Institute for Sustainable Futures

Bathrooms of the Future Forum Summary Report

Prepared for Sydney Water and Caroma
by University of Technology Sydney
Institute for Sustainable Futures

April 2023

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Citation

Butler, A., Kim, Y., Fane, S., Zhu, J., 2023 *Bathrooms of the Future Forum – Summary Report*, prepared for Sydney Water Corporation and Caroma GWA, Institute for Sustainable Futures, University of Technology Sydney, April 2023

About the authors

The Institute for Sustainable Futures is a transdisciplinary research and consulting organisation within the University of Technology Sydney. Over the past two decades, our research has played a significant role in advancing sustainability in the built environment.

Acknowledgement

The research team sincerely thanks the co-facilitators of this forum, Andre Boerema from Sydney Water and Dr Steve Cummings from Caroma GWA for their extensive collaboration in this research.

We would also like to thank the representatives from the following organisations that participated in the forum for providing key insights into their current work and co-developing the research ideas presented in this summary report.

BMT Global	NABERS initiative	Western Sydney University
Caroma GWA	NSW DPE	Macquarie University
Colliers	NSSN	Water Conservancy
Deakin University	Reid Environmental	UTS Data Science Institute
JLL Australia	Sydney Water	

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Bathrooms of the Future Forum: the next generation of water smart technology

The Institute for Sustainable Future at the University of Technology Sydney (UTS-ISF), in partnership with Sydney Water and Caroma, explored the future for digital water and emerging smart end-use solutions in multi-residential and commercial buildings. This was over a two-day forum attended by select industry representatives including manufacturers, utilities, and building managers together with researchers in related fields.

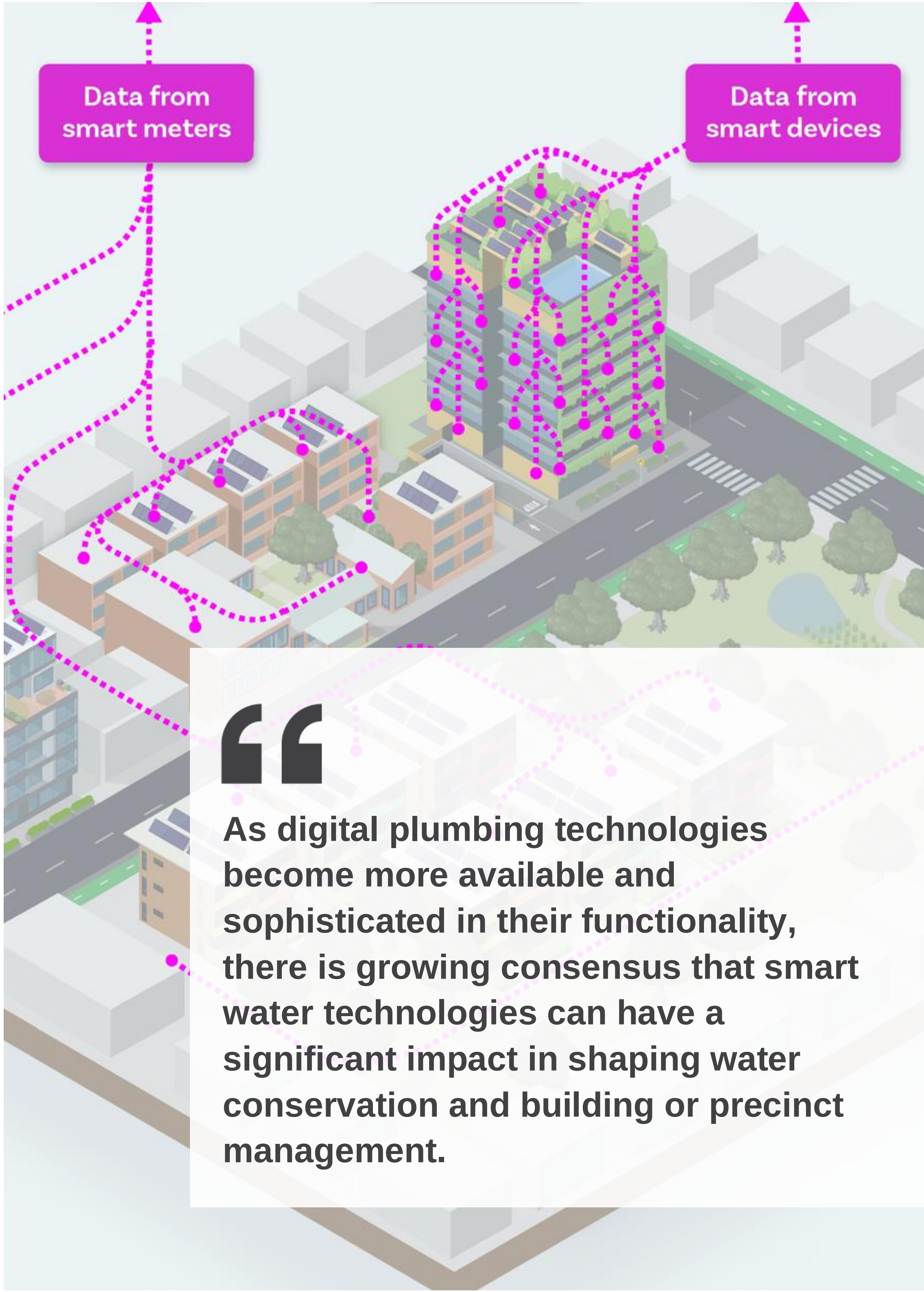
The forum provided an opportunity to define the future opportunities for these technologies, highlighting considerations for incorporating them into buildings and the next steps in terms of establishing a research agenda for the space.

