Wastewater management is one of many challenges that the Latin America and the Caribbean (LAC) region has to confront. Can this challenge be also an opportunity? This paper has been commissioned by CAF and the World Bank to launch a discussion about the potential for adopting a circular economy approach to wastewater management in the LAC region. The paper discusses what makes wastewater a valuable resource, examples of resource recovery in LAC, and the potential elements of an Action Agenda.

Managing Wastewater as a Resource in Latin America and the Caribbean

Towards a Circular Economy Approach

Roberto Martin-Hurtado and Daniel Nolasco

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Acronyms

3R	Reduce, reuse, recycle
AEAS	Asociacion Española de Abastecimientos de Agua y Saneamiento
AEDYR	Asociación Española de Desalación y Reutilización
CapEx	Capital Expenditures
CHP	Combined Heat and Power
EU	European Union
GDP	Gross Domestic Product
LAC	Latin America and the Caribbean
MDGs	Millennium Development Goals
O&M	Operation and Maintenance
OECD	Organisation for Economic Cooperation and Development
OpEx	Operational Expenditures
PPP	Public Private Partnership
SDGs	Sustainable Development Goals
SIWI	Stockholm International Water Institute
UNICEF	United Nations Children's Fund
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WHO	World Health Organisation
WWTP	Wastewater Treatment Plant

Section 1. The circular economy and wastewater management

1.1 Aim, target audience and structure of this paper

Wastewater management is one of many challenges that the Latin America and the Caribbean (LAC) has to confront. In some sense, this is a welcomed challenge as it is originated by the increased number of people that are served by water supply systems and by the growth in industrial output. But that does not make it less daunting, given the institutional, policy, technical, and financial stakes involved.

Can this challenge be also an opportunity? There is now a recognition among the professional water community that wastewater is in fact a valuable resource. This insight is starting to be placed in a broader framework: the circular economy. Indeed, World Water Day 2017 will be dedicated to wastewater, how it is perceived as a valuable resource in the circular economy, and its safe management as an efficient investment in the health of humans and ecosystems.

The aim of this paper is to launch a discussion about the potential for adopting a circular economy approach to wastewater management in the LAC region. This paper has been commissioned by the Development Bank of Latin America (CAF) and the World Bank. It serves as an input to the seminar "Eye on LAC: The Circular Economy of Water: Wastewater Reuse" which will take place at the 2016 World Water Week in Stockholm.

The primary target audience of this paper includes senior government officials in the LAC region from ministries of finance, planning and economic development; municipal governments; the water and sanitation sector (including water ministries, agencies and regulators); and related sectors (such as energy, agriculture, health). The paper is also aimed at managers of water and sanitation utilities.

This discussion paper is structured in four sections. The remainder of Section 1 introduces the concept of circular economy and will discuss its relevance for the water and sanitation sector, with a focus on wastewater management. Section 2 provides an overview of the current situation and challenges with wastewater treatment in the region. Section 3 offers examples of wastewater resource recovery in LAC. Section 4 outlines the elements of an action agenda to implement a circular economy approach to wastewater management in the region.

Box 1. What is wastewater?

Wastewater can be defined as a combination of one or more of:

- domestic effluent consisting of blackwater (excreta, urine and faecal sludge) and greywater (kitchen and bathing wastewater);
- water from commercial establishments and institutions, including hospitals;
- industrial effluent, stormwater and other urban run-off;
- agricultural, horticultural and aquaculture effluent, either dissolved or as suspended matter.

Source: Corcoran et al (2010)

1.2 What is the circular economy and why is it relevant?

The traditional view of economic processes is linear. Resources (water, energy, raw materials) are extracted from the natural environment and used to produce goods with an economic value. By-products of the production processes are considered “waste” and discharged in the natural environment. The goods produced lose their economic value over time, become “waste” and are then discharged to the natural environment. This causes environmental degradation, with significant economic costs that may be in the order of 4% of GDP in LAC countries.[1]

In a circular economy, by contrast, “wastes” are considered resources to be plugged back into the economy. The *circular economy* is a generic term for an industrial economy that is producing no waste and pollution, by design or intention, and in which material flows are of two types: biological nutrients, designed to reenter the biosphere safely, and technical nutrients, which are designed to circulate at high quality in the production system without entering the biosphere as well as being restorative and regenerative by design (Ellen McArthur Foundation, 2015). The concept of the circular economy has been mainly linked to materials management and the 3Rs (reduce the amount of materials used in production processes, re-use the durable goods produced, re-cycle the materials) but it also encompasses a move from non-renewable energy sources to renewable energy sources. The concept has evolved in the EU, North America and more recently in China to revert (reduce) the cost of environmental degradation.

Moving towards a circular economy is expected to produce multiple economic benefits. On the “resources” end, reducing the demand for new resources would reduce the pressure on the resource base – this has an economic value, although it is not always captured by the market price mechanism. When the resource base is actually limiting economic activity, that reduced pressure on the resource base would allow for new economic activities to take place. In addition, the cost of procuring “recycled” resources may become lower than that of procuring new resources. On the “wastes” end, reducing the amount of materials that need to be disposed off would reduce the cost of adequate treatment and disposal, as well as the negative impacts of “wastes” discharged in the natural environment without adequate treatment and disposal.

The concept of a circular economy has been gaining traction in policy and business circles. In 2015, the European Union issued a circular economy package that includes an action plan as well as significant legislative proposals (mostly dealing with waste management)[2]. The World Economic Forum is implementing a global programme (initiated in collaboration with the Ellen McArthur Foundation and McKinsey) to promote the transition towards a circular economy[3].

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[1] In Peru, the combined economic costs of environmental damages from waterborne diseases and illnesses caused by urban and indoor air pollution and from natural disasters have been estimated at 3.7% of GDP (World Bank, 2007). Similarly, in Colombia, the effects of environmental degradation associated with urban and indoor air pollution; inadequate water supply, sanitation, and hygiene; natural disasters (such as flooding and landslides); and land degradation have been estimated to total more than 3.7 percent of gross GDP (Sanchez-Triana et al 2007).

[2] http://ec.europa.eu/environment/circular-economy/index_en.htm

[3] https://www.weforum.org/projects/circular-economy/

While only limited amount of work has been done to quantify the benefits of a circular economy approach, some significant figures are emerging. For example, the UK could save USD 1.1 billion a year on landfill costs by keeping organic food waste out of landfills, and USD 340-630 billion per year could be saved in sectors representing about half of the GDP contribution of EU manufacturing – the latter figure representing 23% of total input costs and 3.9% of the combined GDP of all EU countries in 2010 (Ellen McArthur Foundation, 2015)[4]. These benefits are set to increase overtime as energy and materials continue to experience rising costs and volatility (due to resource scarcity), and environmental demands also increase.

Adopting circular economy approach requires technical, policy and cultural changes. At technical level, it requires changes in the design of products (so that they consume less materials and can be more easily recycled) and production processes. At policy level, it requires changes in regulatory and institutional frameworks so that circular solutions are encouraged rather than prevented[5] – including through innovation and the development of a qualified workforce. At the cultural level, it requires changes in the perception of ownership of products, and a focus on "performance" rather than "products".

