BUILDING ASSET RESILIENCE TO CLIMATE SHOCKS: KEY ENABLERS FROM GLOBAL SUCCESS STORIES

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KEYWORDS

Resilience, climate change, shocks, adaptation, global case studies, flooding, storm surges

INTRODUCTION

Water utilities around the world need to adapt to the impacts of climate change to ensure a reliable and undisrupted service to their customers. The increasing frequency and severity of these impacts means climate resilience must be incorporated into business-as-usual planning and management of infrastructure. Much of the focus in the water sector to date has been on water supply security and increases in rainfall independent supply sources.

Examples from different sectors and actors around the world can help water utilities better understand what others are doing to adapt to climate shocks and prevent impacts to their services. This work can help inform what resilience strategies could be deployed, and what arguments would assist in regulatory changes and investment assurance.

YEAR CASE STUDY WAS IMPLEMENTED

2022 to 2022

CASE STUDY SUMMARY

This paper shares the examination of 10 success stories from around the world that demonstrate how others are increasing resilience by adapting their assets and operations to climate shocks. The success stories cover locations from almost all continents, across several sectors (e.g., water, transport and electricity); among various actors (e.g., companies, utilities, and government); and across project stages (e.g., planning, implementation and operations). A case study methodology was used to identify key learnings from these 10 global success stories which were then synthesised to identify common approaches and enabling factors that contributed to investment in resilient infrastructure. This paper shares how these synthesised key learnings have informed Sydney Water's climate change adaptation approach.

CASE STUDY DETAIL

The Approach

The case study research was structured in three distinct process phases: **Discovery – Best Practice Examples – Synthesis.** The discovery phase consisted of a search for relevant case examples that best illustrate how adaptive and resilient assets have been designed, funded, implemented, and operated across a range of sectors. It involved the scanning of available published literature and the engagement with international partners and linkages in the USA, New Zealand, South America, and South Africa.

The search sought out examples illustrating key enablers and drivers that supported the implementation of the resilience measures against the following six enablers shown in Figure 1 (based on the One Water Paradigm shift framework) (Mukheibir et al 2014):

Figure 1: One Water Paradigm Shift Framework

The definitions for each enabler, shown in Table 1, were used in this research to categorise key learnings from the 10 success stories.

Table 1: Definition of the six enabling factors (based on the One Water Paradigm Shift Framework)

Enabler	Definition
Strong leadership	Leadership from politicians and senior positions is key to drive a climate adaptation vision and make public funds available for the transition. It also drives implementation of strategies and addresses institutional capacity requirements.
Regulation	Enabling regulation that encourage and support climate adaptation explicitly or through collaboration between agencies.
Economics	An economic evaluation framework for representing the value in climate adaptation investment for customers, organisations, and regulators. The framework should include not just the costs and benefits of climate adaptation, but non-monetised social and environmental costs and benefits, as well as avoided costs/impacts from implementing resiliency measures.
Engagement and expectations	Community and stakeholder engagement is key for confirming the vision and to support the implementation of the strategy. Understanding expectations helps clarify drivers for organisational strategies and investment decisions.
Collaboration and co-benefits	Building partnerships and long-term, mutually beneficial relationships with a broad range of agencies, including the private sector, creates the collaboration and data sharing needed for projects to be aligned with the strategy and implemented in a coordinated fashion. This should be driven at both the state and city levels.
Knowledge and experiences	Organisational knowledge and capacity to include alternative approaches and a recognition of using experiences of climate events as a trigger for adaptation action. It may be necessary to set up a dedicated team to implement the strategy and manage related projects, until climate adaptation is integrated into everyday practices and thinking.

Each case study[1] provides: a brief description of the example; climate risk profile; the nature of the response; the enabling factors that supported the delivery; key motivation and/or justification; together with the outcomes and benefits delivered due to the intervention. After a screening process the following 10 case studies summarised in Table 2 were identified as best practice examples. Please note these case studies, researched by ISF, were published by the Water Services Association of Australia (WSAA).

