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Urban Sewage in Brazil: Drivers of and Obstacles to Wastewater Treatment and Reuse

Governing the Water-Energy-Food Nexus Series

Katharina Stepping

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Bonn, December 2016 Katharina M. K. Stepping

Abstract

The case study analyses the factors that drive or hinder wastewater collection and treatment in urban Brazil and discusses the potential for wastewater reuse and its current constraints. The results are based on more than 60 semi-structured interviews with government officials from ministries and environmental agencies; development banks; water and wastewater utilities; business associations; civil society organisations; academia and other experts. The case study concludes that Brazil's urban wastewater sector still largely struggles with overcoming barriers to wastewater collection and treatment, but it has great potential for wastewater reuse that has not yet been fully tapped, despite initial promising initiatives, mainly for industrial reuse. Financial resources have increased in the past, yet access is difficult for small municipalities and, in particular, public utilities forego the revenues needed for investment in maintenance, operation and expansion, due to inefficient management. The strict *de jure* legislation does not reflect reality and complicates processes that are already complex due to the many agencies and bureaucratic levels involved. Politically, although sewage has become more important for voters, it still continues to be only one concern of many. The low connection rate to the public sewerage system is socially problematic and leads to lost revenues for the service provider. In particular, public utilities face limited planning as well as a lack of technical and managerial capacity, which translates into a lack of operational and maintenance skills. Urbanisation pressures and water scarcity can catalyse change, in particular by raising awareness about the importance of adequate wastewater collection and treatment and about the potential of wastewater reuse.

Keywords: Wastewater, sewage, collection, treatment, reuse

JEL: O18, Q25, Q53

Contents

Figures

Tables

Abbreviations

ABNT	Brazilian National Standards Organization / Associação Brasileira de Normas Técnicas
AGENERSA	Regulatory Agency Energy and Basic Sanitation of Rio de Janeiro State / Agência Reguladora de Energia e Saneamento Básico do Estado do Rio de Janeiro
ANA	National Water Agency / Agência Nacional de Águas
ARSAE	Regulatory Agency Water and Sanitation Services in Minas Gerais State / Agencia Reguladora de Servicos de Abastecimento de Agua e de Esgotamento Sanitario do Estado de Minas Gerais
ARSESP	Regulatory Agency Energy and Water Supply and Sanitation of São Paulo State / Agência Reguladora de Saneamento e Energia do Estado de São Paulo
BMZ	Federal Ministry for Economic Cooperation and Development / Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung
BNDES	Brazilian Development Bank / Banco Nacional de Desenvolvimento Econômico e Social
BNH	National Housing Bank / Banco Nacional de Habitação
CAESB	Environmental Sanitation Company of the Federal District / Companhia de Saneamento Ambiental do Distrito Federal
CEDAE	State Company for Water and Wastewater of Rio de Janeiro / Companhia Estadual de Águas e Esgotos do Rio de Janeiro
CEF	Caixa Econômica Federal
CESBs	State Companies for Water Supply and Sanitation / Companhias Estaduais de Saneamento Básico
CETESB	Environmental Company of the State of São Paulo / Companhia Ambiental do Estado de São Paulo
COFINS	Contribution for Social Security Financing / Contribuição para o Financiamento da Seguridade Social
COMPESA	Sanitation Company of the State of Pernambuco / Companhia Pernambucana de Saneamento
COPASA	Sanitation Company of Minas Gerais / Companhia de Saneamento de Minas Gerais
DAEE	Water and Electric Energy Department (São Paulo) / Departamento de Águas e Energia Elétrica
DF	Federal District / Distrito Federal
DIE	German Development Institute / Deutsches Institut für Entwicklungspolitik
EMBASA	Water and Sanitation Company of the State of Bahia / Empresa Baiana de Águas e Saneamento
FGTS	Employment Guarantee Fund / Fundo de Garantia do Tempo de Serviço
FUNASA	National Health Foundation / Fundação Nacional de Saúde
GDP	Gross Domestic Product
IPCA	Extended National Consumer Price Index / Índice Nacional de Preços ao Consumidor Amplo
PAC	Growth Acceleration Program / Programa de Aceleração do Investimento
PIS/PASEP	Social Integration Programs and Public Servant Fund / Programas de Integração Social e de Formação do Patrimônio do Servidor Público
PLANASA	National Plan of Sanitation / Plano Nacional de Saneamento

PLANSAB	National Plan of Basic Sanitation / Plano Nacional de Saneamento Básico
PPP	Public–Private Partnerships
R$	Brazilian Real
SABESP	Company for Basic Sanitation of the State of São Paulo / Companhia de Saneamento Básico do Estado de São Paulo
SFS	Financial System of Sanitation / Sistema Financeiro do Saneamento
SINGREH	National Water Resources Management System / Sistema Nacional de Gerenciamento de Recursos Hídricos
SNIS	National Information System on Water and Sanitation / Sistema Nacional de Informações sobre Saneamento
SNSA	National Department of Environmental Sanitation / Secretaria Nacional de Saneamento Ambiental
UASB	Upflow Anaerobic Sludge Blanket
WWTP	Wastewater Treatment Plant

1 Introduction: why wastewater collection, treatment and reuse matter

The collection and treatment of wastewater is deficient in many countries, despite the human right to water and sanitation (United Nations General Assembly, 2010). Treatment of domestic and industrial wastewater protects human health, preserves water as an ecosystem and in a state that allows use for human purposes (Seeger, 1999). Watercourse pollution implies social costs in the form of negative externalities for both the environment and human well-being due to increased risk of waterborne diseases and artificially reduced water availability downstream. Upper-middle- and lower-middle-income countries treat 38 per cent and 28 per cent of the generated wastewater respectively, whereas low-income countries treat only 8 per cent (Sato, Qadir, Yamamoto, Endo, & Zahoor, 2013). Brazil is average, with approximately 52.8 per cent of the generated wastewater collected and 37.1 per cent of the generated wastewater being treated.[1]

Water quality is threatened by industrial pollution and untreated discharge; in particular in the heart of Brazil's economy, the states of São Paulo, Rio de Janeiro and Minas Gerais "are facing quantitative and qualitative water shortages" (Organisation for Economic Co-operation and Development [OECD], 2015b, p. 33). Most Brazilian cities struggle with water pollution due to untreated sewage discharge in water bodies, aggravated by insufficient rubbish collection, a poorly maintained water and drainage infrastructure, and insufficient wastewater infrastructure. Only 58 per cent of the urban population is connected to the sewerage system (National Information System on Water and Sanitation [SNIS], 2014). Rapid urbanisation with unplanned expansion of its cities increased the urban population from 45 per cent in 1960 to more than 80 per cent in 2000 (Chikersal & Bhol, 2016), but it was not accompanied by the expansion of the wastewater infrastructure. In fact, population growth, unaccompanied by investments in sanitation, etc., was identified as the main cause of a decrease in water quality (National Water Agency [ANA], 2012).

Almost half of all sampling points in urban areas show that rivers are in "bad" or "very bad" condition (ANA, 2012):

> The basins of these urban rivers are for the most part usually impermeable,[2] polluted by domestic sewage, industrial effluents, solid waste and diffuse loads that impact the quality of life in Brazilian cities, as they degrade the urban landscape, reduce leisure opportunities and enable the transmission of diseases. (ANA, 2012, p. 37)

As it is an omnipresent problem, it is visible and tangible in all major cities, for example in Rio de Janeiro, where open sewers connect the noble neighbourhoods Leblon and Ipanema; in São Paulo, where the Tietê River is merely an open sink in the heart of the city; and in Recife and Salvador, where heavy rainfalls regularly cause coastal water pollution.[3]

Demographic and economic growth further threatens water quality and availability, yet investments in wastewater infrastructure help to reduce environmental pollution. The

1 Approximately 70.3 per cent of the collected wastewater is treated based on the following figures: generated wastewater (estimated to equal water consumption): 10,132,306 thousand m³; collected wastewater: 5,357,051 thousand m³; treated wastewater: 3,763,851 thousand m³ (SNIS, 2014, pp. 14, 24).

2 Water is unable to infiltrate through the river bed, resulting in more surface runoff and higher volume and speed.

3 See Chapter 3 for details on the case study cities.

increase in water quality – measured at several sampling points in urban areas – is mainly ascribed to investments in basic sanitation,[4] such as expansion of sewage collection systems, implementation of wastewater treatment plants (WWTPs) or their increased efficiency, and closing of open dump yards, in addition to control of industrial sources and increased reservoir outflows (ANA, 2012).

WWTPs are part and parcel of an effective sewage system. They allow not only sewage to be treated – and, hence, to be reused – but also offer co-benefits for energy efficiency and energy production (e.g. through generating biogas during sludge digestion). In addition, effective wastewater treatment contributes to reduced greenhouse gas emissions, in particular of methane, a very "effective" greenhouse gas. Recycling wastewater can help to alleviate the mismatch between water supply and demand (United Nations Development Programme, 2006, p. 151). Reuse of treated wastewater in urban areas can provide alternative water resources and thus helps communities to become less dependent on groundwater and surface water sources. It can reduce the nutrient loads from wastewater discharges into waterways or can be deployed for industry or irrigation. Beyond the immediate positive environmental effects, wastewater collection and treatment is also of utmost importance for public health.[5]

The recent water crisis in Brazil's economic heart, São Paulo, has underlined the importance of effective wastewater collection and treatment for water quality and public health, and has fuelled a vivid discussion about the reuse of treated wastewater as a means to reduce water stress. In as much as Brazil is one of the most water-rich countries, it faces local water scarcity because water resources and the population are asymmetrically distributed. Yet, wastewater infrastructure has been underinvested in for decades, and the potential of wastewater reuse has barely started to be used. The extension of the sewage system and the links between sewage systems and WWTPs are often insufficient, resulting in many WWTPs not operating to full capacity. In particular in urban informal settlements (*favelas*), land to install sewage systems – and the necessary connections – is a very scarce resource.

The sanitation sector suffers from a multitude of well-known problems (SNIS, 2014, p. 49): the lack of, or bad quality of, projects; obstacles in the environmental licensing process and difficulties in achieving property regularisation where the operational units are planned to be built; very lengthy bidding processes; and, finally, frequent problems with the execution of projects within the stipulated deadlines. Notwithstanding, as an upper-middle-income economy, Brazil has economic possibilities to invest in infrastructure and has a well-developed institutional framework in terms of laws and regulations, compared to many other countries, but it has not yet taken advantage of the co-benefits of combining wastewater treatment, water reuse and energy production. Hence, there is pressure to improve wastewater collection and treatment, to start employing the resource-efficient wastewater reuse and to move towards innovative energy solutions in the

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4 Basic "sanitation" is sometimes understood to be a more comprehensive term than "water and wastewater services" because it "includes the classical components of water supply and sanitation services, but also integrates the collection, treatment and disposal of solid wastes, storm-water drainage, and the control of vectors of transmittable diseases" (Heller, 2009, p. 321). In this paper, the terms "basic sanitation" and "water and wastewater services" are used interchangeably.

5 The Great Stink in London in 1858 is a well-researched historical case about how sanitation services limit the spread of diseases, in this case cholera (see Halliday, 1999).

wastewater sector. As such, wastewater treatment and reuse may contribute to greater water, energy and food security, and be understood as water-energy-food nexus[6] technology.

The results of this paper are based on more than 60 semi-structured interviews, conducted between October and December 2015 on the federal, state and municipal levels with government officials from ministries and environmental agencies; development banks; water and wastewater utilities (state-owned, private, and public–private partnerships (PPP)); business associations; civil society organisations; academia and other experts in Brasília (Federal District), São Paulo (São Paulo state), Rio de Janeiro (Rio de Janeiro state), Belo Horizonte (Minas Gerais state), Recife (Pernambuco state) and Salvador (Bahia state). The cities considered in this study face similar challenges, yet with varying degrees of importance and urgency. The interviews followed the logical chain of water and wastewater, including some or all of the following: water supply, wastewater collection and treatment, wastewater reuse, sludge use, and energy efficiency of WWTPs. Beyond topical questions, the interviews also attempted to cover financial, economic, political and regulatory aspects of water and wastewater in Brazil. Existing sanitation programmes and projects were included in the interviews where feasible and necessary. All interviews were conducted in Portuguese, recorded when possible and transcribed by six student assistants. The interviews were coded with the software Atlas.ti.

The case study analyses the factors that drive or hinder wastewater collection and treatment in urban Brazil – as a prerequisite to wastewater reuse – and discusses the potential for wastewater reuse and its current constraints. The aim is to understand under which conditions and with which instruments integrated approaches towards water, energy and food sectors are useful in the wastewater sector in Brazil. This paper is one outcome of the research project "Incentives and instruments for implementing the nexus water-energy-food-security", conducted at the German Development Institute (DIE) with the support of the Federal Ministry for Economic Cooperation and Development (BMZ). The project analyses incentives, instruments and mechanisms that impact on potential synergies and trade-offs between the water, energy and land sectors (water-energy-food nexus) in Brazil, Colombia, Germany, India and Zambia and in selected international river basins. The case study on India (Never, 2016) also treats the topic of wastewater treatment, reuse and energy, albeit with a stronger emphasis on energy savings, energy efficiency and energy production.