1.3 How is the water and sanitation sector related to the circular economy?

The water and sanitation sector takes up significant resources to deliver services and returns wastewater to the environment. Given its consumption of energy, water and materials, the water and sanitation sector is a good candidate to be part of the initial efforts to adopt a circular economy approach. To simplify, delivering water and sanitation services requires two different phases: building infrastructure and operating it. Building infrastructure requires mostly construction materials as well as energy. A circular economy approach would look at how the need for additional water and sanitation can be reduced – for example by promoting water efficiency or adapting the quality of water delivered to its intended use – and to design facilities in a way that would make them to last longer and easier to repair, as well as would facilitate the recycling of their materials at time of decommissioning. Operating infrastructure, however, requires mostly raw water and energy and it generates wastewater. Wastewater released to the natural environment without treatment generates significant negative impacts – on human health, environmental quality, and the economy (including through higher cost of water treatment downstream and lost opportunities to develop economic activities).

A circular economy approach would look at how to improve resource use efficiency and resource recovery along the "water value chain". The delivery of water and sanitation services is only part of the larger "water story". Applying a circular economy approach to the water and sanitation sector would also require looking at the use of water and the behaviour of water users. For example, more than 95% of water delivered to households is

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[4] Savings described are net of the resources consumed during circular production processes, but they are gross of labour and energy costs. In each case study examined, energy costs represented an additional source of savings. Labour costs represented an additional source of savings for some products but not for others.

[5] Changes in technical and safety standards are needed to allow the use of waste in the design of new products. For example, in the area of wastewater management is standards for disposal (reuse) of sludge from WWTP, which it is not yet allowed to be used even in safe agriculture crops.

needed for non-drinking uses, such as toilet flushing or food preparation, that do not require the same (more expensive) level of quality required of water for drinking purposes. There are often opportunities to increase resource efficiency at the point of use. There is a considerable literature on the opportunities for increasing water efficiency in households, farms and industries. Energy efficiency is another case in point – for example, in may households it may be possible to reduce the amount of energy required to heat water (for space heating, taking showers, washing clothes, or preparing hot drinks) without a noticeable loss of comfort. This paper, however, focuses on the narrower theme of adopting a circular economy approach to the management of wastewater.

The potential for resource recovery and the expected upcoming investments in wastewater treatment mean that wastewater management is ripe for the adoption of a circular economy approach. The water and sanitation sector has grown progressively, first delivering water supply services to urban areas (with rural areas lagging behind), then sewage collection services, and only later treating the sewage so that the effluents discharged into the environment comply with water quality regulations[6]. High income countries are more advanced along this path, while developing countries are still struggling to achieve a high level of nominal coverage. Only about 20% of globally produced wastewater receives proper treatment (UNESCO, 2012)[7]. As discussed later in this report, there are many opportunities for planned recovery of resources from wastewater. Unplanned resource recovery, particularly the reuse of wastewater for irrigation, has a long history[8]. In the Segura basin (Spain), 90% of new wastewater treatment plants (WWTPs) are designed with water reuse in mind.

Policy, regulatory and institutional framework issues are more critical than technical ones. Technical solutions to treat wastewater and recover resources are already available and proven, and more effective and efficient ones will continue to become available. But even in the more advanced economies, implementation of technical solutions is a challenge because the enabling environment is not ready. For example, when Sweden decide to recycle phosphorus present in wastewater (because it is a scarce and valuable resource) the utility serving the city of Stockholm made it possible by improving sludge quality, but the most important challenges faced were about permitting, the allocation of risks and benefits to different "silos"; the pricing structure only reflecting direct costs; and the fact that applicable regulations were written and managed in "silos" (SIWI, 2014). One key aspect highlighted in the literature is the importance of considering wastewater reuse in the framework of integrated water resources management, particularly in basin management plans.

The LAC region might want to look at opportunities for leap-frogging in wastewater management. Wastewater treatment in more advanced economies has been driven by environmental concerns. For example, the European Union issued its Urban Wastewater

[6] Treatment capacity does not equal effective treatment -- it is relatively easy to build a wastewater treatment plant, but making sure that it is connected to a wastewater collection system and properly operated and maintained is another story.

[7] This varies widely across countries. High-income countries have more technical, institutional and financial capacities, and experience higher social demand for a clean environment. As a result, wastewater treatment capacity in high-income countries is in the order of 70% of generated wastewater, but only 8% in low-income countries (Sato et al, 2013).

[8] See Bahri (2009)

Treatment Directive back in 1991 with the aim to protect the environment for the adverse effects of wastewater discharges from cities and certain industrial sectors; the Directive included text to indicate that wastewater and sludge shall be re-used "whenever appropriate". Only in 2015, as part of an action plan for the circular economy, has it set objectives in terms of integrating reuse in water planning, minimum requirements for reused water (such as for irrigation and groundwater recharge), or funding for research, innovation and investments; a coherent and comprehensive legislate framework could be developed by mid-2017. Given that the LAC region is expected to step up its investments in wastewater treatment in the next couple of decades, it would make sense to adopt early on a circular economy approach and in particular evaluate how those investments in wastewater treatment can be made to take advantage of potential of wastewater as an asset for development. At the same time, the poor operation and maintenance of existing stock of WWTPs in the region raises the questions of how to incorporate circular economy concepts in the existing stock, and the sequencing between fixing the existing stock and advancing to a new generation of WWTPs.

1.4 What makes wastewater a valuable resource?

Water recovery

Cleaner water represents the primary resource recovered from wastewater. Wastewater contains over 99% water and less than 1% of pollutants and contaminants. The water recovered after wastewater treatment is generally known as recycled wastewater, reclaimed wastewater, or regenerated water. Water reuse involves two distinct steps: regenerating the water (which involves wastewater treatment) and actually using the water (which involves transporting the regenerated water to the point of use). Regenerated water can be reused "directly" by using a specific pipe system to deliver the water to point of use, or "indirectly" by discharging the water into a water stream or a storage system (like a reservoir) where it is mixed with water from other sources before being used.

Regenerated water can be used for multiple purposes, each requiring a certain level of water quality. Currently available technological options can treat wastewater to almost any level of water quality -- from the simple removal of gross solids to membrane systems that can produce drinking water quality. Indeed, regenerated water is used to increase drinking water supplies in Orange County (California, US), Singapore, and Windhoek (Namibia). Regenerated water can thus be used for environmental purposes (restoration of water bodies and wetlands), aquaculture, irrigation (crops, golf courses), mining, industrial uses (process water and cooling), non-potable urban uses (street cleaning, landscape irrigation), and domestic uses (including drinking water). Spain, which reuses some 400 Hm^3 per year (11% of treated wastewater) provides an example of the multiple uses of regenerated water with 71% of reclaimed supplies used for irrigation, 17% for environmental applications, 7% for recreation, 4% in urban reuse and less than 1% for industrial purposes (Sato et al, 2013). Across the world (including arid and semi-arid countries at all levels of development as well as peri-urban areas in low income countries) the most prominent and rapidly growing use of regenerated water is crop irrigation – in Israel 40% of irrigation uses regenerated water. Different uses imply different degrees of risk for public health and thus the minimum quality of the water should vary according to use. Getting the water quality regulations right (and enforcing them) is a key aspect of water reuse – if they are inexistent they may prevent reuse altogether, if they are too lax they may cause illnesses as well as a subsequent backlash, if they are too stringent they may make regenerated water too expensive to produce. Some international guidelines are available[9].

The characteristics of regenerated water make it a key tool for ensuring water security and adapting to climate change. Regenerated water is a highly reliable source of water – the generation of wastewater from urban centres is fairly stable across the year – which makes it a more valuable source of water than those that are dependent on the weather, specially for those uses that require guarantee of supply. Desalination is also a reliable source of water (in coastal areas), but regenerated water is cheaper and less energy intensive. Regenerated water is a local source, and thus less controversial than inter-basin transfers[10].

