

Harnessing Hybrid Systems for Transformative Cities

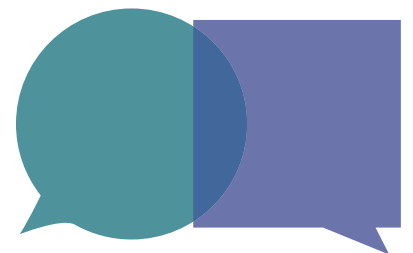


CRC for
Water Sensitive Cities



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Centres Program



ThinkTank

Harnessing Hybrid Systems for Transformative Cities

This paper is released by the Cooperative Research Centre for Water Sensitive Cities (CRCWSC) ThinkTank. The ThinkTank's focus is to challenge current thinking about how to create cities that are liveable, resilient, productive and sustainable. We provide information, ideas and advice on how to address the 21st century challenges facing water providers and policy makers, drawing on research and on-ground experience of the CRCWSC and its partners. Our aim is to broker ideas, stimulate policy debate, influence practice and offer creative yet practical solutions that can help accelerate the transition to being water sensitive.

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**“We envision cities,
towns and their
regions as sustainable,
resilient, productive
and liveable”**



Foreword

There is much to celebrate about the success of the CRC for Water Sensitive Cities over the past 9 years. Water sensitive cities principles are evident across Australia and globally, whether framed as water sensitive cities or as an alternative concept such as waterwise cities. Working with our partners, we have operationalised water sensitive practice at a range of scales. For example, we have demonstrated: (i) proofs-of-concept for new technologies and urban designs, applied in pilot-scale and development-scale works on-ground; (ii) a methodology for determining the 'optimum portfolio of water supply options', based on Greater Melbourne; (iii) a procedure for valuing non-market economic benefits of water sensitive practices; and (iv) water policy reforms in local and state governments that reflect research insights and outputs. Importantly, these achievements demonstrate water sensitive city practices can be implemented in Australia and overseas.

But we know—and our partners have reinforced—that there is more to do. We need to keep building and refining the institutions, regulations, technical tools and industry networks necessary to scale up and lock in water sensitive practices. We need to keep challenging the status quo, and support science-based advocacy for holistic urban transformation. We imagine cities that have the drive and the capability to keep innovating and adapting as circumstances change. These transformative cities harness the power of water to catalyse opportunities for greater urban liveability, sustainability, productivity and resilience. To realise this aspiration, the CRC for Water Sensitive Cities submitted a 2019 bid for a new Cooperative Research Centre—the Transformative Cities CRC. We embarked on a 'deep dive' with our partners to understand how we can enable this next wave of interdisciplinary research-to-practice innovation translation.

Our imagined transformative cities step up the use of hybrid systems, by progressively combining critical existing infrastructure with flexible decentralised local solutions as part of their urban renewal program. These hybrid systems merge conventional engineering with nature-based solutions. They can be integrated with urban systems for energy, waste, transport, housing and food. And they can be co-created with community and delivered through private-public or whole-of-government co-investment schemes. The results are fit-for-purpose urban services, and cool green places that also provide a host of broader liveability, ecological and community health benefits.

We envisaged flexible modular solutions that can respond quickly to changing future circumstances and development timing and patterns. They are also efficient, effective and value driven. Changing the scale and scope of investments may create opportunities for innovative business models, which allow for more multi-sectoral and public-private partnerships.

While unsuccessful in our 2019 CRC bid, our 6-month deep dive galvanised focus and momentum among our research and industry partners. We feel it's important to document the thought leadership behind the bid's mission statement, and research and research translation programs. This paper sets out the agenda for transformative cities in the hope it provides a framework and direction for collective research and action.



Professor Tony Wong FTSE
Inaugural CEO, CRCWSC

PART 1: THE CASE FOR HYBRID SYSTEMS

The outlook for future cities

Cities, home to more than half the world's population, are confronted with complex challenges that are driving transformations across the globe—and threatening the health and sustainability of people and nature in cities.¹

In Australia, almost 80% of the population lives in cities and towns¹. Larger and denser places present significant opportunities for innovation and increased productivity—about 80% of Australia's GDP is generated in our cities². But they can also overwhelm services and assets, resulting in road congestion, overcrowded public transport, compromised servicing, poor access to green spaces, increased heat islands, habitat erosion and biodiversity loss. For example, across a large part of Australia, water infrastructure assets such as supply, stormwater and wastewater networks are at the end of their lifespan³ and service capacity, with increasing operational and maintenance costs and declining service quality. Yet opportunities to develop transformative initiatives associated with planning for growth and climate resilience, might be present and more effective in smaller urban settlements like towns, where services and assets are not yet as overwhelmed as in larger cities.

Climate change is also driving major changes in cities, as more extreme weather events (e.g. flood, drought, bushfire, heatwave) have unprecedented and devastating impacts. At the same time, cities are a major carbon emitter. In Australia, transportation alone accounts for 17.6% of greenhouse gas emissions, and is the third largest contributing sector. Sprawling urban growth fosters motor vehicle dependency that reinforces these impacts, and damages both human and environmental health.

While the challenges of the new urban era are significant, they are not insurmountable. The health and sustainability of our future cities depend on whether we can respond with agility and flexibility to rapid changes. Can we turn the challenges of urbanisation and climate change into catalysts for transformative action that disrupts the resource-intensive ways we have traditionally planned and developed our cities?

We urgently need to take up this quest and transform our approach to city development, or we risk devastating consequences.

Passive, reactive responses perpetuate the status quo, which focuses squarely on the immediate future and is driven by sectoral silos. We know that no individual sector can singlehandedly engage with urban complexity to steer positive outcomes for climate change, biodiversity, resource security, and ultimately human health and wellbeing.

In this paper, we offer perspectives on how Australian cities may become proactively transformative. We define transformative cities as being capable of innovating and adapting under rapidly changing circumstances to ensure long-term liveability, sustainability, resilience and prosperity.

We have learned—from over 10 years of collective effort to foster water sensitive cities through interdisciplinary and cross-sectoral collaborations^{4,5}—that building the momentum for transformative change can be a slow and extensive process. It involves progressively developing knowledge and industry capacity, continued professional and community advocacy, pilot and larger-scale demonstrations, and keeping the doors open to unconventional approaches and innovations.

“Transformative cities are capable of innovating and adapting under rapidly changing circumstances to ensure long-term liveability, sustainability, resilience and prosperity.”

While there is no single recipe for transformative change, we know that transition strategies will be informed by good understanding of local contexts and driven through concerted and deliberate efforts of many stakeholders across organisational, sectoral, and political domains.

We present insights for integrating more hybrid solutions across multiple city-shaping sectors, which can enhance the health and sustainability of Australian cities and towns. Our perspectives largely stem from our experiences in water, but they have a fundamental basis that is applicable to other sectors and disciplines.

¹ By “cities” we mean cities, towns and other human settlements in an urbanised environment.

Urbanisation, or the expansion and concentration of people in cities and towns, is 'one of the 21st century's most transformative trends'⁷⁴:



Urban areas will absorb nearly all future world's population growth.⁷⁵



Doubling of urban population across the world by 2050.

Climate change can have devastating impacts, including extreme weather events and significant job losses. Cities and towns are places where climate change phenomena converge and their impacts are magnified owing to the density of population and assets:



The Senate Standing Committees on Environment and Communications estimated the total financial **cost of extreme weather** events in Australia ranged from **\$0.9 billion to \$4 billion** per year.⁷⁶



The tangible and intangible impacts of the 2010-11 **Queensland floods** are estimated at around **\$6.7 billion** and **\$7.4 billion** respectively.⁷⁷

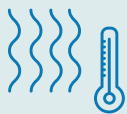


Deloitte forecast a staggering **loss of 880,000 jobs by 2070** across Australia for failing to take climate action.⁷⁸

Health impacts of urbanisation and climate change can be devastating:



Noncommunicable diseases (NCDs) including cardiovascular diseases, cancers, chronic respiratory diseases, diabetes, and mental health, account for **70% of deaths globally, killing more than 38 million people annually**, with 40% of those who die aged under 70 years of age.⁸²



Heat stress cost the Australian economy nearly \$7 billion through productivity losses in 2013-14.⁸⁰ The 2009 heat wave in Victoria led to 374 excess deaths.⁸¹



A vast body of evidence now shows that climate change is one of the biggest threats to human health.⁷⁹



A vision of health and sustainability in cities

The way we design places where we live, work and play profoundly affects the health and wellbeing of both people and planet.

Land use, transport and infrastructure policies and interventions create the circumstances in which people grow, live, work and age, and are known as 'social determinants of health'.⁶ They contribute to—or reduce—inequities in health.⁷

Together these policies can create liveable communities that enable healthy and sustainable lifestyles and opportunities:⁶ access to walkable neighbourhoods, safe walkable and cycling infrastructure, shops, services, public transport, employment, public open space, leisure and culture.

For example, large-scale Australian studies show that having 30% or more tree canopy was associated with a reduced risk of dementia⁸, and an 18-31% reduced incidence of diabetes, hypertension and cardiovascular disease⁹. Another study found that tree canopy cover of 40% or more has been associated with the greatest decrease in daytime temperatures and concluded that it can enhance the resilience of cities to a warming climate¹⁰. People living in inner and middle-level suburbs have had significantly better access to amenities that promote healthy and sustainable lifestyles than people in low-density outer suburban areas.¹¹

With urban growth comes the opportunity for new sustainable living that deliberately designs for these types of protective factors, for example, by incorporating water sensitive and low carbon designs in greenfield developments and urban renewals. Compact urban forms that promote density, mixed land use, connectivity and urban greening are common urban design approaches in urban renewal projects within existing developments. They reduce infrastructure augmentation needs and greenhouse gas emissions.