The case study concludes that Brazil's urban wastewater sector still largely struggles with overcoming barriers to wastewater collection and treatment, but it has great potential for wastewater reuse that has not yet been fully tapped, despite initial promising initiatives, mainly for industrial reuse. Financial resources have increased in the past, yet access is difficult for small municipalities and, in particular, public utilities forego the revenues needed for investment in maintenance, operation and expansion, due to inefficient management. The strict *de jure* legislation does not reflect reality and complicates processes that are already complex due to the many agencies and bureaucratic levels involved. Although sewage has become politically more important, it continues to be only one concern for voters, who also worry about public health, education and security. The low connection rate to the public sewerage system is socially problematic and leads to lost revenues for the service provider. In particular, public utilities face limited planning as

6 Also known as water-energy-land nexus.

well as a lack of technical and managerial capacity, which translates into a lack of operational and maintenance skills. Urbanisation pressures and water scarcity can catalyse change, in particular by raising awareness about the importance of adequate wastewater collection and treatment and about the potential of wastewater reuse.

The paper is organised as follows. In Chapter 2, the reader learns about the water and sanitation sector in Brazil, in particular the institutional and financial framework as well as key facts about water and wastewater services and their tariff structure. Chapter 3 briefly introduces the cities of Brasília, São Paulo, Rio de Janeiro, Belo Horizonte, Recife and Salvador. Although each city faces particular challenges related to geographical and climatic conditions, most barriers to wastewater collection, treatment and reuse are similar and allow for generalisations. Chapter 4 discusses the challenges and opportunities for wastewater collection and treatment, addressing the financial and economic, institutional, politico-economic, and socioeconomic context, as well as limited capacity. Chapter 5 discusses the potential for wastewater reuse in Brazil and highlights the constraints related to the identified barriers for wastewater collection and treatment. Chapter 6 summarises the lessons learnt about how relevant the nexus approach is in practice. The last chapter concludes and presents some policy recommendations.

2 Water and sanitation in Brazil

2.1 Institutional background: past and present

Municipalities supplied water supply and sanitation services until the 1970s under the supervision of the National Health Foundation (FUNASA), a subordinate agency of the Health Ministry (Seroa da Motta & Moreira, 2006, p. 186). The “main features” of today’s structure in the sanitation sector were laid in the 1970s through the implementation of the National Plan of Sanitation (PLANASA) from 1971 onward (Heller, 2009, p. 323). The military regime (1964-1985) transferred the responsibility for water supply and sanitation from municipal to state authorities and thereby concentrated power in the hands of the states (Heller, 2007): 26 new regional state companies for water supply and sanitation (CESBs, short for state utilities) were created and were granted concessions from the local municipalities to provide water and sanitation services in their jurisdictions (Table 1 summarises the main developments).[7]

Only CESBs were authorised to obtain financing from the National Housing Bank (BNH) (Sabbioni, 2008). Created in 1964 with the mission to implement a policy for urban development, the BNH carried out the first assessment of the sanitation sector three years later (Santejo Saiani & Toneto Júnior, 2010). Although about 3,200 municipalities awarded concessions to the state-owned companies for the next 20-30 years, about 1,800 municipalities never adhered to PLANASA (Sabbioni, 2008).

CESBs became responsible for seeking funding, developing and expanding water and sanitation systems, as well as operating and maintaining the services, and gained the right to collect service fees. PLANASA used the Employment Guarantee Fund (FGTS),

7 Since 1989, when the northern part of the state of Goiás became the new and additional state Tocantins, Brazil has had 26 states plus the Federal District.

workers' pension contributions, as a new source of public funding for sanitation.[8] PLANASA established the compulsory self-sufficiency of CESBs based on service fees, allowing cross subsidies within each company's jurisdiction. The system of cross subsidies between different classes of consumers (e.g. large-scale consumer, low-income consumer) was extended to municipalities, and a single state-level tariff was adopted (Tupper & Resende, 2004).

In the 1980s, state-level public utilities lost financing capacity due to high and unpredictable inflation and were unable to finance the required expansion of the water and wastewater infrastructure (Sabbioni, 2008; Seroa da Motta & Moreira, 2006, p. 186). The lost decades of the 1980s and 1990s strongly impacted public and private financing in basic sanitation. The growth of the sectors linked to construction and housing slowed down, and the BNH, overburdened by debt, was abolished in 1986. The Caixa Econômica Federal (CEF) assumed the assets from the BNH. Given the budget restrictions of the federal government during the economic crisis, the CEF drove urban policy – which was still without any formal and explicit orientation – thanks to its power as the official provider of the FGTS, the biggest source of public financing for housing and sanitation. The cut in public investments and the credit restrictions for the public sector, following recommendations of the International Monetary Fund, fostered a strong drawback of activities in the sanitation sector, in particular between 1998 and 2002 (Ministério das Cidades, 2004). In 2000, the National Water Agency (ANA) was created as a regulatory agency for the water sector to monitor the use of water resources and the discharge of wastewater in water basins, including the implementation of the National Water Resources Management System (SINGREH) and the National Policy of Water Resource[9]; independent from, yet formally associated with, the Environment Ministry (Tupper & Resende, 2004). Three years later, the Ministry of Cities and its National Department of Environmental Sanitation (SNSA) was created. The SNSA is entrusted with, among other things, the universal access to water supply and sanitation (Heller, 2009).

The Ministry of Cities is structured to unite the most important (from an economic and social viewpoint) and the most strategic (environmental sustainability and social inclusion) areas of urban development. The CEF plays the key role in urban and related politics, whereas the Brazilian Development Bank (BNDES) also handles urban politics, in particular sanitation and transport (Ministério das Cidades, 2004). The Ministry of Cities is responsible for investments in water and sanitation projects in municipalities with more than 50,000 inhabitants – approximately 80 per cent of the population – whereas FUNASA is responsible for municipalities below this limit and is still under the supervision of the Health Ministry.

The National Sanitation Law No. 11,445/2007 builds the regulatory framework for the sanitation sector in Brazil. It declares universal access to basic sanitation (Art. 2 I) for drinking water supply, sanitation sewage, street cleaning and solid waste management, and drainage of rainwater (Art. 3 I). Municipalities can delegate the organisation,

8 The National Housing Bank (BNH) managed the Financial System of Sanitation (SFS), created to centralise resources and to coordinate actions within the sanitation sector, and was responsible for handing out loans with resources from the Guarantee Fund for Employee (FGTS) to finance part of the investments (Santejo Saiani & Toneto Júnior, 2010).

9 Law No. 9,433/1997, also known as the "Water law", outlines the national policy of water resources, including fees for water extraction and for wastewater discharges.

regularization, fiscalisation and provision of services (Art. 8).[10] They have to elaborate a sanitation plan (Art. 9 I) and provide or delegate the services and define the entity responsible for regularization and fiscalisation (Art. 9 II). Article 52 obligates the federal government, under the coordination of the Ministry of Cities, to elaborate the National Plan of Basic Sanitation (PLANSAB).

Table 1: Overview of historical development of water and sanitation services

Period	Characteristics
1500s to 1850s	Early development and the implementation of the first sanitary actions
1850s to 1910s	Raising awareness about the interdependence of sanitary actions in a context characterised by an ambiguous relationship between public and private water and sanitation services
1910s to 1950s	The consolidation of the national state as coordinator of sanitary policy
1950s to 1969	Reorientation of sanitary policies, their separation from health policy and the autonomy of water and sanitation services, supplied at municipal level
1970 to 2002	Reorganisations of sanitary policies during the military dictatorship; majority of municipalities award concessions to 26 state companies for water supply and sanitation
From 2003 to date	Institutional changes implemented during the Workers' Party national government; the National Sanitation Law declares municipalities as the rights-holder of basic sanitation

Source*:* Based on Heller (2009, p. 322); similarly, Rezende, Heller, and Queiroz (2009), including details on the early development since 1500

Hence, the municipality can grant the concessions to a public or private company or provide the services directly. Yet, few municipalities provide their own services or are privately supplied; state utilities provide sanitation services to 55.1 per cent of municipalities that participated in the National Information System on Water and Sanitation (SNIS) 2014 and to 66.6 per cent of the urban population (SNIS, 2014). Many CESBs are badly managed and rather inefficient, which is apparent when looking at the great volumes of non-revenue water (see Section 2.3) and indebtedness.

> [The National Sanitation Law] is arguably the most important legislative innovation in the basic sanitation sector in decades and, as such, the first-ever federal law for water and sanitation services. This is a groundbreaking initiative that fills a historical gap in the sector's legislation after about 30 years of debate, and that for the first time in history makes possible the adoption of national guidelines for public policy and management in the basic sanitation sector. (Heller, 2009, p. 333)

PLANSAB (2013) establishes targets for each region of the country – taking into consideration the distinctive features of each area – and defines short-term (2018), medium-term (2023) and long-term goals (2033). The ultimate goal is to provide universal access to basic services (water supply and sanitation) as a social right.

10 The Law of Public Consortia No. 11,107/2005 "sets the ground rules for the creation of new public bodies for the delivery of basic sanitation services, including inter-municipal and municipal-provincial partnerships" (Heller, 2009, p. 333).

Although quality standards for drinking water are very well developed and the level of monitoring and enforcement in place are acceptable, the regulatory system for wastewater discharge has been orientated towards strict standards based on international levels rather than the available technology and local knowledge. This has resulted in years of non-compliance of WWTPs, which have only gradually progressed towards enforcing better quality standards (Global Water Intelligence [GWI], 2015, p. 49).

Today, 80 per cent of the population lives in urban areas, up from 30 per cent in 1950. The number of cities with a population greater than 50,000 inhabitants increased from 38 in 1950 to 409 in 2000, of which 202 had a population greater than 100,000 inhabitants. Brazil has 16 urban agglomerations with more than 1 million inhabitants, with the megacities of São Paulo and Rio de Janeiro at the forefront. By and large, all Brazilian cities face the same challenges regarding the lack of planning, land reform and land use control. The population concentration has been largely unmatched by a growth in the necessary infrastructure, such as sanitation (Ministério das Cidades, 2004, pp. 33-34).

2.2 Financing of sanitation

The large sunk costs due to large-scale and long-term investments in sanitation infrastructure are characteristic of the sanitation sector (Seroa da Motta & Moreira, 2006, p. 185). The Growth Acceleration Program (PAC 1 from 2007 to 2010, and PAC 2 from 2011 to 2014) has "significantly boosted" wastewater investment after decades of underinvestment; this became visible through the increase in investment from 2008 to 2010 (GWI, 2015, p. 18). Federal wastewater funding amounted to 14.7 billion Brazilian reais (R$) in PAC 1 and R$ 14.5 billion in PAC 2, yet "federal funds are slow to reach their destination" (GWI, 2015, p. 29).[11] On average, investments in water supply and sanitation equalled R$ 7.2 billion in the period 2004-2014 (SNIS, 2014). Investment programmes tend to correct the distortions in resource allocation and to address the deficits, yet "these investments are often executed with less agility than necessary" (SNIS, 2014, p. 49). Federal funding, aside from tariffs, is the key source of financial resources for many service providers.

Water and wastewater services moved financial transactions worth R$ 99.7 billion in 2014 (investments: R$ 12.2 billion; revenues: R$ 45.1 billion; costs: R$ 42.4 billion), according to SNIS (2014). From 2004 to 2014, investments in water supply and sanitation equalled R$ 7.2 billion on average, with an annual growth rate of 29 per cent. Total investments in the water supply and sanitation sector amounted to R$ 12.2 billion in 2014, of which 42 per cent was invested in the water sector and 46 per cent in the wastewater sector. Most investments (R$ 6.4 billion, or 53 per cent) in the sanitation sector were undertaken with service providers' own funding, 29 per cent were loans and 18 per cent grants. The majority of investments in the wastewater sector (R$ 3.5 billion, or 62 per cent) were provided in the south-east, accounting for 29 per cent of the deficit in wastewater, whereas the north-east accounted for only 13 per cent of all investments in the wastewater sector, despite the highest deficit in wastewater of 32 per cent. The south-east, in particular the Company for Basic Sanitation of the State of São Paulo (SABESP) in São Paulo, was able

11 In the average five-year exchange rate, R$ 1 corresponds to € 0.33; hence, to convert Brazilian reais into euros, the amount needs to be divided by three, approximately.

to undertake the majority of investments with own funds, thanks to better technical and financial capacity, compared to great parts of the country.

Investment needs for expanding the wastewater structure were estimated to be R$ 41.2 billion for 2011-2015 and R$ 32.9 billion for 2016-2020; more than 95 per cent of investments were planned in urban areas, of which only 15-20 per cent was planned for rehabilitating existing infrastructure (GWI, 2015, p. 29). ANA recommends the implementation of sewerage systems and WWTPs to focus on protecting and recovering surface water upstream – as well as on urban agglomerations with great population pressures – which serve as sources for urban water supplies; ANA identifies a need of R$ 40.8 billion for investments in wastewater collection and R$ 7 billion in wastewater treatment (ANA, 2010, p. 60). During PLANSAB, from 2014 to 2033, investment needs for basic sanitation are estimated to total R$ 322.1 billion, on average R$ 16.1 billion per year. This is more than the investment amount of R$ 304 billion deemed necessary to meet PLANSAB’s goals (SNIS, 2014, p. 72). Due to the major ongoing political and economic crisis, however, it is very likely that projections – and, hence, expectations – have to be scaled back.