Background: Smart devices and intelligent buildings project

This event marked the final stage (Stream 3) of a multi-year project that sought to address what new disruptive digital plumbing technologies could mean for customers, the community, and the environment. The project has explored the potential insights of this technology through a pilot study in an office building in Western Sydney (Stream 1), and conceptualised what water smart homes might encompass in the near future, including anticipating the risks that may arise and ways to navigate these issues (Stream 2).

Further information on the initial two stream of research can be found at the following links:

- **Stream 1: non-residential pilot study of smart bathroom fixtures**
  https://www.uts.edu.au/isf/explore-research/projects/bathrooms-future
- **Stream 2: visualising the future of water smart homes**
  https://www.uts.edu.au/isf/explore-research/projects/future-water-smart-homes-greater-sydney



As digital plumbing technologies become more available and sophisticated in their functionality, there is growing consensus that smart water technologies can have a significant impact in shaping water conservation and building or precinct management.

Motivation: Why focus on smart water technology?

The introduction of digital command and control elements into water technologies is providing new opportunities to understand and engage with how people use water in buildings. Novel insights gained from these devices should allow for the development of more efficient and sustainable water use practices in addition to many other beneficial outcomes for building owners, communities and the environment.

Depending on how the water industry prepares for the integration of smart technologies, they have the potential to greatly enhance our water systems and how customers engage with water use. This provided the main motivator for the forum, gathering key industry personnel to map the opportunities for and current barriers to realising the potential of these technologies and determining a potential research agenda in this space.

> “ The emergence of smart water technologies within homes is likely to have a range of anticipated and unexpected impacts on utility systems and water users.

Stream 1 technology pilot: smart command environment

The Caroma smart command environment was the focus of the Stream 1 pilot study. These provided the inspiration for the types of emerging smart water technologies discussed during the forum, those that are envisioned to significantly disrupt the water industry in the near future.

Caroma’s technology involves an integrated suite of smart devices, communication components and software. The devices are all installed with a Bluetooth module that enables remote configuration of the system e.g. runtime and operation from the Caroma Cloud, Customer Bluetooth Management System or a Smartphone Application. Each of the devices are enabled with a sanitation activation option, this enables a hygiene flush of the fixture at regular intervals as set by the user. They are mains-connected and equipped with a backup battery to maintain functionality during a potential mains failure. These devices do not include meters recording water usage but estimate consumption based on number of activations.

When installed in a smart command ecosystem, the devices are able to report on water consumption, device activation and enable real time control of device settings. Examples of devices that are part of this environment include the urinal system, electronic shower system with feedback monitor, hand wash basin taps, control valve with leak detection and shut off capabilities, toilet suite, and gateway communication component.

Approach

The forum was run over two half days with the goal of establishing a number of ways forward for integrating and optimising digital water technologies within buildings.
Day 1 intended to explore the opportunities and outlook for key industry sectors in relation to these technologies, as well as identify current barriers and concerns. Day 2 focused on exploring potential research opportunities based on the previously identified challenges from Day 1 and establish the foundation for future strategic partnerships.

