d·i·e

Deutsches Institut für
Entwicklungspolitik

German Development
Institute

Discussion Paper 12/2016

Wastewater Systems and Energy Saving in Urban India

Governing the Water-Energy-Food Nexus Series

Babette Never

Wastewater systems and energy saving in urban India

Governing the Water-Energy-Food Nexus series

Babette Never

Bonn 2016

Discussion Paper / Deutsches Institut für Entwicklungspolitik

ISSN 1860-0441

Die deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data is available in the Internet at http://dnb.d-nb.de.

ISBN 978-3-96021-000-9

Printed on eco-friendly, certified paper

Babette Never is a researcher at the German Development Institute / Deutsches Institut für Entwicklungspolitik (DIE) in the department "Sustainable Economic and Social Development".

E-mail: babette.never@die-gdi.de

Published with financial support from the Federal Ministry for Economic Cooperation and Development (BMZ)

Tulpenfeld 6, 53113 Bonn
☎ +49 (0)228 94927-0
🖷 +49 (0)228 94927-130
Email: die@die-gdi.de
www.die-gdi.de

Acknowledgements

This report is one component of a larger project on the "Water-Energy-Food-Nexus" carried out by the German Development Institute / Deutsches Institut für Entwicklungs-politik (DIE). The project investigates incentive structures, governance mechanisms and policy instruments which take intersectoral interdependencies in the use of natural resources into consideration and contribute to increased water, energy and food security. This case study would not have been possible without the financial support of the German Federal Ministry for Economic Cooperation and Development (BMZ). The author is particularly grateful to the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) "National Urban Sanitation Policy Programme"-team in India for their valuable advice and practical help as well as to all interview partners in Delhi, Kochi and Nashik. Special thanks also go to the GIZ team of the project "Water & Wastewater Companies for Climate Mitigation" who provided helpful feedback on earlier versions of this paper. All remaining errors are the author's sole responsibility.

Bonn, June 2016 Babette Never

Abstract

This paper analyses the interdependency of water and energy in India's wastewater sector. Wastewater treatment plants consume a great deal of energy. Energy-efficient technologies are available, but are only spreading slowly in developing countries. In India, only 10% of all wastewater generated is treated, while energy demand is soaring. The case for investments in energy-efficient solutions thus seems clear. This case study analyses under which conditions and with which instruments integrated approaches to the water, energy and food (land) sectors (WEF-Nexus) are useful in various different wastewater systems across the country. It focuses on the identification of existing drivers of and barriers to the diffusion of energy-efficient technologies in India's urban wastewater sector, uncovering how investments in resource- and lifecycle-oriented solutions could be enhanced. Key findings are that India's urban wastewater sector is still largely in a situation of lock-in although first innovative initiatives that focus on more resource-footprint, lifecycle-oriented approaches exist in some niches. The diffusion of energy-efficient technologies is driven by pricing, mandatory regulations and standard-setting that are gradually being tightened. The privatization of building, operation and maintenance of treatment plants together with green procurement can be helpful if designed carefully. The main barriers against technology diffusion and a shift of the sector towards integrated approaches are a lack of cost recovery; vested interests in the status quo; a lack of operation and maintenance skills; and complicated processes, with many agencies and bureaucratic layers involved. Land and water scarcity are found to be catalytic to a change in planning, depending on local conditions.

Contents

Abbreviations

BOD	Biological oxygen demand
capex	Capital expenditure
CPHEE0	Central Public Health and Environmental Engineering Organisation
CHP	Combined heat and power
DBOT	Design, build, operate and transfer
DJB	Delhi Jal Board
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
kVA	Kilovolt ampere
kWh	Kilowatt hours
MBR	Membrane bioreactor
MLD	Million litres per day
MoUD	Ministry of Urban Development
Mwh	Megawatt hours
NUSP	National Urban Sanitation Policy Programme
opex	Operational expenditure
PPP	Public-private partnerships
UASB	Upflow anaerobic sludge blanket
USD	United States dollar
WEF-Nexus	Water-Energy-Food Nexus
WWTP	Wastewater treatment plant

1 Introduction: energy saving and production in wastewater systems

The energy consumption of wastewater treatment plants is substantial and shows how interdependent water and energy are in the wastewater sector. In the United States for example, water and wastewater systems constitute 35% of a typical municipality's energy consumption (Copeland, 2014). Energy efficiency offers a means of cost reduction for utilities and municipalities and contributes to reducing energy demand. An increase of energy efficiency in wastewater treatment plants is possible by replacing plant components (such as pumps and air blowers) or by the complete re-engineering of the treatment process. Sludge drying through solar radiation in a greenhouse instead of drying through thermal energy also saves energy. Biogas and combined heat and power (CHP) technologies offer opportunities for energy production in wastewater treatment, either to cover the plant's own energy needs (heat and electricity) or to feed electricity back into the grid. Here cogeneration of biogas during sludge digestion or incineration of sludge pellets after drying in power plants present two technical possibilities.

The most energy-efficient centralized wastewater treatment plants available on the market can cover up to 80% of the plant's own electricity requirements. For CHP technologies that take solid wastes as well, even 100% coverage of electricity needs (self-sufficiency) is possible. Decentralized wastewater management systems generally have a smaller resource footprint and consume less energy through savings on transportation costs; innovative biological treatment systems also use 30-35% less energy on-site (Dhakal, Shrestha, Shrestha, Kansal, & Kaneko, 2015). Today, the promotion of energy efficiency, biogas or CHP happens in most industrialized countries, but the diffusion is slower in the developing world. In developing countries, municipalities simultaneously struggle with the provision of sanitation and stable electricity supply for their citizens. Farmers in water-scarce areas tend to use untreated wastewater for irrigation (Amerasinghe, Bhardwaj, Scott, Jella, & Marshall, 2013). The rate of sewage collection in developing countries is low and the rate of wastewater treatment is even lower (upper middle income countries 38%, low income countries 8%) (Sato, Qadir, Yamamoto, Endo, & Zahoor, 2013), impacting both human and ecological health. Furthermore, only a very small part of treated water is reused.

In India, despite being an emerging economy, only 10% of all sewage generated is treated; 32% of urban households are connected to a piped sewer system (Sugam & Ghosh, 2013). Many existing wastewater treatment plants do not operate to full capacity. Additionally, the availability of land for installing sewage systems and wastewater treatments plants is becoming limited in India's rapidly growing urban centres. Water is scarce in many regions. Thus, there is pressure to invest more in wastewater treatment and to move towards innovative, resource-efficient energy solutions in the wastewater sector in India. This report analyses under which conditions and with which instruments integrated approaches towards water, energy and food (land) sectors (WEF-Nexus) are useful in various different wastewater systems across India. It focuses on identifying the existing drivers of and barriers to the diffusion of energy-efficient technologies in India's urban wastewater sector, uncovering how investments in sustainable solutions could be enhanced. The cities Delhi, Nashik and Kochi considered in this study face very diverse challenges in this respect.

This paper is one outcome of a research project conducted at the Deutsches Institut für Entwicklungspolitik / 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 food (land) sectors in Brazil, Colombia, Germany, India and Zambia. The case study on Brazil also treats the topic of wastewater treatment, reuse and energy, albeit with a stronger emphasis on reuse of treated wastewater. The Indian case study has been carried out with the support of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) – National Urban Sanitation Policy Programme (NUSP). Since 2008, GIZ-NUSP has been working with India's Ministry of Urban Development on the development of urban sanitation policies at state level and city sanitation plans at city level. This includes technical cooperation and support of pilot projects for resource-efficient, sustainable urban sanitation, waste and wastewater management in various different cities and towns across India.

The results of this report are based on 20 semi-structured interviews conducted with public utilities, private wastewater companies, city administrations (called 'urban local bodies' in India), consultants and experts on the topics of wastewater, recycling and reuse of water. The interviews took place in Delhi, Nashik and Kochi in November and December 2015. GIZ-NUSP supports the building of a waste-to-energy plant in Nashik (wastewater and solid waste) and an innovative septage pilot project at the household-level in Kochi. This combination of a birds' eye view on the one hand and concrete projects/programmes from various stakeholder perspectives on the other has allowed for an in-depth analysis of the sector, complemented by findings from a range of grey literature.

This report concludes that India's urban wastewater sector is still largely in a situation of lock-in although first innovative initiatives that focus on more resource-footprint, lifecycle-oriented approaches exist in some niches. The diffusion of energy-efficient technologies is driven by pricing, mandatory regulations and standard-setting that are gradually being tightened. The privatization of building, operation and maintenance of treatment plants together with green procurement can be helpful if designed carefully. The main barriers against technology diffusion and a shift of the sector towards integrated approaches are a lack of cost recovery; vested interests in the status quo; a lack of operation and maintenance skills; and complicated processes, with many agencies and bureaucratic layers involved. Land and water scarcity are found to be catalytic to a change in planning, depending on local conditions.

