of your treatment plants will probably suffer inundation of some sort and stress their ability of respond, I think your organisation goes 'but what do you want me to do?' That level of clarity.

Our participants particularly discussed their lack of knowledge of climate change impacts on the sewerage systems and lack of useful tools for more detailed site-based and whole of network assessment of climate change impacts. Interviewee 17 considered this as an important factor contributing to vulnerability of its organisation and noted: "we appreciate there are risks on the water supply side, but the sewage side is perhaps where we're a bit more exposed because of our lack of understanding". Interviewee 4 related this to the difficulties in understanding existing infrastructure systems and noted:

In a lot of areas of the sewerage network, we're blind. We don't know what happens, apart from when customers ring up and tell us something has happened. So we are trying to change that, but because we have got an uncertain level of knowledge around the sewer system right now, we are having to build that, just as a baseline, before we can even start to then say what might happen if things change.

The majority of the participants considered *political factors and lack of leadership* from higher levels to be an important roadblock to action on climate change. One interviewee discussed the lack of effective direction from the board of directors within the organisations and suggested "I'll call out leadership [...] I think there is a degree of lack of [climate change] knowledge in this space [...] this is one of those big pieces that you look at and go, 'I'm sorry, You need to have a degree of literacy in this space'". There are also political factors from higher levels of government that shape the local adaptation context for water/wastewater utilities to a great degree. This was potentially the case in Victoria's 2018 State election, with the possibility of a change in climate policy due to government change as suggested by Interviewees 16 and 17. The reliance of climate policies in Australia to the discretion of political parties does not provide water utilities with enough leadership and guidance to take action. This is particularly important considering that political cycles are getting shorter. Interviewee 6 framed this as political "short-termism" and noted "How do we drive 50-year strategies when our politicians, our leaders, our CEOs, our executives, not because it's necessarily their own choice, because it's the way that society is, do not think very much beyond that four to five-year span?". He then continued "Well, how do we get those leaders, politicians, et cetera, to think about not 'What am I going to achieve in my tenure?' but 'How do I contribute, what am I going to contribute to this country's, to organisation's 50-year, 100-year plan?' I think that's a real challenge."

The majority of the participants referred to *lack of flexibility of current planning systems* to accommodate practices that are outside the business as usual of the organisations. Interviewee 5 related this to the conventional ways in which infrastructure planning has taken place and suggested, "the process was historically to put together on the assumption that what you had was the right approach, and that what you planned from there were additions for growth and renewals. So you just maintained your assets and added new capacity as growth came on [...] this makes it difficult to plan for the change". Interviewee 4 related this to lack of integration between different stages of planning and noted "one of the weaknesses will be that it's potentially quite hard to change planning processes [...] because we have got a lot of processes set up to avoid wasted expenditure, but they typically then fall back to a design standard approach [...] and to get people to change that, you have to engage with a lot of groups within the organization. [...] it may need to be a project outside of the normal business as usual to actually develop the changed approach". Interviewee 17 considered the challenges related to planning systems as the main reason for the lack of good examples of organisations that have successfully adapted to the impacts of climate change and noted "We've gotten into this space now where there's a good understanding of what the risks are, a good understanding that we need to do something, and we're starting to plan, but the translation of planning into action is still the missing piece."

The majority of participants also discussed the *lack of financial resources* for adaptation (particularly in terms of building more resilient assets) and the constant struggle to reduce customers' bills as important barriers to adaptation. Interviewee 16 suggested, "We have a lot of political sensitivity about investing for climate change if it is going to affect water prices. Climate change is identified as a very critical and pressing challenge, but it is not as pressing as day-to-day operating challenges and keeping prices low".

Many participants discussed the *rigidness of financial decision-making processes* in this context that would not allow for change/innovation. Interviewee 5 suggested:

We have difficult decisions to make because the assets that we put in place are very long-term assets. We tend to have a very long-term view but it is hard to make long-term decisions in a concrete way. [...] We do have a requirement in terms of our regulatory structure that we need to be able to prove that all our investments are prudent, and prudent is assessed as meeting a legislative obligation or a requirement from our stakeholders or shareholders which is clearly demonstrated. That is a struggle. It does mean that if you are going to make an investment for something like climate change it needs to be connected to some reason [...] because that is the community expectation.

