Knowledge Brief

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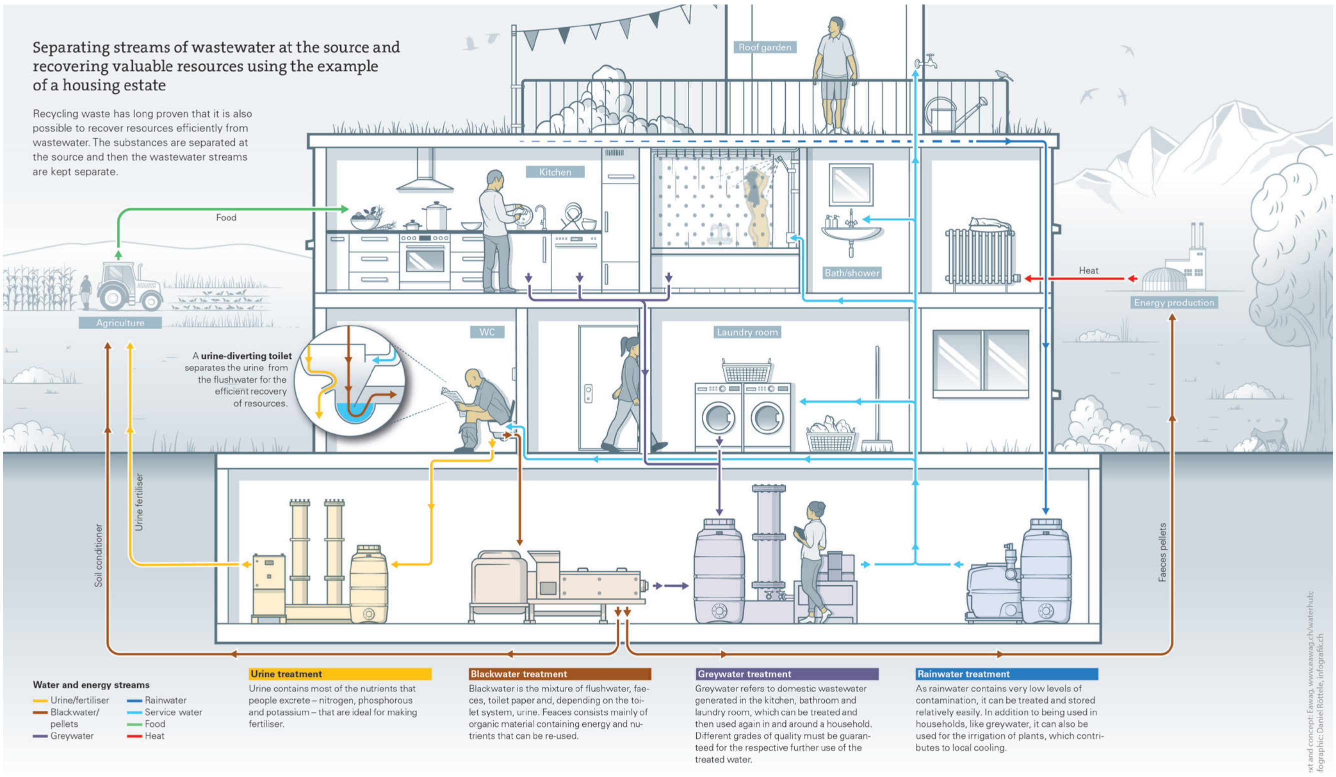
Resource-oriented wastewater infrastructures for sustainable cities: ways forward



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Executive Summary

Decentralized resource-oriented wastewater infrastructures can enable cities and municipalities to adapt to rapidly changing conditions and to become more resilient and resource-efficient in the future. Instead of pursuing a one-size-fits-all approach, decentralized resource-oriented technologies can be combined in a modular way depending on local preferences and specific economic, social and environmental needs. In addition, they allow for high flexibility, adaptability and context-sensitivity. This knowledge brief shows why and how decentralized resource-oriented technologies can serve as an alternative or supplement to conventional sewer infrastructure, and discusses to what extent they still face barriers to implementation in practice. It concludes by deriving specific recommendations for moving forward, above all targeted at public authorities and water utilities, but also providing insights to other key actor groups such as urban planners, architects and policy makers.

wings non-grid solutions
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Key recommendations of the research program Wings

1. Facilitate lighthouse cases by providing protective spaces for experimentation: Visible implementation projects can demonstrate how decentralized resource-oriented technologies operate under real-world conditions at larger scale (e.g. district or city-level). This requires full backing by local authorities and decision-makers, particularly to grant protective spaces for experimentation to let innovations thrive. For instance, the costs for the connection to a centralized network could be suspended on a case-wise basis, at least temporarily, to facilitate experimentation.

