Closing the water loop: Reuse of treated wastewater in urban India

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Foreword

India's urban population is growing at a fast pace and is expected to be approximately 50% of the total population by the next decade. While it can be argued that this can provide economic benefits, it also puts utilities under pressure to supply potable quality drinking water to the population. This will also impact the ability of utilities to service the demand of commercial and industrial outfits. In addition to the challenges in meeting the demand, this may also lead to further increase in water tariffs in order to subsidise residential water supply.

This situation warrants utilities and the government to ensure optimal use of available water resources while duly addressing the social, economic and commercial considerations. Institutionalising the reuse of treated wastewater can help utilities in addressing this challenge in an effective manner.

In this context, PwC is pleased to present this white paper on the urban wastewater sector. The paper aims at highlighting the need for developing wastewater reuse as a sector, identifying the interventions that could help in the development of this sector and also identifying suitable structures that can help in mainstreaming the implementation of wastewater reuse projects in the country. The structures have been arrived at after considering technical, financial and economic aspects of wastewater treatment, non-potable water usage in the urban scenario, with focus on industrial water usage and the risks associated with implementation of reuse projects.

This study is an outcome of stakeholder consultation with utilities, technology providers, industry experts and is supplemented by extensive research, involving review of successful projects in the country and international case studies. The structures proposed in this paper have evolved after multiple iterations of possible structures, keeping in view the nascent stage of this sector in the country, willingness of private sector participation across the value chain of wastewater reuse, financial viability and learnings from some of the existing successful reuse projects, etc. Although the implementation structures have been developed considering the potential to attract private sector investment, it is essential for the government to focus on the broader objective of developing the sector, while identifying the viable nodes of the value chain that can be developed on a public-private partnership (PPP) basis.

We hope this publication triggers the thought process of policymakers, implementing agencies, funding agencies, technology providers and other relevant stakeholders for institutionalising the reuse of treated wastewater.

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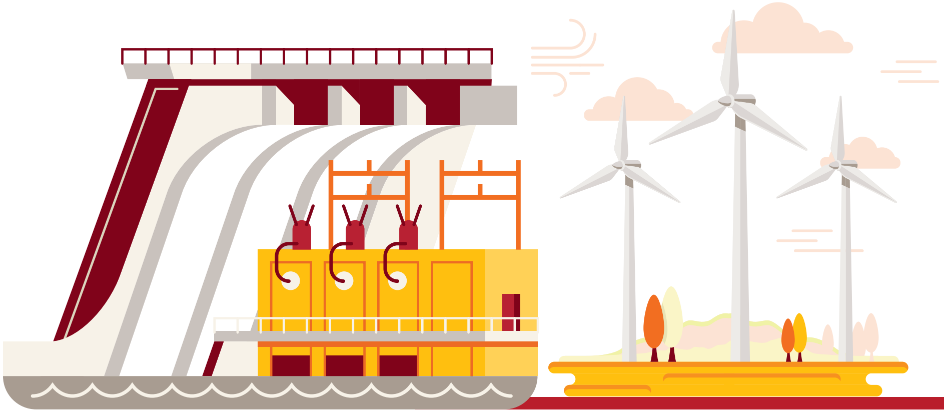

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Preface

The wastewater sector has traditionally been a slow-moving market driven by compliance with regulation. The advent of wastewater reuse changes the sector to one generating a valuable product—safe and reliable water supply. This opens up the possibility for new project structures and inflows of private investment and provides powerful incentives to devote more resources to develop promising technologies. Indian entrepreneurs are taking note of these opportunities and are seeking ways to work with the government and other private partners to support the growth of this nascent market together and, in so doing, contribute to the sustainable development of this sector in India.

There are three forces that are propelling the business case for reuse of treated wastewater in India. First and foremost: water security. At present, this issue ranks high in the minds of policymakers in India with several cities facing water crises. During periods of supply scarcity, household demand takes precedence over industrial demand, potentially leading to supply restrictions for industrial users, therefore leading to lost output. In this context, the advantages of reclaimed water as a more robust 'climate-proof' source of water supply for the industry are becoming increasingly compelling.