The report is organized as follows: The following section presents some background on the ongoing debates on wastewater, energy and transitions to more sustainable wastewater systems. The third section gives an overview of the various different empirical settings in Delhi, Nashik and Kochi, outlining the main actors, regulations and practices. Section 4 discusses the identified opportunities and challenges in the light of current and future instruments and incentives. The conclusion provides lessons learned and offers some recommendations on the future use of the Nexus frame.

2 Background: lock-in and transition of wastewater systems

Wastewater sectors across countries are generally considered to be very resistant to change: socio-technical systems are in a situation of lock-in (Fuenfschilling & Truffer, 2014; Maurer, Rothenberger, & Larsen, 2006; Molle, Mollinga, & Wester, 2009). Socio-technical systems encompass the production, diffusion and use of a technology as well as the social groups carrying and reproducing it – the actors and stakeholders involved (Geels, 2004; 2006). Lock-in takes place when rules, organizational structures, actors' mindsets and interests as well as investments, including costs sunk in infrastructures or particular types of training for engineers, together stabilize a certain vision and approach (Geels, 2004). Path-dependent decision-making, development and use of corresponding products and technologies further fortify dominant paradigms.

Water and wastewater systems have been driven worldwide by a dominant sector logic for the past hundred years: the provision of a secure, clean water supply and ideally piped sewage systems connected to a large centralized wastewater treatment plant (WWTP), usually employing activated sludge and aeration technologies or membrane bioreactors (MBR). For a long time, the responsibility to organize this has been ascribed to the state, turning public utilities and the engineering divisions in state and city administrations into central actors. Often, wastewater services and technology markets are dominated by a few large companies that exert a lot of economic and lobbying power. In developing countries, the role of the state can be particularly strong, not only because of its supply and collection mandate, but also because water tariffs are often subsidized and not market-driven, that is, cost-covering. Additionally, the capital intensity of wastewater system infrastructures is high. Physical assets have a long lifetime, making socio-technical systems with a lot of infrastructure even more stable than other socio-technical systems (Markard, 2011).

Shifting to more energy-efficient, sustainable solutions in wastewater systems is therefore generally considered challenging. While it is not entirely clear yet under which conditions decentralized systems and innovative combinations of septage, centralized and decentralized systems offer feasible alternatives in various different developing country contexts in this regard, it is safe to assume that opening up the path for such solutions can contribute to breaking the lock-in. There is an agreement in the literature that incremental transitions through small steps are more likely to be possible than big transformational shifts in socio-technical systems involving a great deal of infrastructure such as wastewater systems (Fuenfschilling & Truffer, 2016).

Against this background, the integration of energy and possibly land and food considerations in wastewater systems presents a particular challenge. On the one hand, the phasing-in of sustainable, green technologies in developing countries depends on the combination of instruments and incentives in a suitable sequence for the local context. Barriers involving political actors and local stakeholders, processes and institutions, power and local context conditions need to be considered and overcome. On the other hand, existing literature on the nexus shows that there is a gap between understanding and developing the nexus as a concept and actually connecting sectors on the ground (Allouche, Middleton, & Gyawali, 2015; Leck, Conway, Bradshaw, & Rees, 2015). In current policy debates, the idea to foster nexus implementation primarily via a national planning approach (that is, top-down) seems popular. However, to what extent this is feasible in developing countries is an open question.

Political options to phase-in green technologies such as energy-efficient wastewater treatment technologies can be classified into *command-and-control instruments*, *financial incentives* and *information-based, often voluntary tools*. Phase-in happens through a smart combination of instruments in a sequence that allows for policy learning and gradual change (Never & Kemp, forthcoming). In the wastewater sector, the pricing of water and electricity as well as fees, service charges or taxes for sewage collection are important instruments of the first category. Mandatory standards for the discharge of wastewater into surface waters and mandatory requirements for WWTPs to cover their own electricity needs through biogas and combined heat and power add to this range of possibilities. Bye-laws for the construction industry and power plants to use only treated wastewater present another option.

Financial incentives can take the form of preferential loan schemes and subsidies for private investments in the sector, tax redemptions for investors and guarantees of price (often combined with operation and supervision agreements) in contracts and concessions to support business model and market development. These mechanisms to reduce capital expenditure (capex) and operational expenditure (opex) for utilities and private companies offering sustainable solutions can be combined or used separately. Since private companies are more interested in water supply than sewage collection in developing countries due to higher profit margins, setting attractive incentives may be required to increase engagement in the wastewater sector.[1] The debate about the privatization of water and wastewater sectors in developing countries is ongoing. The effects of different privatization models, including the variation of contract types (see Table 1) differs across developing countries (see, for instance, Bakker, 2003; Budds & McGranahan, 2003; Marin, 2009; Schiffler, 2015; Vedachalam, Geddes, & Riha, 2016). In India, several public-private projects in the wastewater sector have existed since the 1990s, with increasing financial support by the national government from 2005 onwards. However, public scepticism about the privatization of the water and wastewater sectors is still strong and the debate among Indian experts about most suitable types of contracts is still underway (Vedachalam et al., 2015). As of now, it is unclear what effect public, private or various different public-private models have on the interdependency between water, energy and land.

Table 1: Types of contracting in the wastewater sector

	Service contract	Management contract	Lease	Concession	Design, build, operate and transfer (DBOT)*	Divestiture
Asset ownership	Public	Public	Public	Public	Public or private	Private
Capital investment	Public	Public	Public	Private	Private	Private
Commercial risk	Public	Public	Shared	Private	Private	Private
Operations/ maintenance	Private/ public	Private	Private	Private	Private	Private
Usual contract duration	1-2 years	3-5 years	8-15 years	25 years	20-30 years	indefinite

*Variations: Build, own, operate; Build, own, train, transfer.

Source: Budds & McGranahan (2003)

1 Interview 18: 24 November 2015, Delhi; Interview 19: 17 November 2015, Delhi.

The Nexus as a management approach is currently rather fuzzy. A great deal of the literature on the water-energy nexus concentrates on calculations of possible cost and resource savings (that is, energy efficiency in desalination plants or alternative cooling in power plants) and on the management of the environmental and social consequences of large hydropower dams (Rodriguez, Delgado, DeLaquil, & Sohns, 2013; Scheumann & Hensengerth, 2014). Critics argue that the concept only recycles the ideas of integrated water resource management frameworks (Allouche et al., 2015; Muller, 2015), does not sufficiently take power and institutions into account (Allouche et al., 2015; Bazilian et al., 2011; Villamayor-Tomas, Grundmann, Epstein, Evans, & Kimmich, 2015) or may simply be unrealistic in complex, economically driven regimes that rely on transnational trade systems (Allan, 2011). The level of abstraction and the vision to integrate all resource and technology planning is likely to be hard to translate into feasible options that correspond to governance realities. In developing countries, the functioning of a single sector may already constitute a substantial challenge. In India, the water-energy nexus has been investigated from the perspective of technical energy and greenhouse gas savings in WWTPs (Dhakal et al., 2015; Kapshe, Kuriakose, Srivastava, & Surjan, 2013) and electricity use in irrigation and reuse of water in agriculture (Amerasinghe et al., 2013; Mukherji, Shah, & Giordano, 2012; Starkl et al., 2015). Moreover, toolkits and guidelines for decision-making for wastewater system and reuse options are being developed by a number of consultancies and donor agencies (e.g. Deutsche Gesellschaft für Internationale Zusammenarbeit [GIZ], 2016; NJS Engineering Services [NJS], 2015).

The instruments and incentives available meet governance realities in urban India that are composed of a scattered mosaic of partly working, partly failing practices and piecemeal solutions, for instance in Delhi’s slums (Zimmer & Sakdalporak, 2012). When one understands the WEF-Nexus as an umbrella concept to mobilize synergies and manage trade-offs between sectors, the smart combination of instruments and incentives without sending contradictory signals becomes even more challenging.

3 Wastewater treatment, reuse and energy in India

3.1 Overview of issues and actors

The water and wastewater situations across Indian cities and towns are diverse, depending on water supply/scarcity, the existence and type of urban industries and peri-urban agriculture, and realistic options to lay or alter sewerage systems. For the vast majority of urban India, no secure data on the amount of sewage generated exists. Usually, municipalities work with an assumption of 70-80% of the water supplied. The share of non-revenue water is high (lost in transmission or because no water meters exist) and freshwater and sewage often mix through broken pipes or unauthorized disposal, seeping back into the groundwater.

