From Waste to Resource

Shifting paradigms for smarter wastewater interventions in Latin America and the Caribbean

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Executive summary

Population and economic growth have driven a rapid rise in demand for water resources, and already 36 percent of the world's population lives in water-scarce regions. In particular, rapid urbanization, especially in low- and middle-income countries, has created various water-related challenges. These include degraded water quality and inadequate water supply and sanitation infrastructure, particularly in expanding peri-urban and informal settlements. In Latin America and the Caribbean, only about 60 percent of the population is connected to a sewage system and only about 30–40 percent of the region's wastewater that is collected is treated. These percentages are surprising, given the region's levels of income and urbanization, and have significant implications for public health, environmental sustainability, and social equity.

The Sustainable Development Goals (SDGs) are adding a new dimension to the challenges faced in the water supply and sanitation sector, by focusing on sustainability. Associated targets include improving water quality, implementing integrated water resource management, achieving water use efficiency across sectors, reducing the number of people suffering from water scarcity, and restoring water-related ecosystems. If the Latin America and the Caribbean region is to achieve the SDGs, the region's governments will need to significantly increase levels of wastewater treatment.

The investment needs in the water supply and sanitation sector are very large, and to improve the wastewater situation in the region, countries are embarking on massive programs to collect and treat wastewater. As cities continue to grow, there is an opportunity to ensure that investments are made in the most sustainable and efficient way possible. Future urban development requires approaches that minimize resource consumption and focus on resource recovery, following principles of the so-called circular economy. In this context, wastewater is and should be considered a valuable resource from which energy and nutrients can be extracted, as well as an additional source of water.

This report summarizes the work of the World Bank's initiative "Wastewater: from Waste to Resource," launched in 2018 to raise awareness among decision makers regarding the potential of wastewater as a resource. The report highlights the findings and conclusions from six technical background papers and from an in-depth analysis of several case studies. The case studies illustrate international best practices and provide examples of projects and programs that promote the implementation of one or several circular economy principles. The initiative involved a participatory process, including multiple consultations and workshops with key stakeholders working on wastewater management projects in the Latin America and the Caribbean region. A key regional workshop was organized in Buenos Aires, Argentina in November 2018 together with CAF, where counterparts from Argentina, Bolivia, Brazil, Colombia, the Dominican Republic, Ecuador, Honduras, Paraguay, Peru, and Uruguay participated. The initiative's findings have also been presented at several international conferences, raising awareness of the issue and promoting dialogue among governments, international organizations, and the private sector. Feedback from these events and from the workshops enabled the team to shape the main messages of the initiative into more practical recommendations.

The purpose of this report is to share the knowledge created and the conclusions from the initiative with stakeholders and practitioners involved in wastewater planning, financing, and management (including water utilities, policy makers, basin organizations, and ministries of planning and finance) to encourage a paradigm shift in which the value proposition of wastewater in a circular economy is recognized.

Wastewater can be treated to various qualities to satisfy demand from different sectors, including industry and agriculture. It can be used to maintain the environmental flow, and can even be reused as drinking water. Wastewater treatment for reuse is one solution to the world's water scarcity problem, freeing scarce freshwater resources for other uses, or for preservation. In addition, by-products of wastewater treatment can become valuable for agriculture and energy generation, making wastewater treatment plants more environmentally and financially sustainable. Therefore, improved wastewater management offers a double value proposition if, in addition to the environmental and health benefits of wastewater treatment, financial returns can cover operation and maintenance costs partially or fully. Resource recovery from wastewater facilities in the form of energy, reusable water, biosolids, and other resources, such as nutrients, represents an economic and financial benefit that contributes to the sustainability of water supply and sanitation systems and the water utilities operating them. One of the key advantages of adopting circular economy principles in wastewater management is that resource recovery and reuse could transform sanitation from a costly service to one that is self-sustaining and adds value to the economy.

To achieve this paradigm shift, four key actions have been identified:

1 ***Develop wastewater initiatives as part of a basin planning framework to maximize benefits, improve efficiency and resource allocation, and engage stakeholders.*** There is the need to move from ad hoc and isolated wastewater solutions, such as one treatment plant per municipality, to fully integrated river basin planning approaches that yield more sustainable and resilient systems. By planning and analyzing water quality and quantity at the basin level, integrated solutions that are more financially, socially, economically, and environmentally sustainable become possible. Basin planning allows for the optimal deployment of facilities and sanitation programs, including the location, timing, and phasing of treatment infrastructure. It also enables decision makers to set priorities for investment planning and action. The basin planning framework also allows for more efficient investments by designing effluent standards based on the specific contexts of particular water bodies and ecosystems, instead of uniform or arbitrary water pollution control standards. Moreover, by including wastewater in the hydrological system as a potential water source, it is possible to account and plan for wastewater reuse, limiting incidental and unplanned water reuse that can have negative health and environmental consequences. This approach is explored in chapter 2.

2 ***Build the utility of the future by shifting away from wastewater treatment plants to water resource recovery facilities, thus realizing wastewater's value.*** Traditionally, treatment focused on removing contaminants and pathogens to recover water and safely discharge it into the environment. Today, treatment plants should be viewed as water resource recovery facilities that recover elements of the wastewater for beneficial purposes: water (for agriculture, the environment, industry, and even human consumption), nutrients (nitrogen and phosphorus), and energy. These resources can generate revenue streams for the utility, which would potentially transform the sanitation sector from a heavily subsidized one to one that generates revenue and is self-sustainable. To move toward the ideal utility of the future, facilities must first be properly run. Second, they must be designed, planned, managed, and operated effectively and efficiently. Finally, countries need to recognize the real value of wastewater and the potential resources that can be extracted from it, incorporating resource recovery and circular economy principles in their strategies, investment planning, and infrastructure design moving forward. Infrastructure is a long-term investment that can lock countries into inefficient and unsustainable solutions. This highlights the importance of having resource recovery in mind when planning wastewater investments. This topic is explored in chapter 3.

3 ***Explore and support the development of innovative financing and sustainable businesses models in the sector.*** Financing sanitation infrastructure and recovering its costs is a challenge throughout the region. Many utilities do not collect sanitation tariffs that cover the costs of operation and maintenance, not to mention capital investment or future expansion. Hence, there is considerable agreement that more efficient subsidies are needed for sanitation, at least during a transition period. The existence of subsidies, however, does not mean that the sector must rely on conventional financing without taking advantage of market conditions and incentives to enhance sustainability. Given the potential for reuse and resource recovery in wastewater treatment plants, the sector should pursue innovative financial and business models that leverage those potential extra revenue streams. These new approaches are explored in chapter 4.

4 ***Implement the necessary policy, institutional, and regulatory (PIR) frameworks to promote the paradigm shift.*** For this paradigm shift to happen, PIR incentives are needed to encourage sustainable wastewater investments that consider reuse and resource recovery and that exploit circular economy principles. The case studies analyzed show that this kind of project usually unfolds in an ad hoc fashion and with no national or regional planning, with the enabling factors often being physical and local: water scarcity and distance to the nearest water source, among others. To enable the development of innovative projects, changes in the PIR environment and accurate valuation of water resources are also needed. Current basin planning efforts in the region need to be strengthened: governments need to support basin organizations so they can improve their technical expertise and exert oversight powers to enforce the implementation of planning instruments. Regulations and standards also need to be tailored to the needs of the region and the current trends in the sector, embracing and promoting gradual compliance and fostering reuse and resource recovery. Finally, countries in the region need to ensure they have the required institutional capacity to enforce environmental regulations such as water pollution control standards. PIR interventions are explored in chapter 5.

1. Wastewater as a resource in a circular economy

> *"In a world where demands for freshwater are continuously growing, and where limited water resources are increasingly stressed by over-abstraction, pollution and climate change, neglecting the opportunities arising from improved wastewater management is nothing less than unthinkable in the context of a circular economy."*
>
> ***UN World Water Development Report*** *(WWAP 2017)*

This report summarizes the work of the World Bank's initiative "Wastewater: From Waste to Resource" (World Bank 2018a). It contains the findings from several case studies and six technical background papers developed by the initiative as well as from the feedback received during workshops (World Bank Group and CAF 2018) and seminars with key stakeholders. The purpose of the report is to share the knowledge created in the course of the initiative with stakeholders involved in wastewater planning, financing, and management (including water utilities, policy makers, basin organizations, and ministries of planning and finance). Specifically, the initiative seeks to encourage a paradigm shift in which wastewater's potential to create value in a circular economy context is recognized. (The circular economy is explained in box 1.1)

1.1 A growing global challenge

Population and economic growth have driven a rapid rise in demand for water resources (WWAP 2015). As stated by the High-Level Panel on Water (HLPW 2018), 36 percent of the world's population already live in water-scarce regions, and by 2050 more than half the world's population will be at risk of water stress. Competing demands for water are adding pressure to the allocation of freshwater resources. Governments around the world face an array of water policy options for managing structural water scarcity, droughts, and floods; improving water quality; and protecting ecosystems and their services. Careful planning promotes long-term water security and resilience to climatic and nonclimatic uncertainties. Water, importantly, connects to wider policy goals of mitigating poverty and ensuring social equity, public health, and macroeconomic performance, among others.

Rapid urbanization, especially in low- and middle-income countries, has created a host of water-related challenges. These include degraded water quality and inadequate water and sanitation infrastructure, particularly in expanding peri-urban and informal settlements. As cities continue to grow rapidly, and climate change alters the availability and distribution of water resources, it will become increasingly difficult and energy intensive to meet the water demands of populations and economies. Combined, these problems present a challenge for policy makers and municipalities in providing services to their citizens; ensuring that there are enough resources such as food, water, and energy; and protecting public health—all while protecting the environment. In this context, wastewater becomes a valuable resource from which water, energy, and nutrients can be extracted to help meet the population demands for water, energy, and food (WWAP 2017).

Wastewater can be treated to various qualities to satisfy demand from different sectors, including industry and agriculture. It can be used to maintain the environmental flow, or even reused as drinking water. Wastewater treatment is one solution to the water scarcity issue, and also to the problem of water security, freeing water resources for other uses or for preservation. The diversification of water supply sources is critical for enhanced security and resilience, and wastewater should be considered as an additional source when estimating water balances. Meanwhile, the by-products of wastewater treatment can become valuable for agriculture and energy generation, making wastewater treatment plants more environmentally and financially sustainable. Treating wastewater as a valuable resource can thus contribute to a region's sanitation sector, as well as its major economic sectors.

1.2 The sanitation sector in Latin America and the Caribbean: A call for a new vision

Population and sanitation coverage

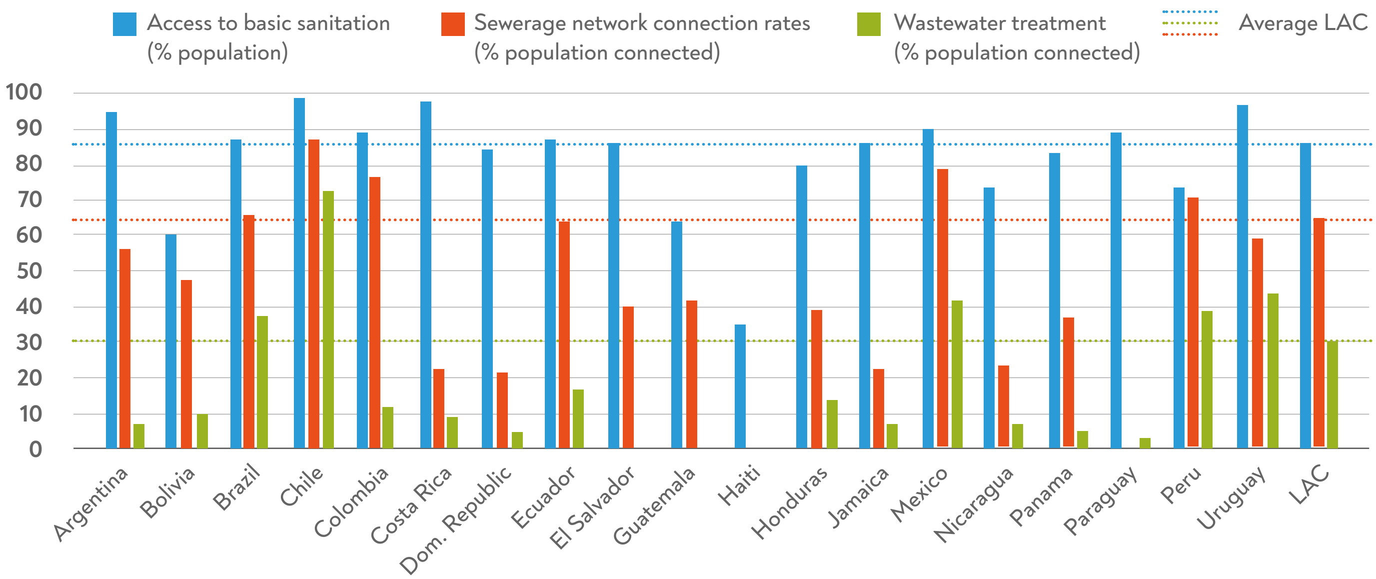
In 2017, the population of Latin America and the Caribbean region[1] reached 644 million people, 80 percent of whom lived in urban areas. Between 2012 and 2017, the population increased by around 34 million, or approximately 5.4 percent. During the same period, rural communities' population dropped by 1 percent (WDI 2019). According to *World Urbanization Prospects: The 2018 Revision* (UNDESA 2018), by 2030, the total population in the region will be 718 million, with an urban concentration of 84 percent.

Regarding access to water supply and sanitation, historically, countries in the region have prioritized investments in water supply, achieving good coverage in past years. According to data from 2017 (WHO and UNICEF, 2019), around 97 percent of households had access to an improved source of drinking water, although this average hides the gap between rural (88 percent) and urban (99 percent) coverage and does not reflect the sustainability and quality of the level of service. The share of the urban population with access to safely managed drinking water services was only 74 percent. About 87 percent of the region's population had access to some form of basic sanitation, with an important difference between rural (70 percent) and urban (91 percent) areas. However, only 31 percent had access to safely managed sanitation services.[2] Moreover, it is estimated that only about 66 percent of the population is connected to a sewage system (18 percent in rural and 77 percent in urban areas) and only about 30–40 percent of the region's wastewater that is collected is treated (FAO 2017). This value, however, does not reflect the quality of the discharged water or whether it complies with the regulation. The figure is surprisingly low, given the region's levels of income and urbanization, and has significant implications for public health, environmental sustainability, and social equity. In comparison, in the countries of the Organisation for Economic Co-operation and Development (OECD), 81 percent of the population is connected to a sewage system and 77 percent of people benefit from wastewater treatment by being connected to a wastewater treatment plant (WWTP) (OECD 2017). As shown in Figure 1.1, wastewater management and treatment levels vary significantly across the countries of the region, and regional averages mask this significant variation.

1 https://www.worldbank.org/en/region/lac

2 Improved sanitation facilities are those designed to hygienically separate excreta from human contact (excreta are safely disposed of *in situ* or transported and treated off-site) and that are not shared with other households.

Figure 1.1 Access to sanitation services in selected countries of Latin America and the Caribbean, 2017



Source: WHO and UNICEF 2019.
Note: LAC = average in Latin America and the Caribbean. Data for Argentina is from WHO and UNICEF 2017.

The potential for better investment

To reach universal coverage of basic and safely managed sanitation services by 2030, the region will have to reach a total of 307 million as-yet-unserved people.[3] Hutton and Varughese (2016) estimated that the level of investment in the region (excluding Chile, Uruguay, and most of the Caribbean countries) needed to meet the UN Sustainable Development Goals (SDGs) for sanitation ranged between $3.4 and $11.8 billion per year for the period 2016–30, of which approximately 95 percent would be devoted to urban areas. It is worth noting the challenge added by SDG target 6.3: “by 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.”

