From Waste to Resource

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

Background Paper VI:

Market Potential and Business Models for Resource Recovery Products

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

The World Bank is working with partners around the world to ensure that wastewater's inherent value is recognized. Energy, clean water, fertilizers, and nutrients can be extracted from wastewater and can contribute to the achievement of the Sustainable Development Goals (SDGs). Wastewater can be treated up to different qualities to satisfy demand from different sectors, including industry and agriculture. It can be processed in ways that support the environment, 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 are potentially valuable for agriculture and energy generation, making wastewater treatment plants more environmentally and financially sustainable. Improved wastewater management thus 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 in part or in full. Resources recovered from wastewater facilities—such as energy, reusable water, biosolids, and nutrients—represent an economic and financial benefit that contributes to the sustainability of water supply and sanitation systems and the water utilities operating them. Reuse and resource recovery (R&RR) could transform sanitation from a costly service to one that is self-sustaining and adds value to the economy.

This background paper is one of several supporting materials for the report "From Waste to Resource: Shifting Paradigms for Smarter Wastewater Interventions in Latin America and the Caribbean", a product of the World Banks' Global Water Practice Initiative Wastewater: From Waste to Resource.

The paper analyzes the market for resource recovery products in Latin America and the Caribbean (LAC), as well as business models for the development of waste-to-resource projects. It draws on the findings of numerous case studies and on consultations with stakeholders.

Case Studies Analyzed

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 and fat oil and greases purchased to nearby haulers.	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	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.
Mexico: Tlanepantla de Baz	Treated wastewater reuse for industrial users	DBOT	100% Municipal bonds Sovereign guaranty	**Institutional:** Strong support from municipal authority and from association of industries

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

The market for resources recovered from wastewater treatment

Market volume

We estimated the size of the potential market for three recovered resources: treated water, energy, and biosolids. To express the estimate in monetary terms, we had to assign a value to each of the products based on worst- and best-case scenarios drawn from the case studies. In the worst-case scenario no recovered products are sold—that is, there is no revenue. Even in this case, however, it is possible to assign a value to the product based on the savings from avoided costs. For example, wastewater and biosolids can be provided free to farmers, thus saving on discharge and landfill fees. Electricity produced from recovered products can be used by the treatment plant, lowering its energy bill. The best-case scenario assumes that the product is sold, providing additional revenue to the wastewater treatment plant.

Treated wastewater. Using the "polluter pays" principle, one can estimate the potential cost savings for a wastewater treatment plant. The "polluter pays" principle dictates that utilities should pay the cost of residual pollution abatement connected with their discharges. The cost of pollution abatement is estimated at $1.17 per unit of pollution (defined as 1 kg/l of BOD[1]) (ITAC, 2019). In the worst-case scenario, the treated wastewater can be given away free to farmers, saving the cost of pollution abatement. Treated effluents still contain some pollutants. The cost avoided can be assumed to be 0.03 pollution units, which are equivalent to 30 mg/l BOD_5, the allowable concentration in the effluent[2]. The cost avoided in this case would be $0.0351 per cubic meter[3].The highest market price for the wastewater can be assumed to be $0.75/m^3, which is the price industry pays for wastewater in the San Luis Potosi case (World Bank 2018a).

Biosolids. The lowest market price for biosolids would be the cost avoided by the operator if it were to give away the biosolids it produced. The lowest market price would therefore be the avoided cost of transporting the biosolids to a landfill. We estimate this as $5/ton.[4]
The maximum market price is the sale price of the biosolids, plus the saving on landfill fees. The bulk compost price can be estimated at $20/ton[5]; landfill fees can be as high as $80/ton.

1 Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed (i.e. demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. The BOD value is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C.

2 Secondary treatment is designed to remove 85% of BOD. The average BOD in the untreated domestic wastewater is 200-220 mg/l. The BOD contained in the WWTP effluent is therefore around 30-33 mg/l. Allowable discharge varies depending upon the water body where it is discharged, the size of population served, etc. In Mexico, Conagua classifies the water bodies according to the pollution. This classification considers water is polluted when BOD is above 30mg/l. The EU directive requires less than 25 mg/l. (ITAC, 2019)

3 0,03 X 1,17$ = 0,0351$.

4 Source: ITAC, 2019. Based on conversations with operators in the Latin America and the Caribbean and in the European Union.

5 Source: ITAC, 2019. Based on conversations with EBMUD (a U.S. operator).

Energy. The cost avoided by not having to purchase electricity varies with countries' energy profile, power generation structure, demand, and the utility's purchasing power. A reasonable range for retail electricity costs is $0.04–$0.20/kWh[6].