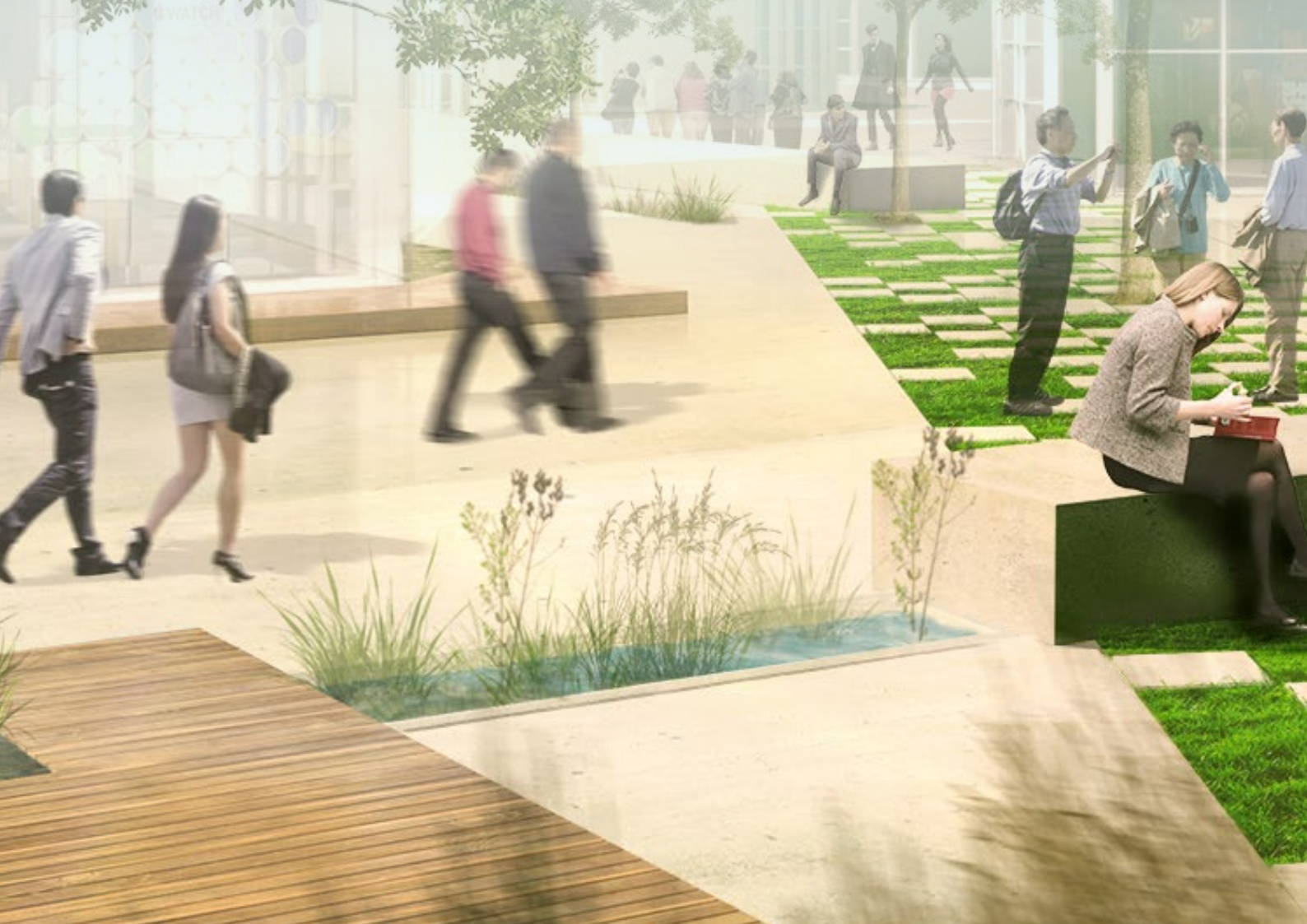
In Australia, there is growing recognition of the need to create more compact liveable cities with local amenities and proximate and frequent public transport. These approaches can foster sustainable mobility, and reduce travel and traffic congestion. A number of new urban policies across Australia promote these directions. Western Australia has adopted the Liveable Neighbourhood Guidelines, Victoria the concept of the 20-minute neighbourhood¹², and Sydney the 30-minute city which includes employment being accessible within a 30-minute walk or public transport trip.¹³

Compact development also presents opportunities to integrate solutions that bring multiple benefits. For instance, transport corridors can be supplemented with nature-based flood infrastructure to enhance flood resilience and safe conveyance of flood water, urban amenity, including urban heat mitigation, and ecosystem values.

As our cities densify, we need to enhance their urban amenity and maximise efficiency of infrastructure investment. Urban greening is important for physical and mental health in humans, as well as for ecosystem health.¹⁴ Given predictions that the length, intensity and frequency of heatwaves will increase, policies that protect and enhance green space and tree canopy in new and established areas generate co-benefits. Yet, these amenities are unequally distributed across cities, with detrimental effects on residents.¹⁵ A major concern with heatwaves is their impact on health, particularly more vulnerable populations such as older adults, children and the socially disadvantaged.¹⁶

The vision of transformative cities points to some key policy directions that will create important protective factors for human and environmental health—connecting people with place through compact mixed use development with urban greening and integrated infrastructure systems that deliver multiple benefits.

“Connecting people with place through compact mixed use development, urban greening and integrated infrastructure”



The transformative potential of hybrid urban services

Delivering these health and sustainability outcomes is not possible with traditional infrastructure services and planning approaches.

They are typically designed to deliver one kind of service, which operates in silos with a single performance objective. They tend to involve large-scale projects with long implementation periods, and that substantially lock-out new and transformative technological advances in future years. While generally reliable within a set of anticipated parameters, overdependence on such large infrastructure reduces agility in responding to unexpected crises, such as prolonged drought.¹⁷

Instead, the vision of transformative cities calls for new, more sustainable solutions across sectors.^{18,19} It requires a shift in practices away from siloed sectoral thinking and technocratic approaches, which propagate one-size-fits-all solutions. We use the term 'hybrid' to describe the alternative—the building block of our proposed way forward for cities.

Hybrid urban systems integrate different forms and modes of service provision—for example, centralised and decentralised, grey and green, social and technical, public, private and multi-level government investment and operation—to produce better overall outcomes for communities. We argue that hybrid systems are key to increasing the transformative capacity of cities.

Hybrid systems combine critical existing infrastructure—based on traditional centralised networks—with flexible, decentralised solutions that can be tailored for local conditions. They are designed to deliver multiple functions and benefits in responding to the socio-economic, political,

biophysical and climate vulnerability context of individual sites and their environs, at a range of scales. This means they can be customised and implemented as and when needed. They enable out-of-sequence urban development that otherwise challenges the capacity of centralised infrastructure to meet demand growth. They enable different infrastructure investment and operational models involving different levels of government and the private sector. This could mean that investments for major resource development and trunk infrastructure augmentation can be deferred or avoided. Coupling decentralised infrastructure with existing networks can also increase system robustness and modularity.

Hybrid systems merge conventional siloed engineering with nature-based and cross-sectoral solutions across the social-technical domains. This means they can provide reliable core urban services and contribute to broader health, sustainability, and liveability objectives (e.g. urban greening and cooling). Urban systems based on circular economy principles take advantage of the nexus between water, energy, food and waste, recovering resources and reducing pollution.

Hybrid systems complement technical solutions to city servicing needs with social solutions that engage with people's attitudes and behaviours. As populations grow and climate change causes more intense rainfall, longer droughts and more frequent heatwaves, the demand for urban services will only increase. It will be too costly to address this need through infrastructure alone. Instead, citizens and communities must be a fundamental part of a systemic response to climate risks and sustainability challenges. Cities will only be transformative if city shaping processes are guided by the community's aspirations and vision for their local neighbourhoods and able to adapt and innovate as situations change.

Hybrid systems, in their many dimensions, are key to unlocking a city's transformative capacity.

“Hybrid systems are key to increasing the transformative capacity of cities”



Transitioning to hybrid water systems—an illustrative example

Australia's water sector illustrates the changing paradigm from traditional urban servicing towards hybrid systems.

Australia's traditional water infrastructure was implemented over 100 years ago to provide clean drinking water, followed by removing wastewater (sewerage and stormwater) from our urban environment. This has led to important public and environmental health outcomes for the community.

However, separating water into different piped systems has compartmentalised water in the urban environment. This segregated water cycle management remains today, due to the longevity of water infrastructure, commercialised infrastructure asset ownership, funding approaches to water networks, and the environmental water quality and catchment controls that operate in parallel with urban water infrastructure. Consequently, water does not have a 'single master'; rather the responsibility and any associated risk for water systems lies across several service authorities and with both local and state governments for different parts of the water cycle.

Further, traditional water infrastructure is sized for peak conditions and operates under a pre-set mode, requiring manual intervention to change its operation. These networks can be considered 'lazy' civil assets designed for the extreme worst-case events, so their individual capacity remains underutilised for 99.9% of their lifespan. This drives up costs for water infrastructure at all phases of development—construction, operation and maintenance—without any additional benefits to the community, neighbourhood or city.