Secondly, reuse of treated wastewater is getting strong support from government policy. It is an important element in the ambitious plan to clean up the River Ganga, a flagship initiative of the ruling government (Clean Ganga Mission), and is also included in other urban policies and their related funding streams. The central government has committed to provide initial financing to get projects off the ground. The long-term strategy is to shift towards covering operating costs through user fees. Adding a revenue-generating water reuse component to a project boosts a project's financial viability and reduces the burden on public finances. Accordingly, government policies are also aligning to support the development of treated wastewater reuse as a financially sustainable sector.

Finally, by signing the Paris Agreement on climate change in April 2016, India has signalled its concern for the sustainable use of natural resources. Water reuse fits well with these broader environmental goals, helping, as it does, to conserve scarce resources and to promote efficient use. Industrialists and other private players have an important role to play in taking forward this agenda.

With this paper, we hope to bring these valuable opportunities to the attention of policymakers and companies and help in focussing on the ongoing discussions between these parties to accelerate the growth of wastewater reuse in India.

1

Motivation and scope of the paper

Introduction

Water stress has become a perennial concern in most Indian cities. With a growing population, the per capita availability of water has dropped from 1,816 cubic metres in 2001 to 1,545 cubic metres in 2011.[1] The latest census reported that only 70% of urban households have access to piped water supply. The average per capita supply to these households is well below the recommended 135 litres per day in many cities.[2]

India is expected to add approximately 404 million new urban dwellers between 2015 and 2050.[3] This rapid urban growth will be linked with higher industrial output and greater energy demand. There is a domino effect here, with water demand from households, industries and power plants growing simultaneously and adding to the urban water stress. This is particularly visible in industrial metros such as Chennai, Bengaluru, and Delhi, where acute water shortage has driven up the cost of fresh water production and industrial water tariffs.

To mitigate the severity of this impending crisis, there is a need for innovative alternatives to fresh water. Reuse of treated wastewater or reclaimed water is one such alternative that is gaining currency. Pilot wastewater reuse plants are already in operation in many states in India.

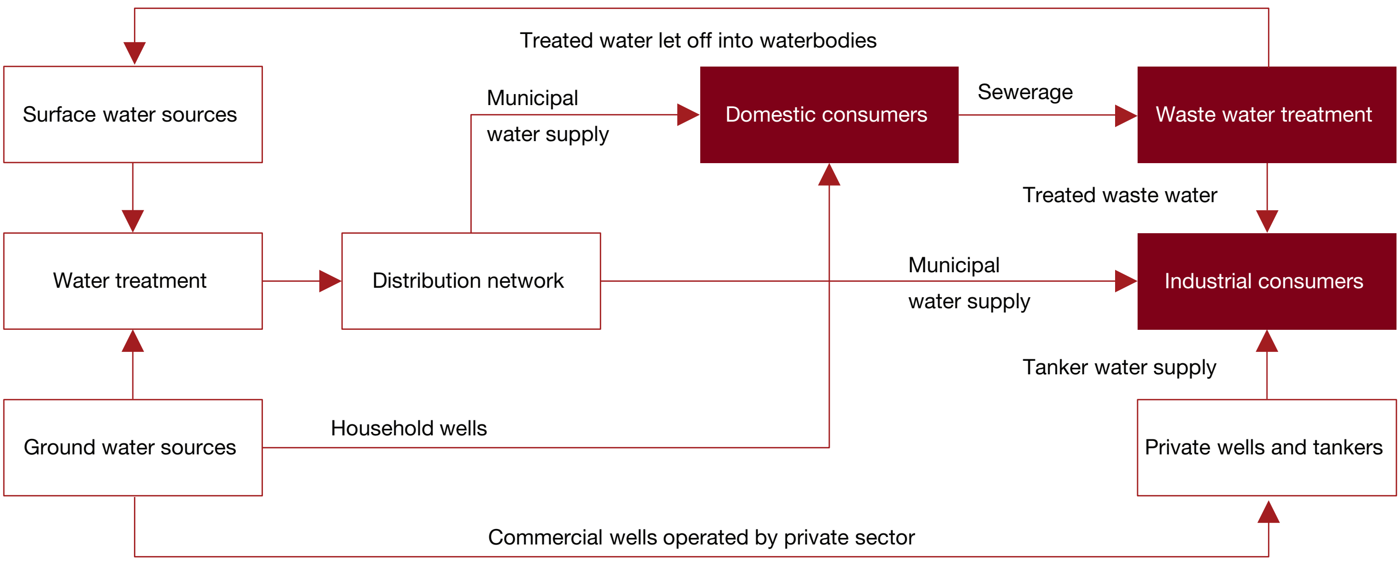
This paper highlights the key considerations while developing such projects to ensure viability and sustainability. We focus on projects in which municipal sewage is treated for supply to industrial customers, which we believe have immediate potential in the Indian market. Other structures are possible—industrial effluent could be used for input water, and the reclaimed water could be used for agricultural or domestic purpose—but these project structures will take longer to gain traction in India.