[1] These case studies can be found at this link: https://www.wsaa.asn.au/publication/building-utility-resilience-climate-shocks-lessons-global-case-studies

Table 2: Case studies snapshot

Case study names	Case study actors	Initiative type				
		Strategy/Policy	Planning	Implementation	Operational	Pilot
1: Copenhagen Metro: Integrating climate adaptation	Metroselskabet (The Metro Company)		✓	✓		
2: Brisbane Airport: The New Parallel Runway	Brisbane Airport Corporation		✓	✓		
3: SSEN UK: Flood mitigation of electricity substations	Scottish & Southern Electricity Networks (SSEN)	✓	✓	✓		
4: Santiago: Adapting to high turbidity	Aguas Andinas (Andean Waters)		✓	✓		
5: Cape Town: Stormwater management	City of Cape Town		✓			
6: Victoria: Healthy Homes Program	Victorian Government			✓		✓
7: New York City: Wastewater Resiliency Plan	New York City Department of Environmental Protection	✓	✓	✓		
8: Copenhagen: Cloudburst solutions	City of Copenhagen		✓	✓		
9: Northumbrian Water: Collaborative Flood Alleviation	Northumbrian Water, Environment Agency & Newcastle City Council			✓		
10: United Utilities: Improving Operational Response and Recovery	United Utilities				✓	

Table 3 lists the 10 case studies explored and summarises the enabling factors for resilience to climate shocks that were evident. There was a spread of the six factors across the case studies, with stronger emphasis on Economics, Collaboration & co-benefits, and Knowledge & experience. For many of the cases, previous experience with climate induced disruptions was a key motivator for considering future climatic impacts in their operations and investment planning.

Table 3: Enabling factors for resilience to climate change shocks identified in the case studies

Case studies	Enablers					
	Strong leadership	Regulations	Economics	Engagement & expectations	Collaboration & co-benefits	Knowledge & experience
1: Copenhagen Metro: Integrating climate adaptation	●	●		●	●	●
2: Brisbane Airport: The New Parallel Runway	●			●		●
3: SSEN UK: Flood mitigation of electricity substations		●	●		●	●
4: Santiago: Adapting to high turbidity in raw water		●	●	●		●
5: Cape Town: Stormwater management	●				●	●
6: Victoria: Healthy Homes Program	●		●			
7: New York City: Wastewater Resiliency Plan	●		●		●	●
8: Copenhagen: Cloudburst solutions			●		●	●
9: Northumbrian Water: Collaborative Flood Alleviation				●	●	
10: United Utilities: Improving Operational Response and Recovery		●	●			
Totals	5	4	6	4	6	7

Key learnings and outcomes

A synthesis of the key learnings from the 10 successful adaptation case studies (based on the six enabling factors) is presented below.

Strong leadership

Over half the case studies identified that leadership both by senior positions within organisations and by local and state government is a key enabler. The cases that showed senior management leadership were Copenhagen Metro and Brisbane Airport, where climate change adaptation was integrated into the planning process and resulted in assets built to be operationally reliable during climate shock events such as flooding and heavy rainfall.

Three case studies also highlighted the need for a focus on advocating for city/state/national leadership to support climate adaptation within water utilities. Copenhagen Metro and New York City (NYC) benefited from city-wide adaptation plans developed by local government and Victoria Healthy Homes benefited from state government support in climate adaptation investment. Importantly, the development of city-wide adaptive plans by government was in response to experiencing a severe climate shock event. For example, after Hurricane Sandy, New York City's local government provided a comprehensive strategic response with large amounts of associated funding; enabling the NYC utility to develop a program of works to build resilience into all wastewater treatment plants and most sewer pump stations.

A key leadership attribute for all five case studies included having clear strategies, policies and/or plans for responding to climate change in place at the corporate executive level to drive adaptation integration in planning and delivery of infrastructure. Clear strategies often enabled expenditure on climate adaptation – from climate modelling, project design to construction. For example, Brisbane Airport invested in climate and flood modelling, and the design and construction of stormwater drainage, an elevated runway and a sea wall – all seen as necessary climate adaptation measures to ensure operational reliability.