The investment needs in the sector are significant, and to improve the wastewater situation in the region, countries are indeed embarking on massive programs to collect and treat wastewater. There is a huge opportunity to ensure that these investments are made in the most sustainable and efficient way possible. As indicated by lessons learned in Latin America and the Caribbean and other regions, investment in technology alone will not guarantee meeting the SDGs. There is a need in the region to invest better. Efficiently investing in wastewater and other sanitation infrastructure to achieve public health benefits and environmental objectives, and to enhance the quality of urban life, is a major challenge. As stated by a recent World Bank report (2017) on infrastructure in Latin America: “dismal wastewater performance is a real emergency, and one that epitomizes the potential for spending better.” As described in this report, the revalorization of wastewater as part of a circular economy process can contribute to an improved investment efficiency.

Complementing the shift toward resource recovery in the sector, the World Bank and other partners are also promoting a broader change in the sector through the Citywide Inclusive Sanitation (CWIS) initiative, to move away from business-as-usual models and encourage cities to think about a diversity of technical solutions for the provision of

3 Approximately 233 million people who currently do not have access, plus 74 million additional people.

services along the entire sanitation service chain. The CWIS initiative advocates adaptive, mixed, and incremental approaches, combining on-site and sewerage solutions in either centralized or decentralized systems, and considering effective resource recovery and reuse, to allow all urban inhabitants to benefit from safely managed sanitation services.

Although this report focuses on centralized treatment solutions, it is important to recognize that decentralized sewage collection systems and the separation of different types of wastewater effluents are innovations that could lower the cost of sanitation services and improve sustainability. Given that most estimates show that half or more of the investments in the sector need to be made in sewerage infrastructure, an in-depth analysis of all infrastructure opportunities is also advised as part of any sanitation plan and/or strategy.

1.3 The opportunities presented by circular economy principles

Wastewater: An as-yet-untapped resource

The challenges mentioned above present an opportunity to plan and invest in sanitation services— in particular, wastewater treatment—in a new way. The long-standing, linear approach of abstracting freshwater from a surface or groundwater source, treating it, using it, collecting it, and disposing of it is no longer sustainable.

Future urban development requires approaches that minimize resource consumption and focus on resource recovery under circular economy principles (box 1.1). At its core, a circular economy aims to "design out" waste to achieve sustainability. Waste does not exist; products are designed and optimized for a cycle of disassembly and reuse. In line with this, wastewater should not be considered a "waste" anymore, but a resource.

Box 1.1 The principles of a circular economy

A circular economy is an industrial system that is restorative or regenerative by intention and design. It is an economic system aimed at minimizing waste and making the most of resources. The traditional approach is based on a linear economy with a "make, use, and dispose" model of production. The circular economy approach replaces the end-of-life concept with restoration, shifts toward the use of renewable energy, eliminates the use of toxic chemicals that impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems, and business models. Such an economy is based on three main principles: (i) design out waste and pollution, (ii) keep products and materials in use, and (iii) regenerate natural systems.

Sources: Ellen MacArthur Foundation n.d.; WEF 2014.

However, in most countries of the region, sanitation and wastewater treatment services are still thought out and planned in a linear way. Furthermore, very often water supply is planned first, sewerage systems are planned next, and energy inputs for both are sometimes considered only after the systems have been designed and constructed. In order to change how institutions approach wastewater, a paradigm shift is required in the region. Wastewater should not be seen as a burden to governments and society, but as an economic opportunity that can be turned into a valuable resource (figure 1.2).

Improved wastewater management offers a double-value proposition: in addition to the

One of the key advantages of adopting circular economy principles in the processing of wastewater is that resource recovery and reuse could transform sanitation from a costly service to a self-sustaining and value-adding system.

environmental and health benefits of wastewater treatment, financial returns that partially or fully cover operation and maintenance (O&M) costs are possible. Resource recovery from these facilities in the form of energy, reusable water, biosolids, and other resources (such as nutrients and microplastics) represent an economic and financial benefit that contributes to the sustainability of these systems and the water utilities operating them.

As documented in this report, WWTPs can:

- Sell treated water for reuse to industry and potentially cover all O&M costs, as in the case of San Luis Potosí, Mexico (box 3.3); Durban, South Africa (box 4.3); and Aquapolo, Brazil (WWD 2011).
- Generate energy for self-consumption, save energy costs, or generate revenues by selling energy, as in the case of Atotonilco, Mexico (World Bank 2018c); Santiago, Chile (World Bank, 2019a); the East Bay Municipal Utility District, United States (box 3.4); and Ridgewood, United States (box 4.2).
- Dispose of biosolids at no cost, as in the case of Cusco, Peru (Background Paper VI); and Brasilia, Brazil (box 3.5).
- Sell recovered phosphorous for fertilizer, as in the case of Chicago, United States (ASCE 2013).
- Cover capital and operating costs completely, as in the case of Cerro Verde, Peru (box 4.4).

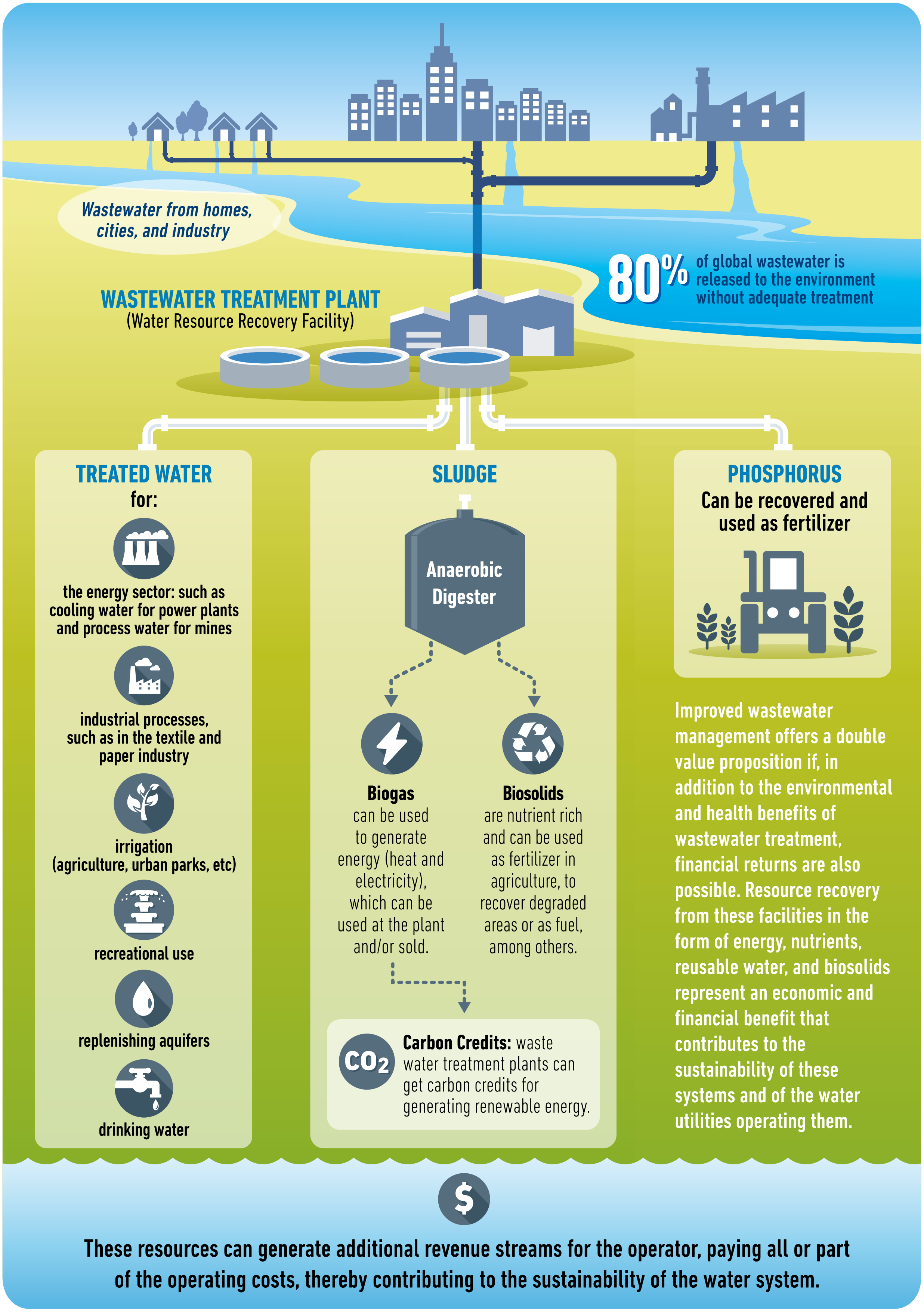
Cost-saving and environmental considerations are among the main reasons to consider resource recovery and to incorporate circular economy principles in WWTPs in Latin America and the Caribbean and elsewhere in the world. The challenge remains one of scaling up the successful experiences and projects.

Fostering these new business models with extra revenue streams would in turn attract the private sector to close the funding gap. The private sector is often reluctant to invest in the sanitation sector given the low return on investment and the high risks. There is a need for an enabling environment that fosters business models that promote shifting from waste to resource and enable private investment in infrastructure. The enabling environment should be created in tandem with improved efficiency in public financing to promote sustainable service delivery, especially in the poorest countries.

La Farfana, Santiago, Chile

Durban Water Recycling Plant, South Africa

Figure 1.2 Resource recovery in wastewater treatment plants



This new approach is also necessary to achieve the SDGs, which are adding a new dimension to the challenges in the sector through their emphasis on sustainability. The SDGs focus not only on the provision of sanitation services but also on improving water quality, implementing integrated water resource management, improving water use efficiency across sectors, reducing the number of people suffering from water scarcity, and restoring water-related ecosystems, among other relevant targets. Sustainable wastewater treatment and management will be crucial to achieve SDG 6, and can also contribute to the achievement of meeting several other goals. For example, electricity generation in WWTPs, using the biogas produced, can contribute to the achievement of SDG 7 (on energy) and SDG 13 (climate action). Treating wastewater and restoring watersheds also contributes to SDG 3 (good health and well-being), SDG 11 (sustainable cities), and SDG 14 (life below water), among others.

Resource recovery is not new: Why hasn't this approach caught on in the region?

Numerous challenges—institutional, economic, regulatory, social, and technological—will need to be overcome to achieve the needed paradigm shift, outlined as follows.

Institutional challenges

A knowledge gap and a lack of political will uphold the status quo. There is a general lack of understanding regarding the concept of water resource recovery and how to implement it in practice. Wastewater is still considered a hindrance or a substance to be dealt with and disposed of, rather than a resource. This results in a lack of political will to develop policies and regulations that support and incentivize wastewater reuse and resource recovery.

There is a lack of coordination across institutions, legislatures, and sectors. In most countries in the region, regulations in the water sector are not aligned with the energy, health, industrial (including mining), and agricultural sectors, thus limiting resource recovery and reuse from wastewater (energy, irrigation water, nutrients, preservation, etc.). Moreover, responsibilities for the provision of wastewater services are often fragmented across various levels of governments. The national government sets policies and targets, while service provision, including investment, O&M, and monitoring, is usually delegated to municipal governments, which in many cases lack the technical and financial capacities to adequately provide services (Trémolet 2011). There is also a lack of coordination between water resource management institutions and those responsible for sanitation service delivery. As a result, sanitation plans are usually not incorporated in river basin planning efforts, leading to inefficient and costly systems.

Economic challenges

Water is undervalued. Unless water resources are properly valued (HLPW 2018), it will be difficult to promote resource recovery initiatives. The inadequate valuation of water also leads to improper pricing of water resources and water services, which deters resource recovery projects. For example, if industries pay a very low fee to withdraw freshwater, they have limited incentives to pay for treated wastewater unless there is a significant short-term water shortage or long-term water scarcity.

There is excessive emphasis on promoting and financing new infrastructure, without sufficiently considering the life cycle of a plant or the sustainability of the system (e.g., coverage of O&M costs) and without evaluating the real capacity of existing infrastructure and maximizing its use.

WWTPs rely on conventional (i.e., public) financing without taking advantage of market conditions and incentives to enhance sustainability. There is a need for innovative financing mechanisms that can encourage the development of and investment in wastewater systems to promote the sustainability of operations and the health of local ecosystems.

Regulatory challenges

Current regulatory standards are often too restrictive and/or inconsistent. Countries adopt internationally accepted regulatory standards for water quality that are not tailored to their specific needs. Often regulations are designed without considering the financial implications of their implementation (especially their operational costs). More flexible standards that can be introduced gradually and that are suited to the objective of wastewater investment will encourage innovative solutions needed to provide wastewater services as well as create value from water reuse and resource recovery.

Control over industrial discharge is inadequate. Inadequate legislation, enforcement, regulation, and monitoring of industrial discharge mean that excessive pollutants are released untreated into the environment or left to an already overburdened WWTP. Where untreated industrial discharge is released directly into receiving water bodies, water quality deteriorates, with numerous economic, social, and environmental implications. Where the effluents are left to the WWTP, customers end up paying through tariffs for industrial treatment.

There is a near total absence of regulatory frameworks and guidelines for water reuse, beneficial use of biosolids, and energy generation in WWTPs. In Latin America and the Caribbean, various regulations limit or forbid resource recovery at WWTPs. For instance, in some countries, the reuse of wastewater is permitted only for a limited set of activities, such as restricted irrigation. In others, the use of biosolids is forbidden in the agriculture sector. Clear regulations and guidelines are needed to ensure the safe use of human-waste-derived products and to widen their market potential. Moreover, a lack of regulation of the pricing of resources recovered from wastewater deters utilities and the private sector from investing in resource recovery projects owing to uncertainty about the return on their investment. The clear and fair pricing of reclaimed water, biosolids, and energy would foster much-needed innovation and investment.

Incentives for wastewater reuse and resource recovery are absent or insufficient. There is a need for new regulatory mechanisms that specifically provide incentives to all stakeholders to consider wastewater systems as resource recovery facilities. Today, in many countries, the benefits and extra revenue reaped from recovery interventions go only toward tariff reduction. The existence of perverse incentives such as the low price of freshwater abstraction is also a barrier to resource recovery initiatives.

Social challenges

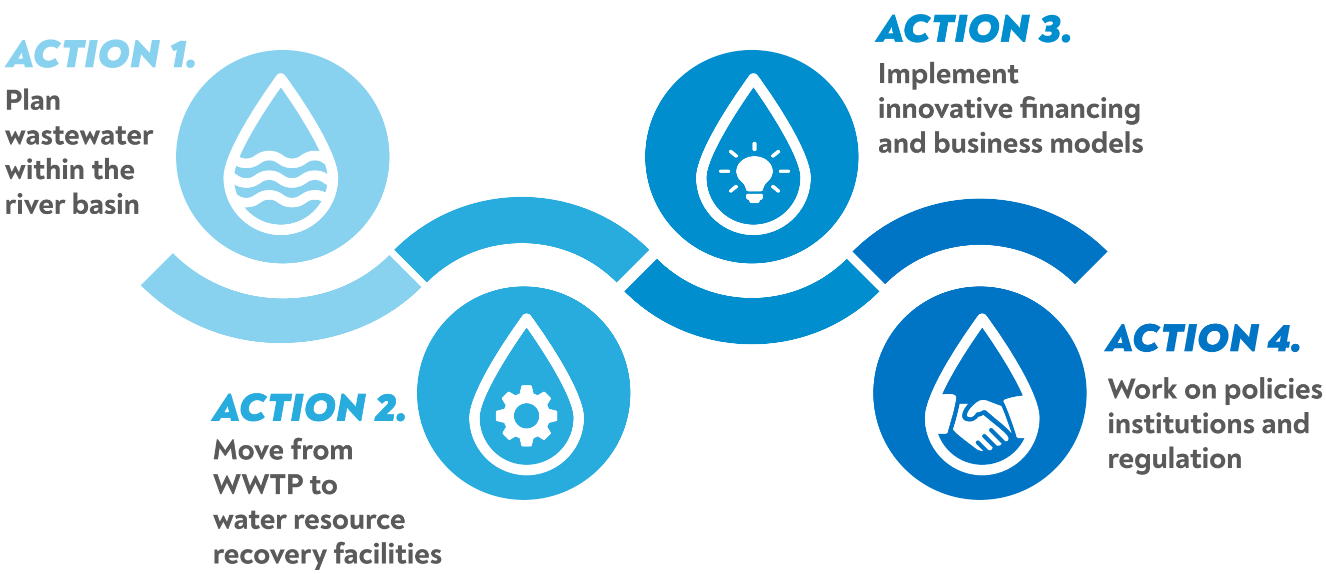
Negative perceptions of reclaimed water and reuse products have not been adequately countered. A major challenge to the development of the resource recovery market is the low social acceptance of the use of products made from recycled human waste. Also, among farmers already using untreated wastewater, many are against treating it because they believe that wastewater nutrients will be removed and that their crop yield will diminish. Public awareness and education campaigns are needed to build trust and change negative perceptions.

