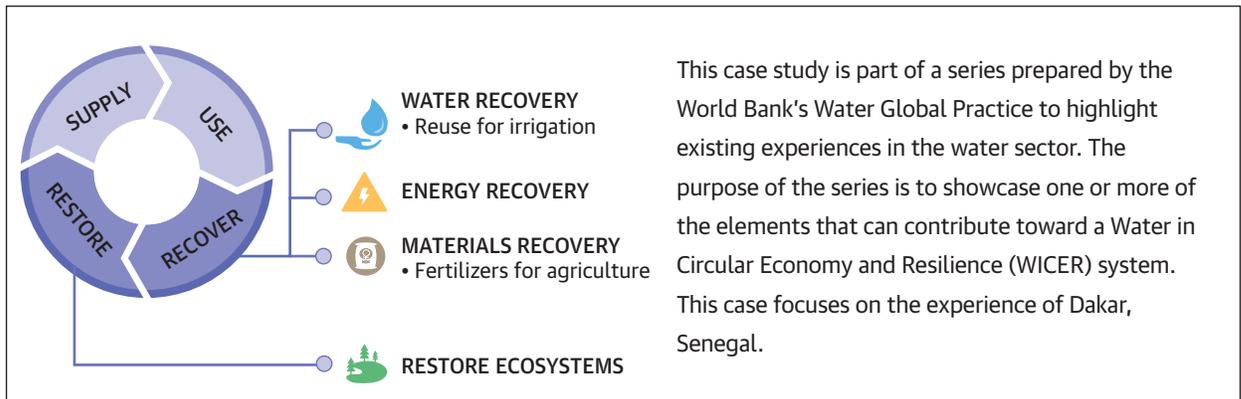


Water in Circular Economy and Resilience (WICER)

The Case of Dakar, Senegal

Recovering Resources from Wastewater and Fecal Sludge under Circular Economy Principles



This case study is part of a series prepared by the World Bank's Water Global Practice to highlight existing experiences in the water sector. The purpose of the series is to showcase one or more of the elements that can contribute toward a Water in Circular Economy and Resilience (WICER) system. This case focuses on the experience of Dakar, Senegal.

Context

Senegal's Sahelian climate is marked by hot, arid conditions compounded by variable rainfall and a changing climate. In the absence of demand management, these conditions threaten water security. Water stress has grown at the national level because of droughts, floods, and deteriorating water quality, while economic growth continues to depend on water-intensive sectors like agriculture, mining, and tourism. Surface

water, which makes up most of the country's renewable water resources and is the main source for agriculture, is largely transboundary and already fails to meet demand fully in dry years. Potable water and most industrial uses rely on groundwater, which is threatened by overuse and pollution. A recent study¹ estimates that current water withdrawals are projected to increase by 30 to 60 percent by 2035, further exacerbating water stress and straining the country's ability

to meet the demands of a quickly urbanizing population and to achieve stated socioeconomic development goals

This pressure is felt most acutely in the Greater Dakar area, where a third of the Senegalese population resides and half of the country's gross national product is generated. Ninety-five percent of the Greater Dakar population receives improved water supply services, and over 90 percent improved sanitation. At close to six million people in 2020², the population in the Greater Dakar area is projected to grow by 3 percent per year until 2035, aggravating water stress.

The Greater Dakar area has faced a water deficit since 2011. In response, the Société Nationale des Eaux du Sénégal (SONES) has launched ambitious investment programs to secure and diversify water supply. This has also resulted in the tripling of the marginal cost of water since the 1990s. Its current water portfolio consists mainly of Guiers lake (40 percent), which reaches the city through a 300 km conduit; local groundwater; and, more recently, desalination.

Most of the metropolitan area presently relies on onsite sanitation, primarily in the form of latrines. Only 32 percent of the population is covered by the sewerage system (122,258 connections). The Office National de l'Assainissement du Sénégal (ONAS) is responsible for both aspects of the sanitation service (onsite and sewerage), as well as for stormwater management. It is the first Sub-Saharan entity to successfully delegate some onsite sanitation functions to the private sector, as shown in figure 1.