2. Mix policy instruments to incentivize implementation and to address barriers to adoption: To adopt novel technologies, it requires the elimination of barriers to implementation and operation, while also providing incentives for adoption and supporting cooperation between different actors. Mixing substantive (regulatory, economic, informational) and procedural (inquiry commissions, advisory committees or public meetings) policy instruments is particularly effective. In addition, if different actors and future users are included in the policy-design process, this can increase the perceived fairness of the process and the likelihood of successful adoption.

3. Become a role model and install novel technologies in public buildings: When public authorities set an example and implement decentralized resource-oriented technologies in public buildings, they help create a social norm towards adopting such technologies. Additionally, it will give the general public the opportunity to gain experience with these alternatives. Altogether, this can increase the chance that the general public is open to installing these technologies within their own four walls or move into residential neighbourhoods that are equipped with this infrastructure.

Why should we care?

Preparing cities' and municipalities' wastewater infrastructure for the future is an important condition for achieving many of the Sustainable Development Goals (SDGs) by the United Nations (UN): good health and wellbeing (SDG 3), access to water and sanitation for all (SDG 6), sustainable cities (SDG 11) and conserving water bodies (SDG 14). Decentralized resource-oriented wastewater infrastructures are able to support these goals, regardless of whether they are built in a water-rich high-income municipality in Switzerland or a water-scarce low-income city district in India. By contrast, conventional, large centralized sewer infrastructure may not – at least not alone – be able to meet future challenges such as rapid urban growth, climate change, resource scarcity, aging or deficient infrastructure in every context. This is due to their high economic costs and their limited flexibility to adapt to changing conditions.

What has worked in the past, does not necessarily work in the future

Large and centralized sewer networks coupled with flush toilets depict the symbol of the sanitary revolution in the Global North in the late 19th and early 20th century. These innovations managed to put an end to cholera epidemics and other water-borne diseases. What tends to be forgotten, is that this revolution has until today mainly taken place in the Global North, as it requires large financial investments. However, even for the Global North, research found that sticking to the conventional infrastructure is not always the best option in sight of changing conditions. For instance, San Francisco has already acted with foresight rather than being overwhelmed by sudden accelerating developments. It therefore passed regulations that require new major buildings to install decentralized resource-oriented technologies and allow the recycling of wastewater for reuse, such as for irrigation or toilet flushing.

Background and definitions

'Conventional' or centralized infrastructure: large network of sewer pipes, tunnels and pumps, which collect, mix and transport wastewater to a central treatment plant.

Decentralized infrastructure: on-site treatment technologies which can vary in scale from a single building (non-grid) over a neighborhood to a whole district (small-grid).

Hybrid infrastructure: integration of decentralized technologies into conventional centralized infrastructure.

Resource-oriented infrastructure: configuration of technologies separating wastewater streams at the source of generation such as greywater (e.g. shower, dishwasher), urine, brownwater (feces & flushing water) and blackwater (feces, urine & flushing water) with the aim to recover resources.

Benefits of a decentralized resource-oriented infrastructure from an integrated perspective

When building resilient wastewater infrastructure for the future, it is key to consider a variety of dimensions:

Economic: It is worth considering the installation of these novel technologies when municipalities and cities need to replace parts of their centralized sewer infrastructure. Such replacement requires substantial investments, given that 80 percent of the total annual costs are related to the sewer infrastructure. The actual costs and the optimal moment of switching to a decentralized resource-oriented infrastructure vary depending on the specific local conditions and the chosen technology, and must therefore be calculated separately for each case. However, in sight of planning uncertainties (i.e. how cities will actually develop), decentralized infrastructure might be a valuable alternative as it can be adopted more quickly, resulting in lower retrofitting costs.