Technological challenges

Technology selection criteria are biased toward expensive technologies without considering which possibilities best suit local conditions. A challenge related to this point in some countries is a lack of engineers and planners with knowledge of different wastewater treatment and resource recovery technologies.

What must be done to overcome these challenges and achieve the needed paradigm shift?

In order to achieve a paradigm shift in the sector, and based on the case studies analyzed and the lessons learned in the region, **four key actions have been identified**. First, at the country or regional level, wastewater initiatives need to be planned within a river basin framework to ensure that the most cost-optimal and sustainable solution is achieved. Then, at the project level, WWTPs need to be operated in an efficient and effective way, considering resource recovery opportunities. This will make it possible to explore innovative financing and business models that leverage circular economy principles. Simultaneously, countries need to develop the right policy, institutional, regulatory frameworks to promote the paradigm shift.



ACTION 1.

Develop wastewater initiatives as part of a basin planning framework to maximize benefits, improve efficiency and resource allocation, and engage stakeholders

There is the need to move from ad hoc and isolated wastewater solutions, such as one treatment plant per municipality, to integrated river basin planning approaches that yield more sustainable and resilient systems. Basin planning offers a coordinating framework for water resources management that focuses public and private sector efforts to address the highest-priority problems within hydrologically defined geographic areas, taking into consideration all sources of water. By planning and analyzing water quality and quantity at the basin level, integrated solutions that are more financially, socially, economically, and environmentally sustainable are possible. Basin planning makes it possible to identify the optimal deployment of facilities and sanitation programs, including the location, timing, and phasing of treatment infrastructure. It also enables decision makers to set priorities for investment planning and action. The basin planning framework also permits effluent standards to be designed to improve a specific receiving water body instead of uniform or arbitrary water pollution control standards, allowing for more efficient investments. Basin planning is, therefore, an iterative process that allows decision makers to move from the traditional reactive approach to a serious environmental problem to a proactive approach of managing available resources in a given basin through a structured, gradual process. Moreover, by including wastewater in the hydrological system as a potential water source, it is possible to account and plan for wastewater reuse. This shift must be reflected in the water policy framework. The approach is explored in chapter 2.

ACTION 2.

Build the utility of the future: Move from the concept of WWTPs to one of water resource recovery facilities, realizing wastewater's value

The practice of wastewater treatment continues to evolve, not only technologically but functionally as well. Traditionally, treatment was focused on removing contaminants and pathogens from water before discharging it safely into the environment. A decision to turn a wastewater treatment plant into a water resource recovery facility (NSF, DOE, and EPA 2015) reflects the realization that many components of wastewater can be recovered for beneficial purposes: water (for agriculture, the environment, industry, and even human consumption), nutrients (nitrogen and phosphorus) and energy. These resources can generate revenue streams for the utility that would potentially transform the sanitation sector from a heavily subsidized one to one that generates revenues and is self-sustaining. To move toward the ideal utility of the future, utilities must first be properly run and perform adequately. Second, treatment facilities must be designed, planned, managed, and operated effectively and efficiently, taking the basin as the unit of analysis. Finally, countries need to recognize the real value of wastewater and the potential resources that can be extracted from it, incorporating resource recovery and circular economy principles in their strategies, investment planning, and infrastructure design. Infrastructure is a long-term investment that can lock countries into inefficient and unsustainable solutions. This highlights the importance of having resource recovery in mind when planning wastewater investments. This topic is explored in chapter 3.

ACTION 3.

Explore and support the development of innovative financing and sustainable business models in the sector

Financing sanitation infrastructure and recovering associated costs are challenges throughout the region. Many utilities do not collect adequate sanitation tariffs to cover the costs of O&M, not to mention capital investment or future expansion. Hence, there is considerable agreement that more efficient subsidies are needed for sanitation, at least during a transition period. The existence of subsidies, however, does not mean that the sector has to rely on conventional financing without taking advantage of market conditions and incentives to enhance sustainability. Given the potential for reuse and resource recovery in WWTPs, the sector should pursue innovative financial and business models that leverage new revenue streams. These approaches are explored in chapter 4.

ACTION 4.

Implement the necessary policy, institutional, and regulatory frameworks to promote the paradigm shift

Finally, for this paradigm shift to happen, policy, institutional, and regulatory (PIR) incentives are needed to encourage sustainable wastewater investments that promote circular economy principles. The case studies analyzed show that such projects are usually developed in an ad hoc fashion and with no national or regional planning, with the enabling factors often being physical and local: water scarcity, distance to the nearest water source, and so on. To enable the development of innovative projects at scale, changes in the PIR environment and proper valuation of water resources are also needed. Wastewater treatment technologies for reuse and resource recovery have been progressing much faster than the enabling environment. Weak policy and governmental systems are among the key constraints to utilizing technologies for reuse and resource recovery. Basin planning efforts in the region also need to be strengthened: governments need to support basin organizations so they can improve their technical expertise and exert oversight powers to enforce the implementation of planning instruments. Additionally, the interventions prioritized in basin plans should be aligned with municipal and regional priorities. Regulations and standards also need to be tailored to the needs of the region and the current trends in the sector. The vast majority of legislation in Latin America and the Caribbean was created for the sole purpose of meeting environmental standards. Most of the region's laws and regulations are copycats of instruments from Europe and/or the United States, which have very different capacities and financial means. However, the changes in the sector call for new legislation and regulation that embrace and promote gradual compliance, are flexible, and foster reuse and resource recovery. Finally, countries in the region need to ensure they have the required institutional capacity to enforce environmental regulations such as water pollution control standards. PIR interventions are explored in chapter 5.

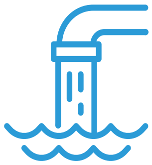
2. Repurposing a traditional water resources management tool for the sanitation sector

River basin planning has been traditionally known by water resources management practitioners as a tool to regulate water use, allocate water resources, and increase the efficiency of basin-level interventions. This approach, also promoted as a part of the Integrated Urban Water Management Framework, characterizes existing conditions, identifies and prioritizes problems, defines management objectives, develops protection or restoration strategies, and implements selected actions. The guiding principles of the river basin planning approach are: (i) multisector stakeholder partnerships, (ii) a focus on the basin as the basic planning unit, and (iii) coordinated multidisciplinary science-based actions.

Despite the widespread use and holistic perspective of river basin planning, it is rarely used in the planning and design of sanitation projects and particularly wastewater treatment plants (WWTPs). Some of the case studies presented in this report, such as the Rio Bogotá cleanup project (see Background Paper II [World Bank 2019b]), demonstrate how the use of a river basin approach helps to reduce investments by distributing the responsibility for water quality improvement among different interventions and stakeholders.

2.1 Why do we need river basin planning?

Considering an entire river basin can help planners understand different water quality stressors and how they interact in the basin, and can lead to smarter project designs. Impairment of a water body is a result of pollution from various land uses and wastewater discharges that drain into it. Pollution can come from point sources (e.g., from WWTPs, industrial plants, storm water outfalls, sewer overflows, agricultural drains, etc.) and nonpoint sources (e.g, illegal dumping and litter, fertilizers and pesticides, agricultural runoff, oil and gas from vehicles, etc.). These various pollution sources exert a cumulative effect on the receiving water bodies, depending on pollutant



Wastewater needs to be part of the water balance in basin planning, given its potential as a resource, especially in water-scarce areas.

types, loads, timing, and discharge locations in the basin; therefore, their collective impact must be evaluated when planning wastewater treatment investments. Understanding these cumulative effects at the basin level and their interactions can lead to solutions that target distinct pollution sources, reducing the burden on WWTPs and thus resulting in cost efficiencies and greater environmental benefits. River basin planning allows for better treatment processes to be designed as it considers the upstream characteristics of the river basin (existing pollution sources and hydrology) and the characteristics of the downstream users and the receiving water body. The river basin approach can also inform the adaptation of effluent standards to the specifics of a receiving body.

Box 2.1 Using a river basin approach to plan wastewater treatment and reduce investment needs: Guayaquil, Ecuador

The municipality of Guayaquil, Ecuador, has promoted the creation of a water fund (Fondo de Agua) to clean and preserve the Daule River Basin (Santos 2018). Its action plan includes monitoring and control of water quality, treatment of wastewater, erosion and sediment control, and reforestation, among other actions. The municipality has also developed an integrated plan for wastewater management (Santos 2018) that includes a hydrological modelling of the receiving water body (Daule Basin) to understand its characteristics and assess the needed level of treatment to meet existing regulations. The modelling showed that the treatment level needed in the planned wastewater treatment plants was lower than initially estimated since the water body had a higher absorption capacity than had been accounted for. This resulted in more efficient and effective investment.

The coordination of multisectoral, public, and private interventions in a basin maximizes their combined impacts on water quality. Multistakeholder platforms are essential for the development and implementation of a river basin plan. Usually structured around river basin councils or similar institutional bodies, these platforms aim at building consensus among competing needs and defining common goals for a basin. The partnership building effort aims at reaching all stakeholders in a basin: that is, in principle, anyone who directly or indirectly benefits from a basin's resources and those who contribute to water pollution. Through a holistic assessment, this process promotes the identification of coordinated multisectoral investments, from both public and private sources, that aim at achieving a common vision for the basin in terms of water quantity and quality. As a result, project overlaps are avoided, and higher efficiencies are achieved by taking advantage of project complementarity.

This basin planning process can facilitate the identification of reuse and resource recovery opportunities for WWTPs. Through a basin planning framework, treated wastewater can be included as part of the basin's water balance. Offtakers for treated wastewater can be identified, and its use promoted. A participatory process can bring in other entities (i.e., biogas, electricity, and biosolid clients) that would benefit from the development of a resource recovery facility (see chapter 3) within the basin. This fosters synergies across sectors and promotes the development of projects that bring in key offtakers (e.g., in energy and agriculture) from the beginning (i.e., design and conceptualization).

Stakeholders' platforms developed as part of the river basin planning process have been seen to reduce conflicts at the basin level, streamlining the implementation of interventions. River basin councils act as neutral fora where basin-related initiatives, including infrastructure projects, can be discussed and negotiated. In this space, project beneficiaries and affected groups can have a voice and influence project design. This process not only improves design but also facilitates smoother implementation.

As described in the next section, basin planning is an iterative process that allows the application of adaptive management in the face of climate change impacts. Basin plans can be revised to account for changes in climatic variables, which can avoid overly conservative investments that cannot be justified given the level of uncertainty typically surrounding climate change predictions.

2.2 The process of river basin planning

Despite variations in planning methodologies around the world, the basin planning process is generally conceived as a cycle with seven main stages. The outcomes of this process are documented in a basin plan that summarizes the analyses, stakeholders, actions, schedules, and resources needed to develop and implement the plan. As the plan is implemented, new data and lessons learned are used to revise and adapt the plan. The seven stages of the planning process are outlined below. Further details can be found in Background Paper II, which showcases the river basin planning process through a concrete example: The Río Bogotá cleanup project (World Bank 2019b).

Stage 1: Build partnerships. This is the most important component of the basin planning process. Failure to include essential partners often leaves plans to collapse due to a lack of ownership of their implementation. The lead government agency in charge of the basin planning process must institute a robust governance structure that allows stakeholders' participation in the planning process and clearly establishes their duties.

Stage 2: Characterize the basin. The purpose of this step is to understand the problems in a basin and identify their potential causes. Multiple data sources are used for this purpose. The data that support a basin plan tend to draw from several sources of varying age and resolution. In the absence of reliable local data, global data and remote sensing can be important. Models, too, are fundamental tools to further understanding of a system. Background Paper III (World Bank 2019c) provides an overview of the main types of models used in basinwide water quality assessments, and their data requirements.

Box 2.2 Using river basin planning to find low-cost solutions for controlling pollution: Kentucky, United States

The basin planning process identified a range of potential pollution controls, covering both green infrastructure (e.g., stormwater management) and conventional infrastructure (e.g., sewer system improvements). Models were used to define the costs and resulting water quality associated with various combinations of controls. The results of this assessment were used to prioritize which controls to implement.

Model results demonstrated that an integrated solution combining watershed controls with infrastructure improvements provided more water quality benefits at a lower cost than a traditional solution based solely on infrastructure controls. The approach was used to guide expenditures so that money would be spent first on controls that resulted in cost-effective improvements.

Source: LimnoTech 2018.

Stage 3: Define management goals. The next step is to define the desired conditions expected from the execution of a basin management plan. These management goals correspond to the desired uses for the basin, which will require specific targets of water quantity and quality. Once these targets are defined, the next step is to determine the load reductions that will be necessary to meet the targets. Modeling tools can help to make this determination since they allow an understanding of the relationship between the sources of pollution, the pollutant loads, and the response from the receiving water bodies.

Stage 4: Formulate potential solutions. At this point, planners seek to identify engineering and nonengineering measures to accomplish the goals that were agreed among stakeholders. For sanitation programs, the engineering solutions generally consist of the installation of a sanitary sewer collection system and deployment of one or more WWTPs. Nonengineering measures may include on-farm controls for agricultural runoff, closure and relocation of pollutant activities, public education, improvements in solid waste collection, etc. A well-designed basin plan should include both types of measures and formulate control solutions for all significant sources of pollution beyond untreated wastewater.

Stage 5: Develop the basin plan. At this point, several alternatives, represented as ensembles of solutions, have been identified to meet the goals for the basin. Now planners seek to choose the "best" of those alternatives using technical and nontechnical criteria. The selected alternative becomes the basis for the basin management plan, and cost estimates, scheduling, financing plans, and institutional arrangements are set.

Stage 6: Implement the basin plan. Implementation of the basin plan entails the execution of all related projects. To implement these complementary multidisciplinary solutions, strong governance, clear accountability, sufficient resources, and an appropriate level of authority are required. Operation and maintenance (O&M) of the individual projects are also part of the implementation plan. Often, long-term operation is seen as an activity separate from planning because O&M is conducted by disparate agencies. But proper and adequately funded O&M is essential to the success of the basin plan as it maintains the intended functions of the infrastructure installed.

Stage 7: Monitoring and evaluation (M&E). An effective M&E program is vital to track progress over the long term. In urban environments, it is possible that early indicators show some deterioration before the situation improves, reflecting ongoing population growth even as projects in the basin plan begin to come online. Solutions to basin problems need to be seen as intergenerational, although it is always possible to make quick progress in high-value activities. The most valuable function of the M&E program is that it allows learning from implementation, which in turn enables adaptive management—that is, the ability to adjust the implementation plan according to lessons learned in the process (Hooper and Lant 2007).

The 7 steps of river basin planning

Box 2.3 Basin plan for the Bogota River, Colombia

A watershed management plan developed for Río Bogotá in Colombia focused not only on wastewater and sanitation but also on general water quality in the river, flood risks, and the supply of water for both potable and nonpotable uses. After a thorough inventory of current conditions, environmental, operational, and ecological goals were defined. With the help of sophisticated water quality, water supply, and flood-risk models, the plan laid out several management alternatives that were consolidated into a detailed investment schedule as well as a monitoring plan to evaluate progress toward the goals.

2.3 Key considerations in the implementation of river basin plans

Despite its many advantages, challenges still remain in the implementation of the basin-level planning: (i) budgets for government agencies are rarely linked to river basin plans and are usually targeted to independent, sector-specific interventions; (ii) the economic development benefits of a basin plan can be difficult to demonstrate as they usually take place over a long time and feature several nonmarket benefits; (iii) multistakeholder planning and public outreach can be difficult and resource intensive; (iv) stakeholder representation and decision-making power can be hard to balance; (v) enacted national legislation may not allow application of the watershed approach; (vi) coordination of all relevant government agencies may be difficult due to siloed functions and objectives and differing political interests; and (vii) in some cases there is a need to bring in new technical capacities for the development of the river basin approach.