Although Greater Dakar consumes 445,555 m³ each day, only 126,000 m³/day of wastewater is collected by the sewerage system. The capacity of Greater Dakar's 12 wastewater treatment plants (WWTP) is 35,531 m³/day. This means that only 28 percent of the collected wastewater is treated, of which about 9,500 m³/day is treated to tertiary levels. The untreated portion pollutes the environment through discharge to the sea or by seeping into the water table. In addition,

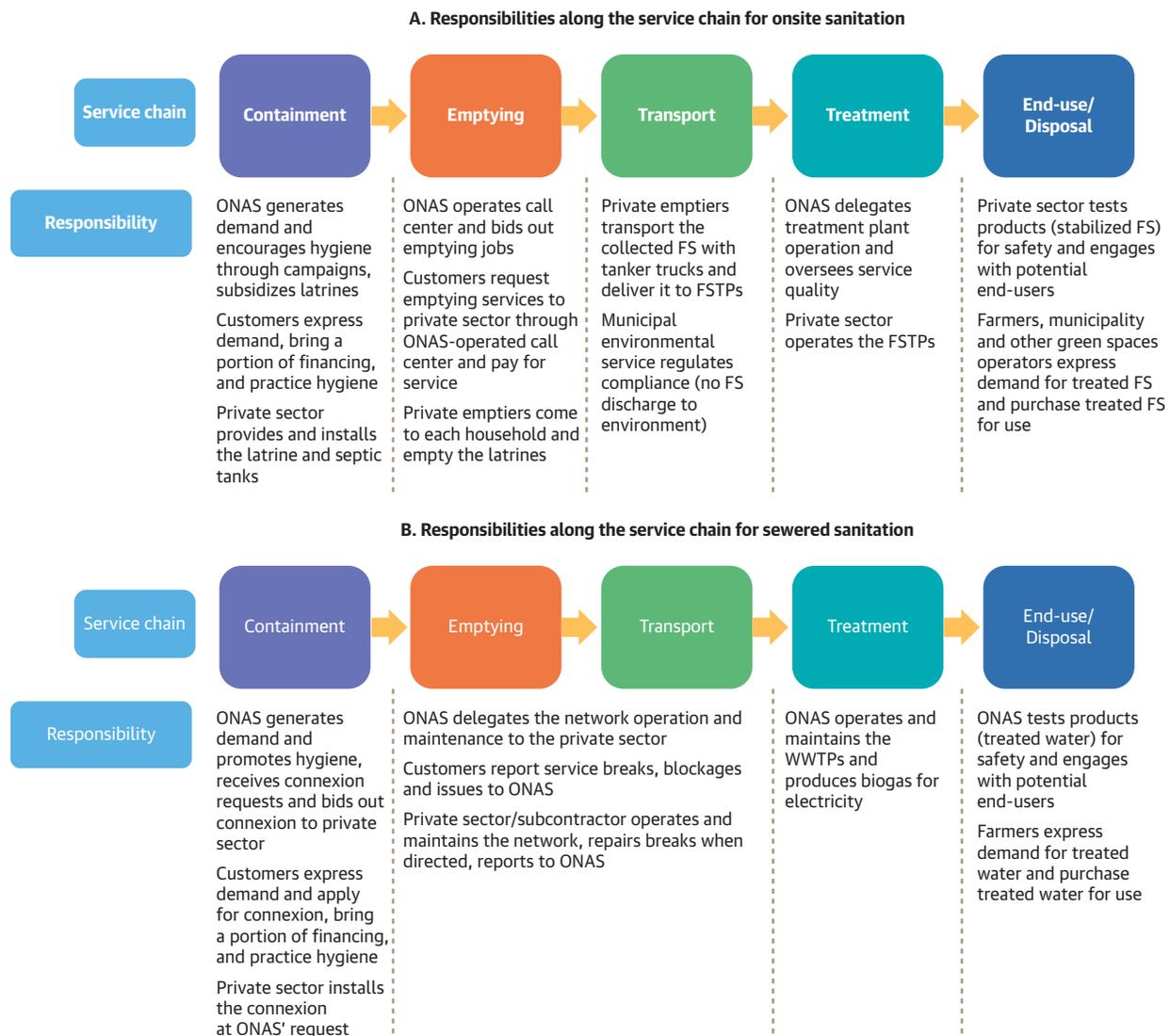
most onsite sanitation systems have not been installed in accordance with technical standards and contribute to groundwater pollution. Industrial effluents are another major source of pollution, as illustrated by the Baie de Hann, where untreated industrial wastewater is discharged into the sea. Nitrate pollution of the Thiaroye aquifer, formerly used as a potable water source, clearly shows the impact of inadequate sanitation systems on groundwater resources, portending major economic consequences.