The assessment of construction projects to execute collection networks and/or WWTPs in Brazilian cities with more than 500,000 inhabitants is, however, disillusioning (Trata Brasil, 2015a). At the end of 2014, only 42 per cent of the 111 works of PAC 1 had been finished and 12 per cent were on track; a significant number (46 per cent) were in a problematic condition, either suspended or delayed. With regards to the 70 works of PAC 2, only 2 projects had been finished, 41 per cent had not started yet, 16 per cent had started, and 24 per cent had been suspended or delayed.[12]

2.3 Water supply and consumption

Brazil[13] is one of the most water-rich countries, with an average discharge of almost 180,000 m³/s, but it is characterised by an asymmetric distribution of water resources in relation to population, with 45 per cent of the urban population concentrated along the coast but with access to only 3 per cent of the available water (ANA, 2010). Surface water and groundwater supply 47 per cent and 39 per cent, respectively, of Brazilian municipalities (ANA, 2010). The semi-arid regions in the north-east struggle with scarce

12 Trata Brasil, a civil society organisation formed by companies interested in advancing basic sanitation and protecting water resources, accompanies on an annual basis the evolution of construction projects of wastewater collection and treatment in Brazilian cities with more than 500,000 inhabitants, focussing on those contracts that involve the execution of collection networks and/or wastewater treatment plants: 181 in 2015 (Trata Brasil, 2015a, p. 4). Sixty-eight per cent of the projects are located in the south-east and north-east regions. The selected projects total R$ 10.87 billion in investment, representing almost 25 per cent of all investments in the sanitation sector, totalling 45.9 billion: 111 works in PAC 1 with a total value of R$ 4.91 billion, and 70 works in PAC 2 with a total value of R$ 5.96 billion. Fifty-five per cent were financed by the Caixa Econômica Federal, 28 per cent by the federal budget and 17 per cent by BNDES. Twenty-five per cent of the resources are allocated to projects in the São Paulo state, 11 per cent to Rio de Janeiro state and 10 per cent to Minas Gerais state.

13 The Federative Republic of Brazil is divided into 26 states and the Federal District, where the capital Brasília is situated. Each of the states is divided into municipalities, totalling 5,565 municipal units nationwide. Brazil’s territory is divided into five large regions: north, north-east, central west, south-east and south.

water resources, the central and southern states need large quantities to irrigate water-intensive crops and the south-east faces competition in water access due to rapid industrialisation and urbanisation (OECD, 2015b, p. 33).

In 2014, there were 163.2 million inhabitants supplied with water, on average 93 per cent of the urban population[14] and 83 per cent of the total population, according to SNIS (2014).[15] The water supply network supplied 53.8 million households – compared to 36.9 million households 10 years earlier – with great variations emerging across municipalities (see Figure 1). There were 15.9 billion m^3 of water produced and 10.1 billion m^3 of water consumed.

On average, 37 per cent of the water supply is lost in distribution in Brazil, declining 45 per cent in total since 2004. Most of the providers with loss rates higher than 50 per cent in 2014 were situated in the north and north-east regions. Water loss, or non-revenue water, is "one of the big problems" in the Brazilian water supply and represents a "waste of natural and operational resources as well as revenue losses for the service provider" (SNIS, 2014, p. 34), whose costs are passed on to the customers. Non-revenue water consists of apparent losses and real losses. Apparent losses refer to water that is effectively consumed by the customer but is not billed due to metering inaccuracies, theft (known as "*gato*" in Brazil), etc. Real/physical losses refer to water that is produced but lost before it reaches the customer due to leaks and exacerbated by poor-quality or old pipes, a low-quality workforce, a lack of monitoring, etc. The rehabilitation of existing infrastructure in order to lower the amount of physical water losses receives little attention (see Section 2.2); in particular, state utilities prefer investing in new water supply infrastructure.

The daily water consumption per capita was 162 litres in 2014, up from 142.7 litres in 2004.[16] The water crisis in the south-east led to less water consumption (SNIS, 2014): after almost continuous growth up until 2012, the water consumption rate declined by 0.7 per cent in 2013 and 2.6 per cent in 2014.

14 In 2014, the estimated total population was 202,799,518 inhabitants, and the estimated urban population was 171,302,550 (Brazilian Institute for Geography and Statistics [IBGE], 2016) .

15 The 2014 data are based on the water supply in 5,114 municipalities, with an urban population of 168 million inhabitants, representing 91.8 per cent of all municipalities and 98 per cent of the urban population in Brazil. For sewerage, the data are based on 4,030 municipalities, with an urban population of 158.5 million inhabitants, representing 72.4 per cent of all municipalities and 92.5 per cent of the urban population in Brazil.

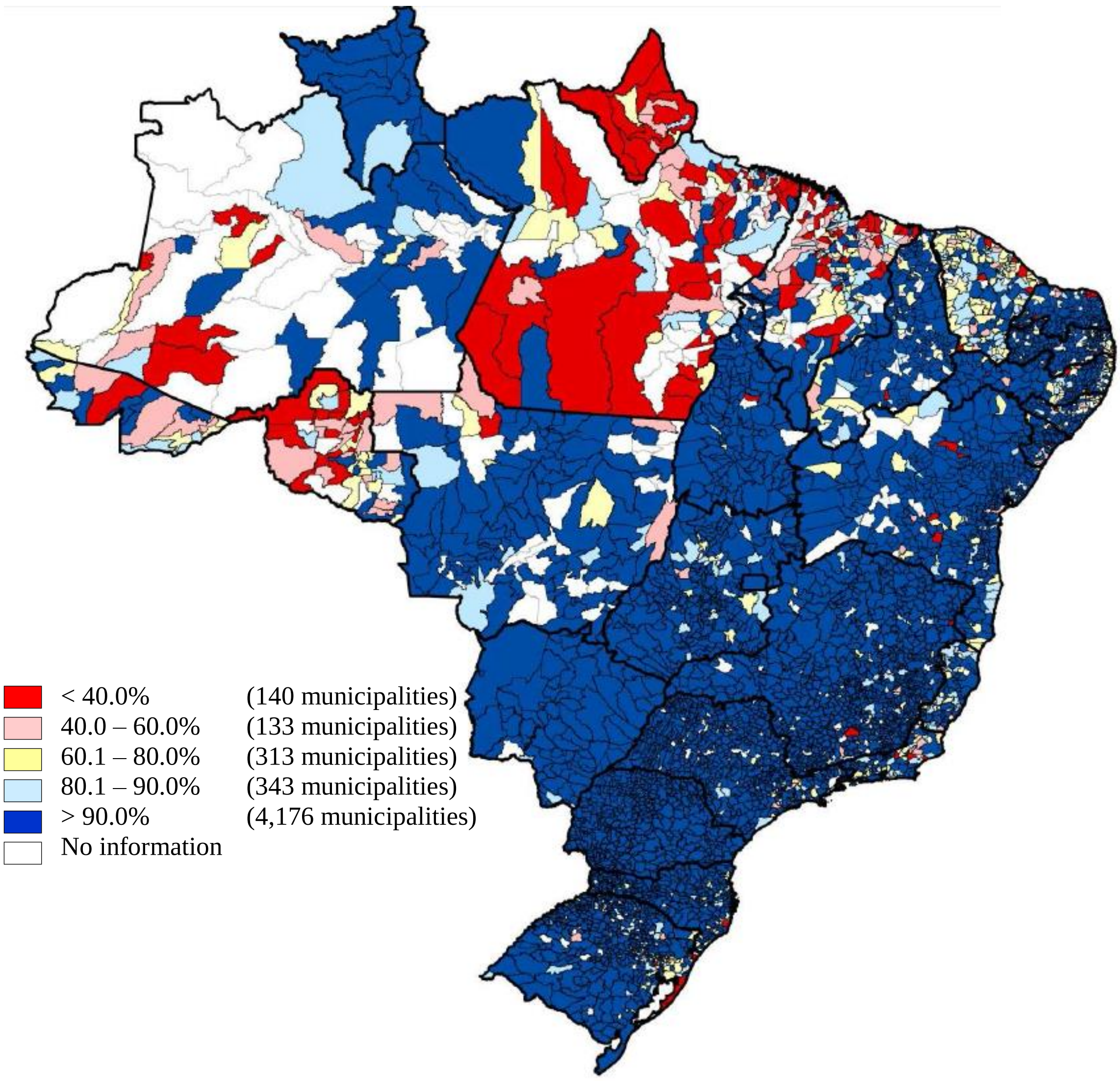
Figures of the population served/attended to are reported by service providers and can be overestimated due to inconsistencies in the methodology used for calculation among service providers (SNIS, 2014). The total population figures are estimated by the IBGE (see footnote 14).

Water and wastewater services refer to the access via the water supply and sewerage networks and do not include any individual solutions considered inadequate, such as connections to the drainage system in the case of sewage.

The submission of data to the SNIS is the condition to gain access to resources for investments from the SNSA.

16 The outlier is the state of Rio de Janeiro, with 250.8 litres per capita per day.

Figure 1: Urban water supply (in % per municipality)



Source: SNIS (2014, p. 28)

2.4 Wastewater collection and treatment

There were 98 million inhabitants connected to the sewerage system in 2014, which represents 57.6 per cent of the urban population and 49.5 per cent of the total population, with great variations across municipalities (see Figure 2) (SNIS, 2014). On average, 40.8 per cent of the generated wastewater and 70.9 per cent of the collected wastewater was treated.[17] From 2004 to 2014, the sewerage network grew 8.3 per cent annually and attends today to

17 These average values are provided in SNIS (2014, p. 24). The reader may notice a slight difference between these figures and those based on own calculations using data provided by SNIS, presented in the introduction and in footnote 1. It is unclear why the figures diverge but the difference is negligible and does not change the overall message.

31.4 million households. In 2004, only 18.5 million households were connected to the sewerage system, and only 31.3 per cent of the generated wastewater was treated.[18]

In urban areas and in rural areas with a more concentrated population, usually collective solutions for water and wastewater services are used, including the division of construction and operating costs for the jointly used network among the service users. In rural areas with a dispersed population, individual solutions are generally used that are not connected to each other and, hence, each household bears the costs individually. Approximately 15.7 million urban inhabitants (about 9.2 per cent of the urban population) and 9.4 million rural inhabitants (about 29.8 per cent of the rural population) were served by individual solutions in 2014.

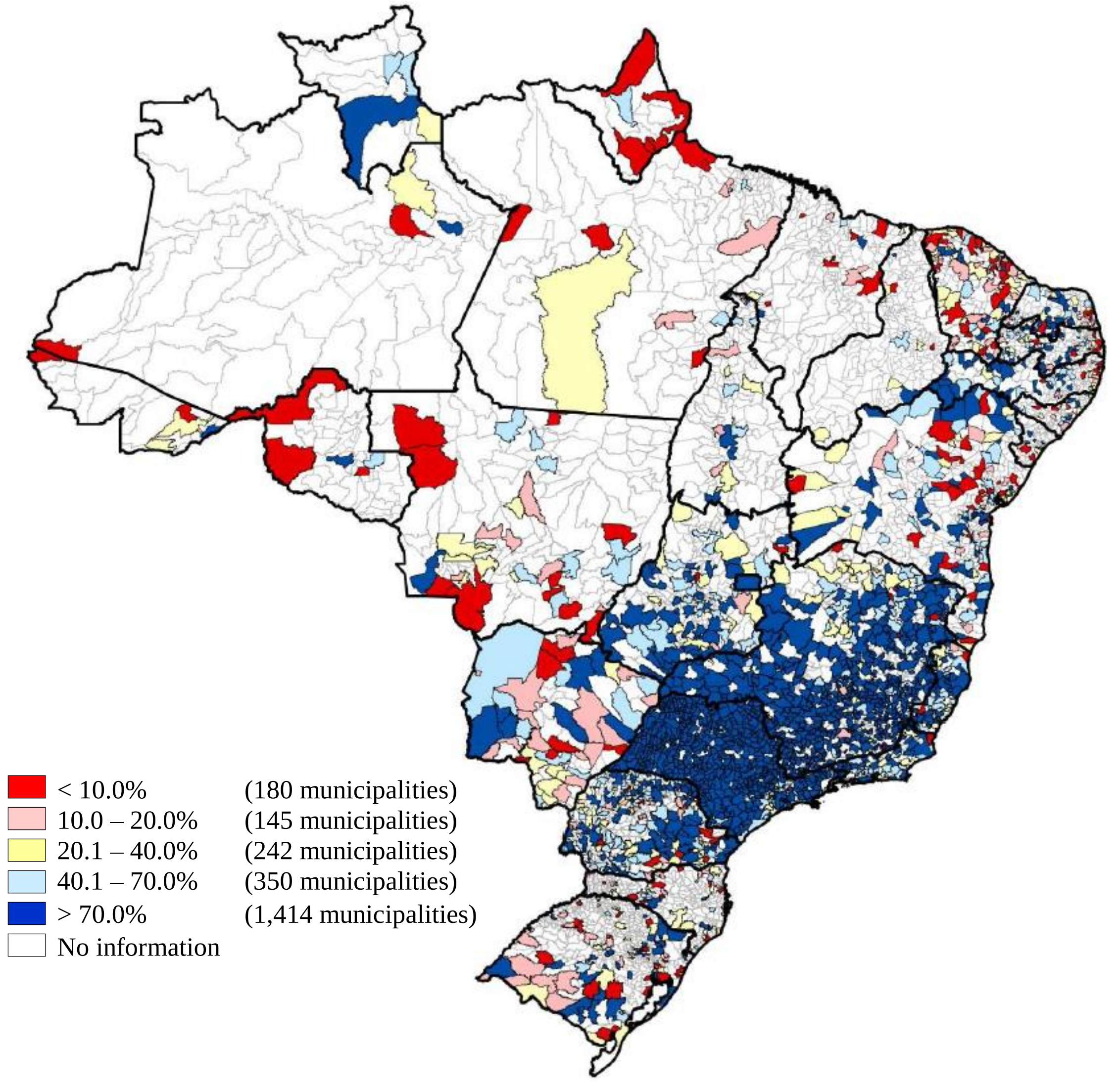
Individual solutions for wastewater disposal include septic tanks, rudimentary pits, open sewers, the launching of wastewater into watercourses and rainwater galleries, but only septic tanks are considered adequate in PLANSAB, including adequate planning and construction as well as the post-treatment of septage or final disposal unit (SNIS, 2014).[19] Sixty-seven per cent of 1,578 municipalities with individual solutions reported septic tanks as principal alternatives, serving approximately 10.7 million inhabitants, mostly in the north-east, south and north regions (SNIS, 2014, pp. 84-85). What is remarkable is that 81 municipalities with a total population greater than 50,000 inhabitants – including 18 municipalities larger than 100,000 inhabitants – do not utilise a collective system for wastewater collection (SNIS, 2014, p. 86).