Basin planning efforts in the region need to be strengthened. Governments need to support basin organizations, so they can improve their technical expertise and exert oversight powers to enforce the implementation of basin plans. The sanitation sector—as one of the key beneficiaries of river basin planning—needs to be present in basin organizations and active in promoting basin planning. Instead of fostering one WWTP per municipality, countries should assess the real needs of basins, and work to achieve a water quality standard consistent with the goals established at the basin level (e.g., accounting for the diluting capacity of a local river).

3. Shaping the utility of the future: From wastewater treatment plants to water resource recovery facilities

The utility of the future aims for efficient operation and full resource recovery with improved productivity and long-term sustainability. The utility of the future operates under circular economy principles (see box 1.1) and recognizes the real value of wastewater as a resource: it aims to be net energy neutral or even energy producing, implements beneficial use of biosolids, and reuses water. Ideally, all these elements provide an extra revenue stream or help cover operation and maintenance (O&M) costs, making the utility more environmentally and financially sustainable. Therefore, the utility of the future does not operate wastewater treatment plants (WWTPs) but water resource recovery facilities (WRRFs). The utility of the future also manages its infrastructure efficiently, while protecting the environment and the health of the population.

The first condition is to be well run. Wastewater treatment and sanitation projects are designed to provide service for decades. The previous chapter makes the case that planning at the water basin level is most advantageous because it leads to the best possible solutions under a wide range of situations. However, unless the O&M of the expensive infrastructure laid out in the plan is in the hands of robust water utilities, the benefits of the basin planning approach to sanitation and wastewater treatment will be severely compromised. In Latin America and the Caribbean, as in many regions of the world, poorly operated utilities jeopardize the sustainability of the solutions deployed. There are several examples in the region of very well run utilities– for example, in Brazil, Chile, and Colombia. The issue of utility performance is complex and is not the main purpose of this report. For further reading, the World Bank has published several materials on the topic, including a publication that defines the characteristics of well-performing public utilities (World Bank 2006) and a recently published report that provides water utilities with guidance on improving performance (Soppe, Janson, and Piantini 2018).

3.1 Efficient and effective management of water resource recovery facilities

The first requisite of moving toward a circular economy and implementing reuse and resource recovery in treatment facilities is to ensure that the facilities are managed in an efficient and effective way. Effective and efficient management of WRRFs starts with smart planning and design. When treatment facilities are planned with resource recovery and sustainability in mind, the road to the circular economy is paved. Smarter O&M of WRRFs is then the next natural step to sustainability.

An inadequate characterization and projection of wastewater influent can lead to oversized facilities with unnecessarily high costs.

Adequate planning, design, and operation entail a series of actions that are summarized below (and in more technical detail in Background Paper I [World Bank 2019d]).

Projecting wastewater influents: Understanding the demand side of treatment

Projecting wastewater influents through a textbook approach often results in treatment processes being improperly selected or sized, and in higher-than-necessary capital and operating expenditures. Every municipality has unique characteristics (e.g., climate, seasonal variations, urban infrastructure) that shape the flow rate of its wastewater, the concentration of contaminants, and so on. Despite these differences, treatment plants are often designed based on textbook parameters. Theoretical wastewater flow rates or oxygen demand loadings are poor substitutes for localized sampling and laboratory analysis. In most cases, these textbook approaches result in projections and loadings that exceed the actual ones, thereby unnecessarily increasing the size of treatment facilities.

When planning new treatment facilities, wastewater influents should be characterized in advance, so the facility can be built around the characteristics of the sewage to be treated. In many cases, this is done so as to not only determine the concentrations of various contaminants, but also to map flow rates. When expanding existing facilities, records of the characteristics of wastewater influents should be obtained and studied. Such records should be checked for accuracy and complemented, when needed, with additional sampling and monitoring at the existing plant and immediately downstream from preliminary treatment.

Even when all these considerations are taken into account, planners in low- and middle-income countries often face other challenges to project and understand wastewater influent characteristics. Ensuring the connectivity of households, setting up adequate pretreatment programs for industries, and reducing infiltration and inflow (including illegal connections) into the sewer system are all issues that should be considered when designing a treatment facility.

Setting sustainable targets for effluent quality

Reasonable targets and standards for effluent quality are crucial to reuse and resource recovery. Standards should be based on the characteristics of the receiving water body and/or on water reuse needs. Countries tend to follow general discharge standards because they are easier to implement and enforce, but standards based on the receiving water body are more efficient and effective. As mentioned in chapter 2 and exemplified in the case of Guayaquil, Ecuador (box 2.1), modelling a water body's receiving capacity can, for example, reduce capital and O&M expenses for treatment down the road.

Moreover, gradual or staged implementation of targets, where applicable, will likely improve the sustainability of the treatment system by gradually improving operators' knowledge of the characteristics of the influent wastewater and the effects of treatment on the quality of the receiving water body. Gradual application of effluent requirements will also make it possible to extend the coverage of treatment within the basin (i.e., more than one plant discharging), as opposed to having high levels of treatment in one plant and leaving larger areas without treatment. For example, Mexican legislation has implicitly promoted a gradual approach to wastewater standards (a WWTP can move from the laxest of limits, 150 milligrams per liter [mg/L], to the reuse condition: 30 mg/L of Biochemical Oxygen Demand (BOD)). On the other hand, extremely stringent effluent quality imposed on areas with low levels of treatment coverage prevent, in many cases, the utility from reaching adequate treatment coverage. This is because building new plants or upgrading existing plants becomes too expensive compared with existing funding. Therefore, expansions, upgrades, and greenfield WRRF projects elsewhere in the catchment are postponed, resulting in lower coverage, with detrimental implications for population health, receiving water body quality, and environmental conditions.

Copying standards from other countries (e.g., EU directives for effluent quality, EPA 503c for biosolids management, etc.) without adequate attention to the local context can have negative environmental and financial implications.

Selecting an adequate treatment process

Careful selection of the treatment processes to be used in the WRRF is key to sustainable resource recovery. The capital and operating costs of processes vary widely. In most of the region, there is a strong tendency to prefer activated sludge systems to other treatment processes. A clear exception is Brazil, which has become a global model for the use of upflow anaerobic sludge bioreactors (UASBs). Activated sludge is a proven technology that results in the removal of more than 90 percent of the biochemical oxygen demand. However, the energy requirements and operating costs of activated sludge plants are high and cannot always be supported by tariffs. The energy required for aeration accounts for the largest share of the plant's energy needs, varying from 45 percent up to 75 percent when using extended aeration. The situation is worse for plants operating at a high altitude. For example, at 3,500 meters above sea level, a plant will consume approximately twice as much air than the same plant operating at sea level. This is especially relevant for the region of Latin America and the Caribbean, since several of its cities are located at altitudes 2,000 meters above sea level. The impact of operational expenses on the sustainability of WWTPs must be taken into account when selecting the right treatment process. For activated sludge systems, the influence of capital and operating costs can be conceived as an iceberg, where the capital cost is the tip of the iceberg, with the operating costs over the life of the investment concealed below the surface. Therefore, activated sludge systems should not be the default option; all technologies and solutions should be considered (UASBs trickling filters, aerated lagoons, covered anaerobic ponds, etc.) and the one best suited for local conditions should be chosen.

When selecting the treatment technology, it is important to assess not only capital expenditure but also operating expenditure. O&M costs are usually significant. In fact, in the long run, O&M costs dwarf constructions costs; yet they are often neglected when estimating required expenditures, thus impacting the sustainability of these systems.

Sizing treatment systems: Bigger is not better

Traditional design guidelines for WWTPs developed in the 1970s and using knowledge from the 1960s are still cited in the current literature. These conservative guidelines yield plants that are larger than necessary. For these reasons, their use has been discontinued in most of the developed world. Currently, process specialists use dynamic simulators with realistic mathematical models for sizing reactors and other treatment systems. The use of such simulators results in more efficient plants.

Unfortunately, the 1970s design guidelines are still common in Latin America and the Caribbean. One could argue that the reason for their use is simplicity and savings of time and money during the initial stages of planning. Their analysis requires little in the way of mathematical skill or forecasting data. But the gross oversizing of infrastructure affects the sustainability of systems, increase capital and operating costs, and limits the capacity for resource recovery.

Using existing infrastructure correctly

Infrastructure already in place can be a valuable resource, once its actual treatment capacity is assessed to determine the maximum flow rate it can treat while still meeting effluent criteria. Yet the possibility of adapting existing infrastructure is often overlooked or miscalculated, leading to unnecessary expansions that waste valuable resources, raise costs, and enlarge the carbon footprint.

Analysis of existing plants can reveal excess capacity in some aspects of the treatment processes. Armed with that knowledge, expansion can focus first on processes that present a bottleneck, which can lead to considerable savings. Both evaluating existing infrastructure and utilizing modern design methods (e.g., dynamic simulation) maximize the use of infrastructure and enhance its sustainability. Related evaluation techniques (explained in Background Paper I [World Bank 2019d]) are not necessarily complex or expensive and can lead to significant savings and improved efficiency (see box 3.1).

Box 3.1 Saving by utilizing existing infrastructure: Buenos Aires, Argentina

AySa, the water and wastewater utility in Buenos Aires, had already planned the expansion of its wastewater treatment plants to increase capacity. The expansion costs were around $150 million. However, the application of process audit techniques allowed the utility to use its facilities to the fullest potential, resulting in cancellation of the expansion plans and saving around $150 million in capital expenditures.

Reducing energy consumption (“negawatts”)

In the region, the vast majority of water utilities and WWTPs are struggling to be self-financing. Because energy is often the largest component (30–40 percent on average) of operating costs, rising energy costs have direct implications for service affordability and sector financing (WWAP 2014). Audits designed to reduce energy consumption—to produce “negawatts”—can result in substantial savings to the utilities (Nolasco and Rosso 2015; Environment Canada and Ontario Ministry of the Environment and Energy 1995). Technical measures that improve energy efficiency can cut consumption by 10–30 percent and have payback periods as short as a year (Rodriguez, van den Berg, and McMahon 2012). Moreover, reductions in consumption can and should be planned at the design stages, when processes are selected and sized, as mentioned earlier. Despite their advantages, however, energy audits are seldom done at WWTPs in the region. Before WWTPs can implement resource recovery projects and become energy producers, it is crucial that they be energy efficient (for further guidance on the potential to implement energy efficiency and energy recovery initiatives in WWTPs, refer to Lackey and Fillmore [2017]).

Box 3.2 Identifying low-cost energy efficiency solutions to transform a wastewater treatment plant from energy consumer to energy producer: Guanajuato, Mexico

San Jeronimo wastewater treatment plant uses a conventional activated sludge process with anaerobic digestion to process sludge. Biogas generated in the digesters is processed and burned in 500 kilowatt (kW) electricity generators. Currently, with the biogas generated in a full day of operation, the plant can cover electricity use during peak tariff hours (three hours a day). During the rest of the day, the plant relies on electricity bought from the network. When biogas is not enough to generate the electricity needed at peak hours, the plant turns off the aerators of the activated sludge system to keep the electricity bill within the plant's allocated budget. Because these saving measures affect effluent quality, the plant underwent an energy audit. The audit showed that a series of low-cost energy efficiency measures in the aeration system (automatic control of the dissolved oxygen concentration, cleaning of the air diffusers, introduction of anoxic zones for denitrification), combined with co-digestion of external waste in the existing anaerobic digesters, could tilt the energy balance at the plant, switching it from a net energy consumer to a net energy producer. Since electricity generators were already in place, the payback for these modifications could be measured in months.

Source: IWA n.d. (http://www.iwa-network.org/WaCCliM/mexico/).

3.2 Valuing wastewater: Reuse and resource recovery

Wastewater is not waste; several resources can be recovered from it, namely water, energy, biosolids and nutrients. All these resources, once recovered, can either generate an extra revenue stream or can help reduce operating costs, thereby contributing to the sustainability of the plant and the operator.

Although the resources are explained separately below, the ideal scenario is that utilities would explore the recovery of several of them, as exemplified in the case studies in this report. A paradigm shift from wastewater treatment plants toward water resource recovery facilities offers new possibilities to create new and more sustainable business models, involve the private sector, and enable new modes of financing (given the potential for additional revenue streams), as explained in the next chapter.

Water reuse

Agriculture is the largest user of water, and the utilization of treated urban wastewater for agricultural irrigation is a growing practice worldwide. The use of partially treated wastewater in agriculture helps conserve and expand available water supplies and can contribute toward a more integrated management of water resources. Moreover, the nutrients (phosphorous and nitrogen) found in treated wastewater can be very valuable for farmers. Depending on the treatment technology employed, the levels of phosphorous and nitrogen in the treated wastewater effluent can be very high. These elements in the effluent can increase crop yield and size. Yet if not planned, managed, and implemented properly, water reuse can be associated with a number of risks, including public health, agronomic, and environmental risks.

Table 3.1 Potential for wastewater reuse

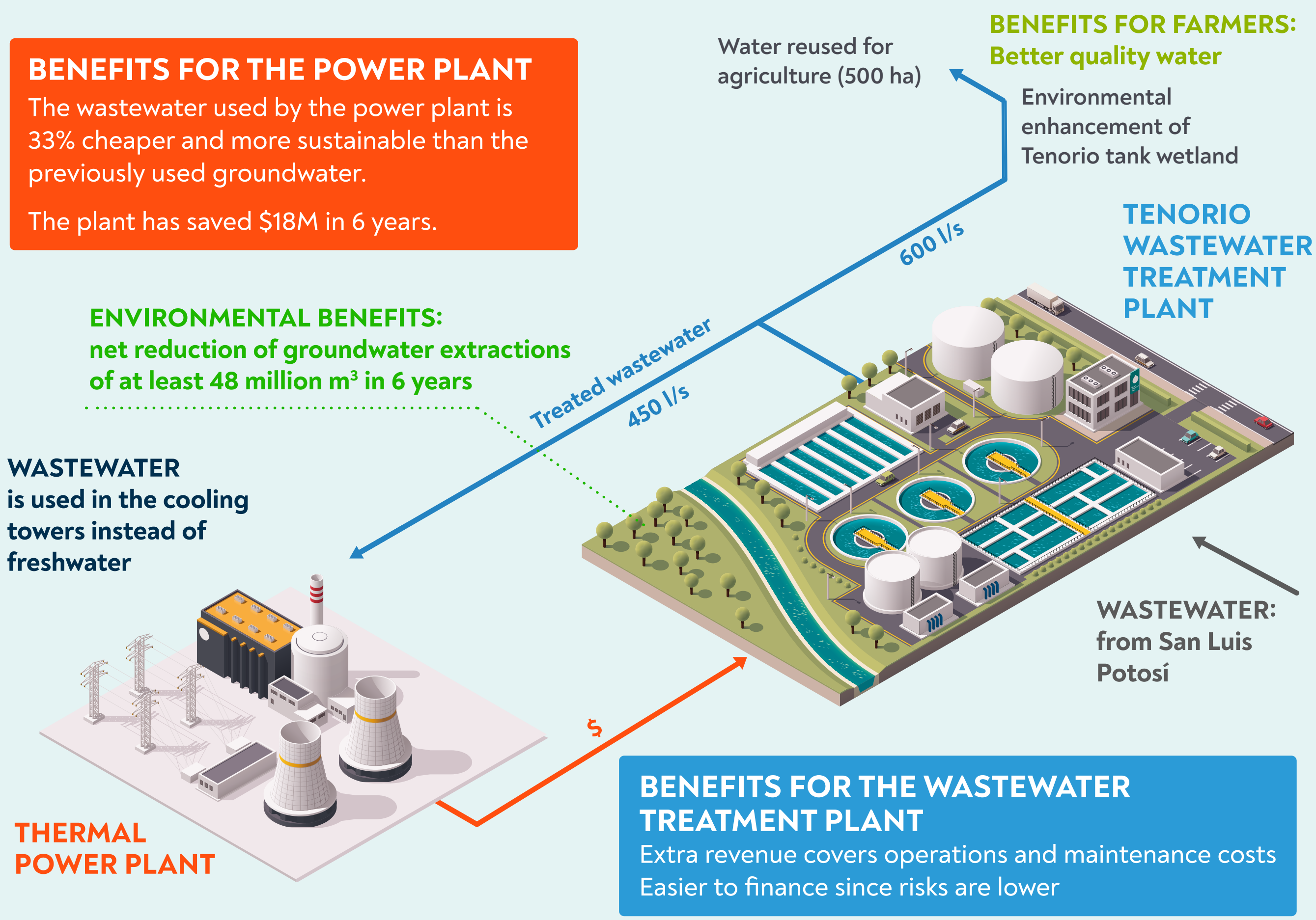
Agriculture	Recreational	Industry	Environmental
Food crops	Landscaping water features	Washing/cleaning (beverage, food)	Groundwater recharge
Food crops using drip irrigation	Boating lakes	Cooling (power generation, paper, and textile)	Flow augmentation
Nonfood crops	Swimming lakes	Process water, boiler feed water (all industries)	Dryness amelioration
Livestock drinking water	Snowmaking		

Source: US EPA 2012.