As in most rapidly urbanizing areas, conflicts between the use of space and the use of water resources are growing in the region surrounding Greater Dakar.³ The region includes important economic areas like the Niayes, Littoral Nord, and Horst de Diass. It produces more than 60 percent of the country's horticulture and 80 percent of its agricultural exports, while also supplying Greater Dakar's urban markets. However, as urbanization shrinks agricultural land and drives land prices out of reach for most farmers, demand for water for municipal purposes rises, leading to costly investments in water supply, which are then passed onto ratepayers in the form of higher water prices. Development also invades the beds of intermittent streams, worsening flooding with serious consequences. Mining for zircon and phosphates, along with extraction of sand, have had dire effects on groundwater, aggravated erosion, and pushed out horticulture.

In the face of competition and water stress, ONAS has been exploring and implementing several circular economy opportunities. This case study documents its efforts in Greater Dakar to recover and use resources from wastewater and fecal sludge as it continues to invest in developing its infrastructure.

To summarize, the challenges are water stress, competition among users, and the insufficient capacity of present wastewater and fecal sludge treatment infrastructure. The objective is to make the greatest possible use of waste products and to engage in a new type of sanitation planning.

FIGURE 1. Responsibilities Along The Sanitation Service Chain in The Greater Dakar Area



Policy, Institutional, and Regulatory Environment

The policy and regulatory environment in Senegal encourages reuse. The national sanitation code⁴ explicitly allows for the reuse of treated domestic effluent (article 75) for restricted irrigation (horticulture and recreational green spaces) and unrestricted irrigation (woody crops, fodder, and fruit trees) if the effluent observes WHO rules⁵ (article 76 of the Code). Although

the code does allow for the application of fecal sludge as a soil amendment with authorization from the water and environment ministers (article 81), the widespread reuse of treated fecal sludge products is not included. However, ONAS is currently working with the Ministry of Water and Sanitation to develop a decree to authorize and define the terms of use of treated fecal sludge. The sanitation code also requires all communes to develop sanitation master plans, most of which report

the existing capacity and potential for reuse of purified wastewater and stabilized sludge. Energy policy⁶ also promotes the development of alternative and renewable energy sources, in alignment with the focus on energy neutrality and biogas generation.

Testing and scaling of reuse has been made possible by collaborations between development partners and the Senegalese government. Successful projects have been financed by the UN Food and Agriculture Organization (FAO) and the Nordic Development Fund. The Program for Structuring the Fecal Sludge Market (PSMBV) for poor households in Pikine and Guediawaye was funded by the Bill and Melinda Gates Foundation. It supported the development of fecal sludge by-products using marketing technology, including the widely known Omniprocessor⁷. All projects in Senegal are overseen by steering committees, legally constituted at the start of each project and consisting of representatives of relevant government bodies and affected stakeholder groups. In the case of projects involving reuse, the steering committees provide a way for actors representing various sectors and interests, including the potential users of the treated wastewater and biosolids, to be involved in the decision-making process.