The market volume in Latin America can be calculated using these price ranges for treated wastewater, biosolids, and electricity, and extrapolating using the case study of the Atotonilco (World Bank 2018b) plant's production, using as a proxy the population equivalent served by the plant (10.5 million people). The results shown in the following table are based on very rough assumptions but still demonstrate the potential of recovered resources.

Table 1 Potential market volume for wastewater, biosolids, and electricity in Latin America and the Caribbean

US$ million	Low-price scenario	High-price scenario
Wastewater	1.980	42.303
Biosolid	870	17.409
Electricity	480	2.398
Total US$ million	**3.330**	**62.110**

Source: ITAC 2019
Note: These are very rough assumptions, since no firm global statistics exist on the selling prices of products of wastewater treatment plants.

The results illustrate a large market potential. Presently, however, not even the low-price scenario is being reached in the region. Many utilities do not pay the discharge fee even if they fail to comply with effluent standards; only a small number of plants self-generate electricity; and many plants store biosolids on-site or in a landfill instead of selling them or giving them away to farmers.

Co-digestion. By implementing co-digestion, wastewater treatment plants can increase their production of electricity and biosolids as much as fivefold. The increase consists of fees for accepting the organic matter collected and the value of the electricity generated from that organic matter.

Market growth

The potential for market growth varies with geographical, institutional, and socioeconomic factors. For example, in Mexico, wastewater reuse is more developed than in other countries because of the country's water scarcity. Scarcity triggered initiatives to promote wastewater reuse in the most water-scarce areas. Other case studies confirm that the potential for market in water reuse depends heavily on the availability of water resources and their extraction costs.

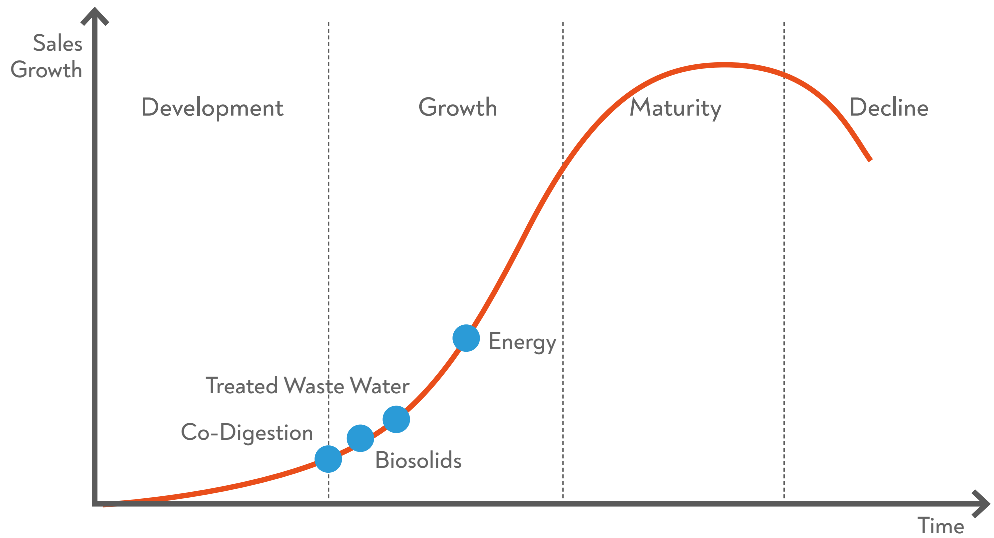
Within the LAC region, the market for energy produced from biosolids is most developed in Chile, though growth potential and opportunities are present in all LAC countries, since energy can be used for self-consumption or sold provided proper regulations are in place.

The biosolids and co-digestion markets are mature in the United States and Europe, but LAC is still in the development stage, with only few examples in the region. The potential for co-digestion in Latin America is therefore very high.

The position of the different business segments in Latin America and the Caribbean are presented in figure 1.

6 Latin America Energy review 2016. Leaving away highly subsidized prices like in Venezuela and high cost island nations like Haiti.

Figure 1 Current status of four wastewater-related business segments in Latin America and the Caribbean



Source: ITAC 2019.

All four business segments have passed the development stage and are in the growth phase of the product cycle. Energy generation is the most developed, though still not widespread, followed by treated wastewater, as evidenced by experiences in Mexico, Brazil, and elsewhere. Several of the Mexican experiences are profiled in the case studies. Biosolids and co-digestion are just emerging from the development stage.