In addition to its reuse for irrigation, various ways to use treated wastewater are listed in table 3.1. Examples are growing every year, especially in water-stressed regions. However, most treated water is still discharged back to the nearest water body. Instead of discharging it, wastewater can be treated to any level and adapted to the requirements of each potential consumer segment: crop or field irrigation, groundwater recharging, cooling water or process water for industries, drinking water, etc. Ideally, the end user would pay a fee for the treated wastewater, creating an extra revenue stream for the utility that could help cover O&M costs (box 3.3).

Box 3.3 Selling wastewater to cover operation and maintenance costs: San Luis Potosi, Mexico

New water reuse regulations and a creative project contract incentivized wastewater reuse in San Luis Potosi. Instead of using fresh water, a power plant uses treated effluent from the nearby wastewater treatment plant (Tenorio) in its cooling towers. This wastewater is 33 percent cheaper for the power plant than groundwater and has resulted in savings of $18 million for the power utility in six years. For the water utility, this extra revenue covers all its operation and maintenance costs. The remaining treated wastewater is used for agricultural purposes. Additionally, the scheme has reduced groundwater extractions by 48 million cubic meters in six years, restoring the aquifer. The extra revenue from water reuse helped attract the private sector to partially fund the capital costs under a public-private partnership agreement (40 percent government grant, 36 percent loan, and 24 percent private equity). See full case study here (World Bank 2018d).



Bioenergy generation

Wastewater treatment plants with anaerobic processes generate biogas. Biogas can be sold to a third party as gas for heat and cooking (see La Farfana case study in Santiago, Chile), as vehicle fuel or as fuel for a power plant; or it can be burnt on-site to cogenerate electricity and heat for the wastewater treatment plant, improving the energy efficiency of the plant. The heat can be used in the digester to dry sludge and the power can be used in the plant or sold to the grid.

In general, if activated sludge technology is used for wastewater treatment, the plant's full energy needs cannot be met by the electricity generated at the plant. An exception to this would be when anaerobic technologies (anaerobic lagoons, UASBs) are used as the main treatment, and activated sludge is used only as an effluent polishing step. These plants require less energy and have more potential to become energy neutral or energy positive, with the very real option of selling the extra electricity to the grid. Plants with anaerobic digestion of sludge can also cogenerate energy; however, in most cases, the energy produced will only be able to cover the heat demand of the digester and about a third of the electricity demanded by the plant. To increase biogas production and energy generation, co-digestion (when an external waste source is incorporated directly into the anaerobic digesters) can be implemented (box 3.4).

Box 3.4 Implementing co-digestion to increase energy production: San Francisco, United States

The East Bay Municipal Utility District (EBMUD), the utility serving a part of the metropolitan area of San Francisco, California, implemented a program to blend food waste from local restaurants with its own biosolids to produce enough methane-generated electricity to meet its own demand and sell the excess to the local grid. The program cost $31 million and had a generation capacity of 15 megawatts, which has saved the utility $2.5 million per year in energy. Electricity sales bring in $500,000 of extra revenue and income from waste disposal fees charged to the restaurants totals $8 million annually. In addition, the program saves landfill capacity and reduces greenhouse gas emissions.

Source: TPO 2012.

Ensuring that a plant can generate its own decentralized power, using biogas, can improve energy efficiency, decrease costs, and enhance the plant's reliability, which are important in areas that experience frequent power outages. Moreover, biogas is a "green" energy source and therefore using it to generate power and heat can potentially reduce greenhouse gas emissions and other air pollutants (if it replaces fossil fuels) and can allow the plant to obtain green or carbon credits. For further guidance on implementing wastewater to energy initiatives, depending on the size of the WWTP, refer to Vazquez and Buchauer (2014) and Lackey and Fillmore (2017).

Beneficial use of biosolids

Traditionally, sludge from WWTPs has been considered as a waste by-product that has to be disposed of at the lowest cost possible. However, biosolids (WWTP sludge treated to levels that permit its beneficial use) can be used for many purposes given their intrinsic value and nutrient content. Biosolids can be used to recover degraded land, as compost or fertilizer in agriculture, and as compost in gardens and golf courses. Nutrients such as phosphorous can also be extracted and sold. Other applications being explored include using biosolids as a building material and fuel. And it is possible to extract other materials from it, such as minerals and cellulose. The beneficial use of biosolids has been studied extensively but its practice in the region is somewhat limited (see box 3.5 and the case of SEDACUSCO in Background Paper VI [World Bank 2019e]).

Box 3.5 Using biosolids in agriculture: Brasilia, Brazil

For several years, the Companhia de Saneamento Ambiental do Distrito Federal (CAESB), the water and wastewater utility of Brazil's capital district, has been reusing biosolids from its wastewater treatment plant operations to recover degraded areas in its railway operation areas (*patios ferroviarios*) and in agriculture. The effects of using biosolids on corn production—as compared with a mineral fertilizer mixture consisting of equivalent amounts of nitrogen, phosphorus, and potassium—were evaluated in a series of studies (Lemainski and da Silva 2006a). All grain yields were higher than average for Brazilian standards for corn. The biosolids were on average 21 percent more efficient than mineral fertilizers. Similar studies of soybeans have shown that biosolids were, on average, 18 percent more efficient than mineral fertilizers. Therefore, the beneficial use of biosolids can lead to higher crop yields and at the same time save significant transport and landfill costs for the water utility.

Source: Lemainski and da Silva 2006b.

4. New financing and business models for water resource recovery facilities

Wastewater treatment and reuse is a capital-intensive activity often incurring large up-front costs. As described in chapter 1, the financial resources required to implement wastewater projects in Latin America and the Caribbean are often too high for national budgets, creating significant barriers to the development of wastewater treatment and reuse. In addition, wastewater investment is rarely a political priority, particularly when wastewater projects are small and context specific, which pushes up transaction costs.

4.1 Resource recovery as a solution

Resource recovery can help overcome some of the challenges to financing wastewater infrastructure and help to achieve the needed paradigm shift in the sector. Resource recovery can help the sector move away from traditional public financing to innovative financing and new business models that can induce the private sector to finance infrastructure.

Resource recovery projects can leverage new revenue streams or cost savings (see figure 4.1) to reduce the financial risk of infrastructure projects, improve the rate of return, and create a more attractive environment for the private sector. These revenues are not solely reliant on public sector tariffs but on the market for by-products generated during the wastewater treatment process.

Figure 4.1 Potential revenue streams and savings from resource recovery for wastewater treatment plants

ENERGY

Revenue:

- Sale of biogas or electricity
- Sale of carbon credits
- Tipping fees for the collection of organic matter (in co-digestion)

Savings:

- Using own-generated electricity in the plant
- Improving energy efficiency

WATER

Revenue:

- Sale of treated wastewater, especially in water-scarce areas

Savings:

- Discharge fee/tax

BIOSOLIDS and NUTRIENTS

Revenue:

- Sale of phosphorus as fertilizer
- Sale of biosolids as compost

Savings:

- If the biosolids are given away for free (for agriculture, to restore degraded land, etc.) the utility saves transport costs and landfill fees

Source: World Bank.

This requires the identification and development of new markets for treated wastewater, biogas, and biosolids. The rate of return can be high, making these products of interest to operators, private investors, and investment funds.

Reuse and resource recovery projects in wastewater treatment plants can provide a steady, long-term financial return, allowing plants to attract long-term investment funds and institutional investors comfortable with lower, but regular, yields over the long term

This is shown in several of the cases documented, such as San Luis Potosi, Durban, and Ridgewood, where well-designed contracts secured demand for resource recovery products, ensuring a stable revenue stream and attracting private sector participation.

4.2 Toward blended finance

As mentioned in chapter 1, the financing required to achieve the Sustainable Development Goals in the region is substantial, and public funding alone will not be enough. Private sector involvement is needed for both investment capital and new technologies and skills. Reuse and resource recovery projects offer an opportunity to attract the private sector. This is exemplified in most of the case studies reviewed for this report.

Most large wastewater projects, particularly those that involve reuse and resource recovery from the onset, have been implemented through various forms of public-private partnerships (PPPs) using a mix of public and private finance. The funding of the PPP would typically be a blended financing scheme, incorporating a mix of subsidies or concessional finance from governments and partners, plus private equity and debt finance, largely commercial in nature, to be recovered through user tariffs and revenues from the sale of treated water and its by-products. There are several types of financial instruments through which public and private investors can develop their projects. These are described in detail in Background Paper V (World Bank 2019f).

Traditionally, public wastewater finance will entail subsidies or incorporate a high degree of concessionality. There are two main rationales for these subsidies:

- ***Economic:*** public health benefits, as well as environmental factors and other positive externalities of wastewater projects, particularly those involving resource recovery
- ***Practical:*** water tariffs in many countries are below full-cost-recovery levels, and it is politically and socially difficult to increase them when the costs of large wastewater investments are added to the revenue requirements[4]

Subsidies may be particularly relevant for early stage reuse and resource recovery projects. In the early stages of market development, reused water and recovered products may need to be priced below cost, as proof of concept. Once users are familiar with these products and are confident that the regulatory system is operating satisfactorily to ensure adherence to hygiene and safety standards, the prices can then rise to match or exceed production costs. Some of the case studies reviewed show that resource recovery projects can cover all operation and maintenance costs or even generate profits. Therefore, the need for subsidies for resource recovery projects should decline over time once the business model has been proven or if demand for by-products increases substantially (for example, amid growing water scarcity).

Recognizing that subsidies are necessary does not mean that indiscriminate levels of subsidies are to be provided. The level of subsidy that is warranted is to be determined by economic and financial analysis of the wastewater project. Guidelines on how the subsidy level is to be determined are given in Background Paper V (World Bank 2019f). To ensure that subsidies will not impair efficient performance, subsidy schemes should be based on incentives (box 4.1), as also described in Background Paper V (World Bank 2019f).

Finally, given the long-term benefits and potential positive externalities of resource recovery projects, a life-cycle cost analysis could be an important decision-making tool to evaluate and justify the financing of treatment plants and sanitation initiatives. A discussion of how this tool can be used instead of the simple payback method can be found in the World Bank report "Energy Management for Water Utilities in Latin America and the Caribbean" with a focus on financing energy efficiency and energy recovery measures in treatment plants (Lackey and Fillmore 2017).

Box 4.1 Results-based financing of wastewater infrastructure: PRODES, Brazil

The most prominent incentive-based subsidy example that has been used to finance wastewater is the results-based financing scheme PRODES in Brazil. PRODES is a federal financing scheme set up primarily for depolluting important hydrological basins. PRODES does not directly fund the capital costs of wastewater treatment infrastructure. Instead, it provides clear incentives for efficient investment and operation of wastewater treatment plants, because payments are linked to the quality of treated wastewater based on certified outputs. PRODES did not focus on resource recovery; however, having a plan for the reuse of treated wastewater is one

4 There are, however, very important exceptions to this rule in Latin America and the Caribbean. For example, many of the state and municipal utilities in Brazil recover their water supply, sewerage, and wastewater treatment costs through tariffs.

of the criteria for obtaining its support for a wastewater treatment investment.

A secondary results-oriented objective of PRODES is to improve the decentralized management of water resources. Criteria for receiving the resources include for example, the existence of a functioning basin committee and evidence of planned implementation of water resource plans and investments.

PRODES is further explained here (World Bank 2018e).

4.3 Learning from successful resource recovery projects

The case studies analyzed for this report exemplify aspects of efficient subsidies, blended finance, successful PPPs, innovative contracts and partnership models that ensure a stable revenue stream and access to finance, cost saving models, etc.—all achieved through the application of resource recovery principles. The lessons learned and conclusions from the case studies include the following:

Market and business potential

There is significant potential in Latin America and the Caribbean for products recovered from wastewater. The overall market potential for three types of related businesses (water, energy, and biosolids) has been estimated to be between $3 and $62 billion (see Background Paper VI [World Bank 2019e]). These three markets are growing beyond their development stage and have an important growth potential. **If projects are designed correctly, all by-products can be profitable.**

For treated wastewater reuse, the most profitable option is to identify an industrial end user. As shown in the case studies of San Luis Potosi, Cerro Verde, Durban, and Nagpur, the sale of treated water to industry can help cover most or all of the operation and maintenance costs, especially where water is scarce or where water tariffs for industry are high. Under those circumstances, the water utility is in a unique competitive position since the treated wastewater is an attractive option or may be the only available source.

If the end purpose is irrigation, aquifer recharge, environmental remediation, or a similar use, subsidies will likely be necessary, since the price for the treated water will be below cost or even free. For example, farmers are unlikely to pay more for treated wastewater than the amount they pay for freshwater, which in many cases is provided at little or no cost. Moreover, sometimes farmers using untreated wastewater are reluctant to use treated wastewater because they think it will affect their yields, as happened initially in the case of Atotonilco, Mexico. Nevertheless, depending on the local regulations, the operator can still benefit from this business model by saving the water discharge fee costs. Moreover, if all benefits (environmental, social, health-related) would be considered in a long-term cost-benefit analysis, subsidizing these types of projects is economically justifiable, especially in water-scarce areas. In some cases, such as where water and fertilizers are costly or scarce, can treated wastewater be very valuable for farmers due to the potential benefits for crop yields and size. Under the right conditions and with a strong awareness campaign, users might be willing to pay full price for the treated wastewater.

The energy business's profitability and the end uses for biogas will depend on the local prices for energy. If gas prices are high, biogas can be sold to a gas company; if electricity prices are high, the biogas produced in a wastewater treatment plant (WWTP) can be used to generate its own heat and electricity and therefore save electricity costs. This is shown in several cases analyzed: La Farfana sells biogas to the gas company with a long-term agreement, Atotonilco and Cañaveralejo (World Bank 2016a) use the biogas for self-consumption, SEDACUSCO is installing its own power plant for self-consumption, and Ridgewood is producing 100 percent of the energy required by the WWTP.

The energy business can be profitable since the capital expenditure (CAPEX) costs of the energy infrastructure are relatively small compared with the CAPEX costs of the whole WWTP. In addition, the utility can get carbon credits since biogas is considered a renewable source. This profitability is demonstrated in cases like La Farfana in Santiago, Chile, where the operator invested $2.7 million for the needed infrastructure and is getting a yearly net profit of $1 million from biogas activities. This translates into a profit of 40 percent, and the investment is recovered in a little over two years. Demand risk is low because the contract is well structured and there is only one end user. Another example is EBMUD: energy is becoming its main business, producing higher profit than water treatment (box 3.4).

The energy business can be very attractive, but, for several reasons, few water utilities in the region enter it. First, many water utilities do not see themselves as potential energy producers since this is beyond their scope or core business. However, as shown in the case studies, investing in energy generation can generate extra revenue streams that can help finance and/or cover the operating and maintenance costs of the water business. Water utilities could focus on water and outsource the energy business to specialized companies in the sector, though PPPs, subcontracting, or other arrangements. Economies of scale are another preventative factor since there is a minimum efficient size for these types of projects. Finally, and most importantly, most countries lack clear rules, regulations, and institutional frameworks governing the sale of gas or electricity by WWTPs (and even self-consumption, as in the case of Santa Cruz de la Sierra).