The institutional structure, with ONAS responsible for sanitation and stormwater management, provides the right political economy for reuse and circular economy approaches. As the public entity responsible for providing sanitation services in Senegal, ONAS emphasizes protection of the environment and innovative approaches. The organization has become a center of expertise for the sharing of experience, especially in fecal sludge management. Fifteen countries have carried out benchmarking visits, and some have signed agreements to receive experts and technical support. In December 2020, ONAS was recognized as one of the “Water Leaders of 2020” by Global Water Intelligence for its dedication to elevating onsite sanitation and its success in reaching unserved clients through the delegation of sanitation service provision to the private sector.

Senegal is also recognized for its success in involving the private sector in service provision and key aspects of the sanitation service chain. The 2008 law organizing the water and sanitation sector⁸ made the state responsible for providing these services, which it can delegate to any public or private entity using various contractual modes, namely concession, *affermage*,⁹ or management, as well as any variant or combination of these three forms. Private sector involvement in the sanitation sector was promoted through the World Bank-financed PAQPUD project (*Programme d'amélioration de l'assainissement des quartiers périurbains de Dakar*) which improved the framework for private participation between 2000 and 2008. Through the PSMBV, customer requests for septic tank emptying received at ONAS's call center were bid out to private service providers. Collaboration with the private sector has been important in ONAS's success in promoting circular economy principles.

Despite these successes, ONAS still faces the challenge of reaching the last mile and ensuring the sustainability of quality sanitation service. It struggles to keep up with the fast pace of urbanization in the Greater Dakar area, especially given the unplanned patterns of urbanization. Managing sewerage assets also remains an important issue. The World Bank is supporting the government of Senegal in developing a strategy and roadmap for sound reform of urban sanitation under which the private sector would become more involved in operating the sewerage system as ONAS transitions to a full asset-holding company.

The Circular Economy Solution: Recovering Resources from Wastewater and Fecal Sludge

ONAS has had several experiences in the recovery of sanitation by-products, which it considers part of its mission. This note focuses on three experiences centered on Cambérène, the largest sanitation system in the Greater Dakar area: (1) the reuse of wastewater by market gardeners (horticulturalists) around Dakar;

(2) energy production from methane gas produced during wastewater treatment; and (3) recovery and sale of treated fecal sludge.

The Cambérène WWTP (Figure 2) is one of five operated by ONAS in the Dakar area and is co-located with the Cambérène fecal sludge treatment plant (FSTP) operated under contract by DVD, a private company formerly known as DELVIC. The co-location of WWTPs and FSTPs has resulted in two business lines: treated wastewater, managed by ONAS, and stabilized sludge (biosolids), managed by private operators.

Wastewater Reuse

The reuse of tertiary treated wastewater for horticulture in the area around Dakar was first developed in

response to growing water shortages in the Niayes area. In 2000, upstream preparations for Senegal's development plan (*Plan Sénégal Emergent*¹⁰) identified several options for reusing wastewater for green spaces and crop irrigation. Following a successful pilot to reuse treated wastewater from the Cambérène WWTP for crop irrigation in collaboration with the UN Food and Agriculture Organization, growing demand from other market gardeners led to projects to pipe water toward the market gardening areas of Pikine and Patte d'Oie and to extend the system to other points with a grant from the Nordic Development Fund.

Today, 3,000 m³ of the 5,700 m³ receiving tertiary treatment daily at the Cambérène WWTP are sold. Several hundred market gardeners whose activity is located close to the plant purchase the treated wastewater

FIGURE 2. Cambérène WWTP



Source: Incatema Consulting and Engineering.

from ONAS, which is responsible for quality control. The potential for scaling up the system is limited by the geography of horticultural activities and the costs of moving the water farther from the plant (pumping and other infrastructure). The WWTP currently receives 40,000 m³/day of effluent, well above its capacity of 19,200 m³/day, with impacts on outgoing water quality, but a project financed through a loan from the Islamic Development Bank is underway to increase the plant's capacity to 92,000 m³/day, of which 11,000 m³/day would receive tertiary treatment for subsequent reuse and sale.