Social: A variety of infrastructures (centralized, decentralized, hybrid) allows cities and municipalities to choose locally appropriate solutions. Participative tools, such as multi-criteria decision-analysis, can support citizens, mayors, planners and local authorities in selecting a solution that fits their local needs, financial resources and overall preferences best.

Ecological: Decentralized resource-oriented technologies allow for additional benefits such as transforming wastewater into renewable energy (biogas) or producing natural fertilizers by separating and treating urine. Although urine makes up only

1 per cent of the total volume of wastewater, it accounts for 50 to 80 per cent of the nutrient content (e.g. nitrogen, phosphorous). High nutrient discharges lead to eutrophication (the increase of phosphorus and nitrogen in water bodies), which particularly threatens coastal waters and fish stocks. Further consequences are polluted drinking water supplies and degraded recreational opportunities.

Greywater recycling technologies, which collect and treat, wastewater from the shower or dishwasher, provide the potential to use water more efficiently. They allow the reuse of treated water on a building or district level (e.g. for toilet flushing, hand washing, showering, laundry, irrigation), which increases the availability of water in times of water scarcity. This is especially relevant in sight of increasing heat waves and droughts. With the help of greywater technologies, recycled water is then available and can be used for irrigation and cooling of cities. Recycling water is not a radical idea, as humans reuse water all the time: treated wastewater gets discharged into water bodies and makes its way back to households through the natural water cycle. However, the question is: how much control do we want to have over water availability in our municipalities and cities in sight of increasing extreme climatic conditions?

Ways forward

For decentralized resource-oriented infrastructures to be implemented, the inter- and transdisciplinary research program Wings recommends the following actions:

Recommendation 1 – Facilitate lighthouse projects by providing protective spaces for experimentation: Many of these novel technologies have reached technology readiness levels that require a final validation and adaptation in real-world projects at larger scale. Examples include San Francisco (US), Hamburg (GER) or Helsingborg (SE). Lighthouse projects allow to showcase the functionality of these novel infrastructures, create visibility and can inspire and guide similar initiatives who look for best-practice examples to learn from.

Neighborhoods, municipalities or city districts can implement such decentralized resource-oriented technologies, while being accompanied and supported by researchers, practitioners and local authorities. Joining efforts across these actors allows for fast feedback loops and quick adaptation. Local authorities and policies can back such innovations to let them thrive: For instance, protective spaces for experimentation can be granted, as current regulations tend to prevent such innovations: The obligation to connect building zones to the public sewer infrastructure, as it is in place in the Water Protection Act in Switzerland, can be an important security back-up when implementing alternative technologies. However, the costs for the connection to a centralized network could be suspended on a case-wise basis, at least temporarily, to facilitate experimentation. Alternatively, the obligation to connect could be replaced by a disposal obligation, that would only prescribe that wastewater needs to be disposed properly without determining the way of disposal, thereby allowing for a broader spectrum of approaches.

When setting up lighthouse cases, Wings recommends to engage also with actors beyond the classical public actors, i.e. utilities or environmental authorities who have long held the main responsibility for constructing, managing and innovating water and wastewater infrastructures. This would involve additional actor groups such as sustainability-oriented researchers, architects, urban planners or local communities, who increasingly push for alternative, context-sensitive and environmentally friendly solutions. Their expertise is not only key for planning and implementing but also for critically evaluating lighthouse cases and drawing lessons learned from them. Most likely, the involved actors will not automatically work together in harmony as they have diverse and partly conflicting interests and visions. Holistic innovation policies and integrative leadership could mediate between these actors by creating shielding niches to demonstrate various technological options, and foster synergies between them. Following the example of STOWA (Dutch acronym: 'Foundation for Applied Water Research'), one way could be to establish an organisation or centre dedicated to coordinating and promoting innovation projects in the water and wastewater sector.

Lighthouse projects like in Helsingborg (SE) allow to showcase the functionality of these novel infrastructures (Credits: Sandec/Vasco Schelbert)

Recommendation 2 – Mix policy instruments to incentivize implementation and to address barriers to adoption: Policy makers can adopt concrete policy instruments to induce and steer the uptake of novel technologies. To support the structural change that is necessary for implementing such technologies (e.g. adapting regulations, fees), a single instrument might be insufficient. Rather, a combination of several instruments is required, including both traditional 'substantive' policy instruments, which are commonly used by contemporary governments, and so-called 'procedural' instruments:

Substantive refers to (1) regulatory instruments such as laws permitting or mandating the installation of decentralized resource-oriented infrastructure, (2) economic measures such as subsidies, tax expenditures or grant programs that offset or alleviate initial costs for installation as well as water and wastewater pricing schemes and (3) informational instruments such as outreach campaigns or training modules for practitioners. Some of these substantive instruments have the potential to increase perceived distributive fairness among the population.