The biosolids business is the least developed of the three analyzed. In fact, in the region most WWTPs' biosolids are either deposited near the plant, or the utilities pay to deposit them in landfills. The main issue with biosolids is that there is no clear price for the final product since the potential customers (farmers, public authorities for land restoration, etc.) are usually not ready to pay for it. However, trading in biosolids could still be beneficial for the WWTP operator, since it can save transport and landfill gate fees, which can be significant (as shown in the case of SEDACUSCO). Moreover, the use of biosolids can generate important economic and environmental benefits. For example, the case of SEDACUSCO shows the potential benefit of using biosolids for soil restoration to remedy nonpoint-source pollution and to help conserve soil moisture. Reducing the amount of organic matter that ends up in landfills also reduces greenhouse gas emissions. Ideally, the public sector would account for those benefits and create incentives for these types of businesses. As in the case of energy and water reuse, one key aspect that is preventing the beneficial use of biosolids in Latin America and the Caribbean is the lack of clear regulations. For example, many environmental agencies lack the resources to monitor and guarantee the quality of the biosolids; as a precaution, they do not allow their use for agricultural purposes. In a more common situation, biosolids are allowed only for land remediation and soil restoration, with limited potential revenue.

A wastewater treatment plant in Cusco, Peru, operated by SEDACUSCO, saves around $230,000 a year in transport and landfill fees, thanks to an agreement with a local compost producer. The compost produced from the plant's biosolids is then used as part of the water management project to preserve the Piuray Lake.

The co-digestion business comprises components of energy and biosolids combined in such a way as to be attractive to private investors. In co-digestion sludge from the WWTP is only a part of the digesters' feedstock. The digesters also receive other organic matter such as domestic, commercial, agricultural, and industrial organic waste. This extra organic matter allows the WWTP to generate more biogas and, as a result, to produce more electricity, potentially exceeding its energy needs. Any excess electricity can be sold to the market at the feed-in rate. Moreover, the WWTP can derive additional income from tipping fees (or gate fees) earned from collecting other organic waste (i.e., industries pay the WWTP a fee to get rid of their organic waste). The case studies of EBMUD (box 3.4) and Ridgewood (box 4.2) exemplify how both utilities understood the potential of co-digestion, invested in expanding their digesters and their power generation capacity, and started a strong marketing campaign to obtain additional feedstock for digestion, producing larger amounts of biogas and electricity.

Box 4.2 The potential of co-digestion: Ridgewood, United States

In the case of Ridgewood, United States, a well-designed public-private partnership between the Village of Ridgewood's water utility and a co-digestion technology provider and engineering company (Ridgewood Green) led to a successful co-digestion project. The Village of Ridgewood leveraged the potential of resource recovery, attracting the private sector to fully finance the retrofitting of their WWTP for co-digestion under a PPP agreement, implying zero investment costs and minimum risk for the village of Ridgewood.

The project allowed the wastewater treatment plant to generate enough biogas to meet all the plant's power needs, becoming energy neutral and decreasing carbon dioxide emissions. Ridgewood Green made all the up-front capital investment needed to retrofit the plan for co-digestion. In return, Ridgewood purchases the electricity generated by Ridgewood Green for the operation of the plant at a lower price than it used to pay for electricity from the grid. The power purchase agreement includes a fixed increase of 3 percent per year for inflation, establishing the village's price and Ridgewood Green's revenue for the duration of the contract. Therefore, this agreement benefits both parties. Since Ridgewood Green invested in the co-digestion infrastructure, it owns this new equipment, and the Village of Ridgewood owns and operates the plant with technical support from Ridgewood Green. Ridgewood Green expects to receive a reasonable return on its investment through an innovative revenue model that leverages various revenue streams: (i) selling electricity to the Village of Ridgewood; (ii) selling renewable energy certificates to 3Degrees, a leader in the renewable energy marketplace, under an agreement of several years; and (iii) charging tipping fees for the organic matter collected for the anaerobic digesters. The full case study can be found here (World Bank 2018f).

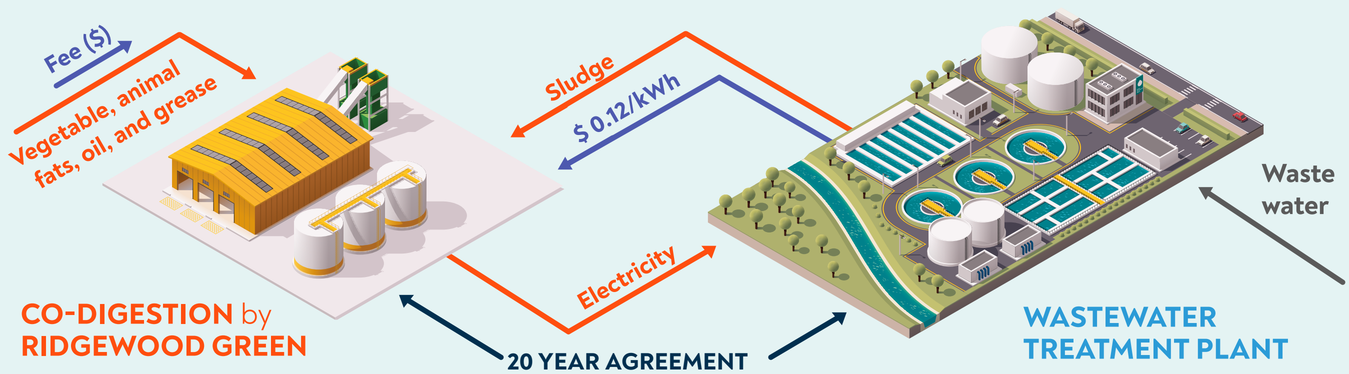
RIDGEWOOD GREEN

- Financed and installed liquid waste holding tanks and a biogas generator and retrofitted the plant's two anaerobic digesters
- Earns revenue from electricity sales, renewable energy certificates, and tipping fees

VILLAGE OF RIDGEWOOD

Owns and operates the wastewater treatment plant. Buys electricity produced from Ridgewood Green at $0.12 per kWh

Value:
- Lowers operating costs
- Reduces sludge hauling costs
- Reduces carbon footprint



Business structures to promote resource recovery projects

The cases analyzed exemplify a variety of business structures that could be replicated in the region. Further analysis can be found in Background Paper VI (World Bank 2019e).

Public-private partnership. A water utility enters into a PPP agreement with a private operator for a specific reuse and/or resource recovery project. The project may be linked to the construction of a new WWTP (as in San Luis Potosi and Atotonilco) or to the retrofitting or adaptation of an existing one (as in Ridgewood, box 4.2, or Durban, box 4.3). The PPP model most often seen in the case studies is the build-operate-transfer (BOT) model. This business model is suitable for water utilities that have limited resources and need to tap private sector knowledge to develop their reuse and/or resource recovery business model. It could apply to many medium-sized utilities in the region.

Box 4.3 Reusing wastewater for industrial purposes under a PPP agreement: Durban, South Africa

In Durban, South Africa, the private sector provided all the capital needed to implement a wastewater reuse project for industrial purposes under a PPP agreement with the local water utility. The arrangement resulted in a sustainable solution at no extra cost to the municipality or the taxpayers.

Durban's sanitation capacity was reaching its limits. Instead of increasing the capacity of the existing marine outfall pipeline to discharge primary treated wastewater to the ocean, Durban explored the possibility of further treatment and reuse for industrial purposes. Mondi, a paper plant, and SAPREF, an oil refinery, expressed interest in receiving the treated wastewater. Given the technical complexity, cost, and risk of the project, the municipal utility opted to implement the project under a public-private partnership.

After an international bidding phase, Durban Water Recycling (DWR), a consortium of firms, was chosen to finance, design, construct, and operate the tertiary wastewater treatment plant under a 20-year concession contract. The municipal utility would still be in charge of the preliminary and primary wastewater treatment, and the effluent would be sent to the plant operated by DWR to be treated and then sold to industrial users. The private sector funded the entire project. It also undertook the risks of meeting the water quality needs of the two industrial users.

The guaranteed demand for treated wastewater from the two industrial users made the project economically attractive and allowed DWR to undertake the investment risks. The sale of treated wastewater to industry has freed enough demand for potable water to supply 400,000 additional people in the city. Moreover, the need for investment in new infrastructure for water treatment has been postponed. See the full case study here (World Bank 2018g).

INDUSTRY	DURBAN RECYCLING PLANT	DURBAN
Savings: treated watewater is cheaper (R 2.8/m^3) than potable water (R 5.4/m^3) **Risk mitigations:** reduced the risk related to water availability and higher security in case of scarcity events	**Reference case in Africa:** first project of its kind in South Africa **Risk mitigation:** ensured long-term revenue stream from industry (contract 20 years)	Freed freshwater for other uses The need for investment in new infrastructure for water treament has been postponed

Outsourcing. A water utility may sell or give away untreated wastewater, dried sludge, or biosolids to an operator who carries out the business. Examples include Cerro Verde for wastewater and SEDACUSCO for biosolids. The benefit for the utility is that it saves the wastewater treatment cost—in the case of Cerro Verde—or the biosolids disposal cost. This is an adequate model for water utilities with limited financial and operational development capability. It is also suitable for small utilities that are too small to be profitable and sustainable in the business of resource recovery. It can also be arranged under a PPP model, as in the case of Cerro Verde (box 4.4).

Box 4.4 Collaborating with a mining company to reduce costs: Arequipa, Peru

Cerro Verde, a mining company near Arequipa, Peru, was planning a large-scale expansion that would require access to additional water supplies in a water-scarce area. The mine explored several options such as using desalinated sea water and water from far-away aquifers, but the cheapest option was to build a wastewater treatment plant to treat and use wastewater from Arequipa. Under a PPP agreement, the mining company agreed with SEDAPAR, the municipal water utility, to design, finance, and build the plant. In exchange, it would be able to use a part of the treated water for its mining processes. Under this agreement, the industry partner (and end user of treated wastewater), Cerro Verde, provided all the needed investment needed for the entire plant, including the wastewater reuse system. The municipal authorities provided the land and permits for the plant. After 29 years of private ownership by the mine, the wastewater plant will be transferred to SEDAPAR. Under this PPP agreement SEDAPAR has avoided the cost of construction and operation of the system, resulting in a net saving of over US$ 335 million. This win-win solution has allowed the mine to expand its operations and brought significant savings for the municipality. The full case study can be found here (World Bank 2019i).

Aggregator. An independent company can collect and transport the raw material from the WWTP, process it in its facilities, and become a seller of energy and biosolids. Examples include compost processers and energy service companies. Financially the aggregators may be private or an association of utilities and operators, and can take the form of partnerships or limited partnerships. Governments may support their development by offering various incentives.

Co-digestion. The water utility itself can become an aggregator, collecting organic matter from other industries. Co-digestion expands the resource recovery business with additional solid waste, which can eventually become the main source of feedstock for the digesters and the main source of income. Examples include Ridgewood (box 4.2) and EBMUD (box 3.4). Co-digestion needs strong landfill and energy regulations in order to expand rapidly.

Biofactory. A water utility, in association with a strong operator, may create a subsidiary company to develop a business model. One example is Aguas Andinas and its *biofactoría* model. The business unit works with potential customers, the government, and the regulator to develop different markets (energy, industry, agriculture). Because it is a subsidiary, the utility can keep part of the additional profit to reinvest in the waste-to-resource business. This business is suitable for already creditworthy utilities that have sufficient financing to enter into new ventures.

Financial structures and instruments

In the cases analyzed, the BOT structure is the most used to finance the resource recovery project and leverage the private sector. The financial instruments used to finance the BOT model are typically a mix of government grants, operators' corporate bonds, bank loans, and operator's equity. Aside from cases such as Cerro Verde or Durban (fully financed by the private sector), government or multilateral grants still make up a large part of the financing in order to reduce the financial risk of the PPP. For low-profit projects, government and other grants may always be needed, but given the multiple environmental, social, and long-term benefits of resource recovery projects, this is usually justified. For profitable projects, government grants may be justified in the demonstration phase of projects, but once profitability is proved, grants can be reduced or replaced by other financial instruments that provide similar guarantees. For different financial structures, it is worth noting the cases of Tlalnepantla de Baz (World Bank, 2016) and SEDACUSCO. In these cases, it was the utility that implemented the business model without any PPP partner. These utilities followed different financial approaches: in Tlalnepantla de Baz, the municipality and the municipal operator decided to carry out and finance the project with their own means. They issued municipal bonds and guaranteed them, pledging future revenues from sales of recycled water and from other municipal taxes. This is a trust fund, similar to federal trust funds like FONADIN in Mexico, although structured at the municipal level, which is quite innovative. The fund is also backed by a partial multilateral guarantee. SEDACUSCO financed the construction of WWTPs with a loan from the Japanese Bank for Development, which assumed the financial risk. A tariff increase made it possible to pay back the loan.

Success and enabling factors

Physical factors. As shown in the case studies, physical factors have often been the main drivers of reuse and resource recovery projects. For example, it is not a coincidence that the reuse of treated wastewater occurs mostly in countries and regions facing water scarcity. Also, the location of the closest potential customer matters, since transporting water over long distances can be very costly. Physical or geographical factors can also trigger changes at the institutional level (i.e., increasing freshwater tariffs for industry) and can incentivize industries to innovate and find alternative solutions. On the other hand, abundant and cheap water resources and energy can be a barrier to the development of wastewater reuse and energy generation projects. If the WWTP has not yet been designed, all these physical factors can be considered together, especially the location of the WWTP in relation to potential end users.

Policy, institutional, and regulatory (PIR) factors. Besides physical factors, strong institutions and/or a clear regulatory framework have also triggered reuse and resource recovery projects in the cases analyzed. In the case of San Luis Potosi in Mexico, the state government and state water commission (CEA in Spanish) have been pioneers in seeing wastewater as a resource to be exploited. To protect the aquifer and promote the use of wastewater for nonpotable uses such as agriculture and industry, the state government implemented an Integrated Plan for Sanitation and Water Reuse. The project had financial support from the National Water Commission (CONAGUA in Spanish) and the FONADIN fund (a financing instrument that promotes private sector participation by providing capital subsidies). This institutional arrangement was crucial for the success of the project. In this case the industry water tariffs were also higher than the price of treated water, making the recycling alternative attractive. On the other hand, there are many places in Latin America and the Caribbean where industries do not pay to withdraw freshwater for their operations. As mentioned earlier, physical factors can trigger the development of reuse and resource recovery projects, but PIR interventions will be needed to scale them up.

Socioeconomic factors are those related to the country's or the region's social organization, level of development, economic profile, and historical traditions. These can incentivize or disincentivize the development of the initiatives mentioned throughout the report. For example, communities engaged in the protection of freshwater resources and the environment can promote reuse and resource recovery projects and can foster initiatives at the basin level via civil organizations or their representatives. Socioeconomic changes can also help shift the paradigm in the sector. In the SEDACUSCO case, the promotion of tourism in the area encouraged the cleaning up of the river and, as a result, the development of the biosolids market. On the other hand, in cases such as Cerro Verde or Atotonilco, social elements and customs posed challenges during the design and implementation of projects. Farmers can oppose the use of treated wastewater because of misconceptions regarding the impact on their crops, or because they have always used untreated wastewater. Citizens can also oppose the construction of WWTPs near their houses because of taboos surrounding sanitation facilities and/or lack of information. To ensure that socioeconomic factors enable a paradigm shift, it is necessary to involve civil society and to design a strong awareness campaign to communicate the potential benefits of reuse and resource recovery projects.

Mitigating the demand risk of by-products. A specific risk associated with reuse and resource recovery and considered one of the most critical obstacles to private financing and participation is variable demand. The actual volume of by-products that will be used by end users or consumers is uncertain but will decide the project's cost-recovery rate. To mitigate this risk, the case studies show that several approaches are possible, but a well-designed contract between the parties is essential. The financial structure will require a long-term purchase agreement that should provide assurances to financial institutions funding the project. Most successful projects involve industries located near the WWTP (La Farfana, Nagpur, Cerro Verde, San Luis Potosi, Ridgewood, Durban) and a contractual structure that mitigates the risk of variable demand. Take-or-pay clauses or a sufficient fixed portion of the payment are common elements in long-term infrastructure contracts and should also be part of reuse and/or resource recovery projects in order to mitigate demand risk.