The event also provided an opportunity to hear from a variety of academics working sigh smart devices and data analysis to understand how different researchers are engaging with this space.

Forum objectives

- Present outcomes of the joint smart devices and intelligent buildings research project.
- Build understanding of the potential opportunities arising from new digital water technologies within buildings.
- Explore the role for these technologies in driving water efficiency though end use data, digital control and/or behaviour change.
- Identify opportunities and elaborate possible next steps for using these technologies across key industry sectors.
- Identify possible barriers at present and in the near future when considering the integration of these technologies in buildings.
- Identify potential research needs.
- Build networks and seed potential partnerships.
- Define an initial research agenda for the emerging field that clearly outlines each industry sectors interests, questions, and potential contribution as well as possibilities for partnerships.

This forum set out to understand the **opportunities** and **challenges** for smart water technology in enhancing building water efficiency across NSW.

Day 1: Where are we now?

The first day of the forum had a particular focus on understanding the current emerging opportunities for implementing the next generation of smart water technologies in buildings. Breaking out into three groups, participants reflected on the following areas in relation to the perspective of key participants in digital transformation across the water industry: building and facility managers, water utilities, and water efficiency practitioners.

- **Strengths -** What are the perceived key strengths of these water technologies that are unique to smart appliances?
- **Current opportunities** – Are there specific problems that these technologies could address now or in the future? What could the technology do that it doesn't yet, to be more useful to each sector?
- **Current barriers -** Are there any barriers that currently exist to using the technologies or data to address the above opportunities?

The discussion from each group across each area has been summarised below and the detailed group notes have been included as Appendix A.

Building and Facility managers

This group provided insight into the considerations of property, building and facility managers. This perspective highlights operational impacts of the emerging technology such as building security, maintenance requirements, and potential to allow for sustainable certification credits.

Strengths

Smart water technology in commercial buildings can provide useful insights related to resource allocation, such as highlighting the low and high usages across the building, as well as any usages that should not be occurring. These insights could be embedded as a form of an alarm/prediction system within a building management system that pinpoints any issues and increase productivity.

Current opportunities

Further opportunities exist for smart water technology , where it can be used to not only inform of current state of usages as described above (i.e. diagnostics), but also recommend steps to improve water efficiency and pre-emptively identify risks requiring maintenance (as a prescription). The expert group also pointed to possibility for the system to automatically take steps to facilitate water efficient behaviours at individual levels (auto-interventions). Opportunities also exist to intervene at a building level, such as learning occupancy behaviours to optimise hot water heating cycles, and automatically managing high water pressure in real time to prevent excess water consumption.

Current barriers

The main challenges for smart water technologies for building management lies in the cost justification. While the additional costs of smart devices and fixtures in commercial settings may be justifiable due to the high volume of traffic, costs still need to come down significantly for most smart devices to be viable in residential settings. Older buildings also face an additional challenge when the required BMS upgrades to implement smart water are considered.

Water Utilities

This group considered how smart water technologies would impact the provision and distribution of water supply from a water utility perspective. They also focused on co-benefits of these technologies across a water network.

Strengths

The technologies can be used to assist with detailed design and development of end use programs. The leakage identification capacity and shut off valves can assist with reducing network leakage. They can also be used to assess and manage water use at different scales of a precinct.

Current opportunities

Utilities see opportunities for this technology to be used in developing and targeting messaging to water users throughout a community. This would replace current generalised approaches to water conservation messaging. There are also potentials for the collected data to be used to measure success against various compliance criteria. For example, using data for sustainable building ratings or state wide conservation targets.

Current barriers

Technological Interoperability, or lack thereof, could result in either technological lock in where users are forced to maintain one brand or type of device to maintain functionality, or could result in divided ecosystems where multiple platforms and data capture methods cause significant difficulties. In particular, collating and understanding insights from data from either individuals or organisations hoping to understand precinct level insights.

Cost of widespread testing and implementation is also a current barrier. Cross-industry partnerships provide some avenues for shared funding.

Water Efficiency Practitioners

This group specifically considered the potential water efficiency benefits from emerging smart water technologies. This included how technologies might influence community perception of the value of water and water use behaviour.