Municipalities have the mandate to collect and treat wastewater, while industries need to meet standards prior to discharge into rivers and other surface waters. Small enterprises organize common effluent treatment in groups to meet these standards. At the federal level, six ministries are involved in different sections of water and wastewater planning:

the Ministry of Urban Development (MoUD), the Ministry of Drinking Water and Sanitation, the Ministry for Water Resources, the Ministry of Health, the Ministry of Environment and Forests and the Ministry of Agriculture. The Ministry of New and Renewable Energies is only concerned when it comes to feed-in tariffs and biogas policies. The Central Public Health and Environmental Engineering Organisation (CPHEEO) is the technical wing of the MoUD. It sets water quality and discharge standards and gives guidelines for technology use in WWTPs, but these guidelines are implemented differently across states and cities. For surface waters, the biological oxygen demand (BOD)[2] value is supposed to be a maximum of 30mg/litre, unless the water body is used as a source for drinking water, then 10mg/litre BOD or less are recommended (before treatment for drinking, then 2mg/litre BOD maximum). For WWTP, additional guidelines for primary, secondary and tertiary treatment exist (Central Public Health and Environmental Engineering Organisation [CPHEEO], 2013).

Water and wastewater are concurrent issues, requiring co-legislation of federal and state levels. The National Urban Sanitation Policy of 2008 provides an overarching framework for states and cities, outlining general policy goals (such as awareness raising and open defecation-free cities) and providing elements of draft state and city sanitation plans. It recommends a minimum of 20% reuse of wastewater in every city. This policy is complemented by the National Advisory Manual on Septage Management and the Manual on Sewerage and Sewage Treatment Systems (both from 2013) which give more concrete suggestions and guidelines on technologies, operation and management procedures. The National Water Policy of 2012 encourages recycling and reuse of water after treatment to specified standards (CPHEEO guidelines) as well as preferential tariffs that incentivize the reuse of treated wastewater in general.

The number and functions of state and urban local bodies vary greatly. Some municipalities handle sewage issues directly, while others have outsourced different parts of the system, such as maintenance or design, building and operation. This often leads to complicated administrative procedures and creates a confusing picture for potential investors. Furthermore, many municipalities do not yet have a strategic plan for the wastewater sector at all.

The Modi government, elected in 2014, has started up some new initiatives in the water and wastewater sectors, but also continues others of previous governments under new names. These offer grants, subsidies and loans for investments. Four national missions are particularly relevant for the wastewater sector: The Swachh Bharat Mission, launched in October 2014 with a total budget requirement of approximately 9 billion USD, aims to improve sanitation and solid waste management. Its focus lies on toilet construction in households, communities and in public spaces. Three of the five thrust areas of the Amrut Mission concern water and wastewater are the enhancement of water supply and sewerage connections for every citizen; sewerage treatment facilities and septage management; as

2 The BOD value captures the amount of oxygen that aerobic organisms need to break down organic particles in the water. It indicates the organic pollution level of water bodies and is the most common value to measure the effectiveness of wastewater treatment plants. For comparison: the BOD level of the river Rhine varies from 2mg/litre to 5mg/litre; German drinking water regulations require a BOD level of 1mg/litre or below; while the maximum BOD level for the discharge from wastewater treatment plants is 40mg/litre, but stricter depending on where it is discharged and whether discharged water is mixed with freshwater from rivers or not.

well as storm drainage systems. The programme commenced in June 2015. Furthermore, thirdly, there is the Smart cities initiative (formerly Jawaharlal Nehru National Urban Renewal Mission) which requires cities applying for funding to come up with sanitation and solid waste management plans. In early 2016, the first 20 cities were selected under this scheme. Finally, the National Mission on Clean Ganga finances WWTP and municipal sewage treatment as well; 6 new plants were commissioned under the scheme along the Ganga in 2014. However, despite these renewed efforts to clean the Ganga, local experts are sceptical about its effect since similar missions have been in place since the 1970s with very limited results.[3]

The Modi government is pushing for a more participatory, people-centred approach, talking about 'people-public-private-partnerships'. In some states and municipalities, this may clash with local political preferences on privatization of water and wastewater. Water supply has been the political priority for decades and still pervades in the mindset of many policymakers and bureaucrats. Freshwater provision at low or no cost is often a campaigning issue, for instance in the latest Delhi elections (see below). Under the Modi government, sewage and septage are now receiving more attention, indicating a possible shift in mindset. In some areas such as Kochi, sewage receives as much attention as water supply, especially since plenty freshwater is available. Recycling and reuse of wastewater is neither a political priority at federal level nor at state or municipal level yet, in spite of the federal policy goal of 20% reuse. It only takes place when water scarcity leaves no other option.

Overall, energy comes into wastewater planning primarily as a cost factor. No systematic, integrated planning of water and energy is yet taking place. Water is reused in agriculture (treated and untreated), partly in horticulture, and in some industries for cooling, especially in water-scarce cities. In some peri-urban areas of India, sludge generated by WWTPs is used by farmers as well. There is no specific regulation for sludge discharge yet; most utilities still see it as a mere nuisance.[4] Regulation for a national feed-in tariff for renewable energies exist that needs state-level adjustments and implementation. There are generally no taxes for water or sewage services. Water tariffs are usually set by the urban local bodies and utilities. Most interview partners agreed that technologies in the sector are generally available and that finances are not much of an issue due to the various national missions and various programmes offered by donor agencies.[5] Usually, central and state governments share the costs for sewage equally.[6] The reasons why there is not more investment in the sector vary from city to city.

3 Interview 16: 4 December 2015, Kochi; Interview 3: 25 November 2015, Delhi.

4 Interview 14: 25 November 2015, Delhi.

5 For instance, Interviews 6, 10, 15, 18, 19 in Delhi, Nashik and Kochi.

6 Interview 20: 20 November 2015, Delhi.

3.2 Delhi

The megacity of Delhi with approximately 18 million inhabitants is composed of eleven administrative districts, governed by the National Capitol Territory state government and three different municipal corporations. The Delhi Jal Board (DJB) is responsible for the complete water and wastewater chain in the whole capital territory, thus functioning as a public utility. The water tariff is set by the DJB, but influenced politically. The recently changed block tariff reflects the now ruling Aam Aadmi Party's election campaign promise of 20,000 litres of free water per month for domestic consumers (see Table 2). The high industrial water tariff cross-subsidizes drinking water for domestic consumers. Water supply, sewage treatment and storm drainage are managed by different divisions. Water provision (through both piped water and bottled water) and wastewater (piped sewerage, septage, open defecation and dumping of sewage) are characterized by a variety of practices and involved stakeholders with differing interests across the city. According to Singh and Kansal (forthcoming), the average energy use in Delhi's urban wastewater infrastructure is 0.26kWh/m3, while the total electricity use in the wastewater infrastructure is 246 Mwh/day. The electricity tariff for the DJB is 125 rupees/kiloVoltAmpere (kVA)/month; high tension). The energy and electricity costs per unit of treated wastewater are difficult to calculate because various operators, different electricity loads and energy-saving technologies exist in Delhi.

The city's rapid population growth, a high share of non-revenue water and system maintenance are key challenges for the wastewater systems. Currently, Delhi relies on centralized WWTPs, in line with the above mentioned dominating vision of key actors and their interests. The DJB plans to expand with decentralized systems especially in unplanned areas (slums) and in those parts of the city that are far-away from rivers and canals for the discharge of treated wastewater.

Table 2: Water tariff in Delhi

	Monthly consumption (kilo litre)	**Service charge** (Indian rupees)	**Volumetric charge** (Indian rupees)
Domestic			
	Up to 20 for households with a functioning water meter	free	free
	20-30	219.62	21.97
	Above 30	292.82	36.61
Sewer maintenance charge: 60% of water volumetric charge			
Commercial/industrial			
	0-6	146.41	14.64
	6-15	292.82	21.96
	15-25	585.64	29.28
	25-50	1,024.87	73.21
	50-100	1,171.28	117.31
	Above 100	1,317.69	146.41
Sewer maintenance charge: 60% of water volumetric charge			
Source: Delhi Jal Board			

In Delhi, roughly 50% of buildings are not connected to sewerage pipelines. 7,000km of sewerage pipelines exist, compared to 14,000 km of freshwater distribution pipes. Of the 20 sewage treatment plants that officially exist in Delhi, 9 are currently fully operational and another 7 to 8 plants are being repaired or rehabilitated. About one-third of Delhi's population lives in unplanned areas (slums and unplanned colonies). In these areas, only 230 km of sewage pipelines exist. The sewage generated in networked areas is estimated to be around 3.33 billion litres per day, but installed capacity only covers 2.71 billion litres per day. Due to a lack of connecting pipeline systems and other maintenance challenges, only about 55% of the sewage generated is currently treated (only 50% of households connected; 80% of their sewage is collected).