The economics of regenerated water is better evaluated in an integrated water resources management framework. As cities continue to grow rapidly and low-cost surface and groundwater sources become depleted or contaminated, it will become increasingly difficult and energy intensive to meet the water demands of their populations and economies (Meda et al, 2012). Regenerated water is effectively an additional source of water, which in itself is of high-value for water-stressed countries and urban areas. To simplify, regenerated water can be used to provide a new source of drinking water (at a relatively high cost), or it can be used to provide a new source of irrigation water (at a relatively low cost) and thus free up other sources of high quality water than can be used to produce drinking water. The cost of using regenerated water increase with the level of water quality required and distance from the WWTP. Leaving aside environmental uses, the lowest cost would be for irrigation of tree crops close to urban areas. As the distance to the crop fields increases, urban uses become "cost-competitive" – initially starting with non-potable uses. Revenue streams from non-potable uses are limited and willingness to pay is low (OECD, 2009).

If not planned, managed and implemented properly, water reuse can be associated with public health, soil productivity, and environmental risks. Microbial health risks are especially severe in low- and middle-income countries, where the practice often involves the direct use of untreated wastewater and/or the indirect use of polluted waters from rivers and streams to irrigate food crops. Many of the 200 million farmers who specialize in market gardening rely on raw or diluted wastewater when higher quality sources are unavailable, with global estimates of "wastewater" irrigation ranging from 4 to 20 million hectares (IWMI, 2006). Farmers and the urban poor are disproportionally affected. Chemical health risks assume greater importance as industrialization occurs (Drechsel et al, 2010).

Nutrient recovery

Wastewater is nutrient-rich and can reduce the need for the application of chemical fertilizers. Phosphorus, for example, is essential to all life and is a key component of fertilizers. The main source of phosphorus (phosphate rock) is non-renewable and is becoming increasingly expensive. Human faeces contains about 0.5% phosphorus by weight and its recovery could improve phosphorus security and reduce pollution (Cordell et al,

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[9] The WHO guidelines for the safe use of wastewater, excreta and grey water were issued in 2006. The ISO 16075 guidelines for treated wastewater use for irrigation projects (crops, golf courses, parks, gardens,..) were issued in 2015.

[10] Regenerated water might also encounter social opposition, in particular for direct drinking water use. Orange County (United States), Singapore and Windhoek (Namibia) show that this can be overcome.

2011). When faecal solids are properly treated and of good quality they can be used on agricultural land or gardens as a soil conditioner/fertilizer and are often termed ʻbiosolids. Soil conditioner may be produced on a variety of scales from municipal wastewater treatments plants down to individual households practicing ecological sanitation (UN-Water, 2014).

Nutrient recovery is not without challenges. One option for nutrient recovery consist in using regenerated water with nutrient content for irrigation. When using regenerated water for irrigation, it may happen that nutrients in the regenerated water are not present in the ideal concentration for direct crop production and meeting one nutrient requirement may lead to an imbalance in another nutrient level. More broadly, irrigation with regeneration water can lead to excess nutrients, pathogens, heavy metals and salts building up on the irrigated land, unless care is taken. Water quality regulations that require the significant reductions in nutrient content (without differentiating it from pathogens) can prevent this type of nutrient recovery. Another option for nutrient recovery consist in extracting nutrients from the wastewater to be transferred and applied in a different location. However, for fertilizer companies to be interested in buying phosphorous or other recovered nutrients large quantities of nutrients need to be recovered in a reduced geographical area (Mujeriego, pers.comm.).

Energy recovery

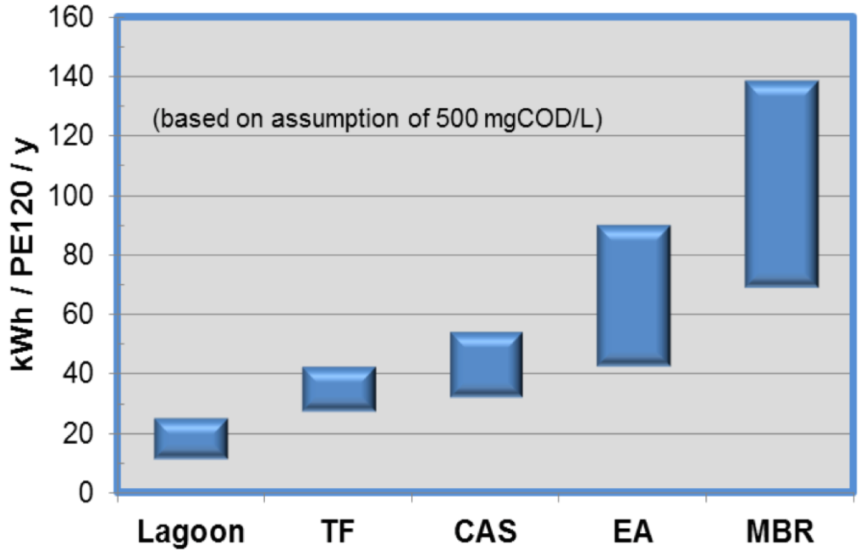
Energy costs represent the second largest component of the operational costs of water utilities, after labour costs. At drinking water plants, the largest energy use is to operate motors for pumping; at wastewater treatment plants, aeration, pumping, and solids processing account for most of the electricity that is used (Copeland, 2014). In LAC, the vast majority of water utilities are struggling to attain self-financing. Reducing energy costs is a promising avenue to help maintain and expand services while keeping tariffs affordable. Enhancing energy efficiency can result in substantial energy and associated financial savings to the utilities (Nolasco and Rosso, 2015). Technical measures to improve energy efficiency derived from energy audits can result in 10% to 30% energy savings per measure and can have as little as a one- to five-year payback period (Rodriguez et al, 2012). In spite of this, energy audits are not commonly carried out in WWTPs in LAC.

Wastewater is a potential source of energy that can help water utilities to reduce their energy costs and increase their reliability. Wastewater treatment plants produce biogas (primarily comprising methane and carbon dioxide) by anaerobic digestion or fermentation of biodegradable materials such as sewage, manure, human municipal solid waste and green waste. Biogas can be burnt on-site to produce electricity and heat for the treatment plant through combined heat and power (CHP) plants. The heat produced can be used in the digester to dry the sludge and for space heating the plant facilities, while the power can be used in the plant (UNESCO, 2014). Depending on local electricity prices, a combined heat and power facility can produce electricity below retail cost, which can create a compelling case for private investors. Having its own decentralized power source also enhances plant reliability, which is important in areas that experience frequent power outages. In several countries, such Austria, water utilities are working towards becoming energy neutral.

Energy recovered from wastewater can be a source of revenue for water utilities. Biogas can be sold as gas for heat and cooking, as vehicle fuel or as fuel for a power plant. And power produced from biogas can be sold to the grid. When co-generation is performed in WWTPs that do not use activated sludge the excess electricity generated may be substantial. In general, if activated sludge technology is used for wastewater treatment, all WWTP power needs cannot be met by electricity generated at the WWTP (UNESCO, 2014).