Toward an integrated and circular approach

The three resource recovery businesses (water, energy, and biosolids) are not incompatible. In fact, they are complementary. To leverage synergies and achieve higher efficiency and profits, it is recommended that planners encourage an integrated approach to WWTP and design bids that will attract operators to implement resource recovery projects. To this end the financial structure must include increasing efficiency challenges. Ideally, resource recovery projects and sanitation programs are not only planned within the river basin framework, but also integrated in urban planning or urban water management plans. This could, for example, ensure the siting of treatment plants close to potential users (industry, irrigation, golf courses, etc.).

Box 4.5 The win-win potential of a circular economy

If reuse and resource recovery projects are designed correctly, as shown in many of the case studies, all parties can benefit. Customers—industry, farmers, and wastewater treatment plants themselves, among others—can potentially get a product (water, energy, biosolids) more sustainably and at a lower cost. Operators can get additional revenue streams to cover operation and maintenance costs (besides tariffs). Water utilities can, depending on the business model and financing arrangement, reduce capital expenditure and operation and maintenance costs, reduce and/or eliminate discharge and gate fees, and decrease and/or eliminate electricity costs. This will promote a shift toward more financially and environmentally sustainable water utilities. Citizens can also benefit from reuse and resource recovery projects, by receiving a more sustainable sanitation service.

5. The policy, institutional, and regulatory frameworks needed to promote a paradigm shift in the sector

As mentioned in chapter 1, many reuse and resource recovery initiatives occur ad hoc, and not at a systematic national or regional level, because they are triggered by specific local conditions. As demonstrated by the case studies analyzed for this report, specific climate and environmental conditions (water scarcity, low precipitation, low water tables) have pushed the public and private sectors to design and invest in innovative solutions. But to ensure that the necessary paradigm shift in Latin America and the Caribbean occurs in a systematic and planned way and at scale, sound policies, institutions, and regulations will be essential.

Policy, institutional, and regulatory (PIR) initiatives can either trigger or become a barrier to reuse and resource recovery projects. Measures by the government, such as pricing freshwater use correctly, especially for industries, could create incentives to switch to treated wastewater instead (see the San Luis Potosi case study in box 3.3). Economic instruments such as pollution taxes and fees can positively contribute to reducing the treatment burden on the wastewater treatment plant (WWTP), with positive effects on capital and operating expenditures. Governments can also promote energy generation in WWTPs as part of their renewable portfolio, providing WWTP operators the same incentives they would offer to the energy sector. A better regulation of landfill use could also promote the beneficial use of biosolids. On the other hand, banning treated water reuse for agriculture, blocking power generation licenses for biogas producers, or classifying wastewater biosolids as dangerous materials can all pose a barrier to the development of reuse and resource recovery projects.

Some recommendations on PIR incentives suitable for developing and investing in wastewater as a resource are summarized below. A deeper analysis can be found in Background Paper IV (World Bank 2019g).

5.1 The importance of clear policies

One of the key factors that can encourage the development of wastewater reuse and resource recovery projects is having a clear national policy objective. A national policy statement, such as the Brazil National Water Resources Policy, shows the government's commitment to the development of wastewater management that includes reuse and resource recovery. As seen in the case studies, this policy vision is missing in several countries. In many cases, projects have successfully been implemented as ad hoc solutions and not as part of a systematic policy objective. Having a national policy that promotes and shelters these initiatives in turn provides positive incentives and guidelines to stakeholders such as:

- **Relevant public sector departments** to consider and develop necessary regulations and develop the institutional capacity of an institution to implement the national policy.
- **Different levels of government** to develop local wastewater management and investment plans that include reuse and resource recovery.
- **Private sector actors**, to invest in wastewater reuse and resource recovery technologies and facilities. In the presence of a solid government commitment and private sector engagement, academia and think-tank organizations will have an incentive to conduct more research into all aspects of wastewater reuse and resource recovery.
- **Donor and development partners** to provide technical and financial assistance to the national and/or local government to implement the policy.

In order to be effective, the national policy needs to be specific about what problem it is designed to address. An effective policy must include a clear reason for reuse and resource recovery that can be embedded in the legal, institutional, and regulatory framework. Clarity as to why the policy is put in place can increase its chances of successful implementation and reduce the possibility of isomorphic mimicry.[5]

The World Health Organization (WHO 2006), in "Guidelines for the Safe Use of Wastewater, Excreta and Greywater," provides step-by-step guidelines for how national governments can develop a policy framework for the reuse of wastewater.

Policy alone is not enough to generate incentives for wastewater resource recovery; policy must be supported by a legal and regulatory framework and an institutional arrangement. The types of legal frameworks for policy implementation are discussed in Background Paper IV.

5.2 Institutional arrangements to create incentives

In order to effectively implement wastewater management programs, suitable institutional structures must be aligned with policy and regulatory frameworks to create the right incentives for reuse and resource recovery. Several institutional barriers, however, hinder the development of these activities. Among the major obstacles, a key institutional challenge is the lack of coordination between different levels of government and between different sectors.

Coordination among various levels of government

Coordination and cooperation among different levels of government help ensure that roles and responsibilities for wastewater management and resource recovery are clearly assigned and fulfilled. In many cases, responsibility for policy development in the wastewater sector lies with the national or state government, while the planning, investment, and implementation of wastewater services are conducted by local or municipal governments (as in Mexico and Colombia). Therefore, it is important to have clear coordination mechanisms between these levels. Various coordination mechanisms can be used to address the institutional disconnect between levels of government: creation of a water/wastewater central institution such as the National Water Commission (CONAGUA) in Mexico; contractual arrangements between levels of government

5 For a detailed description of the isomorphic mimicry concept, see the World Bank (2018b).

clearly setting out roles and responsibilities as well as key performance indicators and other monitoring mechanisms; steering committees and working committees (which are relatively less formal institutional arrangements); reinforcement or creation of strong river basin institutions; and ad hoc and project-based stakeholder engagement (as in the case of Cerro Verde, Peru). These arrangements are discussed in more detail in Background Paper IV.

Cross-sectoral linkages and coordination

Wastewater treatment and reuse and resource recovery also involve stakeholders from different sectors such as water and sanitation, energy, agriculture and food, and health, among others. Coordination between these different stakeholders, in addition to an environmental protection mechanism, is needed to create the right incentives for wastewater resource recovery. Some ways to improve coordination among sectors are:

- ***Alignment of legislation and regulatory frameworks across sectors.*** Public resistance and low acceptance of treated products are often reinforced by legal structures that limit or even prohibit the reuse of reclaimed water (e.g., in Chile, despite the successful experience of La Farfana, the water rights system does not allow the selling of treated wastewater), adding further barriers to the objective of promoting resource recovery. Supportive policy, regulatory, and legislative frameworks in all relevant sectors, including wastewater, agriculture, energy, and health, should be in place to ensure a consistent enabling environment for wastewater investment and reuse.
- ***Contractual agreements between different sectors' stakeholders,*** as in the case of San Luis Potosi, Mexico (box 3.3), where a national agreement was signed between the National Water Commission (CONAGUA), the Federal Electricity Commission (CFE), and the state government for the sale of treated wastewater to a thermal power plant for cooling purposes. This case shows how intersectoral coordination challenges can be successfully addressed if specific conditions are met.
- ***Collaboration in the development of multisector master plans.*** Such collaboration should consider synergies and trade-offs among different sectors to achieve policy coherence, allowing political and market forces such as profit-seeking motives to exploit the full potential of cross-sectoral linkages (see the example of Rio Bogota in Background Paper II).
- ***Other examples.*** Partnerships and agreements between stakeholders from different sectors include commissions such as the Joint Commission for the Reuse of Water for Irrigation in Bolivia, partnerships between farmers and water supply agencies (directly or through agricultural departments), and water user associations, among others.

Private sector engagement

Although wastewater services are typically provided by state-owned utilities, as shown in this report, in most countries of Latin America and the Caribbean, the case studies analyzed have demonstrated that the involvement of the private sector has been key in the promotion (see the Cerro Verde case study; box 4.4) and financing (see the Tenorio case study; box 3.3) of resource recovery projects.

Private sector involvement has supported the development of these projects through funding, promotion, and technology transfer. A properly developed and implemented law on public-private partnerships (PPPs) will therefore be important to attract private operators. The government can also encourage investors with a blend of public/private funds and public grants to finance the project, while also providing advice during the PPP process to ensure a sustainable financial structure and a fair contract between the relevant parties. Other key elements to ensure successful implementation of PPP projects include (but are not limited to) strong stakeholder participation, with dialogue and transparency throughout the project cycle and with strong support from the government; clear allocation of roles and responsibilities, as well as allocation of risks between public and private partners; and the establishment of adequate governance committees to provide guidance. This is particularly evident in the PPP implemented in New Cairo, Egypt (box 5.1), where the government addressed issues resulting from the lack of PPP experience in the country by establishing a central PPP unit, as well as a set of laws and regulations governing PPP projects. Similarly, PPP governance committees were created to supervise the correct functioning of infrastructure and deal with unexpected changes in the contracts.

Internal organizational and behavior changes

Besides external factors, resource recovery initiatives also face challenges within institutions. In order for resource recovery initiatives to take off, it is necessary to change organizational behavior and develop a devoted leadership and team to champion and raise awareness of the importance of resource recovery at all levels in the organization. For example, Aguas Andinas in Chile has a dedicated team promoting circular economy and waste-to-resource principles. Also, specialized units within utilities or ministries may help create the capacity to design, develop, and manage PPPs (box 5.1).

Box 5.1 Using a public-private partnership to increase wastewater coverage and foster wastewater reuse: New Cairo, Egypt

As the first public-private partnership (PPP) in Egypt, the project faced significant governance issues, since there were no legal or regulatory structures to handle PPPs. The solution was to use the process of the New Cairo wastewater treatment plant to design a model for future PPPs in Egypt and eventually approve a PPP law in 2010. To ensure that the first project was a success, outside advisors were enlisted to assess and evaluate broad options for PPP structuring. The government of Egypt worked with the International Finance Corporation and the World Bank Group's Public Private Infrastructure Advisory Facility to create a conceptual framework and transaction model. To facilitate the PPP process, a PPP Central Unit was created to act autonomously within the Ministry of Finance. Following the success of the project, the government has created a set of laws and regulations that will govern future PPP projects in the country, drawing on lessons learned from the New Cairo project. The establishment of a PPP central unit enabled coordination within the government. The full case study can be found here (World Bank 2018h).

Strengthen enforcement capabilities

The management of wastewater is intrinsically linked to an ability to monitor and enforce water quality standards. Countries in the region should strengthen their enforcement capabilities. Without the right monitoring and enforcement agencies and the right administrative procedures to impose sanctions, it will be difficult to promote wastewater and resource recovery initiatives. In several countries, enforcement agencies are weak or they lack infrastructure for monitoring water quality. But advances can be seen in the region. For example, in Peru, the World Bank has been providing support to generate and share information for environmental quality control at the national level, by supporting the government's efforts to improve its environmental monitoring and analytical capacity, increase public access to environmental quality information, and promote public participation in environmental quality management. Transparency and access to information are important aspects of regulatory and enforcement capacities.

5.3 A robust regulatory framework

Designed to support the implementation of policy that encourages wastewater reuse and resource recovery and supported by an institutional structure that can monitor and enforce the regulation, a good regulatory framework provides incentives for wastewater reuse and resource recovery. The wrong framework can create disincentives for wastewater reuse and resource recovery.

Clear regulation of by-products. One of the main obstacles to the recovery of wastewater as a resource is that in most Latin American and Caribbean countries, the by-products (treated wastewater, energy, and biosolids) are not clearly regulated and have no clear value or price. As mentioned chapter 4 (section 4.3; lessons learned from the case studies), this discourages utilities and private investors from getting involved in waste-to-resource projects. For example, if there is no clear regulation for the use of biosolids in agriculture (e.g., legislation in Panama and Colombia is very strict on the reuse of biosolids), there will be no demand for this by-product; or if there is no regulation allowing WWTPs to sell electricity to the grid, no water utility will try to develop that business; or if industries do not pay a reasonable freshwater abstraction fee, they have no incentive to switch to treated wastewater. In the San Luis Potosi example, the power plant paid a price to withdraw freshwater from the aquifer. Treated wastewater was therefore a very attractive option since it was cheaper than the freshwater that the plant was using.

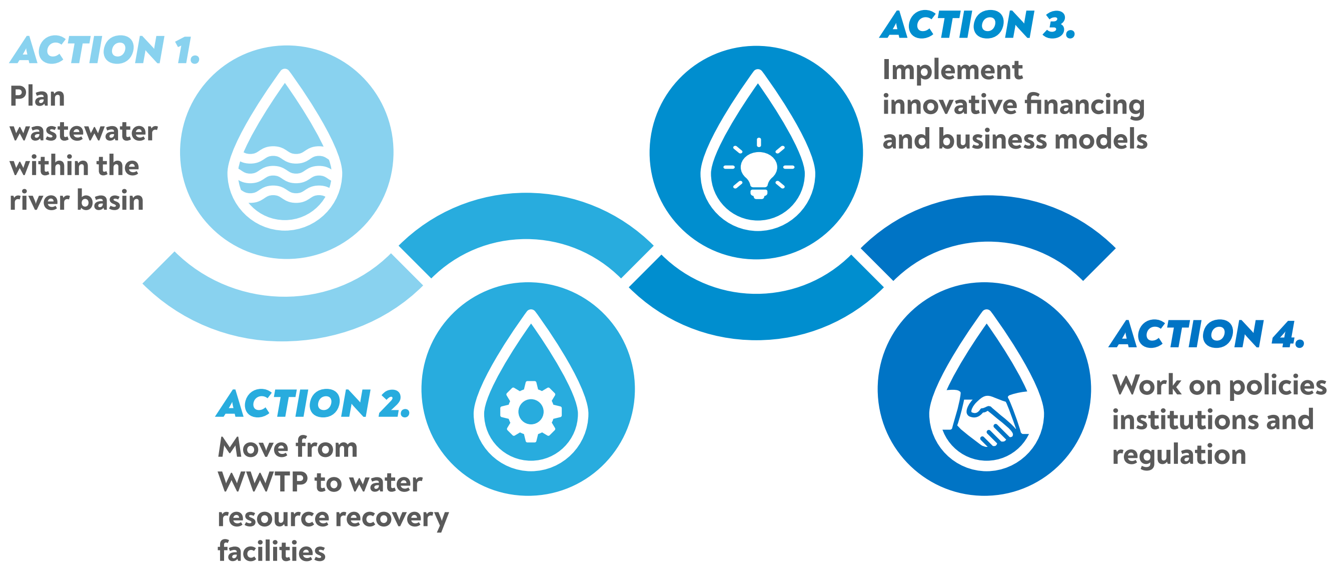
Intersectoral regulation. To create a regulatory framework that incentivizes wastewater reuse and resource recovery, it is imperative that regulatory frameworks from different sectors that are relevant to wastewater reuse and resource recovery be aligned. The SAGUAPAC case study (World Bank 2018i) deals with the difficulties of aligning the regulatory frameworks covering water and energy. The regulatory framework governing wastewater reuse and resource recovery will need to span different sectors, as well as have the flexibility to adapt to local conditions. Both technical regulations (to ensure human and environmental health and safety) as well as economic regulations (to ensure market competition, performance of service providers, and cost-reflective tariffs) are needed. In several sectors, technical and economic regulations for the different sectors already exist. However, to create a regulatory environment that will encourage wastewater reuse and resource recovery, there is a need to align all existing regulation. The case studies depict different ways of bridging intersectoral regulation, particularly between water and energy. In most cases this was achieved through innovative contracting arrangements. Background Paper IV (World Bank 2019g) expands on this issue and on the regulatory frameworks and incentives for resource recovery.