The DJB has been increasingly awarding operation and maintenance contracts or design, build, operate and transfer (DBOT)-contracts with a guaranteed runtime of 10 years for each WWTP. The physical assets remain in the hands of the DJB. Public-private-partnerships including true private equity investment do not exist at this stage. The current Delhi state government has largely stopped efforts to privatize the sector, even though many experts agree that the service and delivery quality in Delhi's wastewater sector increases with a higher private sector involvement.[7] The maintenance of the water and sewerage networks is difficult, also due to the so-called water tanker mafia. Freshwater pipelines are damaged on purpose by this mafia to increase the sales of bottled water and water provided by tankers, leading to an even higher rate of mixed freshwater and sewage.[8]

The electricity supply to WWTPs has been stable for several years. It is mandatory for electricity providers in Delhi to ensure stable supply to WWTPs, thus keeping power cuts to a minimum. Newly built WWTPs are required to cover up to 60% of their own electricity needs, usually via combined heat and power biogas production. Conventional biological wastewater treatment technologies can produce 40-55% of the WWTP's energy needs. Advanced combined heat and power technologies can produce up to 80% of a big centralized WWTP's electricity requirements. Top-rate technologies in WWTPs even manage to feed electricity from biogas back into the grid, for example, in a sludge-to-energy plant in Hong Kong. While the national feed-in tariff for biogas has been implemented in Delhi, none of the WWTPs currently produce excess biogas to feed electricity back to the grid however.

Delhi has started recycling and reusing water and treated wastewater due to rapidly diminishing groundwater levels. Currently, about 630 million litres per day (MLD) are being reused in power plants and horticulture. All government buildings must now use only recycled water for all non-drinking water purposes and the construction industry is required to use only treated wastewater as well, but the latter measure is only working to a very limited extent so far. The Pragati power plant runs exclusively on treated wastewater from the Delhi Gate sewage treatment plant because groundwater levels are now too low. The Nilothi WWTP (90 MLD capacity) in West Delhi built by the company Veolia uses conventional biological treatment processes for the sewage, covering 50% of its electricity needs through biogas production, but more advanced technologies to reduce the amount of sludge. The remaining sludge will be sold as manure to farmers at a low price. The reuse

7 For instance, Interview 4: 21 November 2015 Delhi; Interview 11: 23 November 2015 Delhi; Interview 20: 23 November 2015, Delhi.

8 Interview 2: 20 November 2015; Interview 20: 24 November 2015, Delhi.

of wastewater and sludge in agriculture is somewhat difficult to organize in Delhi as there are hardly any farmers left in peri-urban areas. Supply and demand are located very far from each other, leading to very high transportation costs. Within Delhi, the transport costs of wastewater to the nearest treatment plant are also considerable as parts of the sewage network have not been built with a sufficient gradient, thus requiring electricity-intensive, costly pumping. Some treatments plants are simply far away, making collection paths very long. The discharge of treated wastewater into the Yamuna River and the canals leading to the Yamuna is necessary to allow for the minimal environmental flow of the river. While the quality of the river has a BOD value of only 3mg/litre coming into Delhi, this increases to 45mg/litre BOD within the city’s barrages.

The Delhi draft Water Policy of 2015 outlines elements of a future approach to water management that rests on five pillars: demand management; optimization of available resources; equity; augmentation of internal resources; and building resilience. The draft policy recognizes that a paradigm shift is required, namely one that sees sewage as a resource and reduces the energy and land footprints of wastewater systems, promotes recycling and reuse of water as well as decentralized treatment and alternative treatments systems. There are policy targets to increase wastewater reuse to 25% by 2017, 50% by 2022 and 80% by 2027. Decentralized treatment of wastewater will be promoted, alternative treatment systems will be encouraged and the decrease the energy footprint of Delhi’s entire cycle of water operations (treatment, supply, sewage collection and treatment) is envisioned in the new policy. This indicates that, at the general planning level, some awareness of the water-energy-land nexus and the importance of lifecycle-oriented solutions including decentralized wastewater treatment exist. The success of concretization of this policy into action, including step-wise regulation, planning and implementation remains to be seen.

3.3 Nashik

Nashik is the third largest city in Maharashtra with 1.5 million inhabitants and a highly fluctuating (additional) population due to religious festivals that attract millions of visitors. In Nashik, the municipal corporation is responsible for the whole chain from water supply to reuse; no additional agency or utility exists. Water charges are collected through a water tax that is part of the property tax and through bills based on water meter readings which can be paid online as well. No user charge for sewerage exists, but a share of the property tax is channelled to the water supply and sewerage division under the heading of a ‘sewerage benefit tax’. [9]

The city’s freshwater supply comes from the Gangapur dam. Of the 360 MLD of water supplied, 15% are lost in the system due to leakages, so that only 306 MLD get to the customer. The amount of wastewater is estimated to be between 244 and 263 MLD (75-80% of supply). The city is divided into six sewerage zones with a capacity of 343 MLD in four WWTPs. All of the sewage collected is treated and then discharged into the river Godavari, but there are also unconnected slum areas in the city where sewage is not collected. The largest of these plants (130 MLD) works with upflow anaerobic sludge blanket (UASB) technology and produces biogas. Part of the electricity generated from

9 Interview 15: 30 November 2015, Nashik.

methane is used for the plant's own energy consumption and the generated surplus is sold to the grid under the Maharashtra feed-in tariff for renewable energy. This older UASB technology only treats up to 20-30mg/litre BOD, requiring retrofitting to comply with the new CPHEEO regulations of less than 10mg/litre BOD for discharge. Two more plants using new UASB technology (40 MLD and 32 MLD capacities) will be constructed. They are in different stages of commissioning. Additionally, a waste-to-energy plant is being constructed which deals with both solid wastes and wastewater (see Box 1). The other three existing treatment plants use membrane bioreactor (MBR) technology that does not recover energy. These need retrofitting as well. The retrofitting and expansion of sewerage network are expected to cost about 500 million rupees. The city requires additional funding for that and has successfully applied to become a 'smart city' under the national Smart City programme for this purpose. Private contractors operate and maintain the WWTPs under the monitoring of the municipal corporation, but no extensive 'design, build, operate and transfer'-system with performance requirements for investment returns exists yet.

Box 1: Waste-to-energy plant in Nashik
This innovative waste-to-energy plant will consume both solid waste and 'black' water, making it the first of its kind in India. It will take 10-15 tonnes of food and vegetable waste from 1,300 restaurants and hotels daily, as well as 10-20 tonnes of black water collected from about 400 community toilets in Nashik. Through combined-heat-and power production, the plant is expected to yield 21,000 cubic meters of biogas every day that will convert to up to 32,000 kWh of electricity. Any excess electricity not used by the plant itself will be fed into the power grid under the Maharastra feed-in tariff. The compost the plant generates will be sold to farmers at a low price. Concessions for the constructions of the plant have been awarded; construction is expected to start in 2016. The only two other waste-to-energy plants in India are in Delhi, but they only take solid wastes and have been highly criticized for their low-end technology, polluting adjacent neighbourhoods with unhealthy fumes. The Nashik plant will be situated next to the existing municipal waste plant and will use higher-level filters. The Indian government plans to expand waste-to-energy plants across the country.
Source: GIZ Factsheet Nashik (2014); interviews by author

Despite a relatively good sewage network, the efficient collection of wastewater remains a challenge for Nashik. The city produces approximately 500 tons of solid waste and sewage every day, but collects only 370 tons. Open defecation and irregular emptying of septage tanks and soak pits into storm drains and canals continues to happen in slum areas despite the municipal corporation's efforts to tackle these challenges through their urban sanitation plan. The pollution of the Godavari thus continues to be a serious problem. BOD and chemical oxygen demand levels in the river have not reached the required A2 (bathing) water quality.[10]

The treated wastewater from the WWTPs is discharged into the river to support the environmental flow of the river. Dried sludge and solids are sold to farmers as manure – demand for this is ample.[11] The Nashik Thermal Power Plant and farmers draw their water from the river downstream. However, since the treated wastewater is mixed with untreated wastewater discharged into the Godavari, it is not possible here to speak of a proper, direct recycling and reuse system. According to the municipality, the long transport routes

10 Interview 15: 30 November 2015, Nashik.

11 Interview 15: 30 November 2015, Nashik.

between supply and demand areas for treated wastewater impede a cost-efficient model for reuse, for example, in horticulture and for industrial use. Operational costs for WWTPs are already very high and borne by the municipality. Due to the prevalent water scarcity, the car factory Mahindra & Mahindra covers 30% of its water consumption by treating its own wastewater on-site (Infrastructure Development Finance Company [IDFC], 2011).