In many Australian cities, an increasing amount of water infrastructure is reaching its end of life and water authorities are facing huge replacement costs. Plus, we need to address the already pressing issues and opportunities of climate change, population growth, liveability, drought, flooding, and urban heat so we can accommodate sea level rise and water security over the next 100 years. Do we continue to build systems as we have in the past? Or do we rethink how water services can be delivered in a more innovative and integrated way?

Over the last decade, Australia's water sector has been proactively engaging with this question, supported by research and adoption activities of the Cooperative Research Centre for Water Sensitive Cities (CRCWSC). A key tenet of re-imagining the role of conventional water infrastructure, that are reaching its end of life or servicing capacity, is fostering the multifunctioning of these assets.

The integration, of and active control, of existing systems has the potential to work the assets harder and to serve multiple functions.

Bespoke 'water sensitive' solutions—language often used to describe hybrid water systems—have been developed through numerous pilot projects and demonstrated at larger scales. Water sensitive solutions are a place-based approach to integrating sustainable water management with urban planning and design.

Because they are place-based and context specific, there are no standardised pre-conceived solutions, or solutions that can be readily transposed from one application to another.⁵ However, there are three core principles that guide their design and contextualisation:

1. diversify water sources using a mix of decentralised and centralised infrastructure;
2. provide ecosystem services for the built, natural and social environment; and
3. develop socio-political capital for sustainability and water-sensitive decision-making and behaviours.²⁰

In practice, a water sensitive city would have water supplies augmented with desalinated seawater, harvested stormwater and recycled wastewater through hybrid systems that enable fit-for-purpose treatment and use. Many of these sources of water are available within the city itself, which means our cities are in fact water supply catchments.

The urban form would be part of the hybrid system, for example through buildings and properties that integrate smart tanks, recycled water systems, rooftop gardens and green walls. Streets would be designed with permeable paving, passive irrigation and distributed stormwater storage solutions that are multi-functional, creating recreation space and providing alternative water supplies.

Cityscapes would be cool, green environments, made up of nature-based solutions like trees, wetlands, swales, water bodies and open space irrigation, which also enhance amenity and biodiversity. Water would be valued by the community and managed in place to reduce drinking water demand, support ongoing liveability, reduce the ecological footprint of water servicing, and minimise space requirements in congested urban environments.

Integrating water sensitive solutions—or hybrid water systems—in all forms of urban development (renewal of greyfields and brownfields, as well as greenfields) would deliver maximum community value from water system investments. Some concrete examples of such hybrid water systems in Australia are outlined in Box 1.

Box 1. Examples of hybrid water systems in practice

Fishermans Bend – This Melbourne development represents international best practice for urban water planning. It integrates a range of hybrid water solutions, including rainwater harvesting and sewer mining as alternative water sources for non-potable use. It also integrates nature-based solutions with traditional drainage systems to cleanse urban stormwater runoff and buffer peak discharges through onsite detention in public open spaces and ecological landscapes. This integrated approach reduces servicing costs while ensuring high quality service. It nearly halves the demand on traditional trunk services, which deferred or avoided major infrastructure augmentation and the associated costs on extending water supply mains, sewerage and drainage infrastructure. In addition to reducing infrastructure and water services costs, the water sensitive strategy will also improve urban design outcomes enhancing amenity and liveability through activating streets with greater connection and permeability between building ground floor levels and the street, rather than elevated floor levels above flood levels.

The innovative hybrid solutions at Fishermans Bend were facilitated through collaborative

governance across all stakeholders, government, researchers and the water industry. It could not have been done without ongoing commitment across local and state government, because no individual authority owns the complete 'water story'. By stepping through the opportunities for integrating water at the precinct, street and lot level, water targets were set and are currently being delivered. Collaborative processes explored circular economy opportunities for organic waste processing, energy generation, co-location of council and water authority depots.

Barangaroo South – This state-owned Sydney urban renewal site is being developed with a self-sufficient water recycling system that treats all wastewater (blackwater, greywater and stormwater) for reuse within the precinct and external to the precinct. Collaborative governance involving state and local governments and a like-minded development partner, Lendlease, enabled these innovations. As one of only 19 projects across the world participating in the C40 Cities Climate Positive Development Program, it also includes reduced energy use on site; responsible waste management; zero waste emissions; and prioritisation of community wellbeing.



PART 2: MAINSTREAMING HYBRID SYSTEMS

Enabling and scaling transformative change

A study of Australian cities found a significant gap between policy rhetoric for healthy and sustainable cities, and its implementation on the ground.¹¹

So what needs to change to translate aspirational policies and promising hybrid systems into scalable and widespread action?

CRCWSC research on the dynamics of transitioning to water sensitive cities identified six types of enabling factors that reinforce each other to promote system change:

- Champions and leadership
- Platforms to help people and organisations connect
- Scientific and practical knowledge for new solutions
- On-ground projects and applications
- Technical implementation guidance, and
- Administrative implementation guidance.

These enabling factors are organised into the CRCWSC’s [Transition Dynamics Framework](#) (TDF), which provides a roadmap for mainstreaming water sensitive solutions as the transition unfolds over time through different phases of change (Figure 1). The TDF is rooted in transition theory and draws on empirical evidence from the Australian water sector. It can be a useful tool for thinking about critical paths to successfully embed new solutions for transformative cities beyond the water sector.

Building on the TDF, we can identify overarching strategies to guide progress through the pathways that establish these enabling factors and scale the adoption of new hybrid solutions.

Transition Phase	Champions	Platforms for connecting	Knowledge	Projects and applications	Implementation guidance	
					Technical	Administration
1. Issue emergence	Issue activists		Issue highlighted	Issue examined		
2. Issue definition	Individual champions	Sharing concerns and ideas	Causes and impacts examined	Solutions explored	Data and evidence collected	
3. Shared understanding & issue agreement	Connected champions	Developing a collective voice	Solutions developed	Solutions experimented with	Preliminary practical guidance	Administrative instruments explored
4. Knowledge dissemination	Influential champions	Building broad support	Solutions advanced	Solutions demonstrated at scale	Refined guidance and design tools	Early policy and performance standards
5. Policy and practice diffusion	Government agency champions	Expanding the community of practice	Capacity building	Widespread implementation and learning	Guidance for implementation and cross-sector	Refined policy and standards, early regulation
6. Embedding new practice	Multi-stakeholder network	Guiding consistent application	Monitoring and evaluation	Standardisation and refinement	Comprehensive policy and regulation	Comprehensive policy and regulation

Figure 1. Transition Dynamics Framework: enabling factors for mainstreaming water sensitive solutions

Scaling is a complex process, which can be operationalised in several ways. While there is no single universal definition of scaling²¹, it is commonly agreed that it involves reaching out to many users and large-scale transformation of existing societal rules, relationships, resource flows and cultural beliefs.²¹⁻²³

It is useful to consider three scaling approaches to help identify strategies that can leverage key enabling factors: scaling up, scaling out and scaling deep (Table 1).^{23,24}

In our experience with water sensitive solutions, relatively more focus has been given to *scaling up*, including through policy, strategy and regulatory work. *Scaling out* to a larger audience, through replication and dissemination, has also been achieved to some degree by piloting nature-based solutions, water sensitive designs and planning tools. This scaling out includes replicating pilots within and across cities. Similarly, principles guiding the design of stormwater quality treatment solutions have been developed, adapted and applied to new problems, such as flooding or wastewater management. Scaling out also represents our aspiration in using the experience of water sensitive cities initiatives to scale transformative cities initiatives across other sectors (e.g. energy, waste, transport).

There is also evidence in the water sector of *scaling deep* via communities of practice (e.g. the Water Sensitive Transition Network in Perth). Other learning platforms, such as CRCWSC conferences and capacity building programs, have spread ideas and changed beliefs and norms around water sensitive solutions.

From the outset, it is essential to pursue combined strategies for scaling up, out and deep. This is key to avoiding the pitfalls of a narrow set of *scaling out* strategies that focus primarily on technological replication or knowledge dissemination. Instead, the focus must shift towards the more ambitious and difficult agenda of large systems transformation. Drawing on our water sector experience, we now present three cross-cutting strategies that combine the three scaling approaches into tangible directions that we can collectively pursue.

“Scaling is a complex process, which can be operationalised in several ways”

Table 1. Scaling strategies (adapted from Riddell and Moore^{23,17})

Approach	Purpose	Main Strategies
Scaling up	Drive institutional changes in terms of law, policy, regulation, and resource flows to mainstream solutions	<i>Policy or legal change efforts</i> : New policy development, partnering, advocacy to advance legal change and redirect institutional resources
Scaling out	Reach greater numbers through replication and dissemination, which include adaptation and ongoing innovation across other sectors	<i>Deliberate replication</i> : Replicating or spreading programs geographically and to greater numbers <i>Spreading principles</i> : Disseminate principles, with adaptation to new contexts via co-generation of knowledge
Scaling deep	Influence 'people's hearts and minds' e.g. normalisation of culture, behaviours and practices, changing relationships.	<i>Spreading big cultural ideas</i> and using stories to change beliefs and norms <i>Investing in transformative learning</i> and communities of practice

Scaling strategy 1: Build on pilots for lasting impact

The early stages of innovation typically involve translating new evidence into usable technologies, tools and insights, by and for end users.

Piloting these innovations is critical to lay foundations for mainstream adoption. And scaling out through replication is often the logical next step after successfully incubating new innovative solutions in a pilot setting. This scaling out process emphasises the practice changes needed to support the widespread use of these new innovations or tools.