Strengths

Understanding water use practices and influencing behaviour was identified were key potentials for this technology. Integrating feedback mechanisms at the point of the device was seen to be a streamlined approach to communicating with water users as opposed to requiring additional applications or messaging. Many educational opportunities are likely to exist with the technologies from non-traditional avenues, and emerging brands of these devices may choose to market their products as water efficient and imbed water efficiency education into their devices.

Current opportunities

There are more opportunities to integrate feedback into devices in more creative and intuitive ways. For example, having feedback lights, screens or sounds that indicate usage and could be altered to portray particular messages to users. A large opportunity exists for investment in creating data governance standards for the emerging technologies. These would include standardising collected and reported information and units, ensuring privacy requirements are met for individual data capture, and establishing data storage and management procedures (e.g. who owns and keeps the data?).

Current barriers

The largest barrier to the adoption of these technologies is an education barrier of both users in general and building owners in particular. In general the community is not full aware or understanding that there’s a need for further water efficient behaviours. Current apathetic or wasteful thinking and behaviour by users is of concern.

Images from the Bathrooms of the Future forum

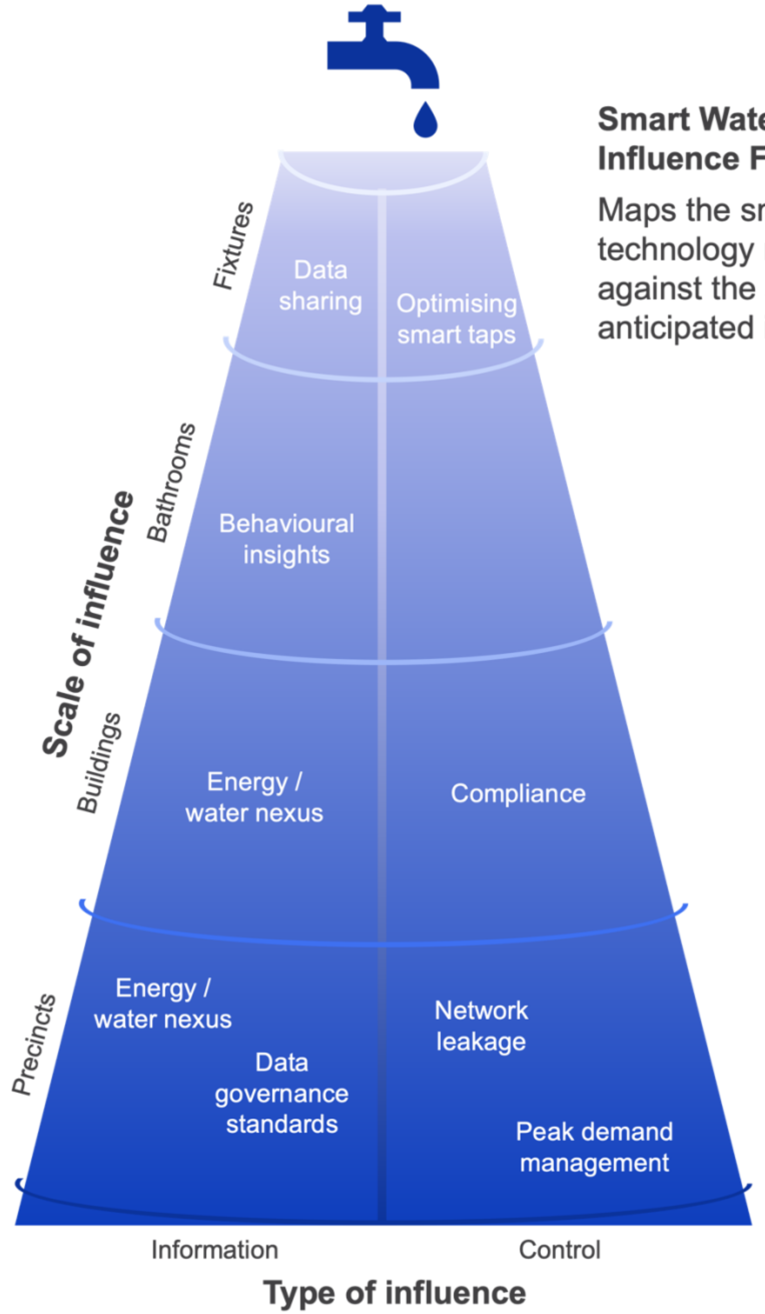
Day 2: Where are we going?