3.4 Kochi

The commercial centre of the state Kerala is a coastal city with a population of 600,000. Comprised of numerous islands and canals, lakes and estuaries known as ‘backwaters’, the city is surrounded by water. The groundwater table is high and land (space) is scarce, making the laying of conventional sewage pipes difficult as these require a depth of 4-6 metres. Indeed, no real wastewater system exists in Kochi yet. The only existing sewage treatment plant with 4.5 MLD capacity was constructed in the 1960s. One more plant is now being constructed in Western Kochi with a capacity of 25 MLD. Two more centralized plants are in the planning stage. The vast majority of water consumers uses septage tanks and soak pits. These are currently not collected and emptied in a systematic way. A large amount of sewage is simply dumped into the canals that serve as stormwater drains, in estuaries or on vacant plots of land. Since solid wastes are often dumped into these canals as well, storm drainage is rendered ineffective and pollution has increased considerably. On the supply side, freshwater is sufficiently available and 83% of the city had access to piped freshwater in 2011 (GIZ/Corporation of Cochin, 2011). In spite of system losses of 50% due to old and leaking distribution pipes, domestic users generally consume 300 litres of water a day – that is more than double the average amount that the CPHEEO recommends for India per person and day (135 litres).[12] Since there is no proper sewage system in place yet, energy costs and nutrient recovery are not an issue in Kochi yet. From a nexus perspective, modern septage and decentralized system solutions offer options for the reuse of sludge as manure and the saving of space (land). An innovative integrated septage pilot project developed by the Kerala state government, Kochi Municipal Corporation and GIZ expects to provide a sustainable, energy and land-saving solution for households (see Box 2).

A state sanitation plan for Kerala as well as a city sanitation plan for Kochi exist, both developed with the support of GIZ in 2010/11, but there are not yet any concrete by-laws for wastewater, septage and sludge yet. The responsibilities for water supply, sanitation and sewerage are shared between Kerala Water Authority (under the Kerala Department of Water Resources) and the Kochi municipal corporation. While the Kerala Water Authority is responsible for constructing and maintaining large items of infrastructure such as treatment plants and the sewage pipe network, for example, the municipal corporation is responsible for actually planning and implementing water supply and sanitation as part of urban development. Within the municipal corporation, responsibilities for water and sanitation are scattered and sometimes overlapping between different departments, increasing the coordination challenge.

12 Interview 16: 4 December 2015, Kochi.

Box 2: Septage pilot project Kochi
This pilot project shows what an innovative, sustainable septage management concept for the city of Kochi could look like, taking into account the high groundwater table and the narrow roads inhibiting traditional sewerage system construction. Drawing on data from a newly developed discharge register in a poor urban area of Kochi, this pilot project seeks to establish a decentralized septage and wastewater treatment system. 'Grey' water from kitchens and bathrooms and 'black' water from toilets will be kept separate (as is already the case in the area). The grey water will go to the collection point, then on to a wastewater treatment plant. These pipes are at a shallower depth than conventional systems, making them apt for Kochi. Black water will be collected on-site in septage tanks for the solids to settle (dewatering) near the households and the sludge turns into biochar by dewatering the septage. The highly concentrated black water effluent will flow into a small, solid-free sewer system that will be treated in a nearby compact sewage treatment plant, thus saving scarce land. The biochar can be used by farmers as fertilizer or for biogas production. In the blueprint design by Hamburg Water, anaerobic treatment of black water and other biomass on-site enables direct heat and power production for the households. However this system is currently not cost-competitive in Kochi and has therefore not been implemented. This pilot project is currently being constructed.
Source: Interviews by author

The water tariff is set by the state government of Kerala together with the Kerala Water Authority. The water price is subsidized by approximately 50% and there is no charge for sewerage. The production and distribution costs are 21 rupees/1,000 litres of freshwater, but the average revenue is only 9.5 rupees/1,000 litres. Domestic users have a volumetric block tariff. For example, for the most common amount of 15,000 litres per month, the charge is 4 rupees/1, 000 and 5 rupees/1,000 litre for 15,000-20,000 litres. For domestic consumers below the poverty line[13], water supply is free. For industry, the tariff also increases. There are about 170,000 water connections. More than 50% of these users fall in the bracket of 15,000/month, thus paying a maximum of 60 rupees per month. In 2011, the collection rate of water user charges was only at 22%, indicating a high level of non-revenue water (GIZ/Corporation of Cochin 2011). Cost recovery within the water chain as such is a challenge, but the city of Kochi has managed to become a 'smart city', thus accessing special funds for sanitation. It counts on accessing finances under the Amrut mission as well. Moreover, there have been several projects with a number of different donor agencies on sanitation and sewerage. Finances are therefore generally not regarded as an obstacle to the development of a modern wastewater system.

13 Kerala has its own definition. Households lacking four or more of the following nine parameters are considered to be below the poverty line: no or less land than five acres; no house or dilapidated house; no sanitation latrine; family without colour television set; no regularly employed person in the household; no access to safe drinking water; women-headed household or presence of widow/divorcee; scheduled castes and scheduled tribes; mentally retarded or disabled member in the household.

4 Discussion of identified challenges and opportunities

The investment baseline and the drivers for energy-efficient technologies and sustainable solutions in the wastewater systems vary in Delhi, Nashik and Kochi, but also across India in general. New dynamics in the sector have only partially succeeded in breaking the lock-in situation and shifting to energy-efficient, land and food-conscious pathways this far. This section discusses the different challenges and opportunities identified by grouping them according to the categories actors/stakeholders' mindsets; power/interests; processes/institutions; and impacts of land and water scarcity. Regional differences in economic, social and political aspects will be indicated where necessary with a particular emphasis on instruments and incentives.

4.1 Actors and stakeholders

The actors working in different parts of the water-wastewater chain – policymakers as well as the consumers of water – have a certain mindset, management capacities, skills and personal preferences which either perpetuate or help to disrupt existing wastewater systems. In India, the dominant mindset among bureaucrats and utilities is still geared towards centralized systems that tend to be conventional:

> Everywhere even at local level in small towns they have their mind set on providing networks and complete sewage system; they don't look at decentralized systems much. At the state level, same thing.[14]

Modern septage systems and combinations of centralized, piped systems with decentralized options are often not regarded as equally viable solutions. Within utilities and urban local bodies, this coincided with engineers' risk aversion during the planning of wastewater systems. In many cases, such engineers stick to well-known and accepted solutions instead of following-up innovative ideas.[15] Sometimes innovative ideas are blocked at higher levels of administration as these bureaucrats then have no interest in risking new solutions. While experts and firms offering these decentralized systems have managed to change the mindset in the sector in some niches, coincidences with practical push factors such as land scarcity are necessary for actual implementation (see below) and deeper shifts towards lifecycle-, sustainability-oriented thinking.

At the operational and control level of wastewater systems, the poor management capacities of the people involved at different stages from groundwater extraction over treatment to discharge and reuse are a clear barrier to the diffusion of efficient technologies.[16] Even if the technology is there, a lack of skills, capacities to control and manage, and sometimes a lack of interest inhibit its full operation.

Corruption among utilities, urban local bodies and at WWTP-level as well as the fuelling of corrupt practices by companies abiding to them shift, stall or foster decision-making

14 Interview 13; 26 November 2015, Delhi.

15 Interview 1: 19 November 2015, Interview 18: 24 November 2015, Delhi; Interview 10: 3 December 2015, Kochi.

16 For instance, Interview 1: 19 November 2015; Interview 5: 19 November 2015; Interview 6: 20 November 2015; Interview 7: 16 November 2015; all in Delhi.

and the type and operation of wastewater system installed. This certainly does not happen everywhere, but the interviewees for this report stressed the connections between the so-called water tanker mafia and urban local bodies (see Sub-section 4.2), the relevance of corruption in the decision-making for or against certain technologies and companies, and the time lag and difficulties of procedures as important reasons why the whole sector is moving only slowly.[17]

In Kochi, the social acceptance of wastewater treatment systems is low despite the absence of any organized collection and treatment system at this stage. The government owns the land, but the surrounding neighbourhoods refuse to have a decentralized treatment plant close to them (the "Not In My Backyard"-effect).[18] While this particular problem has only been mentioned for Kochi and not for Nashik and Delhi, a common theme emerging in the interviews was people's general mentality of 'flush and forget', indicating a disinterest and unwillingness to engage with the topic of sewerage.