But, all too often, piloting is considered as an end in itself. From the outset, we should acknowledge scaling innovation is complex. It can be constrained by regulation, community acceptance, institutional fragmentation and existing funding models. This is not unique to the water sector. Failure to properly scale from pilot innovations has also been reported in public health and social enterprise.²⁵

So, it is important we discuss some of the pitfalls of pilot projects and explore strategies to overcome them. Our experience shows pilot projects can make lasting impact via deliberate and aligned efforts to combine strategies for scaling out, up and deep. This, in part, involves using pilots in a strategic way to deliver proofs-of-concept that secure broader buy-in and influence policymaking.

Combine scaling approaches from the outset to avoid pitfalls

Many pilot projects fail because they have poorly defined impact objectives, or do not consider practice change adequately. These pilot projects are often idiosyncratic, designed within specific contexts, almost without recognising this will limit any real-world scaling potential. Scaling innovation through replication alone tends to focus on standardisation and similarity of context—assuming each site is similar to the original successful pilot site. Instead, we should ask what needs to change in the broader system for the technology to be scaled.

In contrast, hybrid systems that involve context-specific solutions will require adaptations to local biophysical and socio-institutional conditions. So, replicating standardised technology alone will not be sufficient. As well as adapting the technological solutions, it is important to also identify enabling socio-institutional conditions (e.g. as mapped in the Transition Dynamics Framework). In this way, appropriate scaling up and scaling deep strategies can support replication and dissemination.

Often, it is hard to replicate pilots in real-world conditions when their purpose is to inspire future possibility, with little thought of commercial viability. Protecting them from financial sustainability criteria, or exempting them from regulatory conditions, is useful to incubate innovations. However, these factors must be considered as part of a broader set of scaling strategies to make innovations viable for commercial use.²⁶

Shifting attention from an initial focus on nurturing and protecting innovative spaces to understanding the processes and mechanisms of embedding hybrid systems will accelerate their uptake. This also means moving from ad hoc attempts to develop prototypes to overcoming barriers to scaling. Those barriers can include long-term financing, growing the stakeholder networks to include broader groups of investors and end users, and ensuring supportive regulatory, policy and market forces.

Knowing when and how to combine replication and dissemination of pilot projects with scaling out and up strategies is therefore a key skill. Scaling out, in terms of numbers and reach, goes hand in hand with scaling deep, in terms of guiding and nurturing change until a new practice takes off and rapidly becomes the new business-as-usual paradigm²⁷. At this point, practices that were developed by early adopters are now accepted as the new standard, and others are less hesitant about using them. Scaling up by developing policy and regulatory tools can mitigate risks and help aggregate innovations into attractive products for the existing market.²⁷





Use pilots in a strategic way to deliver proofs-of-concept

Our experiences in Lynbrook, Singapore and Kunshan show pilot projects can be used strategically to deliver proofs-of-concept and influence policy reform and political buy-in (see example in Box 2). This ensures pilots have enduring impact.

Importantly, pilot projects develop the evidence base and business case to support widespread adoption. They can be used to engage the community, build industry capacity and build trust with key stakeholders (e.g. regulators). For successful scaling, the evidence for applying the innovation in day-to-day operations must emerge during piloting. Pilots that demonstrate critical elements of the change agenda are as important as technical feasibility.

A strategic pilot will have a different structure and actions than one based solely on the idea of technical replication.²²

Delivering a pilot must be directed and focused on clear objectives, including:

- Make a clear case for change.** Scaling innovation will likely challenge existing regulation, policy and practices. To ensure the new approach is not viewed as a threat, build a case for change that connects with existing policies and strategies to gain political authorisation and to empower staff to work beyond current policy and practice. As the project progresses, find avenues to communicate this change narrative. The more the discussion enters public discourse and connects with other issues, the more legitimate it becomes.
- Focus on commercial outputs and IP management.** Finding a sustainable funding model to continue the pilot work once the initial grant funds expire could be a key challenge. As an innovation matures, new funding and financing mechanisms and market creation opportunities must be identified (discussed further in the next section). Intellectual property must also be managed so that end users gain knowledge about and the benefits from the innovations, while ensuring continued research to monitor and evaluate performance, and further adapt the innovations.
- Challenge the system.** Institutional barriers are consistently cited as the main blockage to the uptake of innovations. Identifying these barriers and working through them during the pilot will help make the case for policy and regulatory changes, as well as build trust with key stakeholders. Continually applying the 'success test' to pilot projects will ask: If this works, what needs to change in the current infrastructure system, business models, regulatory/policy frameworks, political narratives, professional practices and mindsets, and community behaviours? The answers should be explored through the piloting process—if they are not, the opportunity to address them will be missed, which risks losing momentum for change.
- Incorporate into policy and works programs.** Working with policy partners during a pilot will help feed outcomes into relevant policy and strategy. Once technically feasible and widely supported solutions emerge, seek opportunities to promote these as policy options. Working with delivery partners during a pilot will facilitate implementation pathways that can integrate new hybrid systems into daily operations. Once the solutions are developed and there is a broad base of support, embedding them in business plans, budgets, and works programs will complete their institutionalisation as 'best practice'.
- Build industry and community capacity.** Use pilots for industry capacity building and community engagement and education. On-ground pilot projects provide tangible solutions to a broader change narrative, and are critical to build confidence and acceptance by professionals and the general community.

Monitor, evaluate and learn

Commitment to monitoring, evaluation and learning, including through piloting and research, is another important element of scaling.²³ It supports critical learning, provides feedback to refine and adapt new solutions, and builds an evidence base for policy making, business cases, and future investments. Here, we highlight some key gaps in evaluation and research efforts that can be addressed through pilots (and further roll-outs) to scale new hybrid systems.

Implementing hybrid solutions relies on good information, including data on key metrics of liveability, sustainability and resilience. The [Australian Urban Observatory](#) (AUO) was created in 2020 to address a lack of baseline data on the availability of amenities that create healthy liveable communities. Unlike other national indicator programs²⁸, the AUO enables assessment of inequalities in access to amenities to, and comparison within and between, cities. Despite 'environmental sustainability' being a core component of the AUO's definition of liveability, to date it does not include a full range of indicators for monitoring how well hybrid systems mitigate and adapt to climate change and urbanisation impacts. This information is vital to ensure policy makers, practitioners and the community have the data and tools to demand and enact solutions that will lead to healthy people and places in transformative Australian cities and towns.

Currently, studies of completed contemporary sustainability transitions are not yet available, including in the water sector. Ongoing research on transitions in progress would provide much-needed evidence on how to enable and scale transformative actions. For instance, we have much more scientific knowledge about the early phases of transition (e.g. setting up experiments, advocating through champions) than about the enabling factors and actor strategies that can accelerate and establish such innovations as mainstream practices.^{29,30} With action-oriented research, we can evaluate what has worked in different situations to drive transformative shifts in policy and practice. This work will help to develop transition indicators and actionable processes that can be transferred and repeated, themselves being scaled up. We also need to understand how scaling initiatives can phase out unsustainable initiatives.

Extending research to city-shaping sectors beyond water would also be valuable to understand the transition challenges and unique change trajectories that exist for different cities and sectors. Piloting new hybrid water solutions as well as cross-sectoral change strategies for their socio-institutional implementation would generate important new insights that support scaling. Context-specific knowledge and pathways will be critical for adapting hybrid solutions to meet localised challenges.



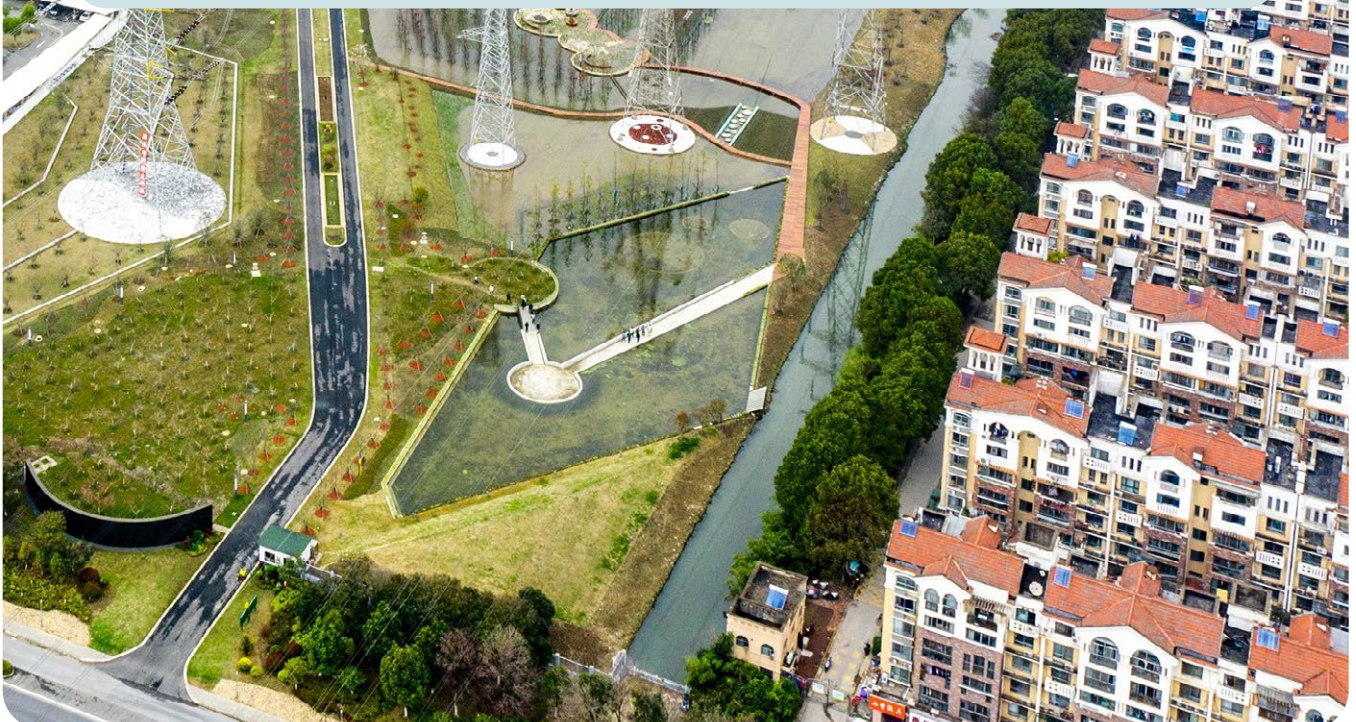
Box 2. International case of scaling water sensitive solutions