The second day of the forum reflected on exploring the key areas for further investigation to allow for the full potential of these technologies to be realised. The goal of this process, a with the entire forum, was to take the next steps towards integrating digital water technologies to ensure the effective and efficient running of buildings. The areas identified were based on the current opportunities and current barriers identified on the first day. The topics developed where also shaped by those present on the day. This means further topics might well be developed in the future with other groupings of researchers and industry. In working together, this exploration also sought to establish the foundation for future strategic partnerships and build networks.

The identified research areas included the following:

- **Optimising smart taps -** Applying Machine Learning to optimize consumption and/or health compliance.
- **Network leakage -** Application of leakage networks with smart fixtures.
- **Peak demand management** – leveraging data in building & networks.
- **Data governance standards** – standardisation of data storage and communication protocols to enable cross-device and cross-system compatibility.
- **Data sharing** – guideline on cross-device and cross-user data sharing approach, investigating issues on data privacy and security.
- **Energy/water nexus** – optimisation across water and electricity networks including capitalising on hot water and electricity flex.
- **Behavioural insights** – behavioural change/messaging study to improve water efficiency at end-use level.
- **Compliance** – ensuring water efficiency performance is met over time (i.e. BASIX).

These ideas have been mapped against the Smart Water Technology Influence Framework to identify how they sit across different scales and types of anticipated influence.



Smart Water Technology Influence Framework

Maps the smart water technology research areas against the scale and type of anticipated influence.

Three of these ideas were taken forward through a workshopping exercise which sought to define the research issue and identify a possible approach by evolving the following:

1. **The idea or problem to be solved**. Consider the dimensions of the problem. Attempt to define a research question.
2. **Addressing the issue**. Considering methods, approaches, and existing tools.
3. **Getting started**. Identifying who needs to be involved, what resources are required and whether there are any known specific funding opportunities for this idea.

The discussion for three of the most promising evolved research area has been summarised below and the research roadmaps for these areas have been included as Appendix B.

Note, due to time constraints not all the above listed research areas explored during the forum were taken forward into group discussions and not all of the group discussion consolidated around a single idea. The potential for further ideas, beyond the three below, are significant with discussions on-going.

Optimising smart taps

How can we leverage the smart tap technology to improve user experience, consumption efficiency and health compliance? Currently the taps are designed for maximum user experience (i.e. tap operates as requested by user), but can we nudge user behaviour towards improved water efficiency? This proposal is that a machine learning algorithm could be applied to derive an improved behaviour of taps, such that water usage can be reduced while maintaining same levels of user experience and sanitation requirements. Variances across time of day, tap location, water temperature would be considered for this process.

Network leakage

Current implementation of smart technologies can detect and shut off leakage at the room level using control valves, allowing for timely response to leak events. Until the actual source of the leak is found, however, the entire bathroom must be placed out of service. This is one of the major complaints for the building owners.

This research project would seek to understand how data from fixtures within each bathroom can be utilized to pinpoint the source of leakage, upon which the suspect fixture can be shut down remotely or repairman can be notified of which fixtures to investigate first, resulting in quicker intervention response and improved user experience.

Peak demand management

Maintaining reliable performance across water supply and distribution networks is a vital aspect of network management. This is a base requirement for network consistency and is not only limited to maintaining supply during times of peak demand. However peak periods can put addition strain on infrastructure resources and do present additional challenges for network reliability.

This research project would focus on harnessing the forecasting power of live data to reduce the risk of infrastructure breakdowns and to optimise the supply of water both potable and non-potable.

Concluding Remarks

The recent emergence of new smart sensing technologies within building water systems presents a unique opportunity for enabling the next breakthrough in water and energy efficiency for buildings. As the technology continues to mature and the input/outputs become even more sophisticated, there is a strong need for a standardised, forward-looking school of thought to shape its growth and ensure smooth integration with other IoT frameworks at individual, building and precinct levels.

This forum represents a step towards establishing an open platform for continued investigation of this topic. The forum identified the key strengths, opportunities and barriers for the considered three stakeholder groups: building and facility managers, water utilities, and water efficiency practitioners. As a next step, ISF will collaborate with the forum attendees and other experts in the field to pursue both the research ideas identified from this forum as well as emerging ideas. We will also look to build on existing partnerships and develop new ones to continue investigating new opportunities to further collaborative work that shapes the future of smart water technologies in buildings.