Business Models

The next section presents models for use in three principal business segments: treated wastewater, energy, and biosolids. Co-digestion is treated as a hybrid of the last two.

Market segment #1: Treated wastewater

Reuse of treated wastewater in industry: two enabling factors and three models

The case studies of San Luis Potosí (World Bank 2018a), Cerro Verde (World Bank 2019a), and Nagpur (World Bank 2019b) establish that the sale of treated water to industry can be profitable, covering most or all of the plant's costs of operation and maintenance (O&M). Profitability rises with water scarcity—in other words, where water is scarce, water tariffs for industry tend to be higher, pushing up prices for treated water. In most cases, however, only one industry in the area is in a position to purchase the treated wastewater produced by the plant. Therefore, seller and buyer must agree on the contract details. Profitability can exceed a 25 percent return on investment—or even higher if avoided costs are also considered. Furthermore, water reuse projects present relatively low risks and are typically sustainable. Stability of supply is thus another advantage for the industrial counterpart. Supplies of wastewater tend to be more stable than supplies from natural reservoirs, from which extractions may periodically be limited (e.g., during droughts).

The case studies reveal two major enabling factors for the implementation of wastewater reuse projects:

- A strong institutional framework for wastewater reuse
- Physical factors, notably water scarcity and the distance to industrial customers.

We will deal with each in turn.

Institutional factors

Successful reuse of treated wastewater usually depends on the existence of a strong institutional framework to promote reuse and shape contract design.

Some countries have multisectoral agencies with experience in planning, financing, and implementing water projects. In Mexico, CONAGUA offers assistance to the weakest party, generally the treatment plant (typically owned by a water utility), so as to achieve a financial structure that makes projects bankable while distributing risks and profits in a balanced manner.
Other countries in the region may wish to consider replicating the CONAGUA model for planning and financing wastewater reuse. One advantage of the model is to ensure the maximum amount of funding from the private sector to leverage limited state funds. Mexico's revolving funds (FONADIN) and trust funds (FINFRA) are also worthy of replication.

An important aspect of overarching planning agencies is their familiarity with the market and its participants, including technology providers, construction companies, financial institutions, and regulators responsible for water, agriculture, industry, the environment, and other sectors. The agencies collaborate with all stakeholders during planning, project preparation, tendering, and project implementation. Often, they are able to identify the most suitable technology and provider for a given project.

The lack of such agencies is an important barrier to the wider implementation of wastewater reuse projects in the region.

Physical factors: scarcity and distance

It is no coincidence that industrial use of treated wastewater is more prevalent in countries where fresh water is a scarce resource. But other physical factors count, too. The location of the closest potential client (industry, power plant, etc.) also matters, since moving water long distances may make it unaffordable. Physical or geographical factors can both trigger changes at the institutional level (by increasing water tariffs for industry) and push the industry to innovate and find alternative sources of water. For example, in San Luis Potosi, the power plant was paying a high price to draw freshwater from the aquifer. Treated wastewater was a very attractive option because it was cheaper than the fresh water the plant had been using.

The most an industry will pay for recycled water is the amount they are currently paying for the right to draw from rivers or other natural resources. If water is abundant in these natural reservoirs, the price of water tends to be low, making wastewater reuse less viable. In such cases, other incentives may be needed to foster resource recovery projects, and the role of the coordination agency (or other institutions capable of inducing change) becomes more important. One option is to raise the withdrawal and discharge fees to reflect full social and environmental costs. Doing so would create an incentive for industry to use treated wastewater when available, as in the case of San Luis Potosi in Mexico. Other, softer measures might be a combination of actions such as (i) performing and disseminating needed studies to demonstrate that investments in reuse of treated water can benefit both parties (utility and industry) if designed correctly; (ii) providing public grants to finance part of the project, thereby lowering risks to investors; and (iii) advising during the process to ensure a sustainable financial structure and a fair contract between the relevant parties.
Decisions on siting wastewater treatment plants should consider the distance to potential industry users. Instead of being located next to waterways to facilitate discharge, plants could be located close to water-intensive industries (power plants, mines, petrochemical facilities, paper mills, etc.) with which the utility or plant operator can conclude long-term purchase agreements, increasing profitability and sustainability.
Strategic siting can create other synergies, as well. Treatment plants located near power plants could provide treated wastewater for cooling at a discounted price. The power plant could use

cleaned biogas produced in the treatment plant to produce electricity. The electricity could then be sold to the treatment plant at a discount. The power plant could also send residual or waste heat from generation to the treatment plant to heat digesters and dry biosolids. Dried biosolids could be burned in the power plant to produce additional electricity.