Implementation of CHP plants at wastewater treatment plants is growing. Biogas is a 'green' energy source and therefor generating power and heat from burning it can potentially reduce GHG emissions and other air pollutants (if it replaces fossil fuels). In the USA, there are 104 wastewater treatment plants using biogas to produce a total of 190 MW capacity (US EPA, 2011 cited in UNESCO, 2014). From an energy sector standpoint, the electricity production of these plants is minimal. However, from a wastewater treatment stand-point, it may represent a considerable reduction in operational costs.[11]

Figure 1. Electricity Consumption per Population Served Per Year for Different Wastewater Treatment Technologies



Note: TF = Triclikng Filters. CAS =Conventional Activated Sludge. EA = Extended Aeration Activated Sludge. MBR = Membrane Bioreactors

Source: Water Environment Research Foundation, by G.V. Crawford GV and J Sandino, CH2M Hill Canada Limited. 2010. "Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches." Report: OWSO4R07e. May.

1.5 How does a circular economy approach to wastewater management relate to current policy and management frameworks?

Wastewater reuse is explicitly included in the Sustainable Development Goals. The Millennium Development Goals (MDGs) included a target aiming to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation. They did not pay specific attention to ensuring that wastewater was adequately collected and treated before being discharged into the natural environment. The Sustainable Development Goals (SDGs), adopted in 2015 to continue and expand the global policy framework laid out by the MDGs, do include wastewater management in its Target 6.3: "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing

[11] UNESCO (2014) does not indicate the total flow treated by these 104 WWTPs. However, overall operational expenses savings of 20 to 30% are not unusual when there is co-generation in WWTPs.

release of hazardous chemicals and materials, halving the proportion of untreated wastewater and increasing recycling and safe reuse globally”[12]. Achieving this target will require significant investments, but the associated costs have not been evaluated – by comparison achieving the targets of reaching universal access to water and sanitation by 2030 (targets 6.1 and 6.2) would require (Hutton and Varughese, 2016) in the order of USD 114 billion per year.

Resource recovery from wastewater has an important place in other policy and management frameworks. Green growth/green economy approaches and objectives, which focus on policy options to increase resource productivity and reducing pollution, are increasingly adopted around the world – the OECD Green Growth Strategy was adopted in 2011 and numerous support initiative are taking place in developing countries, chiefly supported by the World Bank, the Global Green Growth Institute, and UNEP. Integrated water resources management, initially spearheaded by the Global Water Partnership, takes as a starting point the interconnected nature of hydrological resources and has emerged as an alternative to sector-by-sector top-down approach to water management. The water-energy-food-ecosystem nexus concept, initially promoted by the government of Germany, has emerged as a compelling framework to more effectively engage cross-sectoral players in the sustainable management of natural resources, exploiting synergies and managing trade-offs. Resource recovery from wastewater fits well in all those frameworks.

[12] There are no official resource recovery targets for wastewater. Some experts have suggested 50% of water reused, 75% of recovery of nutrients and 50% of recovery of organic matter (presentation by Bruno Tisserand, President of EurEau, at the seminar “La Reutilización de Aguas en el Marco de la Economia Circular” organised by AEDYR and AEAS in May 2016).

Section 2. Wastewater management in Latin America and the Caribbean

2.1 Context

The Latin America and the Caribbean (LAC) region is making progress, although uneven, towards meeting the objective of universal access to improved sanitation. In the period 2012-2015, sanitation coverage in LAC increased from 82% to 88% in urban areas, whereas in rural areas, the increase was from 52% to 58%. If the growth trend observed in the region in the past years were to continue, by 2022 LAC would reach universal access to improved sanitation in urban areas by 2022. Meanwhile, rural areas by 2030 would only reach 88% coverage, thereby not meeting the Sustainable Development Goals (SDGs) (WHO and UNICEF, 2016).

Achieving the SDG target on improved sanitation will require significant investments. To reach universal access by 2030, the 114 million people who currently do not have access, plus 104 million more new people incorporated through observed population growth rates, i.e., a total 218 million people, will have to be provided access to improved sanitation. Using a per capita investment of USD 600 for urban areas and USD 500 for rural areas, the total investment required for the region to meet SDGs in sanitation is in excess of USD 126 billion for the period 2016-2030. Of that total, approximately three quarters would need to be destined to urban areas, with the remaining invested in rural areas, resulting in an average annual investment of USD 6.4 billion and USD 2 billion for urban and rural areas, respectively.

Table 1. Population connected to wastewater treatment

Country	Latest year available	%
Argentina	2001	42.5
Brazil	2006	26.0
Chile	2009	83.3
Costa Rica	2000	2.4
Cuba	2009	24.0
Dominica	2005	13.0
Dominican Republic	2005	12.0
Guadaloupe	2004	38.9
Guyana	2009	0.0
Martinique	2004	48.2
Mexico	2005	35.0
Panama	2007	55.0
Trinidad and Tobago	2007	25.2
Venezuela	2009	23.8

Source: UN Statistical Division, http://unstats.un.org/unsd/environment/wastewater.htm, last accessed 29 July 2016.

Progress towards the water and sanitations targets has knock-on effects on the demand for improving wastewater management. Target 6.3 of the Sustainable Development Goals requires halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally. Data on population connected to wastewater treatment is hard to come by. It is estimated that about 30% of wastewater is treated to some level in the LAC region. This share varies across countries in the region and it is rapidly growing in some of them – for example in Chile it increased from 42% in 2002 to 94% in 2012[13]. Wastewater management represents the largest market for clean technologies in the region, with an estimated size of USD 160 billion in the decade to 2023 (World Bank, 2014).

The region has been making some substantial investments in wastewater treatment, but their effectiveness, efficiency and sustainability are far from guaranteed. Wastewater treatment systems in the region are characterised by an excessive emphasis on developing new infrastructure, poorly developed legislation, lack of policy and regulatory mechanisms to allow gradual improvement, regulations that limit or forbid resource recovery, technology selection criteria biased towards expensive technologies, lack of adequate control of industrial discharges, and reliance on conventional financing. We briefly expand on these challenges in the following paragraphs.

2.2 Challenges

Excessive emphasis on developing new infrastructure. Throughout the region, new wastewater treatment infrastructure is developed without considering the sustainability of the system (such as O&M costs coverage) and without evaluating the existing infrastructure capacity. For example, in Mexico Federal Government funding is used to build wastewater treatment plants (WWTPs) in numerous small- and medium-size municipalities. But since most municipalities do not charge for sanitation or charge very little, they cannot fund proper operation and maintenance leading to the continuous deterioration of the treatment plants and of the receiving water bodies. In Peru, a recent study by World Bank found that most projects do not seek to optimize existing capacity due to the "divorce" between the institution that formulates and executes the project and the institution who must operate the new infrastructure. When the infrastructure is transferred to the EPSA, lack of technical capacity and inadequate tariff structures to support the operation of the new works result in non-sustainable projects.[14]

Poorly developed legislation. There are two key issues. First, legislation is often based on "imported" regulations and standards too stringent for local conditions. In most cases, these regulations and standards are adopted without considering the economic implications of their implementation, regarding both capital expenditure (CapEx) and operation and management expenditure (OpEx). For example, in the Province of Cordoba (Argentina), new legislation approved in 2014 and implemented in 2015 requires that WWTPs discharging in water bodies who eventually end up in a lake (which occurs in most of the cases in this land-locked province) should never exceed concentrations of 10 mg N/l in the effluent. This means that the average design effluent value should be 3 mg N/l, which very few WWTP in the world can meet today.[15] Second, there is a lack of coordination between different

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[13] http://www.bnamericas.com/es/news/aguasyresiduos/cobertura-de-tratamiento-de-aguas-residuales-de-chile-se-ha-duplicado-con-creces-en-10-anos-segun-informe-de-autoridad

[14] "*Estudio Piloto – Procesos de inversión pública en agua saneamiento urbano y rural – Informe resumen.*" Programa de apoyo a la reforma sectorial. Lima, 21 January 2015.