Interviewee 15 echoed this view and emphasised that:

This utopian future where we are all thinking system-wide is lovely, but we have a day-job to do and a financial performance to deliver [...] optimising our resourcing so that we have got enough to be able to do this future-thinking while delivering the day job, but that is a bit of a challenge for us at the moment [...] We have the regulatory system where things have to be prudent and efficient, and yet we are saying 'Well, an adaptive learning future has error built within it' and so how are you prudent and efficient while also being experimental about the future of facilities?

Interviewee 13 compared planning for climate change to other areas of long-term planning and suggested, "the way of predicting the future with climate change is less understood than things like population growth, for instance. So I guess it would be easier for us to convince the financial regulators that [a city] is going to grow by 100,000 people in 10 to 20 years, and that is fairly well understood, but if we were to say that temperatures are going to increase by 1.5 degrees in the next 20 years [...] that is tough to convince a financial regulator."

Some participants also related this to the existing timeframes for financial planning that do not easily accommodate long-term impacts such as climate change. Interviewee 16 from Victoria specifically mentioned "all of our financial planning and price planning takes place over five-year horizons. We are governed by a body called the Essential Services Commission. That is there to protect consumers; because we are essentially a monopoly [...] We are regulated quite tightly to make sure that we keep providing a good service to the community. The Essential Services Commission really looks at cost minimisation over a five-year period. That, maybe, shapes our financial discussions over a shorter timeframe than what would be ideal."

Several participants discussed the lack of clarity around acceptable level of climate change risks in their organisations as an important issue that complicates financial decision-making. Interviewee 10 suggested, "Our financial regulation is a challenge. Generally, the financial regulation pushes us towards the lowest cost solution. But it should be the lowest cost solution at acceptable levels of risk. And our financial regulatory people say that if you can show that there is a risk in the future that needs to be mitigated and it is prudent to do so, then we can spend the money mitigating that risk" and continued "The problem is that we are not mature enough in how we define those risks to convince the financial regulator that we should spend the money." Similarly, Interviewee 16 pointed to the challenges in making a business case for adaptation:

It is very difficult for us to make a business case that accounts for avoiding losses from extreme events or less likely, worst case scenarios. Most of our potential climate change impacts, or higher concentration pathway type weather events would, at the moment, be perceived as less certain, less likely. So, it is quite challenging to demonstrate value of avoiding negative impact. That whole business case structure, and the way that our treasury evaluate business cases can make it quite challenging to build in as much of a climate change perspective as we would like to, and how we consider value for money and how we invest in things now.

This is closely related to the risk appetite of the water sector in Australia as noted by Interviewee 16:

We are a very careful, cautious organisation, which is really appropriate when we deal with something as sensitive as drinking water and wastewater, and the terrible consequences if we get something wrong have made us a really risk averse organization. Perhaps, we are very cautious about risks now, and doing anything that doesn't have a really ironclad business case now, and may, perhaps, blinker us a little bit to what future risks look like. The risks of asset failure

or changing circumstances from climate change are perhaps paler in people's imagination than the risk of doing something a little less conventional now.

Interviewee 6 echoed this view and noted: "infrastructure providers go 'Yes, we get climate change risk. Yes, we have got a climate change strategy', but no one is actually biting the bullet and saying 'We are going to change the way we do business. We are not going to build assets like that anymore, we are not going to build things in that place, and we are actually going to stop putting money in to maintain that, because we are going to build something new or do something different, or bring in new technology and whatever it is'." Acknowledging the importance of compliance with existing/conventional rules at the same time as adapting to long-term impacts of climate change, Interviewee 15 suggested "we had become very compliance-focused [...] they are sort of opposite ends of the spectrum, in many ways. One is a sort of adaptive, experiential way of thinking, and the other is a 'Make sure you have got things covered, and nothing can go wrong' way of thinking. We have got to start, rather than seeing them as you either have one or the other, that actually we need to embrace both. Because we can't take risks with quality and things like that, but we can be more adaptive in how we look to the future."