With these institutional and physical parameters in mind, the case studies can be grouped into several business models.

Model #1: The industrial end user finances, builds, and operates the wastewater treatment plant

As in the cases of Cerro Verde in Peru and Nagpur in India, this business model may apply when no other viable water source is available to the industry, and the cheapest option is to build a plant to treat wastewater from a nearby urban area. The end user receives untreated or partially treated wastewater, treats it to the desired quality and reuses it in its operations. The end user would usually hire a technology provider to build and operate the treatment plant to bring wastewater up to the standard required for its processes.

Such build-operate-transfer (BOT) agreements are typically made for a period of 20 to 30 years. The end user provides risk capital (equity), mixed with loans from commercial institutions, to build the infrastructure, assuming most or all of the risk. The infrastructure includes the treatment plant, the means required to convey the treated water to its installations, and the facilities needed to dispose of used water in compliance with applicable environmental regulations. The design risk lies with the end user, which must make a detailed study of its water demand and the available technology options. The end user has an interest in assuring efficient operation and adequate maintenance of the treatment facility in order to ensure uninterrupted delivery of water for its own use, mitigating any residual supply risks by installing storage facilities or securing alternative sources of supply. Once the investment is made, the cost of water supply (capital costs, financing costs, and the costs of the O&M contract) should be less than any other alternative source of water; otherwise, the business model is unlikely to be attractive, unless the alternative sources are very unpredictable.

Model #2: The utility treats the wastewater and sells it to end users

The model—usually involving a BOT agreement with a private operator—commits the water utility to supply set amounts of wastewater to end users at a specified level of quality. The end user commits to purchase the product for an agreed price over an agreed period. Since the cost of alternative sources of fresh water will depend heavily on abstraction fees established by the government, this type of project can be promoted by institutions responsible for water resource management. Long-term contracts are typically necessary to ensure project sustainability and bankability. In the case of San Luis Potosi, Mexico, the state water commission (CEA in Spanish) signed two contracts: (i) a build-own-operate-transfer (BOOT) contract with a private company (ARTE) to build the wastewater treatment plant and to maintain it for 20 years (2 years during construction and 18 years after completion); and (ii) an agreement with a power plant (CFE) to purchase the treated wastewater. The power plant's guaranteed demand for treated wastewater enabled CEA to undertake the investment risks. CEA and CFE agreed that the fee for the wastewater would be 67 percent of the state's price for groundwater to be used for industrial purposes. Because the cost of water for industrial uses in San Luis Potosí is among the most expensive in Mexico, the agreement benefited both parties, reducing operational costs both for the power plant and the wastewater treatment plant while also protecting the aquifer.

Model #3: The utility outsources treatment to a third party that then sells treated wastewater to industrial users

This model is used in Durban, South Africa (World Bank 2018c). In order to be able to supply recycled water to two industrial users, the municipal water utility (Ethekwini Water Services) had to upgrade the existing activated sludge process, build a new tertiary wastewater treatment plant, refurbish the high-level storage tank, and install a reclaimed water reticulation system. One complexity of the project was that one of the potential clients required high-quality water to produce fine paper. Given the technical complexity, cost, and risk of the project, the municipal utility opted to implement the project under a public-private partnership (PPP). After international bidding, 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 remains responsible for primary wastewater treatment, and the effluent from the primary settling tank is sent to DWR's plant to be treated and then sold to users. The private sector provided all of the funding needed for the project. The guaranteed demand for treated wastewater from the two industrial users made the project economically attractive and allowed DWR to assume the investment risks. DWR also agreed to meet the water quality requirements of the two industrial users. The municipal utility incurred no taxpayer-funded capital cost.

Reuse of treated wastewater in agriculture

The uses of treated wastewater in agriculture call for a business model different from those that apply in industry. The treatment cost is usually lower than for industry, as only primary treatment and disinfection are needed. However, given the intended end use, and in order to avoid health risks, it is important to continuously monitor the treated effluent.

The chief difference from the industrial case is that profitability is more difficult to achieve. As in industry, farmers are unwilling to pay more for treated wastewater than they must pay for fresh water, which in most cases is very low. Moreover, sometimes farmers are reluctant to use treated wastewater because they believe it will reduce their yields, as seen in the case of Atotonilco, Mexico. On the other hand, the use of treated wastewater can be viable if farmers must pump water over long distances, resulting in a high energy price. As in the industrial case, the closer the treatment plant is to agricultural centers, the better the business case.