Regulations

Regulation impacted four case study approaches for investing in climate adaptation, although there was no case where regulation was the primary enabler in the climate adaptation decision, the success stories highlighted that support from state or federal government to help implement long-term planning of climate adaptation is critical to imbedding climate adaptation. Working together with a regulator, e.g., in NSW context IPART (Independent Pricing and Regulatory Tribunal), to agree on an approach to enable investment in climate change adaption activities was also shown to enable asset resilience and operational approaches.

Only Scottish and Southern Electricity Networks (SSEN) in the UK, did the energy pricing regulator mandate a national approach to improve flood resilience of substations to an agreed standard, providing utilities with a clear justification and process for flood mitigation activities. However, the real trigger for this enabling regulation was experiencing a significant climate shock event and the collaborative effort of key stakeholders (including the regulator) to develop an agreed national standard that built resilience against future flooding events.

Three case studies from the UK demonstrated that climate resilience can be incentivised or regulated from the national level[2]. The UK Climate Act requires essential service providers to regularly report on their climate adaptation activities, which forced SSEN, Northumbrian Water and United Utilities to consider climate change impacts in their planning. This requirement supported United Utilities, for example, to include climate adaptation in their long term planning, with their plan released in 2022.

Where there was a similar pricing regulatory environment as that for Sydney Water, they leveraged off existing pricing regulation to enable expenditure in activities that improved climate resilience. Aguas Andinas received approval to construct standby raw water storage, while United Utilities was funded (and incentivised) to improve operational response and recovery, which has also helped to reduce the impacts of climate shock events. In addition, Outcome Delivery Incentive regulated by Ofwat (UK's water economic regulator) requires water utilities to report on the interruption to supply (or customer minutes lost), which further incentivises resilience since a disruption in services results in cash penalties.

[2] which depending on jurisdiction may be equivalent to the state level in Australia.

Economics

Six case studies used an economic evaluation framework to justify the worth of climate adaptation. Several economic assessment methods were used with various drivers, including:

- The city/statewide adaptation case studies (CS 6, 7 & 8) incorporated financial, environmental and social considerations to provide a holistic perspective on costs and benefits.
- SSEN (CS 3) was driven by meeting national industry standards for flooding resilience.
- Aguas Andinas (CS 4) focused on what financial cost was acceptable to add to customers' bills to achieve improved resilience
- United Utilities (CS 10) were incentivised to avoid financial penalties from the pricing regulator, and use customer engagement to place a dollar value on an uninterrupted service.

For SSEN, Copenhagen Cloudburst Solutions and United Utilities case studies, passing on the investment and operational costs to the customers or community was justified based on an assessment of the broader economic benefits to them.

A Triple Bottom Line (TBL) economic analysis (considers financial, social and environmental consequences) was used to enable investment in the city-wide adaptation approaches in New York City and Copenhagen Cloudburst solutions. TBL is generally considered a transparent and holistic approach to presenting the economic costs and benefits. In these two cases, the associated avoided costs of implementing climate adaptation was also determined, which strengthened the case for climate adaptation as the cost of no or inadequate adaptation was much higher than the cost of adaptation.

The setting of industry standards and minimum levels of service has meant that in some sectors, the inclusion of climate shock resilience (such as flooding in many of the examples) has been enabled through the traditional business case process and/or pricing determinations, and importantly the funding of these climate adaption measures was expected by the pricing regulator, and therefore supported (as with SSEN, Aguas Andinas and United Utilities).

Further with United Utilities (CS 10), the pricing regulator Ofwat requires United Utilities to engage with the customer to determine value of investing in service improvements. This "value framework" approach provides a clear method for business case development and therefore funding approval during Ofwat's pricing reviews. It is also worth noting that United Utilities is in the process of shifting economic assessment approach from a cheapest whole life cost model to a best value assessment model.