Despite these various different barriers to both investments in energy-efficient solutions and integrated approaches towards water, energy and land, proactive stakeholders exist as well. Those bureaucrats, utility providers and company members who recognize opportunities, who have understood and are convinced of innovative solutions, lifecycle approaches or the necessity to control the implementation of regulations tend to become active. In Nashik, for example, several committed individuals in the municipal corporation have set-up a tighter control system for regulations, following this up by phone, internet-based monitoring and site visits if necessary. The commitment and control of key actors is important to link – and eventually change – various different mindsets. Additionally, control and compliance mechanisms are important to counteract potential free-riding. The shift in the national agenda towards a stronger emphasis on sewage and sanitation is encouraging, particularly because it is reflected in financially backed programmes with clear targets. The change of mindsets in favour of an integrated, nexus-type thinking can hardly be achieved by force using a specific regulation. It is likely to be a gradual process that depends on interactions and learning as much as political and financial incentives.

4.2 Power and interests

The mindsets outlined above are often linked to broader political and economic interests and power relations in the sector. Both political actors and companies have stronger interests in freshwater supply than in wastewater treatment and sewerage. Many policymakers see water supply and subsidized water tariffs as an election winner rather than prioritizing wastewater treatment and reuse that the public does not like to think about.[19] In India, famers have a strong election power, making any changes in the pricing of water and charges for treated wastewater and reuse extremely difficult. Many policymakers refrain from touching any issues that may contradict farmers' interests in this field. In several states, farmers have been protesting against land acquisition for the

17 For instance, Interview 2: 20 November 2015, Delhi, Interview 14: 25 November 2015, Delhi.

18 Interview 10: 3 December 2015, Kochi.

19 Interview 6: 20 November 2015, Delhi.

construction of wastewater treatment plants, for instance in Dinapur (Uttar Pradesh).[20] In water-scarce states such as Gujarat, the diversion of water to industries is also fiercely contested by farmers, even if it is wastewater.[21]

For companies active in both water supply and wastewater services, cost and revenue considerations prevail. Freshwater supply gives higher revenue and usually requires less complex infrastructure; existing systems can be built upon and used. Additionally, the major players in the field (both international and national firms) offer and prefer centralized wastewater systems to small-scale decentralized systems, using their economic market and institutional lobbying power to influence. Together, policymakers and companies therefore have a set of common, vested interests. These are fortified by the risk aversion in public utilities outlined in the previous section, the political rotation of posts in administration and the water tanker mafia which is partly supported by people in public utilities. Smaller innovative firms such as Organica, which offers decentralized systems based on plant root treatment, do not have the economic power and competitiveness on the Indian market yet and struggle with the existing power relations in the sector.

The frequent political rotation of posts at higher levels of administration in state and city governments is a key challenge from both an investment and technology diffusion and a nexus perspective. The skills and interests of these bureaucrats do not then correspond to their appointed posts (for instance when a medical doctor is appointed as head of water resources), also due to the short time they keep their positions. This makes it difficult for the utilities, private sector and donor agencies to advance their projects. One expert summarizes it like this: “The bureaucrats know they are maybe only there for two, three years and can just wait and let time pass. Even if you have good ideas bottom-up, you get stuck at the top level because there is no interest.”[22] The lack of interest and political priorities thus serves as a strong blocking power in the system.

The linkages between the water tanker mafia and individuals within utilities and urban local bodies create a powerful shadow alliance preventing change. Both parties have an interest in a deficient water and wastewater system: the water tanker businesses keep selling their water while individuals within the urban local bodies receive payments and favours for not repairing and not changing the status quo. While the experts interviewed here outlined this challenge most clearly for Delhi (see above), the problem is also known to exist in other cities and towns across India (for example, Bangalore).[23] Thus, competing forces within urban local bodies and among the private sector make broad, radical changes towards innovative solutions difficult. As long as not all buildings in a city are connected to a functioning piped system of water supply and ideally to either a centralized or decentralized wastewater system as well (to prevent leakage and contamination), the business grounds for the water tankers and bottled water companies will be hard to break. Despite recurring protests, the residents in those areas where only tanker water is available have no choice in the end.

20 http://timesofindia.indiatimes.com/city/varanasi/Farmers-protest-mars-Clean-Ganga-Mission/articleshow/48323268.cms (last accessed: 13 June 2016).

21 Interview 13: 25 November 2015, Delhi.

22 Interview 20: 24 November 2015, Delhi.

23 Interview 3: 25 November 2015, Interview 5: 19 November 2015, Interview 20: 24 November 2015; all in Delhi.

Finally, the interests and powers of different governance levels can either function as a driver or a barrier to energy-efficient technology diffusion and investments in sustainable wastewater solutions. This depends on the concrete issue in question and the actor and agency constellation in each state and municipality. Generally, the central government has the power to set the policy agenda that states and cities have to deal with. The central government also controls a large part of the budget. This can have substantial trickle-down effects: "If the national government sets their mind to something, then it will move. It will probably move slowly, but things move then."[24] However, the enforcement and control of regulations is up to state and local levels, leading to potential power and practice clashes. The privatization of wastewater services provides a good example here. While the central government favours public-private partnerships (PPPs) and privatization as long as the physical assets and regulations remain in public hands, some state and municipal governments oppose them for fear of price hikes and turning a public good into a private commodity, for instance in Delhi. As far as the Smart City initiative is concerned, a lot of disagreements between central and state governments reportedly exist about the degree of privatization that the programme will entail. Since the privatization debate has been ongoing in India's water sector for a long time, the current stalemate is not surprising.

4.3 Prices, processes and institutions

The planning and operational processes by different agencies and institutions impact regulatory change, investments dynamics and regulatory effectiveness. The pricing of water and the lack of regulation for sludge discharge currently hinder energy-efficient technology diffusion and the switch to resource-footprint, lifecycle-oriented technology approaches in India, while high electricity prices, the existence of concrete urban sanitation planning frameworks, and mandatory standards for the quality of water discharged are conducive. The feed-in tariff and taxation hardly play a role as regulatory instruments yet, even though they have a high potential for driving investments. Public-private partnership-type of contracts and green procurement are considered useful by most Indian experts. The Delhi example shows this. Whether they are a solution for all of urban India cannot be answered by this study. Moreover, the high number of bureaucratic steps and agencies in the process, the time it takes from initial expressions of interest to the contracting of WWTP building and the type of technology in tenders often prescribed remain obstacles.

The current subsidized pricing and the amount of non-revenue water can be understood as a barrier to investments in the water and wastewater sectors, especially from a private-sector perspective. The limited amount of revenue generated is hardly cost-effective for private companies. Due to its duration (including operation and maintenance), a DBOT-contract works as a kind of guarantee mechanism for the private company's investments. This lowers investment hurdles. At the same time, these clear, longer-term mechanisms for operation and maintenance simplify the urban local bodies' tasks in implementation and monitoring, also regarding energy efficiency and discharge standards. For public utilities and urban local bodies, non-revenue water is a serious challenge when it comes to leakages and unmetered connections, but a political necessity when it is about providing free or highly subsidized water for the poor. In Delhi, for example, the DJB used to have

24 Interview 11: 23 November 2015, Delhi.

55-60% non-revenue water (of overall supply) before public-private partnerships reduced this to roughly 50% non-revenue water.[25] This figure is likely to increase again with the volume of water given for free and if PPPs are blocked politically. Since there are no, or only low, charges for sewerage, the recovery of the high costs for the infrastructure investments is very tricky. Unless urban local bodies access federal level-funding, donor funding or real equity investments from the private sector, cost recovery is completely out of reach. Opting for the installation of energy-efficient technologies is therefore a rational decision. As the previous section has shown, this is handled differently in Delhi, Nashik and Kochi.

For new WWTPs, command and control instruments that require contractors of utilities to build energy efficiently are easier to implement. However, in the tender processes for these plants, specific technologies are already prescribed instead of setting only the required quality standards and leaving it up to bidders to come up with the most efficient technology. This reflects the tendency of engineering divisions and public utilities to choose what they already know (risk aversion). Furthermore, contracts and tendering often do not take the whole environmental footprint of the WWTP construction and operation over the whole lifecycle into account. Explicit green procurement could be helpful here.