Another important barrier, discussed by the majority of our participants, is *organisational culture/silos and fragmentation of roles and responsibilities* across a utility. Interviewee 4 exemplified the case of adaptation in the sewerage system and noted:

We can start planning sewers or planning changes to our sewerage system so that we account for climate change, but if that doesn't follow through into the operations departments and the maintenance crews, if we say there is a risk of increased sedimentation, we need more maintenance, they may or may not agree with us, and they may or may not get budget to do that. We don't really do that as business as usual, so obviously trying to do a change management process is hard.

Interviewee 6 related to this to the general culture and the perception that "it is someone else's job".

There are also significant issues related to the *fragmentation of the water supply chain* at a bigger scale. Some of our participants (particularly in Queensland) underscored a lack of an integrated approach to water management. This is important considering the disconnect in management of wastewater and potable water and lack of communication between the two entities. Interviewee 7 discussed this in the context of wastewater overflow and water quality issues and noted "I think we as a collective sector need to be able to understand how we collectively address it together [...] Otherwise one organisation wears more of the risk." Interviewee 10 referred to the impacts of droughts and noted:

As the dams get even lower, we start looking for alternative water sources. Now [bulk water providers] need to find those alternative water sources, but usually they are reliant on the effluent from our treatment plants or recycling the waste water that we collect. So, all of a sudden, it is difficult to understand the delineation [of] responsibilities between water supply and wastewater management.

Lack of an integrated approach to adaptation planning with local councils was an important barrier in this context as discussed by many of the participants. Interviewee 11 specifically mentioned "a lack of a holistic integrated [approach] is a significant barrier because we are managing elements of catchments but with local governments making decisions about catchment land use, at the moment we just have the ability to provide advice on, we don't have a strong ability to control that [...] so we have got these fragmented pieces of the water cycle that are being managed separately." Another interviewee (7) referred to some existing level of collaboration, but noted "All of the local governments, of which are shareholders, are grappling with these same problems. They have got responsibilities under Disaster Management Act. So that level of collaboration needs to be happening better, it has improved, but there is still a long way to go." They also referred to lack of collaboration between neighbouring local governments as part of a whole of catchment approach.

One common theme of discussion in this context was "liveability". Our participants particularly discussed the *lack of collaboration* between water/wastewater utilities and local councils as an important issue hindering liveability of cities. Interviewee 3 mentioned "we have a role to play with the use of recycled water, use of potable water in green spaces, but we do not control the urban planning. We influence it." Interviewee 20 discussed this in the context of shared values and noted "the [water] industry is very good at talking amongst themselves and we are a very collaborative industry, but what is happening overseas that is not happening well here [...] industries working together towards common value." Interviewee 9 concluded that "a lot of this, we can't do on our own so we are going to have to partner

and those partners could be our shareholders, regulators, or our communities”. One good example of collaboration across the water supply chain is the case of Western Australia where the focus of the water utility is on managing stormwater to contribute to liveability at local scales.

Some participants pointed to lack of good cross-utility networks and partnerships in Australia to enable climate change adaptation. While WSAA’s climate change networks were mentioned by several participants, lack of effective collaboration and shared learning from other water utilities in Australia and internationally was discussed by some participants. Interviewee 3, for instance, highlighted the importance of leveraging industry knowledge to build on existing capacities and suggested: “there are players in the water industry who I know are far more advanced than [us] in this space.” Several participants also extended this to other service providers and underscored the importance of collaboration with other critical infrastructure providers such as electricity and telecommunication. Interviewee 15 highlighted the importance of a holistic “systems thinking” approach necessary for adaptation and criticised the lack of cross-utility collaboration in Australia, emphasising that “we’re only scratching the surface of that, at the moment.”