Appendix A: Day 1 detailed group notes

In considering the future of digital water technologies and use, we asked participants to consider the strengths, opportunities and barriers associated with these technologies. The participants were grouped into the three sectors to consider each perspective. Each group's workshop notes (example below) have been summarised in the following tables.

Building and Facility Managers

For building owners, the biggest concerns were utilising the data to be more effective and behavioural change.

Strengths	Barriers	Opportunities
• Inform resource allocation – who is consuming more/less, usage where there shouldn't be • Alarm/awareness system – foresee problem, increase proactivity, pinpoint issues • Prediction model	• Maintenance issues (+scheduling) – pinpoint with fixture (non-res), leak detection (res/non-res) • Improve utilisation • Water quality issue – flush after a while (long time), flush after moving • Tech that changes behaviours • Alternative water source insights/management	• Technology that guides/highlights specific conservation opp that's catered towards this building • Justification/value proposition of technology? – non-res vs res different • Learning behaviour to optimise H/W heating cycle – i.e. reduce on weekends, understanding current temp • Challenges with electrification and heater behaviour • Decarbonisation – design of building plumbing services. Code reflects building type

Water Utilities

From a water utility perspective, costs are the biggest challenges associated with smart water technologies.

Strengths	Barriers	Opportunities
• Digital metering for top 250 • Accurate billing • Could turn off all water use in drought? • Plan and model usage - demand forecast • New insights in demands • Rainwater systems functions • Rebate programs • System management capability • Correlation between water and wastewater flows (& filtration) • Program design • Customer leakage rates • Better understanding of peak demands • Opportunity to expand services	• Data ownership/access • Data integration/community access • Hacking • Privacy • Security • Cooling ... market failure • Maintenance costs and access • Increasing customers expectation • Reliability confidence • Cost • Security • RWTs • People's thoughts on reliability of potable water? • What is the timeframe on changing perceptions of risk with smart?	• Leak shut off • End-use model for non-res • Hi-rise pressure management • Links to insurance ind. • energy, quality, occupancy, temp, ... weather • Integrated with policy NABERs etc • Cross integration between systems • brands standards • leakage control as part of Building Code • Rain tanks • Use for bench marking on non sectors • Building in compliance on pressure • Real time 2 way functions • Activate the command • Peak pricing time of use • Peak management • Energy/water nexus

Water Efficiency Practitioners

From a water efficiency expert perspective, the biggest concerns were user-end issues, such as not thinking there is a need for water efficiency leading to wasteful behaviour. Other issues included technological interoperability, specifically standards of data governance and data output.

Strengths	Barriers	Opportunities
• Can connect water savings to cost savings • The technology helps remove the bad behaviours of users i.e. settings • drought preparedness • helps people value water more • Raise awareness • could be cheaper to live in these places • tech is enabling • WE marketing opportunities • easy identify leaks, issues, fast solution • Ability to restrict/turn off supply during drought • data collection and measurement • who makes these decisions • smart taps- people wont forget to turn off • data collection and investment	• perceived WE need • not easy to retrofit • cost benefit analysis • who has access to data • perceived WE need • changing mindsets • end of life i.e. circular economy • maintenance requirements • fear that power outage causing loss of water service • some solutions from low tech devices • data management • carbon footprint • adoption related to cost • feelings of being monitored	• Water sharing in precinct • Shift minimum requirements (policy/standards) • Incentives (govt/utility) • WE marketing opportunities as a sell point • Ability to restrict/turn off supply in part during restrictions and drought • Imbed in certification standards • Water sharing in precinct

Appendix B: Day 2 research roadmaps

Smart Taps	
Problem Description	How can we leverage smart tap technology to improve user experience, consumption efficiency and health compliance?
Existing Tech/Tools/Data	Smart taps have following input controls and output data: • Inputs: Sensor sensitivity, temperature (cold/hot mix), light on tap • Output: Use duration and estimated water use, water pressure Additional information external to taps include: seasonality, business hours, building type, external weather etc. Smart taps have been installed in numerous buildings. Given the collaboration required from building managers, however, the existing Rhodes site (from Stream 1) may be the best ideal site unless another high-traffic site becomes available.
Approach	Two key pathways are identified for leveraging smart taps: **Idea 1**: Applying machine learning (ML) to minimize overall use per visit, while improving user experience, where user experience can be defined as: • Does the tap activate on time? • Does the tap de-activate on time? • Does the tap continue to stay on while in use? • Is the temperature appropriate (not too warm during hot outside weather, etc)? With these constraints in mind, ML can identify any opportunities that can lead to reduced water consumption. For example – can we induce water conservation by turning off the tap after a certain duration of activation? If the tap turns off too soon, the user would most likely re-activate the tap (with reduced user experience). What is the ideal cut-off time at which both the sanitation and user experience needs are met, while reducing water consumption?