Energy Generation

Energy production from methane gas has been possible since the construction of the Cambérène WWTP in 1989. The plant treats 480 m³ of wastewater sludge to produce close to 8,000 m³ of biogas each day, which is then used to generate heat and power in a cogeneration system, yielding 28 percent savings in energy use on

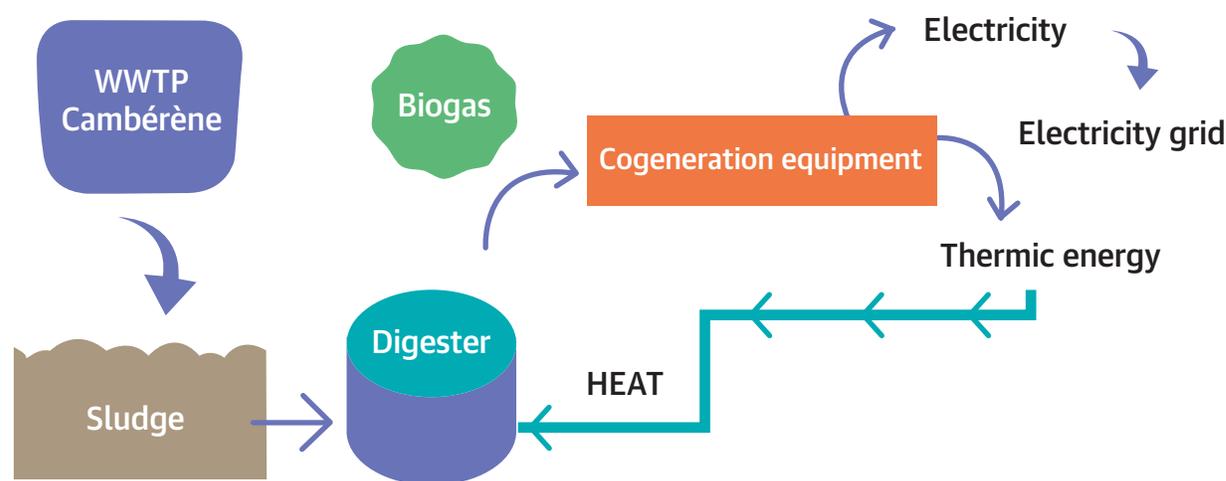
site (figure 3). The sanitation fee charged to customers is a percentage of their water bill. The charge covered only two-thirds of operating costs until 2019, reaching 96 percent in 2020. At USD 0.12/m³, the cost of electricity represents nearly 12 percent of production costs, or CFAF 1 billion out of CFAF 8.5 billion per year (USD 1.82 million of USD 15.5 million). As such, the production of methane gas and its use to run the boilers and part of the treatment works are ways to make the utility more financially sustainable. There is a plan to expand the cogeneration system to 3,200 kW, quintupling the plant's electricity capacity and achieving savings of around 60 percent of the WWTP's electricity costs. This expansion represents USD 720,000 per year in potential savings, or a reduction of 30 percent from current operating costs.¹¹

Finding Value In Fecal Sludge

Stabilized fecal sludge from the Cambérène WWTP and FSTP is sold in two forms after being treated in drying

FIGURE 3. Biogas and Electricity Generation at the Cambérène WWTP

Cambérène WWTP



Source: Incatema Consulting and Engineering.

beds: as an amendment for green spaces, such as the field of the Diambar football club, and as fertilizer for farmers and flower growers. Sludge from the WWTP is managed by ONAS; that from the FSTP by DELVIC, now renamed DVD. The delegation to DVD of operation and management of the FSTP is designed to improve services along the sanitation chain and to expand the possibilities for reuse, thus making the subsector more cost effective. The delegation contract explicitly requires the commercialization of dried sludge if the operator is to increase its profit margin.

Other activities where ONAS has successfully engaged the private sector along the sanitation service chain include the development of a menu of on-site sanitation options to ensure access to pits and the proper use of toilets, support for an association of licensed emptiers, a call center to better distribute the work of emptying pits, and the bagging of treated dried sludge for sale.

