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Why are decentralised urban water solutions still rare given all the claimed benefits, and how could that be changed?

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ABSTRACT

Numerous innovative decentralised urban water solutions have been described over many years, yet their application in practice is still not common at all. While many proposed solutions may have some techno-economic advantages over current systems, the real reasons for the slow uptake have more to do with system-wide inertia and technology 'lock-in' where existing solutions are preferred for simplicity and familiarity. A key factor is also the inadequate assessments in project decision making processes that should consider all relevant social, environmental and economic benefits and values. This paper highlights some key barriers and how to address them in a more holistic way. It also identifies opportunities where more integrated, hybrid solutions could offer significant benefits over current technologies. It calls on all key partners in this sector to foster broad and strong collaborations, and on water service providers to be empowered to take an inclusive leadership role in creating such innovative solutions that help address our growing challenges driven by rapid urbanisation and climate change.

Introduction

For several decades now there have been discussions in academia and practice about the 'optimal' water infrastructure solutions for the future, particularly for our rapidly growing urban population worldwide (Sedlack ,2014). While some argue strongly that the current centralised solutions have served us well for water supply, sewage management and flood mitigation, many also pointed out the shortcomings of these assets and have proposed various decentralised solutions that would achieve better and more sustainable outcomes for our current and future cities (van Loosdrecht and Brdanjovic 2014; Larsen et al., 2016; Roefs et al., 2017).

Numerous academic studies and demonstration projects on the ground have shown the benefits of various decentralised solutions for urban water infrastructure projects (good recent summary in Garrido-Baserba et al., 2022). However, in practice there is often an opposing trend evident since many years whereby smaller plants are decommissioned and larger ones being expanded (particularly for wastewater treatment) as this offers apparently the most cost-effective option to manage existing and growing demands. Meanwhile, only a slow uptake of alternative water resource options is evident, including more decentralised solutions.

This situation is clearly not advantageous to address our growing needs and challenges, including those created by the rapidly urbanising populations and the changing climatic conditions in many parts of the world. While our current infrastructure assets are increasingly under pressure from higher population demands, growing environmental and economic requirements and stronger climate variations, we are not proactively and constructively incorporating novel, alternative solutions at a rate that would help to alleviate these challenges. With the growing push towards a circular economy, including more sustainable energy and resource management solutions, the opportunities and benefits of a more inclusive and integrated approach are becoming even more compelling (Olsson 2015; Estévez et al., 2022).

What are the reasons for the slow uptake of integrated or decentralised solutions?

There are a range of different reasons for the slow and limited implementation of such alternative approaches. Often specific local obstacles can be in the way, but there are also many structural and institutional barriers, plus social acceptance challenges that make the application of such novel solutions difficult.

Here are a few key reasons that may explain the slow uptake, and that also point to what needs to be changed in future to accelerate this transition:

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- The economic value of smaller systems is often difficult to justify, particularly when indirect benefits are not fully recognised and accounted for. The economy-of-scale benefits of large systems are real and significant, both on capital and operational costs. A particular shortfall in some academic papers (eg. Garrido-Baserba et al., 2022) is that the costs of the alternative, decentralised solutions are looking promising when compared to the costs of the current technologies *at the same scale* (e.g. <300 people equivalents), but the authors then fail to recognise the major savings in unit costs of much larger, centralised processes.
- To achieve significant change, many different players need to be engaged, and they typically have poor alignment of their interests, timing, objectives etc. It is difficult to create meaningful and project/time-relevant engagement between regulators (public institutions), urban planners (public/private sector), property developers (mostly private companies), water utilities (public and private sector entities) and customers (private citizens). Yet all these key stakeholder groups need to be involved in the decision-making and implementation process to ensure a successful outcome of a novel, alternative solution.
- Additionally, a culture of poor collaboration is often common between some of these stakeholders, generally due to misaligned or even opposing objectives, with limited or no external drivers or incentives (regulatory or economic). For example, property developers generally are looking for readily available solutions with limited capital expenditure, small space requirements and low complexity (technical and contractual), while most councils, water utilities and end-users may favour integrated solutions with lower overall costs and multiple benefits and value for several players.
- Public health regulators can also raise high expectations and demands at these novel, decentralised technology solutions. These requirements may be partly justified, particularly for high-risk activities like blackwater treatment, but are sometimes also excessively conservative and risk-averse due to a lack of understanding or experience with these new systems. This not only raises the acceptance bar higher than what current technologies may have to achieve, it also creates a substantial compliance burden (sampling, analysis & reporting costs) that can make smaller systems economically unviable.