Another procedural challenge for stakeholders, especially wastewater service companies, is the time that is taken from initial expressions of interest over detailed project plans, the actual tender opening and concessions to the beginning of construction. This varies between cities and depends to some extent on the size and type of project. Generally, however, the possibilities for inefficiency and political influence on the processes are high, making it hard for smaller players in the private sector to survive in the long-term:

> In these processes, there are a lot of possibilities for political influence, corruption. Between the DPR [detailed project report] and the tender opening, a minimum of two years pass in India, often three. It can be up to four or five years even.[26]

Apart from cost considerations, cross-sectoral integration is not part of planning processes yet; no specific governance instruments are used. From a nexus perspective, the current functioning of processes and the high number of agencies involved make systematic sector integration very difficult. In concrete local tender processes, taking energy and land into account is desirable when there is concrete, easy-to-see and understood pressure on these resources. Indeed, in some of these cases, it is already happening or energy and resource-efficient solutions are at least being discussed. Since each of the sub-sectors of the water/wastewater system still face a myriad of challenges in many towns, reducing the degree of complexity and focusing on getting the system running before introducing an even higher level of complexity by asking for systematic actor coordination with the energy and land/food (agriculture), sectors at federal, state and local levels might be more useful. Especially in cities and towns with hardly any wastewater systems in place, careful weighing of options is required: complex integration requirements could lead to inertia. Directly installing high-end energy-efficient, compact or combined systems may have higher maintenance requirements than conventional systems. Conventional systems may have lower costs in the short-term but higher costs in the medium to long-term (lifecycle and resource-wise).

25 Interview 4: 22 November 2015, Delhi.

26 Interview 3: 25 November 2015, Delhi.

4.4 Impacts of urbanization, land and water scarcity

The functioning of India's wastewater systems and the dynamics outlined in the previous section are influenced by local implementation contexts that foster or hinder decisions and developments in a municipality. Urbanization as an overarching issue constitutes both a driver and a barrier here. Land scarcity (Delhi, Kochi) and water scarcity (Delhi, Nashik) drive the diffusion of energy-efficient technologies and first changes in mindsets and investments in more sustainable solutions that integrate water, energy and land considerations. Regarding the implementation of regulations and incentives, a sequential, gradual approach is required.

The increasing urbanization puts municipalities and utilities under pressure, especially in unplanned areas. Often, houses are constructed first and sewage is only thought about later, even though pipes would need to go into the ground at the very beginning. Sometimes, sewage networks are laid too far from the houses, making the connection to the household very expensive. There are no mandatory requirements or tax incentives for house owners or construction agencies to plan sewage accordingly yet. In unplanned slum areas, narrow lanes make an ex post installation of sewage systems difficult. The continuous migration of people to urban areas forces municipalities and utilities to look for alternative solutions such as decentralized systems and modern septage tank systems. Moreover, there is hardly any data on the actual amount of sewage generated and the layout and location of leakages in the system are often not clear either.

Land scarcity caused both by urbanization and territorial factors (as in Kochi) have started to become a factor in urban planning processes. The availability of land as such, the possibilities for government to acquire sufficient amounts of it for large-scale infrastructure in locations not too far from the production of the wastewater, as well as the distances between supply, treatment and discharge options restrict the practical feasibility of traditional centralized wastewater system options. The costs for transporting sewage from households to small decentralized treatment plants are much lower.

The existence and increase of water scarcity forces many stakeholders to rethink their preferences and options. Freshwater is becoming a scarce good in several Indian states, making recycling and reuse of wastewater much more attractive:

> Water stress and availability of water are the drivers of change here in India. Only where there is no water available, for industry for example, things change and then they [regulating agencies and consumers] are open for recycled water.[27]

In water-scarce states and municipalities (including Delhi and Nashik), regulatory efforts requiring the use of treated wastewater are being made and more awareness for water saving exists. Groundwater extraction is more strictly regulated and dropping groundwater levels increase the costs for extraction. However, this does not necessarily coincide with a more efficient management and operation of wastewater treatment plants, as the Delhi example has shown.

Overall, implementation problems of regulations and standards are still widespread. A gradual, staggered approach towards the tightening of discharge standards would be useful

27 Interview 12: 25 November 2015, Delhi.

and is already practiced, for instance, in Maharashtra. The direct attainment of strict regulations and discharge standards without interim targets and time lags may be both unrealistic and discouraging for local actors. In terms of the implementation of the feed-in tariff for biogas, its practical relevance for combined heat and power production in WWTPs has been very limited up to now. The technical losses in the gas conversion processes (especially in older CHP technology) and the high electricity consumption of the WWTPs impede a practical effect of the feed-in tariff incentive. For combined solid waste and wastewater to energy plants such as in Nashik or possible future sludge to energy plants, the feed-in tariff is likely to become an important policy incentive.

5 Lessons learned

This report has aimed to shed light on existing drivers and barriers to the diffusion of energy-efficient, resource-efficient wastewater treatment technologies and the instruments and incentives that could foster integrated approaches to water and energy (and to some extent, land). While there is no specific nexus, governance, pricing and subsidies as well as mandatory discharge standards and electricity-saving regulations are found to be important instruments for technology diffusion. Standards and regulations only work if they are introduced sequentially and gradually tightened and if operation and maintenance controls are installed at the same time. Currently, the feed-in tariff for biogas hardly functions as an incentive for the wastewater sector. Regulatory gaps remain concerning taxation for sewerage when new buildings are constructed, the systematic integration of sewerage into water tariffs and the systematic setting of discharge standards, reuse standards and regulations for nutrient recovery from sludge. Due to 1) the high amount of non-revenue water; 2) vested interests; 3) the still dominant mindset towards centralized, conventional treatment solutions; and 4) a range of procedural difficulties, investments in energy-efficient, lifecycle-oriented wastewater systems that are most suitable for the concrete local conditions are still lagging behind. Concrete problem-driven thinking and cost-reduction arguments as well as land and water scarcity can work as triggers.

In other words, the systematic consideration of water, energy and land/food in policy and investment planning is only taking place to a very limited extent. When it does take place, this is in concrete, problem-driven situations at local level and not top-down. For the nexus approach, the following lessons learned can be drawn:

- The nexus concept in itself is regarded as too abstract by many stakeholders; it would be better to avoid it as a frame and replace it by the language spoken by stakeholders (e.g. ‘holistic’ or ‘cost-efficient, lifecycle oriented approach’).
- A top-down integration of governance sectors is unlikely to work, given the manifold difficulties in each sub-sector and the high number of actors and agencies at federal, state and local level.
- Putting more effort into getting one sub-sector to run properly before adding intersectoral integration requirements is more useful (additional complexity could lead to inertia).

- Concrete problem-oriented thinking and cost-reduction arguments at local levels open up possibilities for both energy-efficient technology investment and holistic approaches.
- The urban sewage master plans and toolkits for decision-making that are currently being developed are likely to be very useful and should be modified and replicated for smaller towns as well.
- Green procurement offers many possibilities to change the wastewater sector; a lifecycle-oriented mindset needs to be further promoted and to be reflected in tenders and cost calculations.
- Donor agencies could support smaller cities and towns in accessing finances available through national missions by providing technical help in preparing the required documentation.
- The high amount of greenhouse gases emitted through untreated wastewater and sludge could open up new investment and financing options (climate funds).

Overall, the current lock-in in much of India’s wastewater sector is likely to change only very slowly and gradually. On the one hand, many regulatory steps to create a supportive regulatory framework at federal level exist, but the adjustment and implementation at state and local levels still needs further work. On the other hand, the gathering of data for each town regarding the state of the whole water/wastewater network (amount of water, wastewater, state of pipes) and the fostering and protection of innovative approaches at local level could support the required change of mindset on a larger scale.

References

Allan, T. (2011, February). *The global energy water nexus: A solution & two problems*. Paper presented at AAAS Washington Annual Meeting 'Science without borders'. Washington, DC: American Association for the Advancement of Science.

Allouche, J., Middleton, C., & Gyawali, D. (2015). Technical veil, hidden politics: Interrogating the power linkages behind the nexus. *Water Alternatives, 8*(1), 610-626.

Amerasinghe, P., Bhardwaj, R.M., Scott, C., Jella, K., & Marshall, F. (2013). *Urban wastewater and agricultural reuse challenges in India* (IWMI Research Report 147). Colombo, Sri Lanka: International Water Management Institute.

Bakker, K. (2003). Archipelagos and networks: Urbanization and water privatization in the South. *The Geographical Journal, 169*(4), 328-341.

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., Steduto, ...Yumkella, K.K. (2011). Considering the energy, water and food nexus: Towards an integrated modeling approach. *Energy Policy, 39,* 7896-7906.

Budds, J. & McGranahan, G. (2003). Are the debates on water privatization missing the point? Experiences from Africa, Asia, and Latin America. *Environment & Urbanization, 15*(2), 87-113.