Engagement and expectations

Stakeholder engagement with a range of stakeholders, including local community environment groups, scientific organisations and traditional owners was demonstrated as key success factor for some resilience projects, especially when they involved large financial investments. Communicating the vision of the project, as it relates to improved levels of service and other ancillary social and environmental benefits, as broadly and early as possible helped to gain community support (Brisbane Airport and Northumbrian Water).

The private sector organisations for Case Studies 1, 3 and 4 also considered customer/stakeholder expectations and impacts if their service levels were not maintained during a climate shock event. SSEN saw prevention of substation flooding as saving not only costs of asset repair and customer compensation but understood that maintaining service levels prevented large costs to the community from lengthy and widespread power outages. Copenhagen metro took broader societal impacts of a reduced or closed metro service into consideration, noting that it would not only impact society, but cause reputational damage and affect meeting Metroselskabet's operation reliability target of 98%. Aguas Andinas, who are dependent on renewal of contracts and concessions also considered the reputational damage on their business if they failed to respond to turbidity events impacting the treatability of their raw source water.

Collaboration and co-benefits

The majority of case studies demonstrated the benefits of collaborating with stakeholders with a view of sharing knowledge and experience and/or sharing the costs and benefits. Stakeholder collaboration took place across sectors (often involving utilities and city planners) and across levels of government – local and state.

Although a collaborative process takes time, the outcomes in these case studies have proven the benefits of multiple parties working towards the same goal of resilience building, often helped by complimentary

knowledge, authority, and funding pools, such as in the UK, there was collaboration between a water utility, council and environmental agency (CS 9) to mitigate local flooding and in the energy sector (CS 3), industry, government and regulators worked together to develop a national standard for flood resilience of substations.

Collaboratively setting design guidelines and zoning regulations for urban greening and infrastructure projects that promote resilience resulted in all parties working towards the same goal with fewer challenges and barriers. For example, in Denmark (Case Studies 1 and 7), the collaboration and sharing of costs across agencies to deal with a common hazard (of increasing flood events) provided multiple benefits for all.

An integrated co-benefit and cost sharing approach through partnerships with different levels of government and utilities was shown to be effective in implementing water sensitive approaches to flood risk management within the UK. This case also shows that adapting to climate change can have multiple objectives, including, liveability by bringing water into the urban environment and creating habitat for wildlife.

Knowledge and experience

Having sound climate change knowledge within an organisation that covers both the understanding of the impacts and the possible response measures is key to progressing the shift from BAU processes to ones that incorporate climate change responses. The case studies that demonstrated this characteristic had the following attributes:

- Acceptance of the climate science as a valid input into the planning assumptions.
- Cultural alignment throughout the organisations on the approach for addressing climate risks from the board, senior management, through to the project teams.
- A process for understanding climate impacts at the asset level, to inform the adaptation response.
- Collaboration with experts from the private sector and research institutions that enhanced the internal capability of many of the organisations leading the adaptation initiatives. This was shown to be beneficial for both the problem definition and planning stages.
- Embedding a continual review and reflection of the performance of infrastructure in terms of resilience to climate shocks.

The case studies showed common steps for implementing climate adaptation within the organisation, which are summarised below:

Understanding climate risk to determine design standards – climate modelling to understand the climate risk was commonly used to answer this question, which required specialised external input (Case Studies 1, 2, 3, 5, 7, and 8). Operational experience from existing assets, as well as emergency response and recovery experience also contributed to this (CS2 and CS7).

Determine acceptable level of service during a climate shock, with a range of inputs used to determine this, including for example: organisational objectives, customer expectations, cost to community, regulated requirements, climate risks, asset criticality, environmental impacts, etc. As was the case with Aguas Andinas, BAC, and CPH metro the level of service was aimed at continuous service. With United Utilities, SSEN, and NYC the level of service underwent a prioritisation process.