The CRCWSC's experience in China demonstrates scaling from discrete pilot projects to larger proofs-of-concept, and finally to mainstream practice. Expansion of single projects began in 2014, when Kunshan used development projects to apply new planning, design concepts and technologies generated from CRCWSC research. These projects addressed Kunshan's pressing water management issues: degraded waterways and poor drainage that often leads to flooding.

The Kunshan City Construction, Investment and Development Company embedded hybrid systems into its open spaces to reduce diffuse pollution. The cleansed water could also be harvested for non-potable use. Two examples were the Kunshan Forest Park Ecological Wetland and the Kunshan Ring Road. Over 30 projects have now been completed in Kunshan, and the work is entering a new phase. The city is now embarking on a A\$1 billion capital works program to scale the adoption of technologies and integrate them into broader urban frameworks.

This city-wide strategy reduces pollution into regional waterways and mitigates flood risk for downstream cities. But even more importantly, it proved water sensitive approaches work. The pilot projects delivered evidence to transform what was once perceived as innovative but risky into standard practice, which in turn authorised the next wave of innovation and collaboration. This evidence underpinned subsequent policy development, helping to overcome the regulations, community perceptions and institutional risk aversion that was limiting innovation and practical action. The approach also fostered collaboration and integrated governance among the stakeholders involved in city planning, infrastructure delivery and water environment protection, each with their own objectives.

Over time, a coordinated whole-of-government approach was systematically built to transform the city. There is now support from the Mayor's office right down to the city's many stakeholder organisations. The partnership activities encompass policy reforms, incentive schemes for public-private participation, design, construction and capacity building.



Scaling strategy 2: Advance new financing and funding models

While the policy environment in most of Australia is relatively supportive of hybrid water solutions, some important gaps in current policies and regulations impede scaling within the water sector and across other city-shaping sectors.

Directing resources into hybrid system investments at scale will need new financing and funding mechanisms. Our experience shows that while knowledge about how to fund and finance hybrid systems largely exists, a range of barriers must be addressed to support their mainstream uptake.

Identify options for financing and funding hybrid systems

Innovative financing and funding models are already supporting investments in services like clean energy, waste, sustainable transport, and urban water and wastewater management. Hybrid systems offer opportunities to

advance these innovations by extending and bundling financing and funding models in ways that enable their widespread adoption. This broadly involves matching finance with the financial and non-financial return that public and private investors want for the level of risk they are willing to accept, and their investment return timeframes. (See Box 3 for key definitions and Figures 2 and 3 for summary explanations of how sustainable financing can work for hybrid systems.)

Financing and funding mechanisms for hybrid systems are already well established. Sustainable financing models and significant private and public investment occur in areas like clean energy in Australia and internationally.³²⁻³⁵ The flow of private and public capital to hybrid system investment in Australia and internationally shows there is a strong appetite and significant capital available to finance these types of investments in Australia.

Importantly, as Figure 2 shows, sustainable financing may not seek a monetary return on every investment. Rather, they invest in portfolios that seek to achieve monetary and non-monetary return on investment in ways that align with investors' environmental, social and governance (ESG) objectives, risk profiles and investment timeframes.³⁶ Australia's sustainable financing market is growing rapidly (Box 4). Around \$25 billion was raised in sustainable finance (green, social impact and sustainability loans and bonds) in Australia alone across 2019-20 according to NAB.³⁷

Box 3. Key definitions in funding and financing hybrid systems

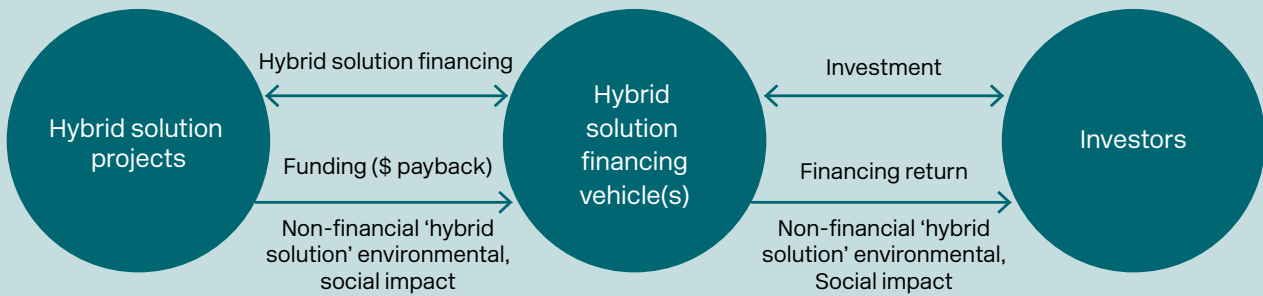
Who finances a project means who raises the cash for its implementation at the outset. This could be the public sector or private sector, raising debt and equity to finance the building of public sector assets. In Victoria for instance, the Treasury Corporation of Victoria (TCV) is the central financing authority for the government. Each year TCV finances billions of dollars of public infrastructure, including schools, hospitals, roads, water treatment plants, public parks, cycleways and housing.

Who funds a project means who pays for it over the long term. It could be the user, the taxpayer

or the customer. For example, in Victoria when TCV raises funds by issuing bonds, the purchaser of the bond does so with the expectation of a return at maturity. TCV expects to generate the return from the performance of assets that it has invested in. These are all state-owned enterprises. The TCV borrowings are guaranteed by the Victorian Government. Therefore, ultimately this repayment may be funded by state revenue.

Risk of investing in hybrid systems. The main risks associated with funding hybrid solutions include: construction and operation risk, demand risk, policy and regulatory risk, and governance and counterparty risk.

Demand and supply side of hybrid solutions



Many factors impact how financing and funding are structured.

Financing, risk and funding are connected

- Direct payback: clear line of sight (user charges, now)
- Indirect payback: cannot direct charge, or cannot direct charge now
- Hybrid solution risk characteristics: project maturities (early stage, proven, mature)

Diverse investor expectations about

- Project delivery requirements
- Return (financial (of- and on-capital), non-financial, payback timeframe)
- Risk
- Impact
- Transparency of underlying assets

Figure 2. Demand and supply sides of hybrid systems: The hybrid solution investment landscape involves matching financing, funding and risk structures with the financial and non-financial return investors want.³¹