Biological filters and activated sludge are the most advanced technologies used in Brazil, aerobic and anaerobic lagoons are popular and upflow anaerobic sludge blanket (UASB) reactors are well-presented. Wastewater treatment is mainly based on biological degradation because of "the availability of large areas for the development of ponds and long periods of sunlight throughout the year" (GWI, 2015, p. 45). Activated sludge treatment is more expensive than other anaerobic treatments, such as UASB and anaerobic ponds, and it is more common in São Paulo, the Federal District and Minas Gerais. WWTPs with anaerobic technology are easy to build (less equipment is needed, as no aeration devices are required) and simple to operate and maintain (no aeration regulation is needed and there is minimal energy consumption), but they require concentrated wastewater to be kept at temperatures of at least 25°C to work efficiently and only treat carbon, not nitrogen or phosphorus (GWI, 2015).

18 Despite these positive trends, it is important to keep in mind that the presence of sewer networks does not tell anything about the quality of the network or wastewater treatment about the level of wastewater treatment, respectively.

19 In any case, individual solutions should only be used if the soil disposes of adequate conditions for infiltration and if the groundwater table is deep enough to avoid contamination with disease-causing microorganisms (SNIS, 2014).

Figure 2: Urban wastewater collection (in % per municipality)



Source: SNIS (2014, p. 31)

2.5 Tariff structure for water and wastewater

The National Sanitation Law No. 11,445/2007 establishes directives for the design of the tariff structure, including subsidies. Water and wastewater services are charged using block tariffs, which depend on the volume of consumption according to usage in residential, commercial, industrial and public sectors; each provider applies its own tariff policy with different tariffs and block limits (see Table 2 for the case study cities and states).

Table 2: Overview of water and wastewater tariffs for case study cities and states

	Brasília	**São Paulo**	**Rio de Janeiro**	**Belo Horizonte**	**Recife**	**Salvador**
State	Distrito Federal (DF)	São Paulo (SP)	Rio de Janeiro (RJ)	Minas Gerais (MG)	Pernambuco (PE)	Bahia (BA)
State company for water supply and sanitation	CAESB	SABESP	CEDAE	COPASA	COMPESA	EMBASA
Average water and wastewater tariff	R$ 3.95/m³	R$ 2.26/m³	R$ 3.64/m³	R$ 2.49/m³	R$ 2.86/m³	R$ 2.91/m³
Average expenses water and wastewater	R$ 4.21/m³	R$ 2.18/m³	R$ 2.77/m³	R$ 2.35/m³	R$ 2.78/m³	R$ 2.86/m³
Minimum tariff for households	R$ 16.6	R$ 17.9	R$ 34.5	R$ 13.9	R$ 30.0	R$ 9.4
Maximum volume	10 m³/month	10 m³/month	10 m³/month	6 m³/month	10 m³/month	10 m³/month
% of households	56.3%	53.1%	37.8%	29.0%	43.3%	74.5%
Social tariff for households	n/a	R$ 10.8 /month	R$ 10.7 /month	R$ 17.5 /month	R$ 6.4 /month	R$ 17.4 /month
% of households	n/a	3.6%	4.2%	18.2%	9.1%	9.9%

Source: SNIS (2014); data refer to the state company for water supply and sanitation (CESB) and the respective city

Most service providers charge a so-called minimum tariff, which is charged regardless of the water quantity consumed. The purpose of the minimum tariff is to guarantee the economic-financial viability of the service provider to sustain the service, operation and maintenance of the water and wastewater system (SNIS, 2014, p. 73; similarly Leite, 2015). Minimum tariffs vary from R$ 3.6/m³ to R$ 53.2/m³, with an average of R$ 22.5/m³; most providers set the limit at 10 m³/month for the maximum volume at the minimum tariff (SNIS, 2014). Consumption above the minimum tariff is usually subject to a progressive tariff structure.[20] Discussions about replacing the minimum tariff with separate fees for connection and consumption have started (e.g. in São Paulo, see Leite, 2015).

Most service providers also offer a subsidised so-called social tariffs, which were introduced at the beginning of the 1970s as part of PLANASA.[21] The objective is to “guarantee equity and universal access to sanitation services”, also for customers with little or no financial means (SNIS, 2014, p. 77). Social tariffs vary from R$ 0.8/m³ to R$ 32.3/m³, with an average of R$ 22.5/m³ (SNIS, 2014). The wastewater tariff is calculated based on the water tariff and amounts to either 100 per cent or 80 per cent of the water tariff. The average water and wastewater tariff was R$ 2.75/m³, and the average expenses of water and wastewater suppliers were R$ 2.68/m³ in 2014. Compared to the previous year, the increases largely reflect the inflation rate of approximately 6.4 per cent, as measured by the Extended National Consumer Price Index (IPCA).

20 Example: the first tranche is compulsory, for example up to 10 m³ the fixed price is R$ 16.6 (corresponding to R$ 1.66/m³); tranche 2 from 11 to 20 m³: R$ 2.00/m³; tranche 3 from 21 to 30 m³: R$ 2.50/m³; tranche 4 from 31 to 40 m³: R$ 3.20/m³ and tranche 5 above 40 m³: R$ 3.90/m³.

21 Only a handful of companies, including CAESB (Federal District), offer a minimum tariff, but no social tariff.

The Environmental Sanitation Company of the Federal District (CAESB) in Brasília charges the highest average water and wastewater tariff in the sample with R$ 3.95/m³. Its average expenses for water and wastewater are greater than the average water and wastewater tariff, reflected in the 0.3 per cent surplus in 2014. It is the only company in the sample that does not offer a social tariff for households. SABESP in São Paulo charges the lowest average water and wastewater tariff (R$ 2.26/m³) of the six cities included in the sample. The State Company for Water and Wastewater of Rio de Janeiro (CEDAE) charges the highest minimum tariff for households in the sample, with R$ 34.5 for 10 m³ per month. The Sanitation Company of Minas Gerais (COPASA), in Belo Horizonte, offers the highest social tariff (R$ 17.5 per month) and to most households (18.2 per cent) in the sample. The Sanitation Company of the State of Pernambuco (COMPESA), in Recife state, offers the lowest social tariff for households: R$ 6.4 per month to 9.1 per cent of households. The Water and Sanitation Company of the State of Bahia (EMBASA) charges three quarters of households in Salvador the minimum tariff of R$ 9.4 for 10 m³ per month.

3 Case study cities

Brasília, the capital city and federal district of Brazil, is an enclave in the south-west of Goiás state, part of the region Central west. It is situated in the highlands of central Brazil at an elevation of around 1,100 metres. It belongs to the outer tropics, with mean annual precipitation of 1,300-1,700 mm, with four times higher precipitation during the rainy season than during the dry season from late March to late September. The Federal District has the largest gross domestic product (GDP) per capita income of Brazil and is the political centre of the country. Most of Brasília’s approximately 3 million inhabitants live in its suburbs. Brasília became a UNESCO World Heritage site in 1987 for urban planning and architecture.[22]

The state company for water supply and sanitation, CAESB, serves Brasília (see Table 2). The capital is relatively well served with sanitation and is the shining example in Brazil. Nevertheless, about 635,000 inhabitants are not served by the urban sewerage system. Brasília’s sewerage network connects 785,362 million households. The sewage generated per year is estimated to be around 156 million m³, of which around 82 per cent is collected and treated, using the volume of sewage charged by CAESB as reference point (SNIS, 2014).[23] It has the lowest water loss in distribution: 27.1 per cent. Its investments in sanitation represent 1.36 per cent of total investments by all state companies.

São Paulo, capital of São Paulo state, is Brazil’s commercial, financial and industrial centre in the south-east region. The climate is mild and there is significant rainfall throughout the year, with an annual mean precipitation of 1,340 mm. São Paulo is an ultramodern metropolis and the largest city in Brazil and South America, with approximately 12 million inhabitants and a metropolitan area population that exceeds 18 million. The city is located in the basin of the Tietê River on a plateau of the Brazilian Highlands extending inland from the Serra do Mar, which rises as part of the Great

22 Encyclopaedia Britannica (2016); Lorz et al. (2014).

23 The reference point is the volume of sewage charged by the respective state company, bearing in mind that only a part of total sewage is billed.

Escarpment only a short distance inland from the Atlantic Ocean. Its rapid economic development and population growth since the 1960s have been accompanied by serious air and water pollution and overcrowding.[24]

The metropolitan region of São Paulo, with 39 municipalities, suffers from intense water stress (Marussia Whately, Lilia Toledo Diniz 2009), which presents the key challenge: low water quality due to polluted sources adds to very low amounts of natural water availability – seven times lower per inhabitant than what the United Nations considers to be critical. Although literally every drop counts, the state company for water supply and sanitation, SABESP, loses approximately a third of its water in distribution (see Table 2). SABESP supplies water and sanitation services to São Paulo city and to most of the other municipalities in São Paulo state (see also Section 4.4). The sewerage network of the city of São Paulo attends to approximately 3.9 million households. The sewage generated per year is estimated to be around 752.8 million m³, of which around 70 per cent is collected and around 51 per cent is treated, using the volume of sewage charged by SABESP as reference point (SNIS, 2014). SABESP accounted for one-third of all investments in sanitation in Brazil in 2014.[25]

Rio de Janeiro is the capital of Rio de Janeiro state, south-east Brazil, and located on Guanabara Bay of the Atlantic Ocean. A tropical monsoon climate, with an average annual temperature of 23.2°C, is characteristic for Rio de Janeiro. The mean annual precipitation is about 1,280 mm. It is the second largest city and former capital of Brazil, with approximately 6.5 million inhabitants, and is the cultural centre of the country and a financial, commercial, communications and transport hub. It is surrounded by low mountain ranges whose spurs extend almost to the waterside, thus dividing the city. The city acquired its modern outline in the early 1900s, and extensive public sanitation and remodelling are continuing. The high levels of environmental pollution of Guanabara Bay and the widespread problem of untreated wastewater are the key challenges and were widely discussed in the prelude to the 2016 Summer Olympic Games. There are approximately more than 1.1 million inhabitants who are not connected to the urban sewerage system.[26]

The water supply and sanitation of the capital, Rio de Janeiro, and many other municipalities in Rio de Janeiro state are provided by CEDAE. The sewerage network of the city connects approximately 1.6 million households. The sewage collected per year is estimated to be around 469 million m³, of which around 71 per cent is treated; remarkably,

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24 Climate Data (2016); Encyclopaedia Britannica (2016).

25 São Paulo faces a huge mismatch between capacity installed to treat wastewater and wastewater generated (Interview 16). Assuming that 80 per cent of the water consumed becomes wastewater, São Paulo generates approximately 64 m³/s and has five WWTPs with a total capacity installed to treat approximately 16 m³/s at the secondary level (25 per cent). The remainder of 48 m³/s is dumped into the Tietê, Pinheiros and Tamanduateí rivers. If SABESP realised the plan to divert another 18 m³/s from a neighbouring water basin, approximately another 14 m³/s (80 per cent) would be produced, adding to the huge amount of untreated wastewater. Usually, the water loss in distribution is deducted from the wastewater generated. In the short run, this seems convincing because the wastewater generated can, in fact, maximally equal the water in the system. However, in the long run, the deduction downplays the negative externalities and the lack of wastewater infrastructure needed.

26 Climate Data (2016); Encyclopaedia Britannica (2016).

CEDAE charges a lower volume of sewage (413 million m³) than it collects (SNIS, 2014).[27] Rio de Janeiro state is the outlier regarding water consumption per capita, with 251 litres per day. At 30.6 per cent, the water loss in distribution is below the national average.