What resilience measures are needed to meet the agreed levels of service, for example, high climate shock resilience (and cost) through infrastructure upgrades like raising some/all infrastructure (as with CS 1, 2, 3 and 7) or operational responses (and lowest cost) as in the case of United Utilities and in some cases with NYC where emergency sandbagging was the adopted mitigation measure.

When to implement resilience measures. In cases where the projects were new builds, these were integrated into the typical capital approvals and prioritisation processes (Brisbane Airport, Aguas Andinas, Northumbrian Water); where an upgrade or modification was required to the asset, this needed to align with planned asset upgrades and funding availability (SSEN, NYC).

A specific knowledge barrier was highlighted in Cape Town due to long lead times resulting in a loss of knowledge and lack of continuity within the planning team. When knowledge of the climate change impacts is not well communicated and understood by elected officials that approve funding for investments, funding for resilience activities can sometimes be denied or redirected to more immediate concerns.

Implementation: Sydney Water's climate adaptation approach

This section outlines how key learnings from the 10 global success stories have informed and enhanced Sydney Water's climate change adaptation (CCA) approach.

Table 4: Actions by Sydney Water based on case study learnings

Recommendations from case studies	Implementation by Sydney Water
Strong leadership 1. **Senior management should, in collaboration with key stakeholders, drive the embedding of climate adaptation into processes for proactive and cost-effective investment in resilience.** 2. **Advocate for city/state/national leadership to support climate adaptation within Sydney Water. For example, through city/regional/state climate adaptation strategies and funding support.** 3. **Leverage off internal and external strategies to gain funding approval for climate adaptation investigation, design and construction.**	In July 2022 the Executive endorsed a Position Statement, which stipulated requirements for adapting to the moderate climate change scenario Representative Concentration Pathway (RCP) 4.5 as a standard requirement and provide adaptive pathways to RCP8.5 for all services and assets. This corporate policy provides the leadership backing to ensure CCA is embedded proactively. Next steps are to embed our assurance activities, e.g., business case/gateway checks and planning audits. Other internal leadership includes CCA governance in Enterprise Planning process. External advocacy includes working with NSW Government Department Planning & Environment (DPE), Environment Protection Agency (EPA) and the Office of Environment and Climate Change (OECC). An important step is linking the Greater Sydney Water Strategy climate-related actions to OECC and EPA's CCA Strategies.
Regulation 1. **Advocate with state or federal government to implement state or national reporting requirement to help utilities implement long-term planning of climate adaptation.** 2. **Identify regulations that indirectly support Sydney Water's climate adaptation approach.** 3. **Work together with economic regulator to agree on an approach to enable investment in climate change adaption activities.**	NSW Treasury released guidance (end 2022) on including CCA in reporting requirements. Sydney Water is exploring a pilot disclosure under the Taskforce for Climate Related Financial Disclosures (TCFD) framework. The intent is to build an action plan for CCA embedment based on its pillars of governance, strategy, risk, and metrics. 2022 regulatory and legislative change scan in partnership with Deloitte, as well as an internal review of Australian regulation and practices identified indirect support for CCA. Sydney Water's Operating Licence is currently under review. Next steps are working with DPE and IPART toward enabling regulation for resilience and climate preparedness. Including presentations to working groups and improving visibility of climate adaptation in pricing submission.
Economics 4. **Incorporate the cost of climate adaptation into the cost of delivering an operationally reliable asset or agreed service levels and strengthen funding request with quantifying the risk and cost of "doing nothing".** 5. **Determine the avoided costs of undertaking climate adaptation/building resilience, including costs associated with emergency responses, clean-up, asset repairs and replacement, customer compensation and reputational damage.** 6. **In collaboration with regulator consider the different economic assessment approaches used in the case studies to understand how best to represent the costs and benefits of addressing climate adaptation requirements, and gain customer support for additional costs.**	The Position Statement has changed equation for internal investment decision making. The base case approach must now assume a climate change future, the "do nothing" costs must be quantified only if adaptation is prohibitively expensive. Next steps include improving assurance and visibility of CCA practices in all stages of decision-making. Sydney Water has written an internal thought paper exploring cost of climate events and the importance of moving away from "assuming normal weather conditions". This is aimed at collaborating internally and with IPART on how to change budgeting methodology to allow for climate extremes and preventing delayed proactive OPEX. Important next steps include targeted ways to change approach to funding to areas of greatest need and ensure capability uplift in data capture to realise true cost of climate -related events. There is also work required to investigate pursuing green bonds as funding mechanism.
Engagement and expectations 7. **Ensure stakeholder engagement in the benefits of climate adaptation investment occurs as**	Sydney Water actively participates benchmarking using the OECC maturity tool and in climate risk workshops with external stakeholders. For example, the Greater Sydney