Financial and Contractual Arrangements

The cost of the Cambérène wastewater reuse project to pipe treated wastewater from the Cambérène plant to the Pikine and Patte d’Oie market gardening areas was CFAF 1,126 million in 2009 (USD 2.05 million), which included pumping stations, pipes, storage basins, irrigation networks, removal of existing networks, and project supervision. The project was financed by the Nordic Development Fund. An initial rehabilitation of the WWTP in 2008 had focused on piping treated

wastewater directly to the nearby golf course and selling the rest at the discharge point to consortia and private companies responsible for roads and green spaces. That activity produced revenues of CFAF 4 million (USD 7,500) in the first year of operation from sales of 2,800 m³/day of purified water, of which 500 m³/day were supplied directly to the Golf du Technopôle. Today, following the second rehabilitation, treated wastewater from the Cambérène WWTP is sold to private companies at the discharge point at a rate of CFAF 200/m³ (USD 0.36/m³) or piped to market gardeners operating close to the WWTP at CFAF 50/m³ (USD 0.1/m³). This price is aligned with their ability to pay but does not cover production costs; for comparison, the average price for drinking water is CFAF 550/m³ (USD 1/m³). A reevaluation of the pricing is underway by ONAS, with a view to maximizing revenues from reuse.

Expansion of the WWTP’s capacity and of the cogeneration plant are being financed by a loan of CFAF 1.8 billion (USD 3.3 million) from the Islamic Development Bank. Cogeneration will yield savings on energy costs of CFAF 400 million per year (more than USD 720,000). This means that the investment in expansion of the cogeneration plan should be recovered in less than five years.

As mentioned, ONAS and DELVIC (now DVD) signed an *affermage* contract in 2012 to operate and maintain the FSTPs at Cambérène, Rufisque, and Niayes. The contract was renewed and extended to operate new FSTPs in 2019 for 10 years. Under the contracts, the private

FIGURE 4. Examples of Reuse Along The Sanitation Chain



Source: Dr Mbaye Mbeguere. 2014. Réutilisation et valorisation des eaux usées et boues de vidange traitées par l’ONAS. Présentation. 5^{ème} semaine de l’eau à Dakar.

operator assumes management and operation risks, collects fees from users, and pays ONAS a fee to compensate it for the use of the premises and the equipment placed at the operator’s disposal. Capital costs at the FSTPs are borne by ONAS. The private operator may make capital improvements over the life of the contract but must hand over any new assets to ONAS upon expiration. Reuse is a key part of the contract; the FSTP operators ensure the quality of products²² and engage potential customers.

Stabilized sludge from the FSTP is sold as fertilizer at CFAF 500/kg or CFAF 450,000/ton (USD 0.90/kg or USD 815/ton) and, although the activity is not in deficit, the profitability threshold has not yet been reached. Under the delegation contract, the private operator keeps revenues from the sale of stabilized sludge and is incentivized to maximize its profit margins. However, negotiations are underway to modify the contract and transfer part of the remuneration back to ONAS.

ONAS had also entered into a short-term contract with ERIC, another third party, for bagging and distributing stabilized sludge, but this arrangement ceased before the COVID-19 pandemic set in. The marketing of sludge from the Cambérène WWTP is currently handled by ONAS; all associated revenues are kept by ONAS.

Benefits

Economic	Environmental and social
<p>For ONAS</p> <ul style="list-style-type: none"> • Additional revenue streams from wastewater and biosolids sales • Lower energy costs at the treatment plant • Greater financial sustainability • Better efficiency through the delegation of services <p>For local farmers:</p> <ul style="list-style-type: none"> • Provision of a cheaper water source to garden marketers near Dakar • Affordable soil amendment for local growers 	<p>The region benefits from less pollution of aquifers through improved wastewater treatment and reuse; reduced greenhouse gas emissions linked to the use of biogas, which is a renewable source; and less reliance on chemical fertilizers.</p>

Lessons Learned

Working along the entire sanitation service chain delivers products of better quality and promotes successful

reuse. ONAS’ role in overseeing and ensuring sanitation services at all stages of the sanitation service chain is a key success factor in controlling the quality of products entering the treatment stage, promoting the reuse of sanitation products, and cross-subsidizing different service functions. Circular economy principles feature in the increased efficiency brought by private sector involvement, the focus on customer-oriented solutions and inclusion, and the use of technology to ensure accessibility and service quality.