For example, the associated costs, risks, and benefits of new technologies can be shared equally by mandating the use of such technologies for all inhabitants (regulatory instrument). Alternatively, in cases where new technologies are mandated only for a certain part of the population or inhabitants decide to voluntarily use them, and thereby bear the costs and risks, can be compensated through economic instruments. Both approaches would result in a fairer distribution of the costs, risks, and benefits, thereby increasing perceived distributive fairness. The absence of such instruments and the lack of distributive fairness can reduce the social acceptance for novel technologies.

For instance, Sant Cugat del Vallès, a suburban municipality in the Metropolitan Area of Barcelona, mandated the use of decentralized greywater reuse technologies for certain buildings. However, the associated implementation and maintenance costs had to be borne entirely by the apartment owners. A survey among technology users showed that the initial high level of acceptance for such technologies slightly decreased, especially during the economic crisis and the absences of resource scarcity. Other reasons for lower acceptance rates were the lack of information and user engagement, which could have been tackled by the use of **procedural** instruments. This type of instrument can facilitate important learnings (e.g., by creating lighthouse projects). In addition it can support the inclusion of and cooperation between different actors and potential users in the design and decision-making process (e.g., by setting up inquiry commissions, advisory committees or public meetings). Facilitating an inclusive and participatory process, which takes the voices of future users seriously, can lead to increased procedural fairness. When procedural fairness is given, people tend to be more willing to accept a decision they don't favour, including decisions that are personally disadvantageous.

Overall, current findings by Wings researchers suggest that at an early stage of implementing decentralized resource-oriented technologies, policy measures should be applied that support this implementation process, such as informational (substantive) and procedural instruments, which are important for gaining high public and political support, forming supportive actor networks and generating crucial learnings about new technologies. However, to increase the uptake of these novel technologies further, it also needs instruments that steer their adoption, e.g. through regulatory instruments, such as mandates or new technical standards.

A case that illustrates the successful combination of these two is the case of San Francisco. Here, informational (education/outreach) and procedural (lighthouse project, regular meetings between stakeholders) instruments have been mixed with regulatory instruments (mandates, performance and quality standards) to implement decentralized water reuse technologies at building and district scale.

Recommendation 3 – Become a role model and install novel technologies in new public buildings: When public authorities implement these novel technologies in their own new buildings, and thus act as a role model, they can create a social norm towards adopting such alternative technologies. In addition, this way, people get familiar with novel technologies themselves. It can be combined with an informational campaign, i.e. putting up informative signs in the building. This can raise awareness about the existence of such alternative technologies, and thereby might influence people's overall openness to install these technologies within their own four walls or moving into residential neighbourhoods that are equipped with this infrastructure. This was for example done in the new office buildings of the Swiss Federal Institute of Aquatic Science and Technology (Eawag), the Forum Chriesbach and FLUX-Building: urine-diverting flush toilets were installed in order to separate and treat urine and produce Aurin – a liquid fertilizer approved by the Federal Office for Agriculture for the fertilization of edible plants. Informative signs in the restrooms explain the wastewater infrastructure, collection and treatment process in a nutshell.

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About WINGS: This knowledge brief is based on research results from several projects within the inter- and transdisciplinary research program WINGS (Water and sanitation innovations for non-grid solutions). This ten-year program strived to develop novel non-grid-connected water and sanitation systems that can function as comparable alternatives to network-based systems. The results were synthesized by Lisa Deutsch (lisa.deutsch@eawag.ch) in collaboration with the program members P. Beutler, C. Binz, G. Congiu, N. Contzen, C. Doll, J. Heiberg, S. Hoffmann, J. Kollmann, M. Maurer, E. Morgenroth, K. Pakizer, P. Reymond, V. Schelbert, B. Truffer, and F. van den Brandeler. The document was reviewed by A. Heidler and the WINGS team.

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