Many of the above points were also identified in a recent analysis of failed, full-scale residential water recycling schemes in Australia (West et al., 2016), which identified as top critical risks: unanticipated operational costs, legal and contractual arrangements, and regulatory requirements.

What would make alternative solutions more competitive?

First and foremost, we need to change our focus from finding a short-term, appropriate technology solution for a particular problem, to one where we look for long-term optimal solutions on a whole-of-system basis. This then often leads to an approach to integrate decentralised and centralised options and their benefits, which may be referred to as hybrid or distributed solutions. Such an approach requires active and genuine collaboration between many entities, and it will ideally also generate benefits and value to multiple or even all stakeholders.

This change of perspective has regularly been advocated by researchers (e.g. Nika et al., 2020) and practioners alike, but its actual application in project development and decision making processes is still very limited. To support and encourage such innovative solutions, stronger drivers are needed that are based on a whole-of-system optimisation and assesses the overall, long-term economic impact on all relevant aspects, including social and environmental values. This may require mechanisms for fair cost-sharing arrangements between players. Importantly, all relevant benefit-cost assessments need to be done on a whole-of-life basis, which means considering both capital and operating expenses and taking into account the *actual* costs of new or additional water supply or treatment options required. Additionally, all relevant externalities like public amenity, environmental impacts/benefits, flood and drought resilience, urban heat mitigation and other community benefits need to be considered as many of these decentralised, "blue-green" solutions offer significant local value. Such broad-based approaches should be mandatory in project planning and evaluation, and suitable tools to assist in these assessments are becoming available (West et al., 2019; Iftekhar and Pannell 2022).

The opportunities for decentralised technologies are typically greatest where there are no or only inefficient/expensive solutions possible in centralised systems, but an existing or emerging need has been recognised for a better outcome than what is currently achieved.

Some examples of such "market niches" for decentralised options are:

- **Stormwater and rainwater harvesting, possibly combined with graywater recycling** to provide alternative, distributed water supply options (non-potable or even potable). Given the highly intermittent and variable nature of stormwater and rainwater generation, decentralised harvesting and storage/reuse options (e.g. rainwater tanks, stormwater ponds/tanks etc.) are generally more suitable due to the very large volumes that otherwise need to be managed in a short time in centralised systems. Similarly, the separate collection and treatment of graywater (household effluent except toilet and possibly kitchen effluent) is only competitive in a localised setting to avoid costly duplication of the sewer networks. As graywater generation is quite continuous, a combined, decentralised treatment of graywater and rain/stormwater (after storage) could boost local water supplies significantly, while also drastically reducing sewage flows, particularly during wet weather periods.
- **Nutrient harvesting from high strength waste streams** such as "yellow" water from urine separating toilets. This solution can take significant nutrient loads off the wastewater treatment system while also allowing local, concentrated collection of nutrients (especially Nitrogen & Phosphorus) to be recovered and reused as part of a circular economy approach. While such urine separating systems have been developed for many years, the key remaining challenge is what to do with the collected yellow water (see excellent review by Larsen et al., 2021). A key solution could be to have many small, decentralised processes that selectively up-concentrate the nutrients from the urine, while the remaining low-nutrient stream is discharged into the centralised wastewater system (Wilsenach and van Loosdrecht, 2006; Freguia et al., 2019). This minimises the storage requirements for the nutrients, while also making use of the existing sewer infrastructure to handle the liquid flows, hence creating a true hybrid system.
- **Integrated, distributed rainwater and stormwater management with centralised control**. This solution combines the benefits of rainwater capture as outlined above with optimal management of the stormwater system that is still required for medium to high rainfall situations. A key feature of this approach is to have highly decentralised storage capacity (rainwater collection at each house for local use) that is actively managed and controlled from a central location (Aquarevo Melbourne, WSAA 2023). This creates maximal rainwater storage capacity before a wet weather event by discharging all rainwater tank contents into the stormwater system (before rainfall). This achieves major reduction of total run-off during the rainfall event creating significant size and cost reductions for the stormwater management and flood mitigation infrastructure. This example again shows the benefits of such hybrid solutions, utilising both decentralised and centralised elements to achieve an optimal outcome for the whole system.