Having the right enabling environment and an institutional champion willing to think outside the box are crucial element to the success of reuse projects. In Senegal, the existing regulatory framework, the impetus from national development policies, and the vision and leadership provided by ONAS all contribute to creating space for testing reuse applications and rolling them out at scale. The national government has encouraged ONAS and other sector actors to seek efficiencies and innovations, more recently working with the World Bank to develop a water security strategy centered on circular economy approaches. The national sanitation code provides the foundations for streamlining wastewater reuse and is being complemented with relevant regulation on reuse of fecal sludge. Finally, ONAS has played an important leadership role by having reuse as part of its mission and by leveraging successful experiences with the private sector to enhance service provision along the entire service chain, in line with circular economy principles.

A holistic approach to planning the infrastructure needed to support wastewater reuse must look beyond WWTPs. Despite recent efforts, the development of wastewater reuse remains constrained by the lack of upstream planning related to the sizing, location, and construction of WWTPs and associated infrastructure. For purified wastewater to be usable in agriculture, its transfer to the places of use (fields) must be considered, but those seemingly obvious considerations are often excluded from project design decisions. As small farmers often

cannot bear the costs of transporting treated wastewater after the fact, this oversight has seriously limited reuse potential in Senegal to date. ONAS is now making such considerations a central element of WWTP planning and rehabilitations.

Stakeholder engagement is crucial to ensure the successful adoption and use of sanitation by-products. The steering committee model, typical of projects in Senegal, lends itself well to the identification and participation of stakeholders to ensure an open dialogue upstream of and during the implementation of reuse projects. In the case of the projects presented here, which could have faced a mixed reception owing to poor public perceptions of reuse, the steering committees played a key role in developing and ensuring public acceptance early on and in establishing a value chain and market for the products.

Reuse is a compelling entry point in the dialogue over broader circular economy and water security for Greater Dakar. Greater Dakar faces significant water security challenges linked to a growing water deficit, unplanned urbanization, overdependence on a few water sources (notably long-distance water transfers from transboundary basins), and a lack of coordination among stakeholders in several sectors. As the area is at the center of the country's development plan—in terms of planning, infrastructure projects, and contribution to the economy—the government of Senegal has expressed growing interest in capitalizing on ONAS's experiences with reuse to further diversify the water source portfolio of the metropolis and hedge against future risks to their supplies, through increased wastewater reuse and managed aquifer recharge. Other circular economy principles at the heart of Senegal's approach to urban water security include refocusing urban centers as users within the basin, closing the resource cycle through efficiency gains, providing resilient water-related services, and regenerating natural systems.

Notes

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2. Agence Nationale de la Statistique et de la Démographie (ANSD). Projections 2020. <https://satisfaction.ansd.sn/> Sum of Dakar and Thiès populations.
3. Greater Dakar encompasses the Dakar and Thiès regions.
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7. The program also funded the development of a model contract for “delegation of public services for management and operation of wastewater treatment plants to private firms.”
8. Law 2008-59 of September 24, 2008, on the organization of public services for drinking water and community sanitation of household wastewater. <http://www.jo.gouv.sn/spip.php?article7345>
9. *Affermage* refers to a contract under which the operator leases infrastructure and equipment from the government for an agreed period. The government usually retains responsibility for investment, while operational risks are transferred to the operator.
10. Senegal Government. 2014. Plan for an Emerging Senegal.
11. Aidara, C. 2019. « Emissaire de Cambérène : ONAS sensibilise les populations sur le projet. » Seneweb.
12. Quality analysis (physicochemical) is carried out onsite for incoming sludge, leachate and supernatants from treatment as well as dried sludge produced, and shared with ONAS and the management committee as part of periodic reporting and oversight. The management committee consists of the client services director of ONAS, representatives from relevant Government services and local government, and representatives from the emptiers' association and consumers' association.

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