Even when water/wastewater utilities have the necessary resources and the political will and support from higher levels and other stakeholders, adaptation actions can be significantly limited by *community values and perceptions*. This has particularly been the case in the context of water recycling and reuse for potable purposes. Interviewee 19 considered community acceptance as an important barrier to their utility’s choice of adaptation option and noted “we might have a great adaptive pathways plan [...] but in the end we might just have to go with one set of options if other things don’t shift in the public sphere”. Another interviewee (16) pointed to the importance of effective community engagement and suggested:

Our structures for engaging with the community are not as good. For example, we might have a whole range of ideas about things we might do to augment water supply or change our sewage system to cope with climate change, but it’s really challenging to have a good conversation with the community about what the 20 or 30-year options are. We need to be doing that now, because it might be that things start to cost a lot more in the future if we do not invest now, or it might be that we have to investigate some politically unpalatable options like building more desalination plants. That would be really unpopular; like recycled wastewater for drinking water, really unpopular.

While community perception was a barrier identified by most participants, a Western Australian (12) interviewee shared positive experiences of their organisation in this space: “We have tried to take a constructive approach and an open one, sharing the issue with the government and community. We haven’t found that it is a barrier, but it is certainly something we have had to be conscious about and also getting people to understand that this is not just a temporary issue, it is something we have to work together on, so because of that the community have accepted indirect potable.” They continued “the community has been fantastic partners with us in the journey.”

Other barriers to climate adaptation that were mentioned by some participants include lack of effective regulatory frameworks, organisational culture and lack of adaptive capacity, existence of other pressing organisational priorities, lack of effective use of technology, and loss of local knowledge due to staff turnover.

How Can Water/Wastewater Utilities Better Adapt to Climate Change?

The interviews point to a number of key considerations for water utility adaptation presented in Figure 2. Addressing the existing barriers that hinder the path towards adaptation (such as lack of resources, community perception, lack of flexibility in financial decision making, etc.) can enable water/wastewater utilities better respond to the impacts of climate change. However, continuity of actions in the long term will need to be complemented by strong drivers for change.

One of the key drivers for utility adaptation is *higher level government policy*, as identified by the majority of the participants in our study. Many participants referred to the impact of higher-level government commitment and policies in the climate mitigation space and suggested the need for a similar approach in the adaptation context. One recurrent example provided by the participants was the case of Victorian government policies requiring utilities to make a pledge and demonstrate how they will commit to reduce their emissions by 2050. Interviewee 20 pointed to the integral nature of mitigation and adaptation measures and noted:

The biggest barriers are really the lack of regulatory drivers. So, what the Victorian government has cleverly done is it has built it into the regulation and policy so that the industry does not have

levels, individual actions can struggle to continue, as noted by interviewee 16: “From the bottom up, we also have some champions who may be informally considering climate change because they think it is important. But, they do not necessarily have enough supportive structure to do that in a rigorous way. That is a gap for us, but we can support those champions better by improving our structures.” Interviewee 11 warned that in the absence of strong leadership from the top adaptation actions might be overlooked and noted: “that is vulnerable to that person leaving or that position being given more work and then the climate change goes off the agenda.”

Equally important is *embedding adaptation within the organisational frameworks* such as organisational risk register. Many participants especially emphasised the need for a “whole of business” approach to building resilience and adapting to climate change across all functions of water/wastewater utilities. Interviewee 6 criticised that “It’s not something we are looking at across the business, ‘What does that mean to you in finance? What does that mean to you in customer and community?’ I think it has to be a collaborative approach”. Interviewee 17 noted: “Ultimately, the asset that you are building is there to provide a service. Climate change is going to impact the ability of that asset to deliver a service. Then you have an obligation to look at that impact and try and mitigate it when possible [...] if you link it back to the service obligation that you have, you link it back to the long term needs of the customer and the organization, then I think there’s a better chance of doing it.” Several participants suggested that acknowledgement of climate change adaptation at strategy/planning level is important for guiding actions across the organisation. Interviewee 17 offered:

The recognition of climate change and the recognition that we’d like to one day become a leader in climate change adaptation has been massive for us in terms of being at a point to, this is something the businesses take on in terms of budget and strategic priority. We then opened the door to the climate resilience strategy, which then adds up to get involved in the act of doing [...] Before that, it was less clear as to whether the business really recognized climate change as a key strategic risk and something that was really important to do. So I think for us, that was the moment that made a big difference. Having that key document recognize climate change risk was massive.