Clear regulation of water pollution and adequate control of industrial discharge. In cities where industries generate a significant amount of wastewater, the enforcement of industrial pretreatment and control programs is essential for the minimization of chemical risks and the successful operation of treatment plants and effluent irrigation schemes. The establishment and implementation of industrial discharge standards is important to promote industrial pretreatment programs and control certain industrial discharges that may be critical to the operation of WWTPs and the quality of treated effluents and biosolids. Quality standards must be set up for industrial wastewater discharged into municipal sewerage systems to ensure that heavy metals, organic toxins, salts, or other harmful contaminants generated by industrial activity do not reach levels that may damage pipes, inhibit the biological treatment processes, remain in the effluent in higher concentrations than permitted for irrigation use or environmental discharge, or accumulate in sludge and limit or even prevent its disposal or reuse as biosolids.

6. Conclusions and the way forward for the region

Wastewater reuse and resource recovery will soon become key aspects of wastewater management strategies worldwide. The scarcity of freshwater in the face of population growth and rapid urbanization, the challenge of meeting the Sustainable Development Goals (SDGs), and the logic of the circular economy have created a compelling incentive to reuse and recover wastewater.

The linear approach to wastewater as something to dispose of must give way to a more circular conception of wastewater as a potentially valuable resource. In the past, the incentives for reuse and recovery were diluted by inconsistent policies, and by institutional and regulatory structures focused solely on wastewater treatment and disposal. The necessary paradigm shift is well under way: wastewater policies in many countries already include reuse and resource recovery. As more join them, the new paradigm will boost the sanitation sector and contribute to the achievement of the SDGs.



Four actions are key:

ACTION 1.

Undertake wastewater initiatives as part of a basin planning framework to maximize benefits, resource allocation, and stakeholder engagement.

Basin planning efforts in the region need to be strengthened. Governments need to support basin organizations, so they can improve their technical expertise and exert oversight powers to enforce the implementation of basin plans. The sanitation sector—as one of the key beneficiaries of river basin planning—needs to be present in basin organizations and active in promoting basin planning. Instead of fostering one WWTP per municipality, countries should assess the real needs of basins and work to achieve a water quality standard consistent with the goals established at the basin level (e.g., accounting for the diluting capacity of a local river).

New or improved institutional arrangements may be needed. Such arrangements could universalize basin-level planning and encourage collaboration between different levels of government, as well as between different sectors. Moreover, budgets for government agencies could be linked to river basin plans instead of targeting sector-specific interventions.

Investment priorities need to be unique for each basin. For this reason, a clear methodology to determine investment priorities (in which areas, cities and towns should investment take place?), the timing or staging of investments, the levels of treatment required, and the technologies to be used must be developed within the basin organization or steering committee. These plans should have legally binding powers and support from the central government to overcome cross-sectoral constraints.

ACTION 2.

Gradually replace wastewater treatment plants (WWTPs) with water resource recovery facilities (WRRFs). At the same time, the efficient and effective management of wastewater infrastructure is crucial to foster reuse and resource recovery.

Promote the utility of the future. To move toward the ideal utility of the future, utilities must first be properly run and perform adequately. Second, treatment facilities must be designed, planned, managed, and operated effectively and efficiently. Finally, countries need to recognize the real value of wastewater and the potential resources that can be extracted from it, incorporating resource recovery and circular economy principles in their strategy, investment planning, and infrastructure design. The utility of the future operates WRRFs, aims to be net energy neutral or even energy producing, implements the beneficial use of biosolids, and reuses water. Ideally, all these recovered resources provide a revenue stream or help cover operation and maintenance (O&M) costs, making the utility both more environmentally and financially sustainable.

Wastewater treatment technology must be adequately understood and used. Adequate guidelines for selecting wastewater treatment processes are needed to avoid unnecessary bias toward activated sludge. Technologies that result in lower capital and operating expenditures must be promoted where possible; these include upflow anaerobic sludge bioreactors, trickling filters, and lagoons. A staged or gradual approach to the implementation of treatment technology must be promoted. The approach should be geared toward meeting limits imposed by legislation in the long term and supported by sound knowledge of wastewater treatment technology and receiving water body capacity.

ACTION 3.

Explore and support innovative financing and sustainable business models that leverage the potential extra revenue streams of resource recovery in WWTPs

Private sector involvement in wastewater has proven to be key for the promotion of waste-to-resource projects. Private sector participation brings technical expertise and technology, as well as investment in infrastructure and technology. When introduced early on, it has led to the successful identification of resource offtakers from wastewater treatment plants. Effective private sector participation, in turn, depends on a conducive enabling environment for investment and a clear policy and regulatory framework.

Various forms of public-private partnerships are often needed for the financing of waste-to-resource projects, especially since the up-front investment requirements of reuse and recovery projects are beyond what many national governments can afford. Blended finance is typically necessary, with subsidies from governments or donors combined with private equity and debt financing that is recovered through user tariffs and resource recovery revenues. The level of subsidy warranted should be determined by economic and financial analysis at the basin level. To provide incentives for efficient performance, subsidies should be disbursed based on achieved results.

Governments should support the creation of markets for resource recovery products:

- **Technical standards and clear regulations for resource recovery products (treated wastewater, energy, biosolids) are important in building public and private confidence and creating a market that makes resource recovery investments viable.** Standards must be flexible and well adapted to local conditions, as standards that are too strict may disincentivize resource recovery. Standards must also be consistently enforced.
- **Cross-subsidies from tariffs on fresh water may be needed to allow the price of resource recovery by-products to be set low enough to allow the market to grow.** Economic regulation can also be used to stimulate and create competition in the bioresource market. There is a great need to align regulatory frameworks from other sectors relevant to wastewater resource recovery, as overlapping regulations can create negative incentives.

ACTION 4.

Review and design policy, institutional, regulatory, and financing frameworks in each context to promote the paradigm shift in the sector.

It is important to align policy, institutional, regulatory, and financing frameworks to encourage and incentivize the development of wastewater resource recovery projects. Although policy and regulatory reforms are context specific and linked to the political economy of each country, a clear policy statement of the reason for resource recovery as part of a broad policy on water is a good first step. Around it, commitments from high-level political leaders can coalesce and public support can be built. A set of policies to create incentives for resource recovery from wastewater comes next, accompanied by complementary institutional, regulatory, and financing frameworks that can be improved over time. In fact, flexibility and adaptability may well be most conducive to progressive adoption of resource recovery practices. The policies and frameworks then need to be cascaded down from the national or federal levels to lower levels. When designing reuse and resource recovery projects, it is imperative that technological and commercial risks be properly assessed and mitigated to instill confidence that projects will be sustainable. The design of PIR interventions to promote resource recovery projects may profitably take place in conjunction with reviews of the country's plans for water preservation, low-carbon development, and climate-change mitigation and adaptation.

Finally, it will be important to raise awareness throughout the region of the potential and the benefits of resource recovery.

Through project design that ensures that those involved in resource recovery projects face appropriate incentives, including measures to mitigate risks, there can be confidence that the resource recovery projects will be sustainable.

6.1 Basic guidelines for planning and financing wastewater treatment plants

When planning and financing WWTPs, priority should be given to projects that meet the following criteria:

- The project is a prioritized component of a larger integrated water-resource management program.
- The project sponsors have adequately analyzed capital and operating costs across the life cycle.
- They have conducted life-cycle evaluations of the project's environmental, social, and financial aspects. Climate resilience considerations and contributions to climate change mitigation are built in. The project will have a measurable contribution to the SDGs.
- The potential for the use of existing infrastructure has been analyzed and integrated into project planning.
- Sponsors have chosen a technology based not only on its suitability for the specific application and initial capital costs but also on its long-term operating costs to ensure that the project can cover operating costs under viable tariffs, taking into account income from the sale of water for reuse, biosolids for beneficial use, and energy generated by the facility (through biogas or hydropower) as demonstrated by the life-cycle analysis.
- The project promotes resource recovery (water reuse, beneficial use of biosolids, and energy generation from biogas or hydropower) in a sustainable way.
- Planners and sponsors have explored innovative and sustainable business and financial models, weighing the benefits of private sector participation in investment and operation while retaining regulatory control (preferably by an independent regulator). If the private sector is to be involved, the project must clearly indicate how it will contribute to the sustainability of the project.
- Clear effluent limits are based either on the loading criteria of the receiving water body (best option) or regulatory requirements based on scientifically/economically sound legislation.
- Industrial discharges are identified and specified in adequate monitoring and control systems. Industries will either pay for treatment (e.g., $/kg treated) or will reduce their discharges to agreed concentrations through in-house treatment.
- The project contributes to the development of the sector by assisting in the training of government employees, local university students, operators from government-run utilities, and other professionals in the region who can gain from the experience.
- There is public and stakeholder awareness and acceptance of the need to implement a WWTP. A communication strategy has been developed that clearly explains the benefits of resource recovery and debunks the misconceptions surrounding wastewater reuse.

6.2 Areas for deeper analysis and future work

Real life-cycle analysis of wastewater treatment plants

During the preparation of this report, it became obvious that reuse and resource recovery projects and initiatives will not always generate an additional revenue stream for the WWTP, usually because the end use generates low revenue—for example, if water is used for irrigation, or to recharge an aquifer, or if biosolids are used to restore degraded land. To understand the full benefits of such projects and assess the desirability of subsidies or grants to promote them, a deeper cost-benefit analysis is needed, one that takes financial, environmental, and social aspects into account.

The potential contribution of wastewater recovery for the environment involves not only improvement in the quality of the receiving water body but also the benefits associated with water reuse (substitution for alternative water sources, which is especially beneficial in water-scarce areas and, in the near future, to respond to potential impacts of climate change), energy generation from biogas (climate change mitigation and adaptation), and beneficial use of biosolids as fertilizers (substitution for synthetic fertilizers, which contribute to pollution). A facility's positive social implications should be considered over the entire cycle: jobs generated by the construction, operation, and maintenance of the plant; increases in property values following improvement of the receiving water body; alternative water sources for farmers from reuse; low-cost, valuable fertilizers for farmers from a biosolids program; and improved health from better water quality. Tariffs for wastewater should be approved and justified based on such a life-cycle analysis. Given its importance, this topic requires further analysis and implementation in future projects and lending operations.

Use of economic instruments for water pollution control

Economic instruments have been used in several countries in Latin America and the Caribbean for several years as complementary to command and control options. Some of these applications have significantly contributed to considerable reductions in wastewater discharges. However, their scaling up has been limited. Future work could consist of an assessment of existing economic instruments and their impacts, and recommendations for their further adoption in the region.

Technical support for the implementation of water resource recovery facilities

Many countries are now in the process of planning, designing, and bidding out WWTPs. The aim of this initiative is to continue providing on-demand and specialized support for the development of water resource recovery facilities.

Background Papers:

"Background Paper I: Efficient and Effective Management of Water Resource Recovery Facilities"

"Background Paper II: Showcasing the River Basin Planning Process through a Concrete Example: The Río Bogotá Cleanup Project"

"Background Paper III: The Role of Modeling in Decision Making in the Basin Approach"

"Background Paper IV: Policy, Regulatory, and Institutional Incentives for the development of resource recovery projects in wastewater"

"Background Paper V: Financial incentives for the development of resource recovery projects in wastewater"

"Background Paper VI: Market Potential and Business Models For Resource Recovery Products"

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Appendix A. Summary of case studies

Case study	Circular economy model	Contract structure	Financial structure	Enabling factors
Mexico: San Luis Potosí, Tenorio project	Treated wastewater reused for industry (power plant cooling), agriculture (irrigation of 500 hectares), and environmental conservation (wetland improvement) as part of a wider sanitation and water reuse plan.	Build, own, operate, transfer (BOOT); 20 years Revolving purchase agreement with the Federal Electricity Commission (CFE)	40% government grant from FINFRA funds 36% from Banobras loan; 18-year maturity period 4% equity by risk capital company Federal government guarantee	Institutional: Strong leadership of the federal and state water authorities. Cross-sectoral collaboration with CFE. Regulatory: Local water prices at contract signing promoted the use of nonaquifer water. Clarity of payment mechanism and risks well defined and allocated. Technical: Scarcity of water resource, multiple quality levels of treated wastewater tailored to different uses.
Mexico: Atotonilco de Tula	Treated wastewater reused for agriculture (irrigation Valle Mezquital). Self-generation of energy with biogas to cover around 60% of energy needs. Biosolids used for fertilizers and soil enhancement.	Design, build, own, operate, transfer (DBOOT); 25 years	49% government grant from El Fondo Nacional de Infraestructura (FONADIN) 20% equity from consortium partner 31% commercial finance	Institutional: Strong ownership of experienced water resources management institutions. Strong experience of public funding agency. Regulatory: Clear regulations allowed the reuse of water and biosolids. Technical: Multiple quality levels of treated wastewater tailored to different uses, Water Treatment Technology Program (WTTP) adapted to dry seasons.
Bolivia: Santa Cruz de la Sierra	Purchase of certified emission reductions (CERs) from methane gas capture. Electricity for self-consumption.	Emission reduction purchase agreement for biogas capture. First of its kind for low-income countries.	World Bank financing CER but withdrew due to change in legislation	Regulatory: Project failed to be implemented due to regulatory limitations in the energy sector. Technical: Methane capture technology adapted to anaerobic lagoons.

Egypt: Cairo, New Cairo project	Treated water reused for agriculture. Biosolids used as fertilizers.	First public-private partnership (PPP) in Egypt Design, build, finance, operate, transfer; 20 years	71% public finance 21% nonrecourse finance 8% equity	**Institutional:** Strong leadership of central government (creation of a centralized PPP unit). **Regulatory:** The full potential of the project has not been realized due to ambiguous or no regulatory frameworks. Both the sale of carbon credits and the use of electricity generated have been stalled. **Technical:** Strong external technical support and advising (Public-Private Infrastructure Advisory Facility, PPIAF).
United States: New Jersey, Ridgewood	Plant energy neutrality through the use of biogas generated by the plant (with co-digestion)	20-year power purchase agreement with municipal utility	4 million private finance (Ridgewood Green) Renewable energy certificates	**Institutional:** Strong public support and commitment form the municipality. **Technical:** Innovation used to retrofit existing infrastructure.
Brazil: PRODES	Output-based grants tied to strict environmental and managerial performance standards promoting resource efficiency. Funding eligibility tied to river basin committees promoting a river basin planning approach.	No particular contracting structure is promoted	Results-based financing	**Institutional:** Strong support from the Finance Ministry and the National Water Agency. **Regulatory:** Strict connection between results and financial aid. **Technical:** Strong technical support from ANA during the certifying process.
South Africa: Durban	Treated wastewater sold for industrial purposes: Modi (paper industry) and SAPREF (refinery).	20-year BOOT contract	47% Development Bank of Southern Africa loan 20% equity 33% commercial loan	**Institutional:** Strong coordination mechanisms supported by the local government. **Technical:** Closeness of treated wastewater off takers. Technological innovations to retrofit existing plant.

Chile: Santiago, La Farfana	Generation and sale of biogas to one end user	Joint Venture + Biogas Purchase Agreement (6 renewable years)	Corporate blended funding instruments (green bonds/debt) Possibility to sell renewable energy certificates	Strong ownership from stakeholders and financially sound partners. Technical: Proximity to the Town Gas Plant. Technological innovations to retrofit existing plant. Regulatory: Regulated gas market allows using biogas for town gas production. Water regulation that fosters innovation: It provides a grace period of five years during which utilities can keep the profits obtained from an innovation before they are obliged to pass them through to consumers via tariff reductions.
Peru: Arequipa, Cerro Verde	Treated Wastewater reuse for the mining industry	BOOT 29 years awarded to End user	100% financed by the end user (private mining company)	Institutional: Comprehensive PPP legislation, strong support from local and federal government Technical: Private partner ensured that the best technology was chosen for the local conditions Water scarcity: the cost of tapping the nearest water source was high.
India: Nagpur	Treated wastewater reuse for cooling purposes in thermal power plant	30-year DBOT-PPP End User Model	50% Government Grant 50% Private (sole end user)	Water scarcity: the cost of tapping the nearest water source was high. Institutional: Strong Regional and Federal Government support Technical: The proximity of the power plant lowered transportation cost

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