In this same market, we can include the use of treated wastewater for recreational and ecological purposes, such as refilling aquifers. For all these end uses, as for agricultural uses, it is challenging to generate revenue streams for the plant. The cost of making the treated wastewater available to the end user usually exceeds the discharge fee saved by the utility. One exception may be the use of treated wastewater to water golf courses, which, depending on local conditions, could be considered either a recreational use or an industrial use.

Most often, however, this type of business must be subsidized by the public sector. The subsidy can come in form of capital investment or included in the water tariff. With subsidies, the business can be viable. Ideally, a strong agency or institution would help design a financial structure that guarantees bankability and a balanced distribution of risk. The main players are the utility and, usually, farmers' cooperatives.

When all benefits and externalities are considered in the analysis, the benefits typically exceed the treatment costs, especially in water-scarce areas and areas threatened by new natural phenomena induced by climate change. Another benefit that should be considered is the power of wastewater treatment to lower human exposure to pathogens.

Common financial structures and instruments used in wastewater reuse projects

Most of the industrial and agricultural cases discussed above follow a BOT or BOOT model financed through various instruments.

The financial structure of San Luis de Potosi, which uses a BOOT model, consists of 40 percent public funds (from FINFRA), 36 percent commercial bank loans and 24 percent operator's equity. The clear contract binding all stakeholders and ensuring the sale of the treated wastewater made the investment attractive for the operator. The

Atotonilco plant, a BOT, is financed at 49 percent by a government grant, 31 percent through commercial bank loans, and 20 percent operator's equity. The Durban recycling project, which is also a BOOT, is financed totally by the project operator (20 percent equity and 80 percent loans). Cerro Verde is an unusual BOT in which Minas de Cerro Verde, the industry partner and user of the treated wastewater, finances the capital investment and operating expenses of the entire wastewater treatment plant, not only the tertiary treatment plant. Nagpur is also an unusual BOT where the power utility, MAHAGENCO, is also the recycling project operator. The municipal water utility contributes with a government grant to finance part of the capital costs.

Tlalnepantla de Baz (World Bank 2016a) uses a different financial structure. The utility implemented the business without a private partner. The municipality and the municipal operator decided to carry out and finance the project using their own means. Municipal bonds are guaranteed by pledges of future revenues from sales of recycled water and from other municipal taxes. The scheme employs a trust fund, similar to the federal trust fund (FINFRA) found in Mexico, but at a municipal level, which is quite innovative. The fund is also backed partially by a multilateral guarantee.

Governments could also sponsor the development of water reuse trust funds to finance wastewater projects destined for agriculture and other low-revenue uses. The trust funds could also be used by water utilities and investors as leverage to guarantee financing of wastewater reuse projects aimed at industrial users.

Market segment #2: Energy

Biogas produced in wastewater treatment plants can be used to generate heat and electricity needed to operate the plants. Depending on market prices, the gas may also be sold to the gas utility or, after conversion to electricity, to the grid or an industrial consumer. Several cases illustrate the potential of energy as a by-product of wastewater treatment. La Farfana (World Bank 2019c) sells its biogas to a gas company under a long-term agreement. Atotonilco and Cañaveralejo (World Bank 2016b) use their biogas to help power the plants. Ridgewood's produces 100 percent of the energy required by the plant (Wolrd Bank 2018d).

The energy business can be very profitable since the capital costs are relatively small compared to the costs of the plant. Operating expenses for the gas cleaning plant and the power plant are also low—less than 5 percent of the capital expenses. Because the biogas is essentially free fuel for the plant once the capital investment is made, electricity can be generated much more cheaply than in a power plant that must purchase gas. Thus, the treatment plant either earns revenue from the gas or electricity it sells or saves on electricity costs if it uses its gas for self-consumption. In addition, the utility can also obtain carbon credits by burning the biogas and transforming CH_4 to CO_2. Some countries include biogas generation in their renewable-energy incentives schemes; in such cases, assuming the right regulations are in place, operators may derive extra income by selling power at the privileged price.

Profitability is evident in cases like la Farfana, where the plant invested $2.7 million and now earns a yearly net profit of $1 million from biogas activities, a 40 percent return rate that enabled it to recover its investment in a little over two years.[7] Demand risk is low, since there is a well-structured contract and just one end user. The main risk in this case is related to the sale price, which is indexed to the price of oil. In case of interruption of demand, the gas would be automatically flared off, though the maintenance costs of the pipeline would remain the same. To mitigate this risk, Aguas Andinas is developing the means to generate electricity for self-consumption. But Aguas Andinas is ahead of the curve—partnerships between the water and energy sectors in LAC remain rare.