Copeland, J. (2014). *Energy-water nexus: The water sector's energy use*. United States Congressional Research Service, 3 January.

Central Public Health and Environmental Engineering Organisation. (2013). *Manual on sewage and sewerage, 2013*. Delhi: Government of India, Ministry of Urban Development.

Deutsche Gesellschaft für Internationale Zusammenarbeit. (2014). *Waste to energy project co-fermentation of organic waste and septage for energy production in Nashik* (Factsheet Nashik). Delhi: Author.

Deutsche Gesellschaft für Internationale Zusammenarbeit. (2016). *Introducing city sanitation plans: Practitioner's manual*. Delhi: Author.

Deutsche Gesellschaft für Internationale Zusammenarbeit/Corporation of Cochin. (2011). Draft city sanitation plan. Cochin, India: Author.

Dhakal, S., Shrestha, S., Shrestha, A., Kansal, A., & Kaneko, S. (2015). *Towards a better water-energy-carbon nexus in cities* (Policy Brief LCD-O1). Kobe, Japan: Asia Pacific Network for Global Change Research.

Fuenfschilling, L., & Truffer, B. (2014). The structuration of socio-technical regimes: Conceptual foundations from institutional theory. *Research Policy, 43*(4), 772-791.

Fuenfschilling, L., & Truffer, B. (2016). The interplay of institutions, actors and technologies in socio-technical systems – An analysis of transformation in the Australian urban water sector. *Technological Forecasting & Social Change, 103,* 298-312.

Geels, F. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy, 33,* 897-920.

Geels, F. (2006). The hygienic transition from cesspools to sewer systems (1840-1930): The dynamics of regime transformation. *Research Policy, 35,* 1069-1082.

Infrastructure Development Finance Company. (2011). *Water: Policy and performance for sustainable development India* (Infrastructure Report 2011*)*. Oxford: Oxford University Press.

Kapshe, M., Kuriakose, P.N., Srivastava, G., & Surjan, A. (2013). Analysing the co-benefits: Case of municipal sewage management at Surat, India. *Journal of Cleaner Production, 58,* 51-60.

Leck, H., Conway, D., Bradshaw, M.J., & Rees, J. (2015). Tracing the water-energy-food-nexus: Description, theory and practice. *Geography Compass, 9(8)*, 445-460.

Marin, P. (2009). *Public-private partnerships for urban water utilities: A review of experiences in developing countries.* Washington, DC: The World Bank.

Markard, J. (2011). Transformation of infrastructures: Sector characteristics and implications for fundamental change. *Journal of Infrastructure Systems, (ASCE) 17*, 107-117.

Maurer, M., Rothenberger, D., & Larsen, T. A. (2006). Decentralised wastewater treatment technologies from a national perspective: At what cost are they competitive? *Water Science and Technology: Water Supply, 5*(6), 145-154.

Molle, F., Mollinga, P., & Wester, P. (2009). Hydraulic bureaucracies and the hydraulic mission: Flows of water, flows of power. *Water Alternatives 2*(3), 328–349.

Mukherji, A., Shah, T., & Giordano, M. (2012). *Managing energy-irrigation nexus in India: A typology of state interventions* (Water Policy Research Highlight 36). Anand, India: International Water Management Institute.

Muller, M. (2015). The 'nexus' as one step on the road to a more coherent water resource management paradigm. *Water Alternatives, 8*(1), 675-694.

Never, B., & Kemp, R. (forthcoming). *Developing green technologies and phasing them in.* Draft chapter for PAGE network Report "Green industrial policy for developing countries". United Nations Environment Programme /United Nations Industrial Development Organization /International Labour Organization.

NJS Engineering Services. (2015). *Draft guidance note for promoting municipal wastewater reuse and reclamation in India*. Delhi: Author/Japan International Cooperation Agency.

Rodriguez, D.J., Delgado, A., DeLaquil, P., & Sohns, A. (2013). *Thirsty energy* (Water Papers No. 78923). Washington, DC: The World Bank.

Sato, T., Qadir, M., Yamamoto, S., Endo, T., & Zahoor, A. (2013). Global, regional, and country level need for data on wastewater generation, treatment and use. *Agricultural Water Management, 130,* 1-13.

Scheumann, W., & Hensengerth, O. (2014). *Evolution of dam policies: Evidence from the big hydropower states*. Berlin: Springer.

Schiffler, M. (2015). *Water, politics and money: A reality check on privatization*. Berlin: Springer.

Singh, P, & Kansal, A. (forthcoming). *Accounting energy use and GHG emissions for urban wastewater infrastructure*. Mimeo.

Starkl, M., Brunner, N., Amerasinghe, P., Mahesh, J., Kumar, D., Asolekar, S.R., Sonkamble, S., ...Sarah, S. (2015). Stakeholder views, financing and policy implications for reuse of wastewater for irrigation: A case from Hyderabad, India. *Water, 7*(1), 300-328.

Sugam, R., & Ghosh, A. (2013). *Urban water and sanitation in India: Multi-stakeholder dialogues for systemic solutions*. New Delhi, India: Council on Energy, Environment and Water.

Vedachalam, S., Geddes, R., & Riha, S. (2016). Public-private partnerships and contract choice in India's water and wastewater sector. *Public Works & Management Policy, 21*(1), 71-96.

Villamayor-Tomas, S., Grundmann, P., Epstein, G., Evans, T., & Kimmich, C. (2015). The water-energy-food nexus through the lenses of the value chain and the institutional analysis and development frameworks. *Water Alternatives, 8*(1), 735-755.

Zimmer, A., & Sakdapolrak, P. (2012). The social practices of governing. Analysing waste water governance in a Delhi slum. *Environment and Urbanization Asia, 3,* 325-341.

Publications of the German Development Institute/ Deutsches Institut für Entwicklungspolitik (DIE)

Studies

90 Brüntrup, Michael, Katharina Becker, Martina Gaebler, Raoul Herrmann, Silja Ostermann, & Jan Prothmann. (2016). *Policies and institutions for assuring pro-poor rural development and food security through bioenergy production: case studies on bush-to-energy and Jatropha in Namibia* (204 pp.). ISBN 978-3-88985-681-4.

89 von Haldenwang, Christian, Alice Elfert, Tobias Engelmann, Samuel Germain, Gregor Sahler, & Amelie Stanzel Ferreira. (2015). *The devolution of the land and building tax in Indonesia* (123 pp.). ISBN 978-3-88985-673-9.

88 Abdel-Malek, Talaat. (2015). *The global partnership for effective development co-operation: Origins, actions and future prospects* (409 pp.). ISBN 978-3-88985-668-5.

[Price: EUR 10.00; publications may be ordered from the DIE or through bookshops.]

Discussion Papers

11/2016 Mueller, Benjamin, & Alexandros Ragoussis. (2016). Minorities and trade: what do we know, and how can policymakers take it into account? (19 pp.). ISBN 978-3-96021-000-6.

10/2016 Stephenson, Sherry, Alexandros Ragoussis, & Jimena Sotelo. (2016). *Implications of the Trade in Services Agreement (TiSA) for developing countries* (49 pp.). ISBN ISBN 978-3-88985-689-0.

9/2016 Niestroy, Ingeborg. (2016). *How are we getting ready? The 2030 Agenda for Sustainable Development in the EU and its Member States: analysis and action so far* (64 pp.). ISBN 978-3-88985-688-3.

8/2016 Paulo, Sebastian, & Stephan Klingebiel. (2016). *New approaches to development cooperation in middle-income countries: brokering collective action for global sustainable development* (13 pp.). ISBN 978-3-88985-687-6.

7/2016 Zander, Rauno. (2016). *Risks and opportunities of non-bank based financing for agriculture: the case of agricultural value chain financing* (48 pp.). ISBN 978-3-88985-685-2.

6/2016 Scarlato, Margherita, & Giorgio d'Agostino. (2016). *The political economy of cash transfers: a comparative analysis of Latin American and sub-Saharan African experiences* (18 pp.). ISBN 978-3-88985-686-9.

5/2016 Ragoussis, Alexandros. (2016). *Government agoraphobia: home bias in developing country procurement markets* (23 pp.). ISBN 978-3-88985-684-5.

4/2016 Mbeva, Kennedy Liti, & Pieter Pauw. (2016). *Self-differentiation of countries' responsibilities: Addressing climate change through intended nationally determined contributions* (43 pp.). ISBN 978-3-88985-683-8.

[Price: EUR 6.00; publications may be ordered from the DIE or through bookshops.]

For a complete list of DIE publications:
www.die-gdi.de