[15] Appropriate limits must be decided, ideally, on watershed-by-watershed basis. However, as a general rule-of-thumb, limits must be set on monthly averages of concentrations (as opposed to a "never to be exceded" limit, like the one legislated for the Provincia de Córdoba). Another very important aspect to do when setting WWTP effluent limits is the cost-benefit analysis of setting such limits. On the benefit side, one would have the

legislation. For example, in Peru maximum discharge limits (LMPs)[16] imposed on WWTPs are not aligned with water quality requirements (ECA-agua)[17] for receiving water bodies. During dry season, when WWTPs are discharging to rivers with no flow, the effluent quality requirements for WWTPs become prohibitively stringent since there is no dilution capability in the receiving water body. There are also cases where the water body is more polluted, than effluent discharged from the WWTP, which causes the WWTP to fail to meet regulated water quality standards for the receiving water body, even if the WWTP itself meets the effluent criteria.

Lack of policy and regulatory mechanisms to allow for gradual improvement. Often, new wastewater treatment projects are forced by regulators to meet stringent effluent legislation from day one. In many cases, this implies a transformation from no treatment whatsoever to full compliance with no intermediate steps being allowed. Without gradual or staged improvement allowances, CapEx and OpEx become prohibitive in many cases, thereby forbidding any type of treatment or focusing treatment only in those areas or regions which procure finance.

Regulations that limit or forbid resource recovery. Resource recovery (i.e., water reuse, bioenergy generation, beneficial use of biosolids[18]) is key to the sustainability of wastewater treatment systems. In addition to a lack of incentives to promote resource recovery from WWTPs, there are numerous examples of legislation limiting or forbidding resource recovery. For example, in Peru, WWTP sludge is considered to be a dangerous solid waste, which has to be disposed of in a confined cell, within a sanitary landfill.[19] This regulation eliminates the opportunity to take advantage of nutrient-rich biosolids for agricultural and forestry use, or for soil recovery, and it also places a financial burden on the WWT utility. The costs of transporting and disposing of plant sludge in a confined cell are prohibitive to most utilities in Peru. In addition to this, only two landfills in Peru (one in Lima and the other one in Ica) have installations that meet this regulation. In Bolivia, the water utility SAGUAPAC has not been allowed to use the grid to sell electricity generated from biogas at its WWTP or to use this electricity in other points of the water utility (see case study later in this report). Many countries in the region have adopted the World Health Organization

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increased economic value of a less contaminated receiving water body. On the cost side, whoever establishes legislation must understand the CapEx and OpEx required to reach those levels of quality. If the cost is too high compared to the benefits to achieve, then the limits must be reconsidered and adapted accordingly. When the WWTP discharges to a receiving water body (RWB) that is under a cleanup program, it is recomendable to set Total Maximum Daily Loadings (TMDL) for different contaminants (expressed in mass of contaminant per day). In this case, TMDLs is the maximum amount of a given pollutant that the RWB can receive and still safely meet water quality standards or recover from a contaminated condition.

[16] Decreto Supremo No. 003-2010-MINAM – Limites Maximos Permisibles para los efluentes de las Plantas de Tratamiento de Aguas Residuales Domesticas o Municipales - PTAR

[17] Decreto Supremo No. 002-2008-MINAM – Estandares Nacionales de Calidad Ambiental para Agua. In: El Peruano. Lima, jueves 31 de Julio de 2008

[18] Biosolids may be defined as organic wastewater solids that can be reused after suitable treatment (sludge stabilization) such as anaerobic digestion and composting. The definition of biosolids may be restricted by local regulations to wastewater solids only after those solids have completed a specified treatment sequence and/or have concentrations of pathogens and toxic chemicals below specified levels, depending on the type of use that will be given to the biosolid. In this report, by biosolid we will refer to wastewater treatment plant sludge treated to such a level that meets local standards for beneficial reuse (such as land application and surface disposal).

[19] Ley No. 30045 – Ley de residuos solidos y su reglamento aprobado por Decreto Supremo No. 057-O4-PCM – Articulo 27, Numeral 3.

guidelines for water reuse, but they are only available in English and are not written in a way that could be easily interpreted by professionals running water utilities.

Technology selection criteria biased towards activated sludge or expensive technologies. The reasons for this bias are not clear. It may be due to a lack of technical process knowledge, combined with an excessive tendency towards copying what is being done in developed countries. Brazil, a country with solid technical wastewater engineering training, has applications of activated sludge but has also adapted and/or developed anaerobic treatment technologies suitable to local conditions, which are now used on a world-wide basis as examples of successful application of energy-efficient systems.

Lack of adequate control of industrial discharges. In cities where industries contribute a significant amount of wastewater, the enforcement of industrial pre-treatment and control programs is essential for the minimization of chemical risks and the successful operation of any treatment plant or effluent irrigation scheme. In many cities in the region, uncontrolled industrial effluents are discharged to collections systems with an existing WWTP and as a result the utility effectively pays for the transport and treatment of industrial pollutants. For example, in the Puchukollo WWTP, located in the city of El Alto (Bolivia), the concentrations of organic pollutants show high industrial contribution to the wastewater, while the industries do not pay their share of wastewater treatment costs.

Reliance on conventional financing. Financing of sewerage and wastewater treatment is a challenge throughout the world. Many utilities do not levy separate tariffs for sanitation, and where such charges exist they are usually insufficient to finance operation and maintenance costs, not to mention capital costs. This problem is particularly acute in countries that embark on ambitious investment programs to increase the coverage of wastewater treatment, like the one needed in LAC to meet the Sustainable Development Goals (SDGs). There is a considerable agreement that subsidies are needed for sanitation, at least during a transition period. For wastewater treatment, the region mostly makes use of upfront public subsidies for capital investments – the inherent incentive structure results in WWTPs being built, but in too many cases wastewater treatment services are not (fully) delivered. One notable exception in the region is the PRODES programme in Brazil (see box), which has applied a results-based financing approach for over a decade. Far too few of the region’s utilities look for alternative revenue streams – such as selling resources (water, nutrients, energy) recovered from wastewater.

Box 2. Applying a results-based financing approach to wastewater treatment in Brazil

Under the PRODES programme, wastewater treatment service providers are responsible for raising funds and building and operating the WWTPs. Instead of subsidising inputs (civil works), the Federal Government pays for outputs (treated wastewater). Up to 50% of the investment costs are eligible to be reimbursed over three to seven years, provided that the wastewater discharged meets the norms. The existence of the scheme makes it easier for service providers to raise funds from commercial financing sources. It also provides a strong incentive for service providers to operate and maintain WWTPs properly. To prevent overinvestment, the WWTPs need to be included in basin plans adopted by water basin agencies in order to be eligible for PRODES financing. Over 60 projects worth over USD 100 million were funded by PRODES between 2001 and 2014.

Source:

Section 3. Experiences with wastewater resource recovery in LAC

3.1 Water Recovery: Wastewater Reuse

There is currently no comprehensive overview of wastewater reuse in the LAC region. It is safe to say, however, that wastewater reuse has been extensively practiced in LAC, though in most cases without meeting any quality standards or local regulations. Indeed, there are many cases throughout the region where raw wastewater is used for irrigation without any control.