7 Aguas Andinas (2017). Aguas de Maipu, a nonregulated subsidiary of Aguas Andinas that develops and operates gas and electricity projects, produced a net result of about $1 million in 2016.

Before entering the energy market on a large scale, water utilities will have to address several challenges. First, they must begin to see themselves as potential energy producers. As shown in the case studies, investing in energy generation can yield additional revenue streams that can reduce the O&M costs of the water business. Water utilities may choose to focus on their core business, outsourcing the energy business to specialized companies in the sector through PPPs, subcontracting, or other arrangements.

Secondly, economies of scale prevent the wide implementation of partnerships with the energy sector. For a small wastewater treatment plant, the investment needed to produce energy may not be profitable. The minimum profitable size for a power plant is about 200 kW, which would require the treatment plant to produce 50–75,000 cubic meters of biogas per day. Although other factors are at play in the sale of gas (notably distance to the consumer), the minimum efficient plant size is similar. To solve the challenge of economy of scale, one solution (if the utility has several plants) is to consolidate all sludge at the largest plant. This is the solution pursued by Aguas Andinas, which collects sludge from all its plants in the Santiago region and sends them to La Farfana for digestion and biogas production.

Lastly, and most importantly, most countries in the region lack clear regulations and institutional frameworks for the sale of gas or electricity by wastewater treatment plants—or even for self-consumption, as in the case of Santa Cruz de la Sierra (World Bank 2018e). This lack prevents plant operators and utilities from entering the energy business or partnering with the energy sector.

Yet, as shown by the case of Aguas Andinas, the potential is great. The investment required to develop a biogas business is small compared with the total investment requirements of the treatment plant. The cost of the digesters, gas cleaning equipment, and generators ranges from 8 to 12 percent of the total plant cost. The biogas investment requirement, including digesters, can range from $2 to $6 million for a plant serving 150,000 to 1,000,000 equivalent habitants.

Common financial structures and instruments used in energy projects

One interesting financial structure might be a PPP for the energy business only, as in the Ridgewood case. The most advisable form of PPP would be a BOT, wherein the operator contributes the financial and technical resources needed to build the digesters and the power plant. The utility might allow the operator to keep all of the revenues from sale of the gas or electricity—or it could agree on a price for the electricity that is slightly lower than what the utility is currently paying (such as in the case of Ridgewood).

In the Atotonilco case, the utility included construction of the power plant (for self-consumption) as part of the BOT contract for construction of the wastewater treatment plant. This allowed the contractor to include energy efficiency measures in the design, enabling the utility to minimize its tariff increase, which had been the main concern of the utility in devising the criteria for selection of the contractor.

Besides PPPs, energy projects can be financed with the debt obtained to build the wastewater treatment plant, as in Cañaveralejo, or with create a special bonds created for the energy project, as in the Tlalnepantla case. La Farfana is a case in which the private operator finances its infrastructure developments with corporate bonds sold to domestic investors and, where applicable, with green bonds.

Other partnerships might involve international technology providers or small specialized companies similar to the energy services companies (ESCOs) that exist in the power sector, which can help select the technology most suitable for each case.

Market segment #3: Biosolids

As with energy production, businesses based on biosolids are relatively undeveloped as spinoffs of wastewater treatment in the LAC region. Most of the biosolids generated by treatment plants in the region are deposited in the vicinity of the plant or in landfills (at a cost to the utility). As in the case of the reuse of treated wastewater in agriculture, the main obstacle to the biosolids business is the absence of a clear price for the final product, since, usually, the potential customer is not yet ready to pay for it. Farmers may be willing to take biosolids from the wastewater treatment plant at no cost. Similarly, biosolids can be used for forest and land restoration, but it is difficult to convince public authorities to pay for them. Until this state of affairs changes, wastewater treatment plants are unlikely to receive any revenue for the biosolids they produce. However, finding takers may still be beneficial for the plant operator, as it may save on transport and landfill fees.

The cases of SEDACUSCO and Ridgewood exemplify this approach. SEDACUSCO is saving on landfill fees and transport costs. Ridgewood is going one step further, collecting disposal fees from other industries for organic matter that it uses for co-digestion at its plant.