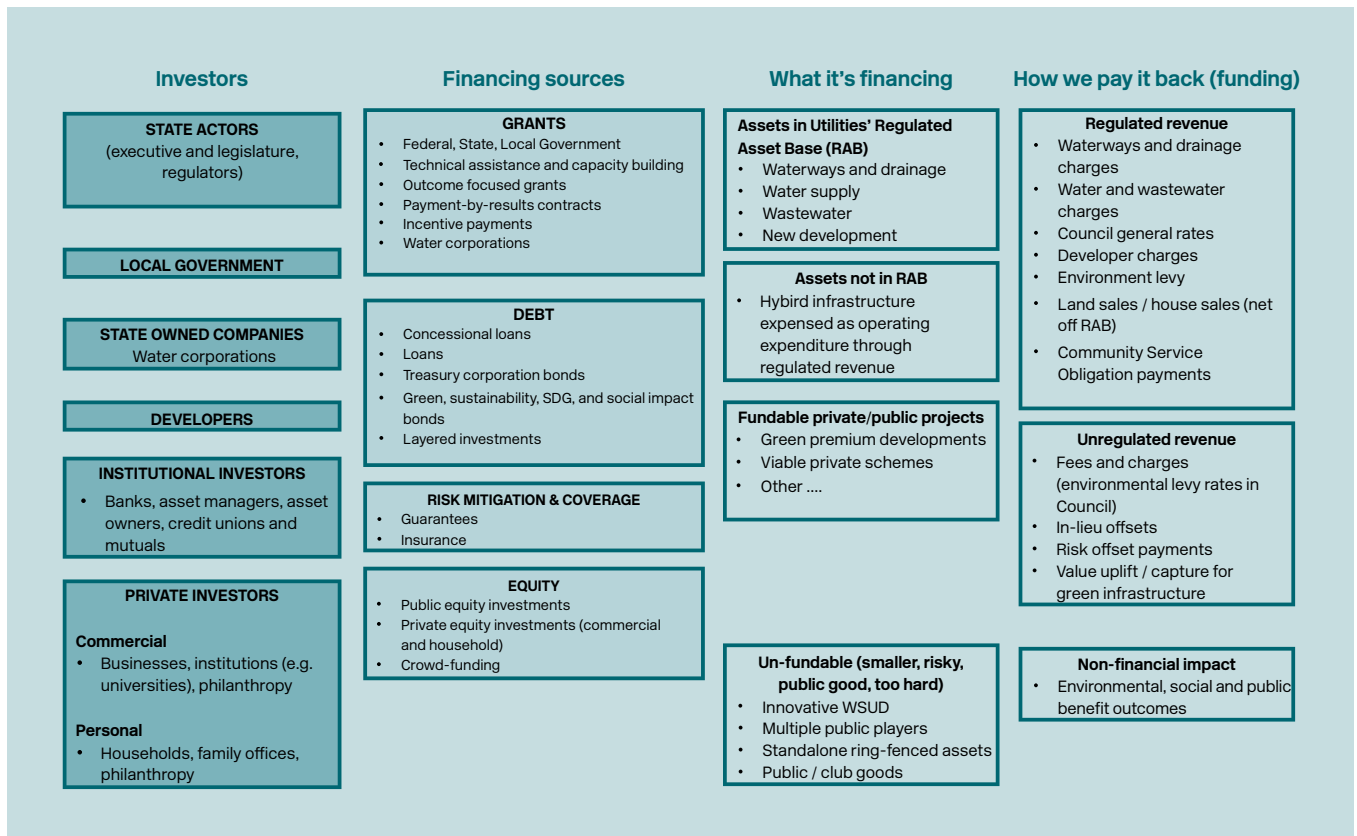


Figure 3. The hybrid systems funding and financing landscape³¹

Box 4. Growing Australian sustainable financing market

- NSW Treasury Corporation priced a A\$1.3 billion Sustainable Bond in October 2020.⁸³ This is the state's second sustainability bond issuance. These bonds finance projects and assets that support government policies and strategies that align with the UN Sustainable Development Goals.
- Lendlease Group priced an inaugural \$500 million green bond in October 2020 to finance green buildings across its global portfolio of 22 urbanisation projects.
- Canberra Metro entered into a A\$280 million green loan⁸⁴ to finance the Canberra Light Rail Project as Australia's first transport project that targets net zero carbon emissions in construction and operation.
- Australian Unity's inaugural issue of A\$100M of listed Mutual Capital Instruments allows retail investors to invest for social impact alongside large institutional investors.

In addition, the world's largest investment management corporations are shifting their investment focus towards ensuring investments meet sustainable investing criteria. In Australia, the 2020 Australian Sustainable Finance Roadmap³³ aims to establish investment signals that drive structural reform in the Australian economy by allocating investments and managing risk in ways that encourage hybrid system investments. Estimates suggest demand for Australian impact investments could grow by \$100 billion over the next five years.³⁸

What we are missing, however, are incentives, policy, regulation and markets for some hybrid system assets and services. These gaps are inhibiting public and private investment in hybrid systems, and associated returns on investment, and will ultimately hold back the mainstream adoption of hybrid systems if not addressed.

Create market conditions that advance sustainable financing mechanisms

Positive and negative externalities are still pervasive, occurring when peoples' consumption, production or investment decisions impact on others in positive or negative ways that markets do not account for.³⁹ When this happens, there are differences between the returns for private individuals, and the costs or returns to society as a whole. For example, if the price someone pays to send material to landfill does not account for its full social costs, more waste will go to landfill than if these externalities are accounted for in the price paid.⁴⁰ Similarly, if carbon emitters do not pay for the negative impacts of their carbon emissions, more carbon will be emitted than is best for society.

Outcomes of hybrid systems are often characterised by so-called 'positive externalities'—benefits to society that the hybrid system asset or service providers are not paid to provide. This means hybrid systems attract less investment compared with more mainstream alternatives, particularly in situations where they cost more to build, operate and maintain. For example, nature-based solutions such as urban wetlands can generate multiple benefits, including improved water quality, flow management, amenity, urban cooling, biodiversity and habitat. Amenity, urban cooling, and habitat are all generally positive externalities—society benefits from their provision without directly paying for

them. Wetlands can be more expensive than alternative water quality treatment infrastructure, however. Without a measurable and agreed monetary or non-monetary return on investment recognised for the positive externalities, they will be under-invested in compared with a solution that explicitly recognises and values the return on investment in monetary or non-monetary terms.

The [INFFEWS Value](#) tool developed by the CRCWSC provides a database of non-market valuation studies related to water sensitive solutions, which has been used to quantify intangible benefits of investments in hybrid solutions.⁴¹ Box 5 provides a practical example of how the tool has been applied to assess the value of passively irrigated street trees in Ballarat, Victoria.

To encourage financing, pervasive hybrid system externalities must be internalised and explicitly recognised and valued. In turn, the growth of sustainable financing mechanisms and financing of hybrid systems relies heavily on government actions to support and de-risk the financing environment, including:

- **Providing a level marketplace for hybrid investments seeking finance.** Governments can do this by reforming policies and subsidies for industries that create significant negative externalities. They can also ensure the social costs of these actions are priced so that consumers using the goods that create negative externalities pay the full, or closer to the full, social cost of their consumption. Landfill levies and carbon pricing mechanisms are examples of these market levelling mechanisms.⁴²
- **Creating and authorising new markets that provide measurable and verified returns on investment for sustainable financing.** Sustainable financing needs hybrid system investments that can provide measurable monetary and non-monetary returns (i.e. recognise and internalise the positive externalities they create). Non-monetary returns need to show environmental and social impacts (such as urban cooling, health benefits, UN Sustainable Development Goal (SDG) benefits) are being delivered in a verifiable and measurable way. The INFFEWS tool is a good example of how quantification of non-market values of hybrid solutions may be undertaken systematically.

Governments can play a key role in establishing and supporting these end markets to bring forward sustainable financing for hybrid systems. Some examples are already available (Box 6).

Box 5. Application of INFFEWS Benefit Costs Analysis Tool

The INFFEWS Value tool was used to assess the value of passively irrigated street trees as an integrated water management design option in Ballarat, Victoria.

An integrated water management plan developed by the City of Ballarat looked at options at a range of scales, including introducing passively irrigated street trees to new development areas. This approach lowers the grass verges around each street tree and directs road runoff to these trees via a gap in the kerb. This differs from standard practice in new developments where trees do not have an irrigation source. Providing irrigation increases the health of the tree and increases the size of its canopy to provide shade on hot days. The option also helps to manage stormwater runoff.



Figure 4 – Examples of new streets scapes in the region without (left) and with (right) passive irrigated street trees.

The proposal included a passively irrigated tree outside every new home, equating to approximately 45,500 street trees. The irrigation would provide a canopy cover of 15m² per tree, resulting in extra 670,000m² of total canopy cover to Ballarat, compared with standard practice.

A business case was developed using the INFFEWS benefit cost analysis tool. This analysis demonstrated an overall benefit cost ratio of 4.21, meaning the estimated benefits significantly outweigh the expected costs. The net present value of benefits was \$165,039,000 and the total costs were \$39,209,000.

Box 5. Application of INFFEWS Benefit Costs Analysis Tool (*Continued*)

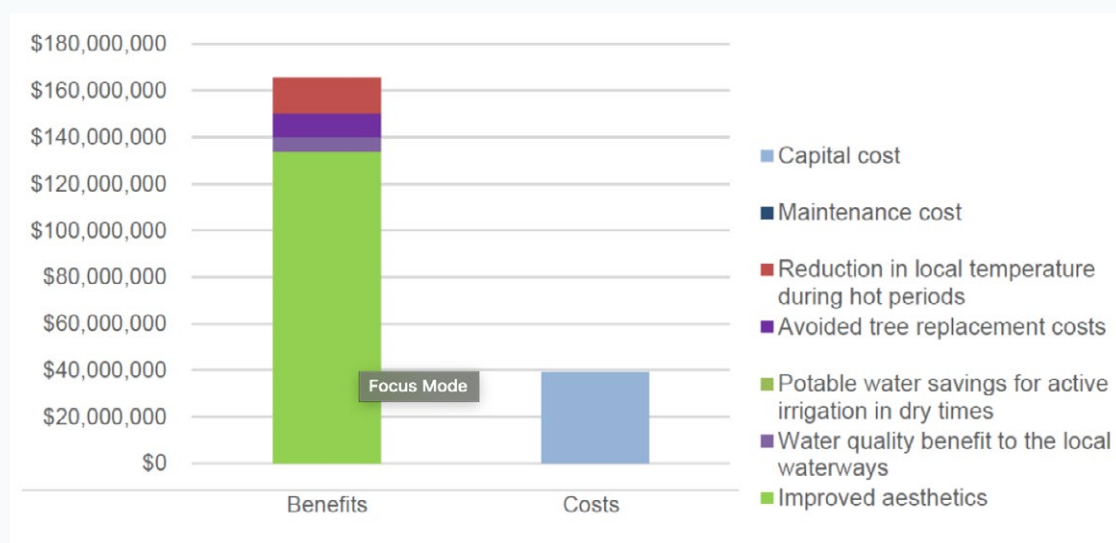


Figure 5 – Comparison of benefits and costs of passively irrigated street trees in Ballarat

INFFEWS also estimated the distribution of these benefits. It showed that benefits accrue to the local community, with the Council and the water manager also receiving some benefit.