There are some noteworthy examples of planned water reuse. We briefly examine below a number of projects and programmes that have been operational for several years, have been delivering results, and have enough information to support the hypothesis that the plant and/or the program will continue to yield the expected results for the rest of its life expectancy.

Irrigation reuse: Atotonilco de Tula WWTP, Mexico

Atotonilco WWTP represents one of the largest wastewater reuse programmes in the world. The capital expenses total about USD 900 million, of which 46% was financed by the Government of Mexico (FONADIN-PROMAGUA) and 54% by private sources. Atotonilco has been developed under a design-build-operate (DBO) scheme that includes 25 years of operation services by a private consortium. The contract was singed in 2010 and the WWTP started to operate in 2014. It has a a dry weather flow nominal capacity of 23 m^3/s and a wet-weather capacity of 35 m^3/s. Atotonilco is the largest of the six WWTPs that will be needed to treat 100% of the wastewater generated in the Valley of Mexico (adjacent to the Valley of Tula). Part of the wastewater treated by Atononilco is currently used to irrigate 90,000 hectares in the Mezquital Valley (Valle del Mezquital), which is the largest agricultural district in Mexico (and probably in LAC) irrigated with wastewater.

Energy generation reuse: Tenorio WWTP, San Luis Potosí, Mexico

Tenorio WWTP started operation in the year 2006 under under a public-private partnership scheme. With a treatment capacity of $1m^3/s$, Tenorio WWTP treats 40% of the wastewater generated by the city of San Luis Potosi. About 60% of wastewater received at Tenorio WWTP undergoes advanced primary treatment and is then used for irrigation of agricultural fields – enough to irrigate 490 hectares (a total of 2,000 hectares are irrigated from treated wastewater treated in the four WWTPs of the San Luis water utility) (Ramirez, 2011; Canales, 2015). The remaining 40% of wastewater received at Tenorio WWTP undergoes secondary treatment and is sold to a thermo electrical plant (owned and operated by the electricity utility) which uses the wastewater for their cooling system. By using regenerated water for cooling, the electricity utility has saved USD 18 million over a 6-year period. The income generated from wastewater for reuse helps the San Luis water utility to cover its operation and maintenance costs. And the 41 million m^3/year of wastewater treated and reused means that an equivalent amount of freshwater resources is protected in an area of Mexico that suffers from severe water stress.

Mining reuse: Enlozada-Cerro Verde WWTP, Arequipa, Peru

Enlozada-Cerro Verde WWTP started operations in 2015 under a public-private partnership scheme. It takes wastewater from the city of Arequipa, provides it with secondary treatment (average treatment capacity of 1 m^3/s), and delivers it for reuse at a mine operated by the mining company Cerro Verde. Before the plant started to operate, raw wastewater was discharged directly to the river Chili. Cerro Verde pays for the full cost of infrastructure development, as well as operations and maintenance. According to staff from the water and sanitation utility, the quality of the river Chili has improved considerably due to the incorporation of this WWTP. By using trickling filters, a technology that does not require the incorporation of forced air to oxygenate the biomass (as it is the case of activated sludge), energy costs are considerably reduced[20].

Industrial reuse: Projeto Aquapolo, Sao Paulo, Brazil

Inaugurated in 2012, Aquapolo is the largest water reuse project in Brazil. It is the result of a partnership between the state water utility (SABESP) and Foz do Brasil (a private company belonging to the Odebrecht group), which required setting up a new company: Aquapolo Ambiental. Through this scheme, the ABC WWTP (operated by SABESP) sells part of its secondary effluent (1 m^3/s) to the Industrial Pole of Capuava. Braskem (an Odebrech company with activity in Capuava) will consume 65% of the wastewater treated for reuse. Provision of water for reuse is guaranteed for a period of 41 years. Water reuse is particularly important in Greater Sao Paulo, an urban area with a water availability of only 140 m^3/person-year (less than 10% of what the United Nations considers to be an acceptable minimum availability) (Instituto Trata Brasil, 2012).

3.2 Nutrient Recovery: Beneficial Use of Biosolids

There are limited experiences in LAC regarding the beneficial use of biosolids. Biosolids (WWTP sludge treated to levels that permit its beneficial use) have been studied extensively in the region. Implementation is limited due, in large part, to the lack of adequate legislation and regulation to allow and encourage the beneficial use of biosolids.

Brazil and Chile seem to be the countries that have developed more experiences. Successful experiences in Chile include the cases of Aguas Andinas, Araucania, and ESSBIO. In the region of Araucania, 75% of the WWTPs have disposed their biosolids in agricultural land for the past eight years. In Brazil, CAESB (the water and wastewater utility of Brasilia) processes 400 tons of biosolids a day and reuses them to recover degraded areas in railway operation areas (*patios ferroviarios*) and in agriculture.

Learning by doing: Curitiba, Brazil

SANEPAR, the water and wastewater utility of the State of Parana, provides wastewater services to 7.1 million people across 345 municipalities through 234 WWTPs. In 1999, SANEPAR started treating part of the sludge produced at one of their facilities to produce “Class B” biosolids[21] to use in agriculture. Problems with the physical properties of the Class B biosolids and restrictions on their use prompted SANEPAR to start a new project in 2003. This involved the treatment of approximately 20,000 tons of sludge at a dedicated processing center at Belem WWTP, converting it into biosolids Class A (considerably better

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[20] Being located at over 2000 m over sea level, the level of energy needed in activated sludge increases almost two-fold, potentiating the advantage of the trickling filters over activated sludge.

[21] Based on the biosolids classification of United States Environmental Protection Agency, Code of Federal Regulations (CFR), Title 40, Part 503

quality biosolids with much more applications in agriculture) (Lucchesi, 2004). SANEPAR has had over 12 years of continuous application of biosolids to agricultural land.

In Brazil, despite the lack of local agronomic criteria for their use, biosolids have found a growing demand in grain, fruit crops, coffee, and pastures cultivation. The immediate (first year) and residual (second year) effects on corn production, as compared to a mineral fertilizer mixture applied in equivalent nitrogen, phosphorus and potassium amounts, were evaluated in a series of studies in Brasilia (Lemainsky and da Silva, 2006). All grain yields were higher than average Brazilian standards for corn and showed the immediate and residual effects of biosolids as fertilizer. The biosolids were on average 21% more efficient than mineral fertilizers. Similar studies performed on soybeans have shown that biosolids were, on average, 18% more efficient than mineral fertilizer (Lemainsky and da Silva, 2006). The advantages in terms of energy, water, climate change mitigation, operational costs and other aspects were not quantified in these studies, but considerable advantages are to be expected from the use of biosolids.

3.3 Energy Recovery: Bioenergy Generation at WWTPs

The generation of energy (heat and electricity) from biogas is common practice in many WWTPs in LAC. In the majority of cases all the heat generated is used within the facility to heat the anaerobic digesters, and the remainder of the energy generated as electricity is also consumed within the utility, since there is no surplus to sell to the network. WWTPs generating surplus electricity to sell to the electrical network are hard to find in the region. However, as discussed in the case of SAGUAPAC, in Santa Cruz de la Sierra, Bolivia (see below), it is possible to design and operate WWTPs that, based on anaerobic technologies, can generate excess energy to sell to the network. Some examples are briefly examined below.