Beneficial uses of biosolids can generate important economic and environmental benefits. SEDACUSCO is using biosolids for soil restoration (to remedy non-source-pollution) and to help conserve soil moisture. In the Ridgewood case, the amount of organic matter going to landfills is significantly reduced, reducing emissions of greenhouse gases.

Governments would be well advised to account for such environmental benefits and create incentives for the use of recovered biosolids. Regulations could incentivize beneficial activities by prohibiting disposal of untreated sludge at plant sites, dumpsites, and landfills and of biodegradable organic matter in landfills without composting. Fees imposed on soil-eroding and -depleting industries like wood, mining, and farming could finance soil restoration and the development of soil restoration projects using biosolids from treatment plants. Such green fees might be included in water tariffs to finance and promote the development in the region of projects similar to the SEDACUSCO example.

As in the energy segment, the absence of clear regulations in the region is a key obstacle to the beneficial use of biosolids produced in the course of wastewater treatment. Many of the region's environmental agencies lack the resources required to guarantee the quality of biosolids; as a precaution, therefore, they do not allow their use in agriculture. The more common form of reuse is for land remediation and soil restoration, which have little revenue potential. Further, regulation of biosolids is usually not done at the national level; instead, departments, provinces, and municipalities maintain different, and in some cases, contradictory, regulations.

Common financial structures and instruments used in biosolids projects

If the biosolids business is to be developed on-site, the wastewater treatment plant must finance the needed infrastructure, as in the case of Ridgewood or Cañaveralejo. If a separate composting plant is used, as in the SEDACUSCO case, the plant does not need to finance additional infrastructure.

If the composting is done within the treatment plant using the plant's sludge alone, the composting plant will be relatively small and, accordingly, have low capital and operating costs. This is very similar to the circumstances of the energy segment, and the same financial solutions may apply: A short-term PPP in the form of a BOT will allow the operator to recover its investment while giving the utility time to learn to manage the biosolids business.

But if the plant operator intends to build a composting facility large enough to accommodate organic matter from external customers, the biosolids business becomes a co-digestion business. As described in the next section, co-digestion can potentially be a large and diversified business with several sources of income and a higher investment requirement. Such business can still be financed with a BOT scheme as in the case of Ridgewood, but more sophisticated financial instruments may be necessary.

Market segment #4: Co-digestion

Co-digestion is a hybrid of the energy and biosolids businesses. It comprises elements of both in a way that can make it attractive to private investors. In co-digestion, sludge from the wastewater treatment plant is only a part of the digesters' feedstock. The digesters also receive other organic matter from residential, commercial, agricultural, and industrial sources. Depending on the feedstock, there may be separate digesters for different feedstocks, or all may be bundled together in a large digester. After digestion, the remaining biosolids can be composted.

The energy output of wastewater treatment plants engaged in co-digestion will be greater than that of plants without co-digestion, potentially exceeding the energy needs of the plant. Excess electricity can be sold to the grid at the going rate. In the co-digestion model, tipping fees earned by collecting other organic waste become an additional source of income for the plant. The utility in the Ridgewood case study, understanding the potential of co-digestion, invested in expanding their digesters and their power generation capacity. It accompanied these steps with a strong marketing campaign to obtain additional feedstock for digestion, enabling it to produce significant amounts of biogas and electricity.

Because co-digestion is a relatively new business, its regulation is undeveloped in many countries. The United States was one of the first countries to implement co-digestion in wastewater treatment plants. But co-digestion is considered a different business and, as such, falls outside the wastewater regulation. One effect of this distinction is that the profits the plant derives from co-digestion are not necessarily passed to consumers in the form of lower water and wastewater tariffs. This has become an incentive for many treatment plants to invest in co-digestion, bringing sustainable revenue streams to the operator, albeit at a high risk of volatility owing to rapidly changing market conditions. As with the biosolids business, regulations that increase tipping fees tend to limit the deposit of organic matter in landfills, incentivizing the development of co-digestion. Common financial structures and instruments used in co-digestion projects

The investments needed to implement co-digestion in wastewater treatment plants (digester capacity, gas cleaning and power generation, feedstock storage, and so on) can be financed in several ways. Large utilities can finance their projects by issuing debt in the form of green bonds or building equity in the form of green shares. For smaller utilities, it may be safer to start the business through a PPP with experienced partners or technology providers, in combination with trust funds or grants. The same is true of utilities that are not creditworthy enough to finance a co-digestion project on their own.