Recommendations from case studies	Implementation by Sydney Water
early as possible and includes a diverse range of stakeholders. 8. **Understand customer/community expectations when determining the level of service and operational reliability planned to maintain during climate shock events. Include key stakeholders such as bulk water suppliers and regulators in this process.**	Harbour Catchment Management Plan engages various councils and agencies to collaborate on CCA approaches for at risk areas within the coastal extent of harbour. Customer insights on levels of service (in various scenarios including drought) have highlighted the importance they place on receiving clean drinking water. This supports the Position Statement on the need to maintain services.
Collaboration and co-benefits 9. **Strengthen the coordination and collaboration between multiple actors with a stake in city-wide climate adaptation, to support effective and good value climate adaptation.** 10. **Consider working with key stakeholders to develop a sector-wide standard for climate resilient measures to sound and consistent approach to funding approval and adaptation.** 11. **Consider developing international partnerships such as the CPH and NYC collaboration. To get support from countries/organisations that are further along on the climate adaptation journey.**	Sydney Water has ongoing collaboration on CCA approaches with key stakeholders including Water NSW, WSAA, IPART, EPA, Hunter Water, local councils and until recently Resilience NSW. Relationships with electricity providers has allowed for knowledge sharing with next steps to include case studies on high-risk interdependencies. The creation of a CCA guidebook has enabled further collaboration on the benefits of CCA being articulated in existing processes and planning approaches. Next steps include activating internal subject matter experts to share their position within their professional associations. This has commenced internationally with US Water Utility Climate Alliance (WUCA) but has not been a formal partnership.
Knowledge and experiences 12. **Consider where climate change knowledge (to understand risks and treatment) can be strengthened internally or with external support** 13. **Consider the common steps undertaken to implement climate adaptation from the case studies and determine what might be applicable.** 14. **Work with external organisations that have knowledge in climate change e.g. Bureau of Meteorology (BOM) to support sound understanding of climate risks and predicted impacts for assets and services.**	The key action to strengthen internal knowledge has been the creation of a CCA guidebook. This has been supported by initial roll out of climate champions in the planning team, including representatives undertaking climate risk ready training delivered by OECC and Western Sydney University. In line with the *common steps* (above) Sydney Water is updating design standards and developing a resilience metric. This will improve understanding of system vulnerabilities that are beyond our scope to respond and recover and help broader resilience investments. There are active working groups with BOM and OECC as well as informal ties to university research centres. Next steps include establishing more formal links.

Important lessons learnt and critical success factors

Researching global case studies beyond the water sector, and not limited to utilities, has provided valuable insights, clarity and support to CCA approaches that are applicable at utility level. Examples of leadership and regulatory changes in other regions / essential services is vital in driving change more broadly across our national water industry.

There is a common approach to climate adaptation linked by six enabling factors, which can be tailored to individual organisations. These accessible learnings are not exclusive to a particular climate shock.

Reflecting on the 10 case studies, and their implementation by Sydney Water the enablers of strong leadership, climate knowledge and regulatory collaboration were key. This was reflected in similar learnings presented in the WUCA “Leading Practices” CCA work.

This case study research was funded by Sydney Water as an individual utility. However, focusing the research on broader applicability and publishing through WSAA enabled these learnings to be shared across Australian utilities. This contributes to national CCA capability uplift at little additional cost.

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