Table 3: Overview of key indicators for case study cities and states

	Brasília	**São Paulo**	**Rio de Janeiro**	**Belo Horizonte**	**Recife**	**Salvador**
State	Distrito Federal (DF)	São Paulo (SP)	Rio de Janeiro (RJ)	Minas Gerais (MG)	Pernambuco (PE)	Bahia (BA)
Region	central west	south-east	south-east	south-east	north-east	north-east
Estimated population (2016)[1]	2,977,216	12,038,175	6,498,837	2,513,451	1,625,583	2,938,092
Population (2010)[1]	2,570,160	11,253,503	6,320,446	2,375,151	1,537,704	2,675,656
Territory (km²)[1]	5,780	1,521	1,200	331	218	693
Population density (inhabitants/km²) (2010)[1]	445	7,398	5,266	7,167	7,040	3,859
GDP per capita[1]	R$ 62,859	R$ 48,275	R$ 43,941	R$ 32,844	R$ 29,037	R$ 18,264
Gini coefficient[2]	0.637	0.645	0.639	0.611	0.689	0.645
State company for water supply and sanitation[3]	CAESB	SABESP	CEDAE	COPASA	COMPESA	EMBASA
Structure of CESB[3]	Mixed economy	Mixed economy	Mixed economy	Public	Mixed economy	Mixed economy
Urban population connected to sewerage system[4a]	2,342,083	11,435,290	5,363,621	2,491,109	622,248	2,278,608
Urban households connected to sewerage system[4a]	785,362	3,856,472	1,619,421	842,441	191,461	787,877
Water con-sumption per capita (liter/person/day)[4b]	181	179	251	154	106	114
Water loss in distribution[4b]	27.1%	31.4%	30.6%	33.6%	51.9%	40.4%
Average water and wastewater tariff[4b]	R$ 3.95/m³	R$ 2.26/m³	R$ 3.64/m³	R$ 2.49/m³	R$ 2.86/m³	R$ 2.91/m³
Investments in sanitation % of total[4b]	R$ 165 million 1.36%	R$ 4,077 million 33.4%	R$ 1,026 million 8.4%	R$ 1,286 million 10.5%	R$ 707 million 5.8%	R$ 588 million 4.8%

Sources: 1: IBGE (2016); 2: Ministério da Saúde (2010); 3: GWI (2015); 4a: SNIS (2014); data refer to city. Figures do not indicate volume or quality of treated wastewater. Source 4b: SNIS (2014); data refer to the state company for water supply and sanitation (CESB).

27 Accessed 11 September 2016 – latest data available is for 2014.

Belo Horizonte, with 2.5 million inhabitants, is the capital of Minas Gerais state in the south-east and is Brazil's second most populous state. The climate is humid subtropical with an average annual temperature of 20.5°C. The mean annual precipitation is about 1,430 mm, with very little precipitation in August and a peak in December, with an average of 310 mm. It was the first of Brazil's planned cities, built on several hills, and is completely surrounded by mountains. As the distribution and processing centre of a rich agricultural and mining region, Belo Horizonte is the nucleus of a burgeoning industrial complex; its chief industries are furniture, textiles, food processing and publishing. Belo Horizonte is also a transport hub, with direct highway connections with Brasília, São Paulo and Rio de Janeiro.[28]

COPASA's sewerage network attends to 842,441 households in the city of Belo Horizonte. The sewage generated per year is estimated to be around 155.9 million m³, of which around 76 per cent is collected and around 68 per cent is treated, using the volume of sewage charged by COPASA as reference point (SNIS, 2014). Belo Horizonte presents an good average case with regards to the challenges in the wastewater sector.

Recife, with 1.6 million inhabitants, is the capital of Pernambuco state in north-east Brazil and has a tropical climate. The annual mean precipitation is about 1,800 mm, with a peak in June with an average of 290 mm. It is an Atlantic seaport located at the confluence of the Capibaribe and Beberibe rivers. Recife is the chief urban centre of north-east Brazil and lies partly on the mainland and partly on an island. It exports great quantities of the hinterland's products, including sugar, cotton and coffee. The majority of the labour force is employed in the service sector; tourism expanded greatly in the late 1990s. The city is a transport centre, with an international airport and good railroad and highway facilities.[29] It is the most unequal city in the sample, with a Gini coefficient of around 0.69.

Recife is supplied with water and sanitation services by the state company COMPESA. At the state level, Pernambuco is among the states with the lowest percentage of urban population (20-40 per cent) connected to the sewerage system. Also in Recife, only 38 per cent of the urban population is connected to the sewerage system; Recife's sewerage network connects 191,461 households. This low coverage rate presents the key challenge.

The sewage generated per year is estimated to be around 43.5 million m³, of which around 89 per cent is collected and treated, using the volume of sewage charged by COMPESA as reference point (SNIS, 2014). Although the water loss in distribution is the worst (more than 50 per cent), the city has the lowest water consumption per capita among the six cities: 106 litres/day.

Salvador, the capital of Bahia state, is a major port in the north-east. The city has a tropical climate with an average annual temperature of 25.2°C. The rainfall in Salvador is significant, with precipitation even during the driest months; mean annual precipitation is 1,780 mm. Salvador was founded in 1549 as the first capital of Brazil and is today the third most populous city, with 2.9 million inhabitants. Salvador is situated at the southern tip of a picturesque, bluff-formed peninsula that separates All Saints Bay, a deep natural harbour, from the Atlantic Ocean. It is the commercial centre of a fertile crescent (the

28 Climate Data (2016); Encyclopaedia Britannica (2016).

29 Climate Data (2016); Encyclopaedia Britannica (2016).

Recôncavo) and a shipping point for the cacao district to the south. Other exports include tobacco, sugar, hardwoods, industrial diamonds, oil and aluminium.[30] Salvador has the lowest GDP per capita in the sample.

EMBASA offers water and sanitation to Salvador and many other municipalities in Bahia state. About 660,000 inhabitants in Salvador are not connected to the urban sewerage system, which presents a key challenge. Salvador's sewerage network attends to 787,877 households. The sewage generated per year is estimated to be around 135 million m^3, of which more than 99 per cent is collected and treated, using the volume of sewage charged by EMBASA as reference point (SNIS, 2014).

4 Wastewater collection and treatment: discussion of identified challenges and opportunities

4.1 Financial factors

Available financial resources and access to finance are crucial for expanding and maintaining the wastewater network. Both are controversially discussed for wastewater in Brazil, and the opinions of specialists strongly diverge. Although the boost in financial means through the PACs is largely acknowledged – whereas the difficulty of small municipalities to access these funds is emphasised – the lack of financial means and the need for them are mentioned again and again. There is broad consensus that the expansion of the wastewater infrastructure only through the (water and) wastewater tariff will be impossible, usually accompanied by the remark that the national government invested heavily in those countries with universal access.

Whereas access to finance is not regarded as a substantial problem in the major cities,[31] smaller municipalities have faced difficulties in gaining access to the available federal funds. The greatest obstacle has been the low or non-existing technical capacities in smaller, often rural and remote municipalities to present valid project proposals for PAC funding (e.g. Interview 18). This concern was already voiced some years ago by SABESP's former president Dilma Pena, who thought that numerous municipalities risked not obtaining lending due to a lack of experience in designing project proposals (Pena, 2013). Similarly, not all municipalities have elaborated a sanitation plan (see Section 2.1) due to missing technical capacity.

Nevertheless, the budgetary means for the sanitation sector are perceived as being insufficient to meet the needs in the face of other necessities such as transport, education, health, etc. (Interview 47). The large sunk costs due to large-scale and long-term investments in sanitation infrastructure present a significant obstacle to universal wastewater collection and treatment (e.g. Interviews 32 and 42). As a rule of thumb, a WWTP usually accounts for one-third of the costs, whereas the sewage system represents two-thirds of the costs. Hence, it is little surprising that the wastewater collection in the community is the most expensive part – in other words, getting the infrastructure in place

30 Climate Data (2016); Encyclopaedia Britannica (2016).

31 Maybe with the exception of Interview 45.

and connecting all households that still dispose of their sewage in rivers to the system (Interview 42).

However, the need for budgetary means varies between companies. SABESP in São Paulo, for instance, mainly uses own resources or those from the capital market for investments (Interview 30). To the contrary, SABESP contributes significantly to federal resources through federal taxes such as Social Integration Programs and Public Servant Fund (PIS/PASEP) and the Contribution for Social Security Financing (COFINS). This tax burden is strongly opposed by water and wastewater companies, mainly because those taxes are not reversed into direct infrastructure investments (Pena, 2013). Similarly, it is criticised that those tax payments (e.g. R$ 680 million annually for PIS and COFINS in the case of SABESP) could be used instead by the company either for investing in water and wastewater infrastructure or for lowering the tariff (Albuquerque, 2014).

Whereas high economic costs characterise wastewater infrastructure investments in general (Seroa da Motta & Moreira, 2006, p. 185), many public companies have difficulties obtaining financing due to their bad management, and therefore depend on public resources in the form of federal grants (e.g. Interviews 17 and 26).[32] It was repeatedly emphasised that most public companies need to improve their poor management, visible, inter alia, in the high percentage of physical water loss (see Section 2.3).

With estimated investments of about R$ 60-70 billion, concessions to, for instance, PPPs are considered necessary in order to raise funds (Interview 47). In fact, given that federal funds have been disbursed rather slowly, state utilities have increasingly sought private financing for wastewater collection and treatment through concessions (GWI, 2015).

The tariff structure of water and wastewater services (see Section 2.5) was raised repeatedly as being a significant barrier to generating sufficient revenues for the utility to expand the wastewater infrastructure network (e.g. Interview 30). The main critique was that the current tariff structure allows the wastewater tariff to be, at most, as high as the water tariff, although the sewage network is twice as costly as the water network; hence, the payback period for sewage investments is twice as long as for water investments. “It exists a restrain to charge a wastewater tariff that is higher than the water tariff” (Interview 37). Yet, many public companies struggle to provide services efficiently and would probably not be able to generate sufficient revenues for investments, even with a (more) adequate tariff structure (Interview 26). The expansion of the sanitation infrastructure financed by water and wastewater tariffs was also criticised because most interviewees argued that the national governments financed the infrastructure with additional funds in those countries where sanitation services are universalised today (e.g. Interview 32). Similarly, it was repeatedly mentioned that it also took developed countries years and enormous efforts to provide universal wastewater services to their populations (e.g. Interviews 21 and 32).[33]

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32 OECD (2015a, p. 81) found that “mobilising equity through capital markets can strengthen financial discipline and improve transparency”, even for companies that are primarily government-owned, such as a number of publicly listed state water companies in Brazil.

33 In many European countries, the rapid industrialisation and urbanisation during the second half of the 19th century boosted the wastewater production – including the spread of the waterborne diseases typhoid and cholera – and made the construction of sewer systems necessary. This was followed by

Financing wastewater infrastructure is, in addition, being challenged by separate sewerage networks – the strict separation of sewage and rainwater into two networks (e.g. Interviews 38 and 42). The use of dry weather diversions/low-flow diversions to collect wastewater was repeatedly suggested (e.g. Interview 38); they divert storm drain flows to the sewerage network during dry weather periods when these flows are low, representing a compromise between separate and combined sewerage. Yet, they are also strongly questioned as to whether they are viable alternative solutions because they may become "the permanent solution" (e.g. Interview 42), meaning, hence, the cessation of the separate sewerage system (e.g. Interview 38).

4.2 Institutional factors

Two main challenges characterise the institutional framework of the sanitation sector: vertical and horizontal institutional fragmentation, and very strict norms and standards. Both increase transaction costs considerably.

The institutional fragmentation generates high coordination costs across the different entities (see also Section 2.1). The three administrative levels of federal, state and municipal government are involved: the federal government defines the national policies and disburses budgetary means; the state is often involved through state utilities; and the municipality has the mandate to provide water and wastewater services (Interview 2). The municipality, as the rights-holder, also determines who is going to regulate and whether a regulatory agency is established (Interview 38). Among the main obstacles to vertical integration – in other words, the coordination of water policy-making, including wastewater between levels of government and among local actors – are impact of sectoral fragmentation, insufficient evaluation of sub-national practices and the insufficient evaluation of central government enforcement (OECD, 2012).

Coordination costs are also high horizontally because, at each level, several actors are involved in water resources and water services, including wastewater. At the federal level, for instance, the Ministry of Cities is responsible for water and sanitation in municipalities with more than 50,000 inhabitants, and FUNASA is responsible in the remaining municipalities. Also at the state level, each state has several agencies for environment and water resources (Interview 45). In São Paulo state, for example (Interview 31), ANA, as the federal agency, is responsible for water regulation, monitoring of water quality and water use of federal rivers. The Regulatory Agency Energy and Water Supply and Sanitation of São Paulo State (ARSESP) regulates the public service at the state level and checks whether an operator provides its services in accordance with the contract and respects the norms. The Water and Electric Energy Department of São Paulo (DAEE) takes care of the state water resources, including the public services of water and sanitation, and, hence, can be dubbed as "ANA at state level". The Brazilian National

wastewater treatment, as the discharge of large volumes of urban wastewater caused significant river pollution (Seeger, 1999).

It is certainly correct that the expansion of wastewater collection and treatment has been a development process that has spanned at least 100 years and influenced by economic and political events. For example, Cooper (2001) and Seeger (1999) recount the development in the United Kingdom and Germany, respectively. Notwithstanding the foregoing, this must not serve as an excuse for any utility to work as efficiently as possible and to advance sanitation services as soon – and as much – as possible.

Standards Organization (ABNT) defines the norms for the river classification; ANA or DAEE define the quality of effluent standards and regulate the granting.

With regards to environmental legislation, Brazil is "a developing country with first-world legislation" (Interview 37) orientated towards international standards and not necessarily adapted to local circumstances: "We have rivers like in Bangladesh, but our norms are like in Scandinavia" (Interview 16). For instance, industries need to meet standards prior to discharging into rivers and other surface waters, and authorisation is needed for both water capture and wastewater disposal. The purpose of the authorisation for wastewater disposal is to buy a certain volume of the river water to dilute the effluent to the necessary degree defined by the river classification (Interview 16). The problem is that often ambitious legislation adopts "norms from industrialized countries or the WHO without comparative analyses or adaptation to local conditions" (Hespanhol, 2014, p. 15). Such stringent norms do not allow for intermediate levels and, hence, result in norms that are too strict and standards for the Brazilian reality that are frequently not complied with. For instance, the regulatory agency the Environmental Company of the State of São Paulo (CETESB) sets the phosphor level at 0.01 milligrams per litre, which is very difficult to obtain (Interview 16). Although ambitious legislation may have a signalling effect and pull compliance upwards, it is questionable whether these stringent norms and standards can accomplish this purpose. Fixed and ambitious standards are "most useful where they can actually be met by treatment, and wastewater use is a planned and controlled activity" (Jiménez et al., 2010, p. 18).