Next steps	This project requires collaboration from a smart tech supplier, building owner, ML researcher, and a contextual water expert (ISF). Potential funding source includes NSSN Grand Challenge (Round 2) this year.

Leakage Networks	
Problem Description	Current implementation of smart devices can detect and shut off leakage at the room level using control valves, allowing for timely response to leak event. Until the actual source of the leak is found, however, the entire bathroom has to be placed out of service. This is one of the major complaints for the building owners. This project seeks to understand how data from fixtures within each bathroom can be utilized to pinpoint the source of leakage, upon which the suspect fixture can be shut down remotely or repairman can be notified of which fixtures to investigate first, resulting in quicker intervention response and improved user experience.
Existing Tech/Tools/Data	Smart fixtures have following output data: • Use duration and estimated water use (by each fixture) • water pressure (for entire bathroom) • Actual water use for entire bathroom (if smart meter installed) Additional information external to fixtures include: seasonality, business hours, building type, external weather etc. Smart fixtures have been installed in numerous buildings. Given the collaboration required from building managers, however, the existing Rhodes site (from Stream 1) may be the best ideal site unless another high-traffic site becomes available.
Approach	Two key pathways are identified for leak network: **Pathway 1**: Develop a simple diagnostic process that tests each fixture one by one and measures corresponding water use to detect anomaly. Easy to implement but can operate only during off business hours – if a leak occurs early in the morning, for example, it may translate to the leak continuing for an entire day until the diagnostics can begin.

	Pathway 2: Develop a M/L algorithm to continuously monitor and detect anomalies from fixture use, pressure and actual consumption. Algorithm can cover temporal and spatial correlation modelling, as well as probabilistic modelling (estimated failure risk rating of fixtures). Can be in operation continuously, even during business hours.
Next steps	Understand the current state of leaks in commercial buildings that are fitted with smart devices. How often and large scale? What would be the scale of financial benefit arising from improved leak detection? Is there a customer with exceptionally frequent leaks? Will they be willing to fund this project? Or their insurance company (if insurance pays for damages)?

Peak demand management	
Problem Description	Maintaining reliable performance across water supply and distribution networks is a vital aspect of network management. This is a base requirement for network consistency and is not only limited to maintaining supply during times of peak demand. However peak periods can put addition strain on infrastructure resources and do present additional challenges for network reliability. This research project would focus on harnessing the forecasting power of live data to reduce the risk of infrastructure breakdowns and to optimise the supply of water both potable and non-potable. It is unclear at the moment where networks exist with the smart capabilities to provide the required information to allow for such a modelling and optimisation exercise. Where devices do exist, issues surround navigating accessing the data.
Existing Tech/Tools/Data	The types of data that need to be accessed at a network scale include pressure, flow, activation, quality, maintenance requests.
Approach	This research project would primarily focus on optimising the distribution of water throughout a network using live data to predict supply requirements. Reducing unnecessary water transportation is expected to result in cost, and emissions savings. Additional streams of this research could be to: • Look at opportunities to replace potable supply with non-potable options. • Consider how to apply this smart technology in new vs existing infrastructure. • Re-design precinct level spaces based on optimisation insights. Ultimately this research would seek to inform a wide range of network decisions including design, policy, upgrade and maintenance schedules. This research could also challenge current network level assumptions. For example current accepted levels of leakage, standards for network design etc, assumed asset failure timeframes.

	Agreements to share and spread loading could be investigated following the examples of what’s currently established in the electricity sector with Sydney Water turning off major assets during peak timeframes. This idea also involves providing incentives for reducing load to large users.
Next steps	Existing smart networks need to be investigated for data access to undertake a modelling and optimisation exercise. If no such network exists, partnerships to create micro scale networks for testing optimisation software should be investigated. Partnership will also be required between domain experts, regulatory bodies and influential stakeholders.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