Table 2 – The distribution of costs and benefits from the option

	Developer	Council	Local community	Waterway manager
Benefits accrued	\$0	\$10,334,000	\$149,228,000	\$6,075,000
Costs accrued	\$39,157,000	\$658,000	\$0	\$0
Benefit cost	-\$39,157,000	\$9,676,000	\$149,228,000	\$6,075,000

Source:
CRCWSC (2020)⁸⁵

Box 6. Examples of innovative hybrid system investment schemes

- **Local councils in Victoria are establishing stormwater offset schemes** in lieu of developers undertaking stormwater compliance on site. These innovative schemes provide a monetary return and a non-monetary return (measured as improved water quality and amenity from water sensitive investments). At scale, these types of investments could attract sustainable financing, given they create a relatively low risk funding source tied to development rates and are underpinned by government regulation.⁸⁶ This has occurred in the United States. Confidence in cashflow from funding gives confidence to finance investments upfront where needed.
- **Queensland's Reef Credits program** creates credits from reducing sediment and nitrogen runoff from private land.⁸⁷ While these credits do not have a financial return, they generate measurable environmental impacts—one Reef Credit is equivalent to one kilogram of nitrogen or 538 kilograms of sediment that would otherwise pollute the ocean. Reef Credits are sold to those seeking to invest in water quality improvements, such as governments, sustainability investors and philanthropists.
- **Singapore National Parks Board** has leveraged existing market mechanisms in an innovative way i.e. leasing of properties located in public park areas for commercial purposes.⁸⁸ The rental income is significant at about a third of the Board's external income⁸⁹, which could be utilised to maintain the parks.
- **Local governments in some US cities** have been piloting forest carbon credits to fund the planting of more urban trees.⁹⁰ They ran these new pilots with the support of City Forest Credits (CFC), a non-profit organisation who offer their service to private sector to offset their carbon emission with climate initiatives, including tree planting and preservation, across cities in the US.⁹¹



Cities present significant opportunities to scale up and extend these missing markets and deliver financing. For example, the Reef Credit approach (Box 6) could be applied to local urban waterways and catchments. Similarly, the same type of financing–funding structures could be used to establish tree carbon credits schemes to support urban greening investment.⁴³ This is already happening on a local scale in Australia. For example, GreenFleet is earning carbon credits by investing in urban trees in western Melbourne as part of the Greening the Pipeline initiative.⁴⁴ These investments will provide the greatest environmental return and be most attractive for sustainable financing when applied at scale.

We could also follow the lead of places like London and create markets for Urban Greening Factors (UGFs).⁴⁵ UGFs could work as stacked credits—combining carbon offsetting, stormwater runoff mitigation, biodiversity and amenity benefits into a single credit.⁴⁶ These credits could be generated on public and private land, creating hybrid system markets and bringing sustainable finance into investment areas that are currently underfinanced or only publicly financed.

De-risk and incentivise private sector financing and investment

Many public utilities (including water, energy and waste) have economic, health, and environmental regulatory oversight in Australia. Good regulation is fundamental for supporting many of the outcomes hybrid systems can provide. The overarching aim of regulation should be to ensure regulated entities act as if they were in a competitive market where (positive and negative) externalities are internalised and goods and services reflect customer preferences.

Current regulation in Australia can be risk averse and, as described above, does not put the citizen–consumer at the front. Regulation is also sometimes unclear or inconsistently applied. The result is that the risk profile of hybrid system investments tends to go up because it is not clear whether the investment will be allowed. And, more importantly, financing often does not get allocated to investments that citizen–consumers want when the regulators are out of step with hybrid system innovations that deliver better outcomes for communities. For example, some health regulators in Australia require water utilities to use the highest quality source of water available, rather than taking a fit-for-purpose approach based on evidence of what citizen–consumers want and are willing to pay for.⁴⁷ These types of policies and regulations can arbitrarily restrict the range of options considered, increasing costs to customers and impeding investment, and hence financing and funding for hybrid systems.⁴⁷

Governments can and should do more to encourage private sector financing in hybrid systems, and sustainability more broadly, including:

- Governments purchasing hybrid systems:** Governments (federal, state and local) are significant purchasers of private sector goods and services. Governments can underwrite and de-risk hybrid system investment markets by targeting investments around a hybrid system framework. An example is the *Beyond Value for Money: support Local Government to drive through Social Procurement for Victorian Local Government* policy.⁴⁸ As another example, governments can make hybrid systems a condition of land developments. Victoria will require almost 70,000 more social housing homes over the next 20 years to meet the needs of lower income households now facing severe housing stress in the private rental market. Requiring that these developments meet carbon, integrated water, liveability, waste and circular economy targets would drive financing of hybrid system investments through 8% of Victoria's developed housing stock.
- Government co-purchasing hybrid systems by providing low or zero interest loans.** For example, the ACT Sustainable Household Scheme⁴⁹ provides financing to eligible households for products that reduce household emissions, including rooftop solar panels, household battery storage, and electric vehicles. Similar schemes could be developed to encourage other hybrid system investments by the private sector.
- Government sharing risk with the private sector.** The construction phase is often the riskiest stage in hybrid system investments. There are also risks associated with trialling new types of hybrid system investments. Governments could target public financing support at this stage through mechanisms including loan guarantees, first loss insurance, issuing bonds and enabling public-private impact investment projects (where private sector takes the risk but gets paid a premium for that risk).
- Government funding research and development.** Research on emerging environmental market development and innovation could be led by governments, given the risk to business is already high at the investment end. The impact of funding innovation incubators / accelerators in this space could be significant given the embryonic nature of the sustainability sector and the complexity of the challenges.

Create a clear authorising environment for hybrid system investments

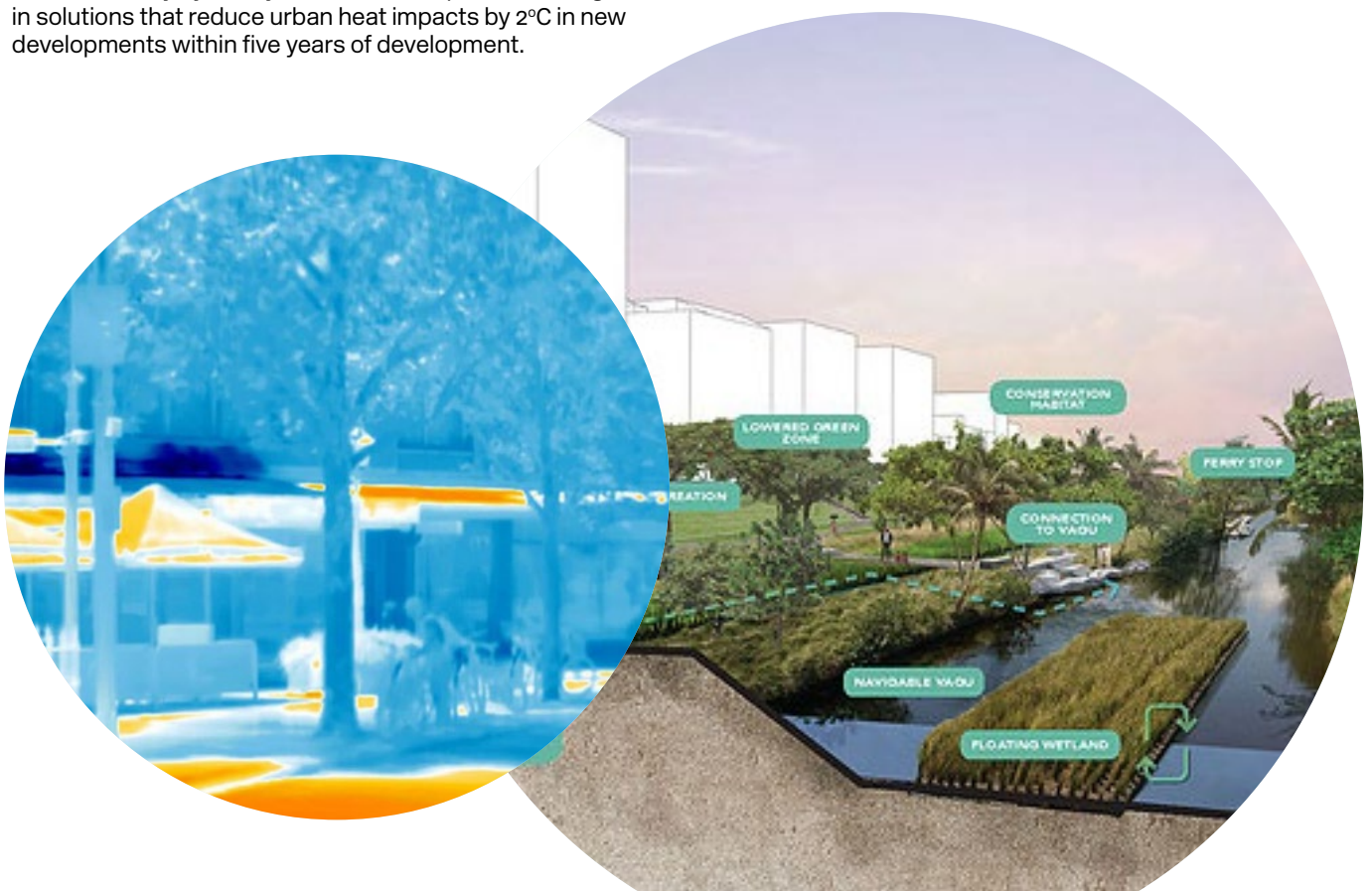
Public utilities across Australia have mandated roles, objectives and service levels that are defined in legislation. The legislation defines the scope of goods and services the utility can provide, and their role in providing the goods and services (e.g. the Water Industry Act 2004⁵⁰). The objectives of some utilities include providing hybrid systems, and statements of support for delivering broader social and environmental outcomes of public benefit. However, these broad statements are not sufficiently clear endorsement that government expects utilities to implement hybrid systems that deliver goods and services for better community outcomes.