Although seen as being too strict in many regards, the insufficient enforcement of the existing legislation is criticised when, for instance, an environmental crime is committed using sewage (Interview 17), which is related to understaffing in the environmental agencies (Interview 45). Although it is noted positively that environmental licences are necessary for collection and treatment, including pre-licences before installation and operation (Interview 28), it is important to keep in mind that, generally speaking, businesses in Brazil suffer from excessive bureaucracy and regulation, in particular when obtaining construction permits and paying taxes.[34]

Yet, selective law enforcement can lead to the inefficient use of financial resources rather than an optimal outcome for the environment (Interview 13). In the example, a judicial decision enforced complete coverage with the tertiary treatment level in a city with abundant water resources whose environmental impact was less than in a city with limited water resources.

Good intentions in environmental legislation can also cause problems (Interview 28). A municipal law in 1998 required all new property developments to have their own WWTPs in case the sewage system could not be connected to an existing WWTP. Still today, SANASA in Campinas, São Paulo state, is struggling to put the sewage system in place, in particular to install all the necessary interceptors (pipes that bring the sewage to the WWTP), especially in some areas of high risk, such as at the margins of creeks where

34 Doing Business presents quantitative indicators on, among others, business regulations across 190 economies, including 32 in Latin America and the Caribbean, which give a sense of the excess bureaucracy and regulation, in other words "red tape". Two areas where Brazil fares among the worst (rank 172) are "dealing with construction permits", which includes obtaining water and sewerage connections, and "paying taxes" (rank 181) (World Bank, 2017).

dwellings make it impossible or difficult to install interceptors. Eventually, SANASA intends to deactivate all other WWTPs once the entire sewage system is in place.

4.3 Politico-economic factors

The political importance of sanitation for politicians and voters translates into a greater precedence of the sector. Wastewater collection and treatment has not ranked among the high priorities of either politicians or voters and has received less attention from both sides. At least part of the remarkable deficit in wastewater infrastructure is owed to most mayors prioritising water supply for decades (Interview 48).[35] In addition to the greater interest in water infrastructure, investments in wastewater infrastructure compete with other public expenditures in health, education, public transport, etc. (Interview 18). Mayors and governors have long preferred public expenditures for water infrastructure as a means to secure votes and tend to see basic sanitation to be of little electoral relevance (e.g. Interviews 17 and 18). Although the approval rate of the current state government correlates with the water availability in São Paulo, the same does not hold for wastewater, for which there "was never a strong social demand" (Interview 22). Supplying the population with clean and safe water is a significant contribution to local development, but it also offers an opportunity for positive news coverage because the politician can, for example, pose next to the well (e.g. Interview 8). Wastewater infrastructure, on the other hand, is much less tangible because it is hidden underground for the most part, whereas the visible parts, such as wastewater treatment facilities, are unattractive for political publicity (e.g. Interviews 33 and 48). In addition, many mayors consider wastewater infrastructure to be "complex and difficult engineering works that disrupt the city" (Interview 18), in other words, an obstacle to their political success rather than a contributing factor. The common perception among politicians is that improving wastewater infrastructure has little political return (Interview 42) and is therefore unlikely to tilt the scales in elections.

The little political interest in wastewater is also reflected in the fact that most municipalities tend to delegate their mandates for basic sanitation – including the planning – to the public utility, though it is "a non-delegable activity" (Interview 18) due to its importance for the general public. In this context, it is important to remember that public utilities also have a stronger interest in the water supply than in wastewater collection and treatment (Interview 6). The economic rationale is that, on the one hand, wastewater investments are much more expensive and, hence, the payback period is much longer; on the other hand, the current tariff structure is not able to reflect these differences (see Section 4.1).

Whereas passing the mandate for the provision of water and wastewater services to a specialised company follows the principle of the division of labour, the municipality should indeed determine and oversee the long-term strategic planning, including the definition of objectives in the short, medium and long runs, as already happens in cases where a specialised regulatory agency is involved (e.g. ARSESP in São Paulo state, the

35 Even today, investments in wastewater infrastructure account for only a slightly greater share than in water infrastructure (46 per cent compared to 41 per cent of R$ 12.2 billion in 2014), although the deficit in wastewater infrastructure is much more pronounced (see Section 2.2).

Regulatory Agency Energy and Basic Sanitation of Rio de Janeiro State (AGENERSA), or the Regulatory Agency Water and Sanitation Services in Minas Gerais State (ARSAE).

Most voters do not point to sanitation as being an important topic and, hence, also pass the message to politicians that it is not important (Interview 18), although public support of – and pressure for – the right to sanitation is crucial. Even residents in irregular areas, where open drains with untreated wastewater and illegal connections to the water network cause, in particular, diarrheal diseases (Interview 1), do not necessarily claim their right to basic sanitation. On the other hand, whereas historically much more attention was paid to water infrastructure, even the less-educated population is increasingly aware of how basic sanitation contributes to the quality of living and reduces diseases (Interview 48). Yet, broadly speaking, the general public rather cares about water supply and sewage being taken "far away from home" (Interview 31, similarly Interview 42). As a consequence, the sewage is no longer important, including whether it is treated at all, once a household is connected to the drainage system and the sewage is somehow, albeit often inadequately, removed from the residence (e.g. Interview 37). "It is unclear whether people understand the importance of wastewater treatment per se. What matters to them is that the wastewater is removed from their residence" (Interview 48).[36] Hence, the general mentality of "flush and forget" prevails and indicates both a disinterest and unwillingness to engage with the topic of sewerage.

Disinterest and unwillingness is also reflected in the alleged low level of community spirit: people do not care about the community or about how their own behaviour affects the community (Interviews 9 and 33).[37] They distinguish between "mine", "not mine" and "what the state has to provide" rather than mine, yours and ours (Interview 8). Yet, on the other hand, the level of environmental education is still low (Interviews 1 and 44), hence, not everyone is conscientious about how inadequate waste and sewage disposal interacts with environmental and human health.

4.4 Socioeconomic factors

Socioeconomic inter- and intra-urban disparities reinforce other challenges in universalising sanitation services. It is technically challenging to provide wastewater services to informal settlements, yet not impossible. Creative and often unconventional solutions are much asked for. The low adherence rate by water and wastewater clients of all strata, not just poor households, troubles all public and private utilities. Yet, also this problem can be tackled, despite the confusing and inconsistent interpretations of the law by some. To sanction illegal wastewater connections to the drainage system, the regulatory agencies need to be better staffed. It is also time to rethink the separate sewerage system and to come to grips with the combined sewerage system.[38]

36 It is preferable, however, to invest scarce financial resources into collecting wastewater to distance it from the population, rather than in building a WWTP and not have any resources left for the sewerage system (Interview 1).

37 The term *imediatista* describes an individual who only considers the immediate but does not care about the long-term consequences of his actions.

38 Separate sewerage carries surface run-off (rainwater and storm water) and municipal wastewater separately, whereas combined sewerage combines both.

The unplanned urbanisation of the major cities in the last century and "the absence of the public authority" (Interview 18) during this period still pose significant challenges for the wastewater sector today. Sanitation companies state difficulties with land legalisation, technical challenges related to the topography and difficulties with user payments as being the three most important constraints to service provision in irregular areas (Trata Brasil, 2015b): about 90 per cent of inhabitants in irregular areas in São Paulo state would connect to water and wastewater services, if they were made available. Ninety-two per cent of total wastewater generated in these areas is estimated to be directly released into the environment. The majority would pay up to R$ 24 per month for service fees.

The common challenge is that solutions for collecting (and ultimately also treating) wastewater are often only searched for after housing is completed (e.g. Interview 42). In *favelas*, dwellings are often constructed without any land rights, which complicates matters considerably. How public utilities deal with service provision in these areas varies greatly: whereas SABESP in São Paulo city seems to hold the view that it is basically impossible to provide conventional wastewater services there, EMBASA in Salvador is searching for unconventional solutions.[39]

Article 45 of the National Sanitation Law 11,445/2007 defines that "all permanent urban buildings will be connected to available public water and wastewater networks and subject to payments of tariffs and other public fees resulting from the connection and use of these services" (author's translation). Despite the legal obligation to establish a connection to the public sewage network and to pay for the service, the law is weakly enforced – and it is often confronted with a lack of willingness to establish such a regular connection (e.g. Interview 37). Irregular wastewater connections are not confined to *favelas* and can also be found in noble neighbourhoods (Lobel, 2016). Nevertheless, the low adherence rate can have a cultural aspect to it: for instance, in Manaus, with the Black River (*Rio Negro*), one of the water-richest rivers worldwide, "the city looks to the river that seems to be an ocean and thinks to itself 'why should my wastewater be treated?'" (Interview 26).

Many households outside of *favelas* have a septic tank in their backyards. Although they are legally obliged to decommission the septic tank and connect their domestic sewage to the public sewerage network, once it is installed in the adjacent road, many owners refuse to do so, making the argument that they already have a septic tank and that the tariff is too expensive. Once the sewerage network is installed, the utility can technically start to charge the abutters for the service; hence, the water tariff is increased by 80 or 100 per cent (see Section 2.5). The utility can only inform the authorities of a missing or faulty connection, whereas the regulatory agency and the state Public Prosecutor's Office have the right to inspect and sanction. The weak enforcement, however, can imply that the culprit will not be charged for the offence. Remarkably, clients that are connected and pay for the service do not seemingly put any social pressure onto those that free-ride (if they benefit from an illegal connection), both from private and public companies (Interview 37).

The opposition to the increase in the tariff does not seem very convincing, given the relatively low prices for water and, hence, wastewater (see Section 2.5). Yet, many

39 The pronounced inequality in Brazilian society also becomes apparent in the wastewater sector: poorer populations may demand to use the same technology that is used in more affluent neighbourhoods – as a sign of equal treatment. Yet, the interceptors with large diameters can be inadequate for installation in the *favelas* due to the topography and limited space (Interview 50).

companies struggle with the subjective perception that the tariff is too expensive and confronted with a low – or lack of – willingness to pay for wastewater services: “Sewage implies costs but the society expects this service for free – and if they pay, they complain a lot” (Interview 47).

To increase the collection of wastewater and the connection rates, SABESP in São Paulo state started on 1 February 2016 to only establish new connections to the water network if the client was already connected to the wastewater network; this was applied to residential, commercial and industrial clients in the 366 cities operated by the company. The same rule applies to re-connections but will not be applied retrospectively at this time. Although the first residential connection to the wastewater network is free, possible costs for internal works have to be borne by the client, and it will cost R$ 248 for commercial and industrial buildings. About 240,000 clients (3 per cent) are not connected to the wastewater network, the majority of which are residential (88 per cent) (Sabesp fará ligação, 2016). The same strategy of conditioning new water connections to regular wastewater connections has been applied previously by sanitation companies in the states of Rondônia, Goiâs and Amazonas (Lobel, 2016).

In addition to irregular wastewater connections, the inadequate use of sanitation facilities leads to many items being found in the sewage that are improper for preliminary treatment in WWTPs and that should not be in the sewage (e.g. cotton swabs, rags, dental floss) (Interview 46). This emphasises the importance of education in general, and for hygiene and the environment in particular; although the problem is more serious for lower socioeconomic levels, it also exists at the higher socioeconomic levels. Inefficient waste collection leads furthermore to many items being disposed of into the sewage instead of put in solid waste disposal. Beyond the challenge for the preliminary treatment level, the solid residuals cause operational problems with scum and sludge management, including the later valuation of these products. A visible example is the Tietê River in São Paulo, which has become a landfill, apart from an open drain (Interview 1).

On a similar note, illegal connections of household drainage systems to the sewerage system overburden the sewerage network and lead to situations in which the installed capacities of the WWTPs are exceeded during the rainy season, which leads to improperly treated sewage (Interview 46).

Faced with the lack of a sewage system, households connect their sewerage systems to the drainage systems, despite the late 19th-century legislation for a separate sewerage system (Interview 21). This fact should be accepted and interceptors should be installed to treat the wastewater; furthermore, separate sewerage cannot be maintained in irregular neighbourhoods due to the limited space.

The backing of wastewater services is low: “You have the law but it does not revert to a practical attitude” because the client does not want to have sewage at their doorstep, but as soon as this is taken care of, the average user does not care too much (Interview 37). All this notwithstanding the significant negative environmental externalities caused by untreated wastewater that ultimately affect the citizens and seriously limit their leisure opportunities along rivers, reservoirs and lakes (e.g. Interview 16).

In line with other consumer rights, decree no. 5440 establishes definitions and procedures for quality control in the public water supply, such as the minimum information to be included in the monthly bill by the service provider, public or private (among other items, a monthly summary for basic parameters of water quality, and problems in the basin that could pose health risks). Although including such pertinent information increases transparency, not all clients are able to understand those parameters or interpret graphical information such as a map – hence, such solutions do not solve the problem (Interview 8).