Selling biogas: La Farfana WWTP, **Chile.**

La Farfana WWTP uses a conventional activated sludge process to treat urban water from 50% of the population of Santiago, Chile (population equivalent of 3.7 million people), and produces around 24 million m^3 per year in biogas. This biogas is sold to the gas utility company (Metrogas) and directly replaces natural gas being used by around 100,000 people in the metropolitan area.

From buying to selling electricity: San Jerónimo WWTP, **Guanajuato, Mexico**

San Jerónimo uses a conventional activated sludge process with anaerobic digestion to process sludge. With the biogas generated in a full day of operation the plant can cover electricity use during peak tariff hours (three hours a day) while during the rest of the day the plant must rely on electricity bought from the network. To keep the electricity bill within the allocated budget, San Jerónimo sometimes turns off the aerators of the activated sludge system, therefore impacting effluent quality. An energy audit funded by an international project has demonstrated that a series of low-cost energy efficiency measures in the aeration system (e.g., 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 can tilt the energy balance at San Jerónimo, 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.[22]

Selling electricity – technological and institutional dimensions: SAGUAPAC, Santa Cruz de la Sierra

SAGUAPAC is the water and sanitation cooperative providing services to approximately two-thirds of the 1.5 million people living in Santa Cruz de la Sierra. SAGUAPAC operates four WWTPs, all consisting of screening, covered anaerobic ponds, followed by (open air) facultative and maturation ponds. Lagoon treatment is demanding in terms of land requirements, but is significantly less expensive than conventional activated sludge – both in terms of capital and operational costs (including energy costs). Currently, SAGUAPAC collects the biogas from the anaerobic lagoons and burns it to reduce greenhouse gas emissions (by transforming methane into carbon dioxide). The logical next step would be to switch from burning to electricity generation. SAGUAPAC would like to install generators with base power of 1,900 kW, which would produce enough energy to supply 30% of the electricity used by SAGUAPAC in different sites, generating savings in the order of USD 1,000,000 per year (the payback period for this system was estimated at two years) (Nolasco, 2014).

The Bolivian electricity law establishes that electricity transmission agents must allow the use of their networks to “self-generating entities” (entities that consume the electricity that they produce) within their concession area, provided that the self-generating entity pays for the use of the network (transmission fee). SAGUAPAC has requested the use of the network to transmit the energy generated at its wastewater treatment plants to other SAGUAPAC sites where it needs that energy. As there is no regulatory framework to determine the transmission fee, a transmission fee is being negotiated between SAGUAPAC and the electricity distribution utility (CRE). But negotiations are being delayed by the lack of incentives for CRE to promote this type of use of its network as well as government policies that do not take into consideration inter sectorial relationships. SAGUAPAC could potentially generate more electricity, but it is not interested because generating more than 2,000 kW would force it to obtain a licence as “market agent”, a more complex, long and expensive procedure than registering with the electricity regulator (which applies to those entities generating less than 2,000 kW).

[22] http://www.iwa-network.org/WaCCliM/mexico/

Section 4. Managing wastewater as a resource – Elements of an Action Agenda

4.1 Planning, Management and Institutional Frameworks

1. Recognise wastewater as a resource within a strategic approach to water and wastewater management. Resource recovery should be identified as a legitimate objective for water and wastewater management -- this would provide the impetus for a full consideration of resource recovery when developing wastewater treatment and disposal practices. Accordingly, governments need to identify clear goals for wastewater treatment and reuse, backed by plans and budgets.

2. Integrate resource recovery in basin, urban, and climate change planning. The role of water reuse should be evaluated as part of a basin approach to water resources management (not as a series of additional projects) so that its broader impacts can be taken into account. Storage, allocation, timely availability of effluent for reuse, and means of cost recovery are some of the issues that need to be addressed. Urban planning should integrate all water dimensions (securing raw water supplies, delivering water services, sewage collection, stormwater management, flood management…) and this should include water reuse as well. These efforts could start in larger cities in water-stressed areas, and should look as well at opportunities for recovering energy and nutrients. Given its reliability as a water source, water reuse can play a prominent role in climate change adaptation strategies. Energy efficiency in wastewater treatment and reuse and the energy recovery potential should be considered when developing climate change mitigation plans.

3. Improve the fragmented institutional setting in the water sector. Management schemes, not technical barriers, are the limiting factor for the development of resource recovery. Skills and administrative responsibilities over different aspects of wastewater management are currently spread over different governmental offices. A stable and strong institutional framework with clearly defined allocation of roles across existing government bodies and responsible authorities is most needed. Responsibilities for planning and budgeting, regulation, control, and evaluation of wastewater management should be identified, and accountability mechanisms be put in place. The roles and responsibilities of the diverse private partners should be clear and tailored to local specificities in order to make the best of their strengths and provide appropriate incentives (OECD, 2008). An "institutional platform" (formed by the water agency, the health protection agency, water and sanitation utilities, and universities) would support the development of safe water reuse, including through promoting its acceptability by users. A single public agency overseeing all water and wastewater operators could facilitate a comprehensive and consistent regulatory approach as well as the alignment of incentives, so that individual operators factor the impacts of their wastewater-related decisions in other actors. The operators that provide services for water supply, sewage collection, wastewater treatment and water reuse should be more closely linked (and in some cases might be integrated).

4. Develop inter-sectoral coordination beyond the water sector. Developing an effective resource recovery programme requires the involvement of other sectors beyond the water sector. The water utilities can treat wastewater but use of regenerated water requires health and agricultural authorities to support it through their policies and regulations. Similarly, the water utilities can generate bioenergy but its potential will not be filled if the energy authorities do not support the use of that bioenergy through its policies and regulations – for example by regulating the sale of energy produced in WWTPs as well as access to transmission networks. The application of biosolids as fertilizer also requires involvement of the agricultural authorities. Exploring the water-energy-food nexus at the country or basin level would provide an opportunity to understand the inter-sectoral links and facilitate the coordination of policies and regulations. Since the different players in the water and water-using sectors often have conflicting interests, organising an informed policy dialogue process involving relevant stakeholders may prove useful to identify and exploit synergies and negotiate trade-offs.

4.2 Legal and Regulatory Reforms

5. Develop a comprehensive, coherent and consistent legislative framework. A complete wastewater collection, treatment, and reuse system requires (in addition to an integrated view and adapted institutional structures) a supportive legislative framework. For example, legal changes might be needed to allow water and sanitation providers to also provide water reuse services. Property rights over regenerated water might need to be clarified through legislation. Secondary legislation (regulations) might need to be developed regarding water quality standards for different uses of regenerated water, aquifer recharge, direct potable use of regenerated water, sales of biosolids and energy, and so on. Whenever possible, WWTP effluent requirements must be developed on a case-by-case basis (based on receiving water body improvement considerations) but in case where maximum loadings to a specific water body cannot be established legislation for both plant effluent and water bodies must be consistent across the country.

6. Get water quality regulations right. Water quality regulations need to be ensure health and environmental protection as well as access of agricultural produce to international markets, while not placing an unjustified burden on the water reuse system through excessive requirements that would make it economically unfeasible. Minimum standards for effluent quality can be set for the whole country, as it is the case of "blanket-type" legislation in several countries in LAC. However, such legislation must be evaluated taking into account the cost of its implementation. Establishing tough effluent standards, just to match or copy those used in developed countries, impacts negatively on the environment by forcing countries to spend too much in a small number of plants, leaving other sources of contamination untreated. Regulations should allow for a gradual application of WWTP effluent quality standards (whether maximum concentrations or loadings) -- switching from no treatment whatsoever to full treatment so as to meet stringent limits has costs that may exceed the capacity of the entities in charge of sanitation.