The utilities that participated in our research ranged widely on a spectrum from those that are not yet planning for climate change risks to those that are considering adaptation and resilience as part of other strategies and/or have separate strategies for climate adaptation. While the effectiveness of having a separate strategy/plan or embedding climate change into existing policies is highly dependent on the context and other factors beyond the scope of this research, Interviewee 10 noted:

Resilience touches every part of our business, be it financial resilience, political resilience, climate change resilience, network resilience. Our community needs to be resilient [...] So I agree that it should be a lot of different things around the business that are happening to make us resilient. But somewhere, we need to bring it together and understand overall how resilient we are and whether there are gaps that we need to fill.

Some participants suggested the need for a central role, a resilience officer or branch across businesses for better adaptation to climate change. Interviewee 4 suggested that “there definitely needs to be a central role, and a central accountability to keep it going. If you just try and cram it on everyone else’s business as usual work, it is unlikely to happen quickly. And, to be fair, it’s unlikely to happen at all in a really positive outcome. We will get bits and pieces, but we will not necessarily get a good, complete answer.” Interviewee 16 discussed the importance of this central role in changing behaviour:

It is a change process which is always hard. So it is one thing to identify all your risks and come up with some great actions but the really important part now is just focusing on embedding that change across the business and actually shifting the mindset of all the people doing the actual work and so it is a real behaviour change... So that is part of my role to make sure we are really doing a good job in building up capacity of all our staff and getting that mindset shift and making sure that actually gets embedded.

While governance frameworks and leadership from higher levels can drive change in climate adaptation, ensuring continuity of action requires capacity and commitment within the organisations, as suggested by some participants. One critical step is *building on the existing strengths* of organisations. The majority of the participants discussed the key strengths of their organisations in managing disasters and emergencies and recovery. Interviewee 6 suggested: “I think we’re really good at responding and managing impacts when they happen, so I actually think we’re fantastic at that. We have got really strong emergency management capabilities. We have got really strong contingency economy plan so we can

respond quite quickly, we can manage that. [...] When something happens, we tend not to build it back the way it was, we tend to improve it." Interviewee 17 echoed this view and added:

So it's every bit of getting our planning right to begin with, building up the organizational capability and technical expertise, then getting on with it. Doing it and getting into the organization when we do projects and recognizing that a lot of risks that climate change presents aren't new ones. They just exacerbate existing ones. So it's about both getting better at what you do anyway. You're going to become more resilient to climate change. The better we are dealing with pipe bursts and plan on ways we're preventing them, the better off we are to climate change. It's very much really continuous improvement, but also improving our resilience.

Some participants also especially highlighted the importance of accumulated learning and capacity in this context. Interviewee 16 noted:

From a bottom up perspective there is a huge amount of technical knowledge [...] My personal feeling is that we can take a lot of the learning that has been developed by our catchments and water supply teams and begin to apply that more rigorously and with more structure across the decisions that we make as a business every day. We make a lot of decisions that have really long-lived impacts. So to adapt, we need to be equipping more staff across the organization with scenario planning tools and skills and structuring our business case.

Interviewee 3 pointed to the diversity of regions and areas that are serviced by utilities and the opportunities that it can provide for long term learning and adaptation "Those are very different skillsets [required] to be provisioning services for the CBD of a global city versus providing regional services. There can be synergies. So the ability to utilise recycled water and biosolids and by-products in that space. It's actually incredibly valuable, but it does come with its challenges."