The case of Ridgewood shows how a well-designed PPP between the Village of Ridgewood's water utility and an engineering company (Ridgewood Green) can lead to a successful co-digestion project. Ridgewood Green made the up-front capital investment needed to retrofit the treatment plant, which implied zero investment costs and minimum risk for the Village of Ridgewood. In return, the village purchases the electricity generated by Ridgewood Green at a price of 12 cents per kilowatt hour (kWh) (lower than the 15 cents per kWh market price). The power purchase agreement included a fixed rate increase of 3 percent per year for inflation, establishing the village's price and Ridgewood Green's revenue for the duration of the contract, benefitting both parties.

Ridgewood Green owns and operates the co-digestion equipment; the Village of Ridgewood owns and operates the wastewater treatment plant with technical support from Ridgewood Green. Ridgewood Green expects to recover its full investment and a reasonable return on investment through an innovative revenue model that leverages several revenue streams: (i) sales of electricity to the Village of Ridgewood; (b) sales of renewable energy certificates to 3Degrees, a leader in the renewable energy marketplace, under a multi-year agreement; and (c) tipping fees collected from entities providing organic matter for the anaerobic digesters.

Risk management

Wastewater treatment plants designed to exploit the downstream products of treatment present various risks that must be mitigated.

Financial risks

Private investors are usually reluctant to invest in water infrastructure, owing to the long pay-off period, lumpy investments, and the sunk nature of the investment. Risks are usually managed through ring-fencing activities in the design-and-build contracts (transferring technology and construction risks to specialized contractors) and through O&M components that transfer some performance and maintenance risks to contractors. Water projects funded only by a cash flow provided by water users (i.e., tariffs paid by customers of water utilities) require strong guarantees from a creditworthy institution. Even sound financial statements from water utilities may not be enough to encourage private investors to enter into a concession agreement. Resource recovery by wastewater treatment plants offers the potential to reduce risk by supplementing tariffs with new revenue streams.

Operational risks

Many utilities lack experience with the waste-to-resource business. In order to mitigate operational risks, many choose to outsource the business to specialized operators, usually through a PPP, as seen in most of the case studies. A PPP can also help to finance the project when the utility lacks the necessary resources. Depending on the arrangement, the PPP can mitigate most or all risks for the utility.

Specialized operators have vital experience with waste-to-resource projects and are often sources of necessary technology. They can also bring investment resources to a project. But if they are to participate, they require the prospect of reasonable profitability and, to the extent possible, mitigation of political, regulatory, and financial risks. Reducing these risks usually requires the government to participate with grants or guarantees to shorten the period of return on investment.

Demand risk

Variability in demand is probably the most critical obstacle to private participation in resource-recovery projects. This risk refers to uncertainty about the actual volume of by-products that will eventually be used. If the demand for by-products (treated water, energy, biosolids) is lower than expected, then the revenue may fall below the level required to meet O&M expenses and service debt.

Of course, projects developed by the end user, as in the case of Cerro Verde, completely remove demand risk and allow the water utility to have its wastewater treated with little or no investment, thus reducing the public sector's risk.

But when the end user is not the project developer, as in many of the cases analyzed, a way must be found to mitigate demand risk. The case studies suggest several options, the most critical of which is proper contract design. The project's financial structure will require a long-term purchase agreement that must provide security to the participating financial institutions. The terms of the agreement will vary depending on the requirements of the parties involved and the funding institutions. Of the cases analyzed, some of the most successful had only one or two major end users (San Luis Potosi, Durban, Ridgewood) and thus were able to structure the contract in a way to mitigate demand risk. Take-or-pay clauses and fixed payments are common features of long-term infrastructure contracts and can be equally useful in waste-to-resource projects. The risk of variable demand rises with the number of end users, which may discourage private investors.

Legislation and targeted regulatory frameworks may be helpful in providing assistance to public utilities during the negotiation and contract-design phases of projects.

Other risks

Other risks include supply risks related to variability in the volume and quality of sewage flows. As in any other infrastructure project, there is the risk of construction delays. Such risks are typically shared between the municipal authority and the project developer. Public utilities may need more time than expected to acquire land and permits (as in Nagpur), raising the costs of construction. Once lands are cleared, the project developer assumes the risks of cost overruns, as specified in design-and-build and turnkey contracts.

Any number of political, regulatory, and economic changes may occur during the project period. The contract must include clauses ensuring stability and guarantees to mitigate significant changes in prices, costs, or volumes. Political actors may alter agreements and force the operator to pass benefits or profits on to consumers in the form of lower tariffs, thus affecting the operator's expected return on investment. Strong institutional and regulatory frameworks will key enabling factors in countries where such interference is possible.

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