4.5 Capacity: planning, technology and management

The capacities to reach the goals established by the National Sanitation Plan for each region and state "vary substantially across jurisdictions and municipalities in charge" (OECD, 2015b, p. 34). The (public) wastewater sector is faced with a gap between technical possibilities and practical implementation, including planning and management. On the one hand, there are no technical limits to treating wastewater in Brazil because any technology could be used to treat wastewater (Interview 45). On the other hand, the low level of – or lack of – maintenance for operational and personnel reasons threatens the sustainability of investments in the wastewater sector in the long-term – and increases the cost of universalisation (Interview 21). Good infrastructure for maintenance and operation, including trained personnel, and the adoption of simple processes for wastewater treatment are necessary to avoid problems due to a low capacity to operate or missing spare parts (Interview 45). This problem seems to be much more pronounced in small and remote municipalities, usually in the interior of the states (Interviews 18 and 45). The limited capacity for maintenance and replacement services provides a strong rationale to use simple technology. In fact, the climatic conditions with extended periods of high temperatures in large parts of the country allow for using natural and technologically simpler processes to treat domestic wastewater, such as stabilisation ponds or UASB reactors (Interview 45).

The serious consequences of insufficient maintenance became apparent in the programme "Água limpa" (clean water) in Rio de Janeiro (Interview 33), which financed wastewater treatment for municipalities with up to 50,000 inhabitants and installed sewage systems with simple treatment. However, after 5 to 10 years, the lagoons for wastewater treatment were clogged with sludge due to a lack of maintenance.[40] In another example, sludge infiltrated and damaged the whole system of the WWTP, and ultimately infiltrated the receiving body of water because skilled labour for quick maintenance and spare parts, or a reserve system, were lacking (Interview 46).

It seems that maintenance costs are not comprehensively considered in project planning: in the past in Campinas, for instance, SANASA's directorate decided to increase the number of WWTPs but only realised later that each WWTP implies maintenance and labour costs (Interview 28) – hence, the number of WWTPs was reduced.

Other planning mistakes include the public utility not knowing its market well enough and having difficulties anticipating the possible fallback options of its clients. In Suzano in São Paulo state, the treatment capacity of the WWTP has never been fully used, as

40 What is remarkable is that, although the lack of maintenance is seen as a problem, it is seen as the symptom of a city administration poor in resources, not as the consequence of a lack of training as part of the investment.

industries opted for own wastewater treatment to avoid high public service tariffs (Interview 23).[41] But it is also possible that the treatment capacity of a WWTP is underused because interceptors are missing – the link to connect the sewerage system with a WWTP (Interview 45). They are difficult to construct, as they usually run at the bottom of a valley and close to the watercourse.

Also, the process from planning to implementation is perceived as being very lengthy. Even the seven-year programme “REÁGUA”[42] is expected to only be able to accommodate those projects that are already developed and for which the financing and licensing have been secured, because new projects would go beyond the scope of the programme (Interview 30).

It was also noted that public utilities have little incentive to innovate, and that “the problem is always someone else’s problem” (Interview 13). Public utilities, for instance, do not use the data on wastewater collection and treatment – collected by the Ministry of Cities for many municipalities – to understand its processes better and to identify opportunities for improvement, but rather to report to the environmental authority and, hence, to fulfil regulatory requirements (Interview 46).

In addition, management skills need to be strengthened because few engineers are concerned about the broader implications of a specific technology and rarely wonder about questions of whether the technology will last and who will pay for its replacement (Interview 50).

Beyond planning, technical and managerial challenges, the debate about the separate sewerage versus the combined sewerage characterises the wastewater sector in Brazil. The Brazilian engineers’ guild, including sanitation engineers and other specialists, seems to fiercely defend the separate sewerage system and is reluctant “to think out of the box” (Interview 13). In the case of Santa Cruz do Capibaribe in Pernambuco, the existing drainage system serves also as a sewage system. The suggestion of intercepting it with dry weather flow-diversions as an option to treat the sewage at a low cost was only accepted after many long discussions. The sanitation engineers in the utility strongly clung to the separate-system solution, despite many disadvantages, such as six to seven years of construction work and high costs. Also, the residents would have to bear additional costs, given that they would have to change their old connections to the drainage system for new connections to the sewage system.

Accepting a mixed system that uses an existing drainage system also for the sewage can be operated at a low cost and, additionally, quickly reduce the negative immediate impact that untreated wastewater has on water resources (Interview 13). Yet, others are concerned that the mixed system is less efficient because – since part of the rainfall is diverted to the WWTP – it can overflow with rainfall and then spill sewage into the river (Interview 21). This seemed to be one of the main reasons for the strong opposition from the engineers.

41 The tariffs were high due to cross-subsidies between large and small consumers.

42 REÁGUA (Programa Estadual de Apoio à Recuperação de Águas) is a World Bank project (2010-2017) implemented by the São Paulo state, with a commitment amount of US$ 64.5 million and total project costs of approximately US$ 107.5 million, of which 65 per cent is destined for the sanitation sector.

5 The potential for wastewater reuse and its current constraints

Wastewater reuse offers a viable and feasible solution to help alleviate the negative externalities for the environment and human well-being caused by untreated wastewater. Furthermore, wastewater reuse gives wastewater treatment a financial value in addition to an environmental value ("double value proposition") because water, nutrients and energy can be reused (Drechsel, Qadir, & Wichelns, 2015, p. 4).

In urban areas, it is most attractive in areas with limited or scarce water availability, where existing wastewater infrastructure can be easily retrofitted with additional equipment. The reuse of treated wastewater allows for the resource-efficient use of water. In addition, if nutrients are not removed using tertiary treatment, reuse for agricultural purposes offers the benefit of recycling nutrients in the wastewater, which, in turn, reduces the amount of fertiliser needed (Jiménez & Asano, 2008b). Middle-income countries such as Brazil tend to use both treated and untreated wastewater, "indicating a transition between unplanned and uncontrolled reuse to planned and controlled reuse" (Jiménez et al., 2010, p. 7).

The costs of wastewater reuse and its economic viability are controversially discussed in Brazil, and expert opinions diverge strongly. Even experts do not necessarily mean the same thing when they talk about reuse in the urban context (e.g. direct and indirect, or potable and non-potable reuse[43]; strictly separate networks for non-potable and potable use; reuse within a utility to reduce the amount of fresh water needed; industrial reuse to close the water circle and engage in water recycling). Yet, some examples of treated wastewater reuse for municipal and industrial purposes can already be found in Brazil.

The most prominent and widely referred to example of selling treated water is the Aquapolo project in São Paulo. SABESP and the private company Foz do Brasil, a subsidiary of the Odebrecht Group, created Aquapolo Ambiental SA to treat municipal wastewater for industrial reuse in the so-called ABC region, with the aim to reduce water withdrawal. The wastewater treatment capacity amounts to 56,160 m³ per day, with the possibility of expansion to 86,400 m³ per day (Aquapolo, 2016).

The EPAR Capivari II in Campinas, São Paulo state, is the first plant of this size in Latin America to treat wastewater for reuse, treating domestic effluents with modern technology such as bioreactors and ultrafiltration membranes (SANASA, 2016). The municipal law 11,965/04 and the decree 18,251/14 prohibit the use of drinking water for street washing, private car washing and garden irrigation.[44] The plant currently can treat the effluents of approximately 90,000 inhabitants; once the second phase of implementation is finished, it will have the capacity to serve more than 350,000 inhabitants. The water produced by the EPAR Capivari II is used for urban and industrial purposes, thereby reducing water

43 *Direct reuse*: Reuse of treated or untreated wastewater by directly transferring it from the site where it is produced to the conveyance facilities for its use. *Indirect reuse*: Reuse of treated or untreated wastewater after it has been discharged into a natural surface water or groundwater body, from which further water is taken. *Potable reuse*: Reuse of treated wastewater that has been conveyed directly from a water reclamation plant to the water supply network. *Non-potable reuse*: Reuse of treated wastewater for non-human consumption (e.g. streetwashing). For a complete overview, please refer to Jiménez and Asano (2008a, p. 4).

44 Similar laws exist in other municipalities in Brazil.

withdrawal from the Atibaia and Capivari rivers. Furthermore, the surplus is released into the Capivari River, with the direct impact of recovering its water quality (SANASA, 2016).

In an attempt to provide much needed solutions to the water crisis, the governor of São Paulo state, Geraldo Alckmin, proposed in November 2014 two plants for wastewater treatment for reuse. The intended purpose was to increase the water availability in the Guarapiranga system by 14 per cent and in the Baixo Cotia system by 100 per cent (Veja prazos e custos, 2014). In July 2015, however, SABESP decided to prioritise the construction work to interlink basins – a decision that was heavily criticised.[45] Scientists see the interlinkages as being a short-term solution for the ongoing water crisis, while the wastewater reuse, directly or indirectly, would take care of the wastewater and the water supply for the population.

Another example of wastewater reuse is the company Prolagos in Rio de Janeiro state. It was the first sanitation company to use membranes to treat effluents. The treatment station is located in the city of Armação dos Búzios and has a capacity to produce more than 2 million litres of reused water per month. Approximately 40,000 litres per day are used to irrigate the golf course in Armação dos Búzios, whose lawns requires water of high quality (Prolagos, 2016).

A typical example of indirect reuse on a grand scale will be the artificial Lake Paranoá in Brasília. Four tributaries make up approximately 63 per cent of the inflows into the lake, while the remaining 37 per cent consists of direct precipitation, groundwater, urban drainage and effluents of the two WWTPs north and south, which are equipped with tertiary treatment for phosphorus removal (Abbt-Braun et al., 2014, p. 74). The public utility CAESB is planning to install a water treatment plant in the central part of the lake to supply several neighbourhoods nearby (Interviews 7 and 14).

Despite some examples, wastewater reuse still faces substantial challenges. The greatest institutional barrier is the absence of national legislation for reuse, in particular municipal and industrial as opposed to agricultural reuse, which was mentioned repeatedly in interviews (e.g. Interviews 17 and 37). The existing legislation only addresses where non-potable water can be used (Veja prazos e custos, 2014). Companies refer to international standards or follow guidelines developed by private institutions (GWI, 2015, p. 47). Although this helps in reusing large volumes of water in the industry, it cannot reduce the uncertainties of potential investors that “there is no market” for wastewater reuse (Interview 16). Establishing national legislation for wastewater reuse would help clarify open questions and incentivise the greater reuse of treated wastewater.

The costs and viability of wastewater reuse are controversially debated, and arguments cover a broad range of opinions. Wastewater reuse still seems to be very expensive, and therefore unviable, for some interviewees (e.g. Interview 2). Although membranes can already be used for water treatment in a cost-efficient manner, they are still too expensive for wastewater treatment and, hence, a greater demand for non-potable reuse for irrigation

45 Earlier proposals for water transfer from distant sources in the metropolitan region of São Paulo have been criticised for not considering the additional volumes of wastewater to be produced, nor the energy needed for pumping large volumes of water over great distances (Hespanhol, 2008).

or street washing is necessary (Interview 17).[46] Indirect wastewater reuse "is of great interest" but too expensive, compared to other sources of water supply, whereas direct wastewater reuse is practiced in few places around the world (Interview 21).[47] One major issue with calculating the costs for treated wastewater is determining which costs are attributed to wastewater reuse. It is often unclear whether the regular costs for wastewater collection and treatment are added to the costs for processing treated wastewater for reuse and then referred to as *the* costs of wastewater reuse, which would obviously overstate them (Interview 16).

In particular in areas with water scarcity, industrial reuse contributes towards reducing water stress. Separating water according to its drinkable and non-drinkable purposes contributes to water savings; regulatory and financial incentives will induce the industry to close the water cycle and to use drinking water only when necessary as well as incentivise WWTPs to produce reusable water for non-drinkable purposes (Interview 21). As industries can often obtain water from rivers, lakes and other natural sources at low cost and with few restrictions, this supply is cheaper than reuse, which requires investments. In Rio de Janeiro state, for instance, many industries use groundwater, for which they only have to bear the energy costs of pumping the water, which is therefore cheaper than treated water. In the future, however, the state should demand that industries reuse water and leave fresh water to the population (Interview 39). The general feeling is that companies need incentives to be stimulated to reuse treated wastewater, including bearing the (real) costs associated with using the resource water (Interview 26).

When relying on water from the water network, however, many industries have an incentive to reuse and close the water cycle where possible due to the high water tariffs for industrial use. In São Paulo state, for instance, the intake from surface water sources by the industry declined 15 per cent from 1990 to 2000, presumably because of the high cost of water (Hespanhol, 2008). Similarly, industries are incentivised to consider treated wastewater as a resource for internal reuse, given the strict environmental regulations for industrial effluents (Interview 16). As stable and reliable access to water is crucial for many industrial activities, reducing or cancelling the right of an industrial company to extract water from a river (e.g. granted by ANA) in favour of reused wastewater supplied by a company is argued to present additional contractual risks (Interview 16). However, this is only true under the assumptions that the water right granted by a public authority will not be revoked, the volume of the river will not be substantially reduced and limit future extractions, and that the stream water is of sufficient quality. To the contrary, the water quality may be a case in point for a contractual arrangement with a supplier of treated wastewater that not only guarantees the volume but also the quality.

The current levels of wastewater reuse are very low. For instance, less than 1 per cent of the current water supply provided by SABESP in São Paulo comes from reused wastewater (Interviews 22 and 23). The demand for treated wastewater outside the industry is being questioned (Interview 13), yet opinions differ, given the use of treated wastewater for street washing, car cleaning and municipal irrigation. In practical terms,

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46 Other potential applications include toilet flushing in public facilities; or road making, dust control, and washing of municipal trains and buses in municipal services (Anderson, 2008).