Discussion and Conclusion

Climate change impacts such as rising sea levels and increased temperatures will have detrimental effects on water. Water and wastewater utilities around the world are at the coalface of these impacts and are taking actions to build their resilience and adapt to the long-term impacts of climate change. This research focused on the adaptation journey of Australian water/wastewater utilities and explored the key barriers and drivers for climate change action.

This research shows that Australian water/wastewater utilities are facing similar challenges and barriers in adapting to climate change as many other organisations including lack of funding and resources, institutional challenges, issues related to planning, and lack of information (Measham *et al.*, 2011, Productivity Commission, 2012). Fragmentation and lack of collaboration has hampered effective water resource management globally even before climate change was on the policy agenda (Dedekorkut 2005). The importance of higher-level government policy as one of the key drivers for adaptation is well documented (Measham *et al.*, 2011, Gurrán *et al.*, 2013, Mukheibir *et al.*, 2013, Nalau *et al.*, 2015, Howes and Dedekorkut-Howes 2016, Torabi *et al.*, 2017). Globally, water/wastewater utilities are demonstrating leadership in adaptation in order to build (and maintain) their reputation (Arnell and Delaney, 2006, Berkhout *et al.*, 2006, Farrelly and Brown, 2011, Gasbarro *et al.*, 2016). While lack of knowledge on the impacts of climate change is still an important constraint for many utilities' long-term strategic planning, our research found that Australian water utilities increasingly recognise the need for adaptation and are taking actions in this regard. Yet, more research is required to understand how utilities can translate this understanding to decision making for adaptation action.

While external factors such as availability of high level policy and regulation are critical in guiding actions at local level for water/wastewater utilities, our research found that internal capacity building through organisational leadership, existence of committed individuals, embedding climate change in organisational decision frameworks, and building on existing strengths of utilities, particularly existing disaster mitigation and recovery, are also crucial for driving water utility adaptation, particularly in the long term. Water utilities in general have cautious business cultures and therefore adaptation to climate change should be reflected in the organisations' risk management approach to drive on the ground actions (Berkhout *et al.*, 2006, Farrelly and Brown, 2011). The importance of leadership in water/wastewater utilities' adaptation, as demonstrated in our research, has also been highlighted in other research (Feldman and Ingram, 2009, Ziervogel *et al.*, 2010, Farrelly and Brown, 2011) particularly for defining responsibilities, prioritising, supervising, and implementation of adaptation actions (Ziervogel *et al.*, 2010). The literature especially points to the existence of key individuals (i.e. agents of change) within the organisation that view climate adaptation as important to be critical for utilities (Grothmann and Patt, 2005, Arnell and Delaney, 2006, Feldman and Ingram, 2009, Ziervogel *et al.*, 2010). For

instance, in UK a number of “champions” within water companies have started conversations around climate change and its impacts in the 1990s (Arnell and Delaney, 2006). Research also underscores the existence of well informed and engaged individuals within different government departments, consulting companies, and NGOs to play an important role in driving adaptation in the broader water sector (Ziervogel *et al.*, 2010, Farrelly and Brown, 2011).

As providers of essential services, water/wastewater utilities have a significant role in the sustainability of cities, as they bring together a strong understanding of the value that water and sewerage services can bring in the context of liveability. Our research highlighted the importance of integration and collaboration across the water supply chain for climate change adaptation. One area of opportunity in this context could be advancing the Sustainable Development Goals as a catalyst for collaboration across the urban water industry, a topic that has recently gained traction in the Australian water sector (WSAA, 2017). More research is required to understand how overcoming the existing barriers to adaptation can drive change in adapting water/wastewater utilities to climate change and contribute to sustainability in the long term.

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Appendix

List of Interviewees:

| State | Interviewee |
|---------------|-------------|
| QLD | 1-11 |
| WA | 12 |
| ACT | 13-14 |
| NSW | 15 |
| VIC | 16-19 |
| Industry Body | 20 |