How to encourage collaboration that can achieve successful outcomes?

To foster stronger and more in-depth collaboration, key entities like planning and building approval departments, water service providers and environmental/public health regulators must raise their technical and risk management capabilities. This should enable increased flexibility for and acceptance of alternative or non-conventional solutions that achieve at least a comparable risk outcome as "business-as-usual". Stronger incentives or legal requirements as well as the removal of institutional or regulatory barriers are needed to promote and support collaborative approaches between different stakeholders across the industry.

A key role in fostering such collaborations often falls to the local water service provider. They (or their private-sector partners) are often the only relevant agency with both the technical and organisational capabilities to help develop, install and operate these novel solutions, including ongoing maintenance, troubleshooting as well as financial and accounting services. Therefore, water utilities need to have a strong capacity and willingness to take on this leadership role, but in a very collaborative and inclusive way with all relevant stakeholders. Importantly, they should also be politically encouraged and legally empowered to take on this critically important role in future.

Finally, researchers and technology developers also need to engage earlier and more strongly with the relevant players in this sector while creating new, innovative designs and solutions. This would maximise the likelihood of ultimate acceptance in practice and avoids 'push-back' from these entities due to a lack of understanding, poor timing or inadequate regulatory support for these novel solutions.

What are key take-away messages?

- Alternative and (often) decentralised technology options struggle to get to implementation partly due to a 'lock-in' effect where existing solutions and technologies are preferred as they are well suited to and proven in the current urban planning and development practices.
- A realistic assessment of the value and benefits of decentralised solutions is critical while also acknowledging the 'economy-of-scale' benefits of current, centralised solutions. In turn, all comparisons and economic considerations must be based on a long-term, whole-of-system perspective that includes the value of non-monetary benefits such as amenity, urban heat mitigation, mental health and other community or environmental impacts.
- The key competitive niches for alternative solutions are likely in areas where they can provide a benefit or value that is not possible, or much more expensive to achieve in existing centralised solutions, e.g. storm/rainwater management and recycling, nutrient recovery, graywater separation and reuse etc.
- Most value can often be created through integrated/hybrid solutions where a decentralised technology can provide significant benefits in combination with the existing infrastructure and management systems.
- To achieve a wider and more impactful penetration of alternative solutions into our urban water systems, an engaged and proactive collaboration between a wide range of professionals and the relevant entities is essential. Economic incentives or legal requirements will be necessary to encourage and foster such critical collaborations.
- Water service providers (i.e. utilities) should be encouraged and empowered to take a strong, future-focused leadership role to help evaluate, test and ultimately implement alternative solutions as they have typically the biggest influence and capacity to deliver these options. They themselves, and their communities, will likely gain the most benefits from such innovations.

Declaration of Competing Interest

The author declares the following financial interests/personal relationships which may be considered as potential competing interests: Jurg Keller reports administrative support was provided by The University of Queensland. Jurg Keller reports financial support was provided by the Cooperative Research Centre for Water Sensitive Cities.

Data availability

No data was used for the research described in the article

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