7. Consistently enforce water quality and environmental regulations. This is required to ensure that the health and economic benefits of water quality regulations are realised. Without enforcement of environmental regulations, there will be little incentive from polluters to engage in safe wastewater treatment and reuse.

8. Regulate all operators. Transparent, effective and accountable regulation should apply to all operators – whether public, private, or public-private partnerships. The economic regulation of operators should be based on the principles of reasonable rent, due diligence, efficiency, and transfer of efficiency gains to the users.

4.3 Technological Solutions

9. Put in place technology-neutral enabling frameworks. Governments and regulatory agencies should refrain from trying to pick winning technologies. Operators should be allowed to select the most appropriate technological options to achieve their operational goals while complying with existing regulations. Public agencies can support the development of wastewater resource recovery through demonstration projects and the development of technical guidance for different using sectors.

10. Design wastewater treatment processes with resource recovery in mind. Operators should aim to integrate resource recovery in the early stages of decision-making about the sizing and design of wastewater treatment infrastructure – for example by considering treatment at source (rather than end of pipe) and by aiming to make the WWTPs energy neutral through the use of co-digestion of industrial waste in anaerobic digesters with resulting excess biogas used to generate electricity.

11. Ensure informed selection of wastewater treatment and reuse technologies. Selection of technological solutions should be guided by regulatory requirements, user needs and cost-effectiveness. Wastewater resource recovery technologies should be included in professional education and training programmes – Brazil provides a good example of university programs that foster wastewater treatment studies and research with international exchanges. Guidelines for wastewater treatment process selection would help to avoid the current undue bias towards certain technologies – such as activated sludge[23]. A better understanding of the capital, maintenance and operation costs of the different technologies would help operators to select lower cost technologies – which include upflow anaerobic sludge bioreactors, trickling filters, and lagoons.

12. Promote a staged approach to the implementation wastewater treatment technologies. Investments in wastewater treatment should be geared towards meeting the limits imposed by legislation, but a realistic timeframe needs to be agreed. Countries should seek to introduce simpler low-cost options as a first step, and progressively move toward more robust treatment technologies as financial and operational capacity grows. A staged approach would also allow to increase the knowledge needed to justify and support implementation of more advanced options. For example, when discharging to open ocean, the use of advanced preliminary treatment systems (bar racks, degritting, fat oil and grease removal, and rotating screens) combined with a properly designed submarine emissary must prevail as a first stage in a new wastewater treatment facility, while additional level of treatment prior to discharging in water bodies that provide large levels of dilution may only be implemented after sufficient scientific proof of the need for this additional investment is provided.

4.4 Economics and Financing

13. Define a sustainable business model. The development of wastewater treatment and reuse technologies has been to a large extent supply-driven. But without a sustainable business model, available technological solutions will not be adopted in a large scale.

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[23] Activated sludge is a legitimate technology option that may be needed to achieve stringent levels of nitrogen removal, but they are not generally recommended in locations above 2,000 meters above sea level unless the proposed system can demonstrate it can reach energy neutrality.

Operators need to develop of a client-centred approach that takes into account the different needs (technical specifications) and willingness to pay of different (potential) users of recovered resources. In many cases, a strong business case can be developed which benefits both the operator and the potential client – for example, in many settings industrial users would benefit from lower costs and guaranteed supply while operators would benefit from more stable consumption patterns. Controlling costs (by matching treatment levels to type of water reuse, using cost-effective treatment options, and adopting a phased approach taking into account financial realism) and securing revenues (through adequate pricing structures and long term contracts) should be the building blocks of a business approach to wastewater resource recovery.

14. Integrate wastewater investments in financially-realistic basin investment plans. The bulk of financing for wastewater treatment and reuse must come from domestic resources – user contributions mobilised through tariffs and public subsides funded by tax revenues. Development grants and loans cannot be relied upon to fill the financing gap and given their scarcity should be used strategically. Wastewater management investments should be included in basin investment plans that will define the specific investment priorities of the basin and ensure integrated planning of water-related infrastructure investments. Those investment plans should be financially realistic – funding sources to pay for investment costs should be clearly identified and likely to deliver the required funding. In order to match costs with available funding, objectives may need to be revised, selection of low cost solutions prioritised, and sequencing of investments delayed. Wastewater investments should be evaluated taking into account the full benefits that will be delivered – including the whole array of economic, social and environmental benefits from resources recovery. Investment plans should include funding for *soft* wastewater management functions -- including planning and evaluation, research and innovation, and monitoring and control. Wastewater treatment and reuse investments should explore the opportunity to obtain budget allocations from non-water budget lines – such as climate change adaptation, climate change mitigation, urban development, and rural development budget lines.

15. Implement supportive pricing mechanisms and structures across the water system. There are several points across the water system where pricing needs to be introduced and carefully defined. Charges for water abstraction should reflect the scarcity value of raw water. Tariffs for water supply, sewerage and wastewater treatment should reflect the cost of delivering the services (although they can be reduced to take into account affordability concerns, as long as public subsidies make up the shortfall in revenues for the operators). Pollution charges (to water bodies) should be high enough to provide incentives for wastewater treatment to a level that is socially optimum. Wastewater treatment charges to contribute to pay for the operator's expenses should be applied to industrial discharges into sewers that exceed the established service, so that industrial users are not subsidised by other users[24]. Regenerated water should command a price – including for agricultural users. Economic regulators have a key role to play in ensuring transparency in costs and pricing structures, and in regulating prices so that they cover the justified costs of service provision.

[24] Industries should not be permitted to pay for exceeding discharge limits of certain contaminants considered to damage the collection network (e.g., low pH discharges) or discouraged to be discharged by the WWTP (e.g., Cr^{6+}).

16. Evaluate the financing of wastewater treatment and reuse projects using a full-cycle approach that takes into account financial, environmental, and social aspects. Sources of funding for operation and maintenance (O&M) must be identified and secured before initiating capital investments in expansions or upgrades. If funding for O&M is not guaranteed, lower-cost technologies must be evaluated, at least in the initial stage in the program. The evaluation of the environmental benefits of the project should include, in addition to the improvements in water quality in the receiving water bodies, the environmental benefits associated to water reuse (reduction of pressures on water resources), energy generation from biogas (reduction in greenhouse gas emissions), and beneficial use of biosolids as fertilizers (reduction in water pollution achieved by the substitution of synthetic fertilizers). Social impacts of the construction and operation of plants can be negative (noise, odours, potential reduction in property values in the areas surrounding the plant) and positive (health benefits of improved water quality, jobs generated in the construction and operation of the plant, potential increase in property values in the areas benefiting from enhance water quality of water bodies, potential lower cost of water and fertilizers for farmers).

17. Encourage economic efficiency through results-based financing and public-private partnerships. Results-based financing can be used to improve the track record of wastewater treatment and ensure that reuse services are actually delivered. Adequately regulated private-public partnerships (PPPs) can improve operational efficiency and deliver higher quality of service. When PPPs are used, the government should incorporate programs and systems that foster adequate knowledge transfer (that is, knowledgeable private operators training government engineers and technologists on site). Also, information generated in PPPs must be shared openly with government officials, not only for the purpose of monitoring and control, but also to facilitate learning and capacity building within government institutions.

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