The Productivity Commission, Infrastructure Victoria, and others have all identified this lack of clear objectives and authorising environment as a barrier to delivering hybrid systems.³²⁻³⁵ It means infrastructure planners and urban planners are less motivated to work together at critical early stages of planning processes to identify and then evaluate a range of hybrid system options. It also provides no clarity about how publicly provided hybrid system investments should be financed and funded.⁴⁷

Governments can support hybrid systems by extending regulated utilities' obligations to include objectives like contributing to specific UN SDGs, or state-based environmental and social objectives (such as the NSW Climate Policy Framework⁵¹). They can also set clear, specific, and time-bound objectives that link to outcomes that can be delivered by hybrid systems. An example is investing in solutions that reduce urban heat impacts by 2°C in new developments within five years of development.

Similarly, regulators need to be held to account when their regulatory frameworks inhibit innovation and elevate the financing risk of hybrid system investments. This is especially the case when there is clear evidence that citizen-consumers are: (1) willing and able to pay additional amounts for the hybrid system investments, and (2) willing to take on any additional risk the hybrid system may present.

Some regulatory frameworks in Australia are already shifting to this more citizen-consumer centric approach. This is enabling investment in so-called discretionary investments in hybrid systems that often deliver outcomes that go beyond the scope of utilities' traditional services. For example, in their last pricing submissions, water utilities in New South Wales, South Australia and Victoria have all received, or are seeking, approval to invest tens of millions of dollars in discretionary investment, based on clear evidence of customer willingness to pay.⁵²⁻⁵⁴ These discretionary investments are financed by water utilities through state loans, and funded through water, sewerage and waterways charges.



Scaling strategy 3: Integrate with sectors beyond water

The water sensitive city solutions implemented in Australia over the past decade highlight the interrelationship between the water system and the broader urban fabric.

It is clear that efforts to mainstream water sensitive cities need to engage with wider city shaping processes to reach the intended broader audience. Going beyond the water sector will also allow cities to respond to urban challenges such as urbanisation and climate change in a more holistic manner using hybrid solutions to deliver health and sustainability outcomes. Two possible actions to support infrastructure integration and cross-sectoral collaboration are discussed below.

Explore new designs and technologies to support infrastructure integration

The possibilities for hybrid systems that integrate across the water, energy, waste, food, transport, and built environment sectors are vast but have not yet been adequately harnessed. We have seen pilot-scale innovation projects such as sewage treatment combined with organic waste and digested locally to generate gas for energy and residual heat for powering district heating and cooling, and the flow of water or sewerage used as a heatsink for heat generators. These types of hybrid opportunities reflect the type of solutions that need to be scaled up and out in creating transformative cities, with healthier and more sustainable people and places.

By exploiting the synergies across multiple sectors, hybrid systems could be designed and optimised to deliver multiple co-benefits. For example, green roofs can attenuate rainfall

runoff to reduce flooding, provide thermal protection, and increase a building's energy efficiency.⁵⁵ Transport corridors can incorporate blue-green infrastructure, which connect landscapes, encourage low carbon mobility, promote active lifestyles and increase access to public spaces that support mental health and wellbeing. Sustainability shifts in one sector can also help to accelerate aligned shifts in another. As Australia transitions towards low carbon energy, there is opportunity for water production (e.g. treatment, pumping) to be powered with renewables such as solar or wind.⁴ The sustainability and resilience of urban and peri-urban food production can be enhanced by reusing and recycling organic waste and greywater.⁵⁶ Compact urban areas may improve climate performance of the waste sector by reducing transport-related emissions.⁵⁷ Waste-to-energy systems can be implemented at various scales to recover resources and reduce greenhouse gas emissions.

Emerging digital technologies hold significant promise for making hybrid systems more intelligent and dynamic. Current advances include data analytics and sensors, robotics and automation, artificial intelligence (AI) and machine learning, the Internet of Things (IoT), blockchain and augmented virtual reality. The power of big data and ICT-based analytics can be harnessed to improve public services, opening up avenues for smart monitoring^{58,59} and optimisation through real-time use of dashboards to run urban infrastructure. They allow systems to be forecast, monitored, controlled and optimised in real time and with a holistic understanding of an integrated, cross-sectoral system. They support infrastructure managers to rapidly adapt their thinking and operations as conditions change. This intelligent control would ultimately increase the efficiency of infrastructure networks, help to manage the risks of integrating hybrid systems across scales and sectors, and enhance overall network performance, while continuing to provide safe and reliable services.

These examples highlight the potential of cross-sectoral hybrid infrastructure systems to increase a city's sustainability, liveability, resilience, and also productivity. Implementing and operating such infrastructure systems in practice, however, requires a sophisticated socio-technical approach to planning, designing and managing urban services.

Nurture place-based and participatory processes to facilitate collaboration

To broaden the appeal, buy-in and impact of hybrid systems integrated across sectors, we can facilitate participatory urban planning processes that reflect a multitude of community and stakeholder perspectives, priorities and aspirations. Integration projects cut across multiple sectors and issues. Actions that are place-based and participatory are a powerful way to integrate the strategic needs of diverse people and environments.

Hybrid systems need to be facilitated through urban growth and renewal processes. Place-based urban planning is a key pathway to better integrating systems to deliver multiple objectives.⁶⁰ Its spatial perspective of societal activity provides a unifying focus, bringing together different sectoral stakeholders to allocate and organise different urban functions.⁶¹⁻⁶³ As well as managing potentially conflicting interests and facilitating cooperation, urban planning can implement a range of instruments, backed with varying degrees of statutory force.⁶⁴ These include long-term spatial visions or strategies, policy frameworks, regulations and codes.⁶⁵

The CRCWSC has proposed an [‘integrated water and urban planning framework’](#) for strengthening connections with other sectors to advance synergies between water systems and other features of urban environments, such as built form, streetscapes and open space networks.⁶⁶ The framework emphasises the importance of engaging Traditional Owners, communities and stakeholders in place-based visioning as a precursor to considering development scenarios and infrastructure servicing options. The ‘human dimension’ of integration can sometimes be more important in achieving transformative city outcomes than the formal processes and instruments of urban planning alone.^{67,68}

While this framework was devised to integrate urban and water planning, its principles apply to planning and developing hybrid systems more broadly. It offers a deliberative approach to planning that integrates typically siloed activities to improve outcomes. It is designed to help practitioners to set up more enabling forms of planning that are responsive to community and stakeholder aspirations, and able to deliver innovative urban form and hybrid solutions that reflect local conditions, constraints and opportunities. This place-based framework can also be combined with tools for envisioning water sensitive futures, which enhance decision making and community participation.⁶⁹⁻⁷²

Digital technologies can also improve planning and participatory processes. There is an urgent need to experiment with more deliberative and participatory governance models that can respond to citizens’ desire to more directly engage in city shaping processes and harness digital tools. In the context of supporting a sustainability agenda, data-driven approaches have been developed to improve the quality of direct citizen interactions in decision making, including by using digital voting apps, location-based review apps, and digital storytelling platforms. Data-powered platforms may even support sustainable planning and management of hybrid services and citizen-driven processes at scale, if properly implemented across governance levels, technical sectors and societal groups.⁷³



Conclusion

Despite the successes of the water sensitive cities agenda in Australia, the water sector is increasingly aware that long-term liveability, sustainability and resilience of cities cannot be achieved through a siloed focus on water.

Achieving those goals requires cities to promote reforms that span city-shaping infrastructures beyond water, and to implement cross-cutting strategies for scaling hybrid systems. While water sensitive solutions can contribute to multiple sustainability goals, integration across sectors will enable cities to maximise synergies and reduce trade-offs.

Our experience in the water sector shows technological solutions alone are not sufficient to realise the vision of transformative cities. The complexity of scaling hybrid solutions requires deliberate scaling approaches which can bring research to practice.

Lessons from the water sector show cross-sectoral integration and hybrid system implementation demands tailored solutions that are adaptive and sensitive to local needs and conditions, while involving a wide range of technical, urban design, policy and social measures. We believe it is possible for cities and towns to use these strategies and lessons to harness the potential of hybrid solutions and integrate them into existing urban services in ways that enhance health and sustainability outcomes for people and their environment.

To transform existing practices, we urge cities and towns to:

- I. **Use pilots in a strategic way to deliver proofs-of-concept and enable learning, monitoring and evaluation.** In this way, cities can maximise the potential for scaling up, out, and deep of new transformative initiatives within and across sectors.
- II. **Identify and unlock new resources through innovative funding and financing mechanisms.** Governments can play an important role in reforming subsidies that harm the environment and redirecting those payments to incentivise more sustainable practices, including acting as a buyer of hybrid solutions. Reforming regulatory and policy barriers, which prevent parties from collaborating and investing in hybrid solutions, will also be important.
- III. **Integrate city-shaping sectors beyond water, which involves exploring new urban designs and digital technologies to support infrastructure integration.** It also requires place-based planning and participatory processes, which support collaboration across sectoral and disciplinary boundaries.
- IV. **Develop a research program for each of the above scaling strategies.** The role of data, evidence and insights, which are underpinned by research, cannot be overstated to support organisational learning, decision making and policy change. Comprehensive data and ongoing research can support evaluation and adaptation of hybrid solutions across various applications.

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