47 The most expensive works for water supply are stated as R$ 2.30/m^3, whereas for reuse more than R$ 5.00/m^3 is claimed.

the location of WWTPs – constructed in residential areas in the past when the agricultural or industrial sector did not have any use for treated wastewater – may limit the potential of wastewater reuse. This would require the treated wastewater to be carried to a wellspring or a water treatment plant, which would increase the costs (Interview 21).

In São Paulo, although reused wastewater costs approximately half the price of drinking water and can serve to supply industries, it is still much too expensive for indirect reuse to refill sources, due to the need for advanced technology, compared to water transfer over long distances (up to 200 km); prices have fallen but not yet sufficiently enough (Interview 23). The need for advanced technology can, however, be an excuse to not further investigate the potential of wastewater reuse given that, in most cases, secondary treatment (physical and biological treatment) would likely be sufficient, and drinking water quality unnecessary. In fact, others see potential in using treated wastewater for refilling springs, with the aim of retaining water within the same basin instead of exporting it, which is a common practice in Brazil (Interview 30). In São Paulo, wastewater reuse could account for 25 per cent of the water supply in the region, but 5 per cent would already be a significant contribution, yet this would require searching for industries that are interested in reusing wastewater (Interview 23).

The incentives for a utility to engage in wastewater reuse are apparently unclear because the business model of utilities is to sell water (e.g. Interviews 7 and 44). In fact, reuse as a source of "new" water is not a disincentive for the utility; possible revenue for the utility is only lost if water is reused at the individual level (Interview 13). Arguing that working with treated wastewater poses specific risks for contamination is in vain, at least for the context of water and wastewater treatment plants, because any worker needs to use professional gear and to follow safety standards when working in a water plant or WWTP (Interview 17).

Barriers to collecting and treating wastewater are also barriers to reusing treated wastewater and, hence, significantly limit its potential. For instance, the low maintenance and poor management leads to the risk of new equipment being worn down in only a couple of years (Interview 17); investments in expensive technology for wastewater reuse would then only be warranted if supported by training the personnel to achieve higher maintenance and management levels. Since many municipalities still struggle with rudimentary problems in the sanitation sector, it is understandable that they focus on universalising basic wastewater services with their – often connected – limited technical and financial capacities before attempting reuse (Interview 32). Nevertheless, the potential of wastewater reuse can already be tapped in municipalities with more advanced and extended wastewater systems.

The opposition to wastewater reuse for social reasons is less pronounced than expected. On the one hand, decision-makers came across as hesitant to stimulate wastewater reuse, at least partly because they fear opposition from the public. Yet, broadly speaking, a sense of precaution and little interest in experimenting with "the new" seems to be predominant (Interview 13). This is in line with the limited amount of technological dynamics and the few available technological solutions (Interview 26). Thus, experts and civil society should foster this topic in order to create "political will" (Interview 1). On the other hand, the cultural identity is shaped by the notion of abundance and, therefore, reuse is generally frowned upon, also for (waste)water. Environmental education needs to be improved to enlighten the population, otherwise reuse "will be limited to indirect reuse and to industrial reuse" (Interview 17). The general public is not aware of either the origins of tap water or the destination of sewage, or that indirect reuse of wastewater is already practiced because rivers often serve as a "natural reactor" (Interview 1). Although direct potable reuse is being hotly debated and seems to be facing fierce opposition, indirect potable reuse via rivers or lakes, however, is widely practiced and not considered a "re-use" (e.g. Interview 14). Commonly, indirect reuse does not cause any concerns but rather the quality of the treated wastewater when it is launched into the receiving water body (e.g. Interview 14). Although the notion of reused wastewater is difficult to grasp for the general public (Interview 37), such concerns are abating (Interview 26) because modern media provides the needed information, which helps to overcome this barrier (Interview 2).

All the same, the recent water crisis in São Paulo – now extended to a developed and affluent state in the south-east and no longer confined to the poor and underdeveloped north-east – has stimulated a discussion about alternative solutions such as reuse and rainwater harvesting,[48] immensely fostered water savings and water reuse by households, and, in general, strongly increased the awareness about water scarcity.

6 Lessons learnt: relevance of the nexus approach

This case study has identified several key challenges for wastewater collection and treatment that translate into important barriers for wastewater reuse. The aim was to identify possible instruments and incentives that can foster an integrated, holistic approach to water and energy as key inputs to the wastewater sector and to understand the practical relevance of the water-energy-food nexus to share lessons learnt.

Sewerage systems, although hidden underground, and WWTPs require land for their installation. In particular in informal settlements, the land for sewage installations is scarce, apart from the often difficult topography. In densely populated urban areas in general, opportunity costs for large-scale WWTPs are high, and public acceptance is often rather low, providing an incentive to search for decentralised, small-scale solutions.

Water and wastewater services consume large amounts of energy. Hydropower supplies more than three-quarters of Brazil's electric power, but the worst drought in 40 years in the south-east has impeded or lowered the electricity production via hydropower (United States Energy Information Administration, 2016). This has led to the increased use of thermal power plants, replacing lost hydroelectric generation with fossil fuel-fired generation, at substantially higher costs. For political reasons, these higher energy production costs were only gradually passed on to the consumers (Interview 5). Once the significant price increase reached (water and) wastewater utilities, they had a strong economic incentive to reduce their energy consumption, and respectively to produce energy. This fuelled the interest in resource-efficient, climate-friendly technologies, such as biogas (Interview 51); hence, the

48 Although this has already become reality in many private residences and commercial buildings (Interview 20), experts see potential in systematic rainwater harvesting in São Paulo city due to the – usually – considerable annual rainfall and the many institutional and commercial buildings with large roof-surface area (shopping malls, supermarkets, schools, etc.); the rainwater could be used for toilet flushing systems, watering, cleaning, etc., and would reduce flooding (Interview 16).

price increase has led the utilities to start internalising the negative externality of CO_2 emissions.

Prices and subsidies, and their changes, can contribute to the diffusion of more resource-efficient technologies, yet the current mismatch between water and wastewater tariffs and associated costs for service provision are a huge economic disincentive for wastewater services. Mandatory wastewater discharge standards and environmental licences can certainly support technology diffusions, yet standards and regulations need to be properly enforced in order to work. Beyond their contribution to technology diffusion, however, environmental regulation reduces the negative health and environmental impacts of untreated or insufficiently treated wastewater. In the current arrangement, biogas production in a WWTP reduces the electricity fees but does not reward energy surplus, as with a proper feed-in-tariff. For wastewater reuse, the crucial stumbling block is the missing regulation.

The systematic consideration of water, energy and land in policy and investment planning, as stipulated by the water-energy-land nexus, happens as long as it has economic implications and occurs in concrete situations at the local level, and not top-down. Prices and subsidies are important instruments to reflect intersectoral dependences. In general, the following lessons learnt can be drawn:

- The wastewater sector is struggling with many fundamental challenges that often need to be solved with limited financial and technical resources. The nexus as a concept has not been internalised by the stakeholders, but interdependences between sectors are considered when they are economically relevant. It does not seem helpful to overstress the nexus but rather to strengthen a holistic approach.
- The wastewater sector involves a great number of actors and stakeholders at the federal, state and municipal levels. Their better vertical and horizontal coordination and integration can contribute to more efficient and effective sanitation. Coordination and integration efforts should aim at reducing possible overlaps in responsibilities.
- More systematic intersectoral integration will be helpful in the long run to lower transaction costs and to reduce negative intersectoral externalities, yet the focus should be first on getting the wastewater sector run properly. This includes a thorough assessment of current bottlenecks due to overlapping or unclear responsibilities between different actors.
- Hands-on solutions to solve concrete problems and reduce costs help to identify possibilities for energy-efficient technology investments and holistic approaches. Searching for such resource-efficient and energy-efficient solutions can be incentivised by a proper economic and legal framework.

Broadly speaking, intersectoral dependences between water, energy and land are relevant in practice, but they are not systematically governed or steered by a specific nexus instrument; but rather influenced by a mix of standards and prices. Water scarcity and urbanisation were identified as the driving factors that trigger changes in the wastewater sector.

7 Conclusions and recommendations

Reduce regional disparities in capacity to broaden access to budgetary means: Financial means have been much more substantial and abundant than in the past, but access to federal budgetary means is difficult for small municipalities that lack the technical capacity. This is related to the observation that, in particular, public utilities often have limited planning, technical and managerial capacities. Sanitation plans help in identifying needs and specifying strategies to address them at the municipal level. However, more attention needs to be paid to the fact that not all municipalities are able to develop such a plan; attention must also be given to the question of how hindering factors can be overcome. It seems surprising that the federal government has not attempted to increase the technical capacity on site or to provide technical capacity from elsewhere.

Reform the wastewater tariff structure to allow full-cost recovery: Conditioning the wastewater tariff on the water tariff is a major obstacle to expanding the infrastructure for collection and treatment. A reform of the underlying legislation seems warranted, including the differentiation between a fixed connection fee and a variable consumption fee. Both public and private utilities have to earn revenues in order to invest in maintenance, operation and expansion of the wastewater network. This being said, the huge differences in household income need to be adequately taken into consideration to not overburden the poor and their limited economic possibilities.

Reduce institutional complexity and adapt stringent environmental legislation to reality: The institutional context is complex given the number of governmental institutions that regulate the wastewater sector. The strict *de jure* regulation for water and wastewater is welcome from an environmental perspective, yet it is not expedient, given the great lack of sanitation infrastructure and the corresponding pollution levels. More nuanced laws and regulations that allow for a gradual tightening of standards could assist in the slow but steady progress towards the targets established in PLANSAB.

Raise public awareness about how sanitation contributes to environmental and human health to increase public demand for sanitation: Wastewater ranks not very high on the preferences of both politicians and voters, and other public goods, such as health and education, still receive more attention in elections. Voters are increasingly becoming aware about how wastewater services contribute to environmental and human wellbeing, but the disinterest and unwillingness to engage with the topic of sewerage still prevail.

Factor in non-payments for sanitation services in the short term and harmonise sanitation legislation and enforcement in the medium term: The low level of willingness to connect households to existing sewerage systems and to pay for the wastewater service presents a real and great problem for all utilities, whether public or private, as it implies foregone revenues. What seems surprising from an economic point of view is that companies apparently have difficulties factoring in their calculations of anticipated non-compliance with legal obligations. Experiences are relatively new, but investment calculations should still use conservative estimates as a basis. It would be technically wrong to calculate investment in wastewater infrastructure on the assumption of complete connection rates, where all household are connected and hence pay their full fees, if there is already evidence available that de facto connection rates, hence the adherence rate, is (much) lower.

Do not unnecessarily stick to the paradigm of separate sewerage but search for unconventional hands-on solutions: One major issue that needs to be resolved is whether it is more important to decision-makers to stick to the stipulated separate drainage and sewerage systems at all costs or to promote the universalisation of basic sanitation as a necessary service for the whole population, at least occasionally implying the acceptance of the mixed drainage and sewage system. This includes the ability and willingness to think out of the box in order to also identify unconventional solutions. A fundamental discussion about combined versus separate sewerage does not seem helpful, given that the Brazilian wastewater sector needs urgent improvements in many areas. The assessment of which system is best suited for a particular situation should rather happen on a problem-orientated, case-by-case basis. This being said, the paradigm of the separate sewerage seems outdated and overcome by real developments in many instances.

Issue a law that regulates the use of treated wastewater to reduce environmental and contractual risks: Wastewater reuse is practiced in a handful of cases in Brazil, but its potential cannot be fully harvested yet, namely due to the lack of national legislation and the still prevailing attitude in politics and society that water is an abundant resource. The price structure of wastewater reuse – compared to alternative, often conventional, means to increase water supply – is controversially discussed. Some opponents seem to use the missing legislation and the supposedly still too expensive cost structure as pretexts. Similarly, concerns about contractual risks of supply and demand show that the discussion about wastewater reuse is still in its infancy. Such risks may be similar for other key production inputs and not unique for – or limited to – water; therefore, they should simply be included in general risk assessments.

Accept the challenge to provide sanitation in inhabited areas: It is without doubt more challenging to provide wastewater services *a posteriori* in a built city than to include it in urban planning *a priori*. If the built city is the status quo being dealt with, however, it should be taken as a given, rather than referring to an unrealistic, ideal reference point.

Do not use the federal government as a scapegoat, but focus rather on own contribution to universalising sanitation in Brazil: The challenges in the wastewater sector were framed, almost without exception, as a national problem and not as a challenge in specific cities or states. This is surprising because a utility operating at the municipal or state level is not expected to solve Brazil’s general sanitation problems, but it is responsible for providing a solution to the pressing problems on site. Although it is certainly correct to emphasise the general and common challenges in the wastewater sector, utilities should avoid generalising and scapegoating the federal government. On a similar note, in particular public utilities should pull their weight and focus on increasing their efficiency, rather than complaining about insufficient funds provided by the federal government. There is certainly room for improvement at their end, yet to blame the federal government for everything seems to be the easy way out. Local politicians, citizens and other stakeholders such as non-governmental organisations need to increasingly care about sanitation and express their preferences to exert pressure on public utilities, in particular.

Use the momentum of the recent water crisis to further raise awareness and exert more pressure: Although the wastewater sector in Brazil is still struggling with some rudimentary challenges, it is precisely the recent drought and subsequent water crisis in the state of São Paulo that has provided a glimmer of hope. It has increased the awareness about how important it is to have access to safe and reliable water, which role insufficient collection and treatment of wastewater plays and what the potential use of treated wastewater could be. The urbanisation process increases the pressure to universalise wastewater services. It seems that wastewater collection and treatment is increasingly seen as a necessity for clean watercourses and a key to human wellbeing.

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