Why reclaimed water for industry?

A simple schema of reuse of reclaimed water by industries in a city is presented in the Figure 1 which also presents alternative sources of water available to industries, showing clearly how reclaimed water could augment freshwater sources and mitigate water stress. Reclaimed water can be an ideal choice for industrial use for the following reasons:

- The quality of reclaimed water can be tailored to meet the needs of the industry.

Figure 1: Schema of the industrial reuse of reclaimed water in a city.



1. Ministry of Water Resources, Press Information Bureau (PIB), http://pib.nic.in/newsite/erelease.aspx?relid=82676
2. Census 2011, Government of India
3. World Urbanisation Prospects 2014, United Nations (UN), New York

- In many cities, reclaimed water could be cheaper than standard piped water supplied by the utility. With industrial tariffs trending upwards, utilities are facing increasing pressure to recover costs, and reclaimed water will be increasingly competitively priced.
- Industries are usually clustered in the outskirts of cities so that distribution of reclaimed water may be comparatively inexpensive.
- Reclaimed water is a reliable source of supply under conditions of scarcity. If water availability is insufficient to meet the demand, utilities must prioritise supply to households. This forces industries to rely on private water suppliers.
- Stricter regulation of groundwater abstraction is being introduced. In some areas, bans on groundwater use by industries are being introduced.

International experience

Reuse of reclaimed water is well established in many countries. In Windhoek, Namibia, reclaimed water is used as the main source of potable water. Globally, reclaimed water is primarily used for non-potable uses. Two leading examples of urban wastewater reclamation for industrial use are presented below.

Singapore's NEWater[4]

Reuse of treated wastewater is popular in many water-starved cities across the globe. Singapore's success in using treated wastewater (referred to as NEWater) for industrial supply is a good case in point and is relevant to the discussion on water supply and reuse of treated wastewater in India.

Singapore imports water from Malaysia, and has very limited sources of water within its boundaries. Since 1958, the country has consistently sought to improve its water security by improving rainwater harvesting and through source diversification. Reuse of treated wastewater is one of the four 'national taps', alongside desalination, rainfall and imports. NEWater contributed towards one-third of the water supplied in Singapore.

Treatment process and plants: NEWater plants use an advanced tertiary treatment process that has three stages—microfiltration/ultrafiltration, reverse osmosis, and ultraviolet treatment. The quality of NEWater meets the standards of freshwater from the catchment lakes.

Reuse approach: NEWater is directly supplied to industries to meet the non-potable water demand, which accounts for 55% of the total water demand. Only a small proportion of NEWater is used to augment freshwater in reservoirs for indirect potable reuse.

By 2060, it is estimated that approximately 70% of water demand in Singapore will be non-domestic, and NEWater capacity would be expanded to provide for 55% of total water demand.

Viability of NEWater: The cost of producing NEWater is in the range of 0.30–0.50 SGD per cubic metre, lower than the cost of producing desalinated water (0.50–1.00 SGD per cubic metre). This has led the government to focus on development of NEWater systems as a viable strategy to achieve self-sustenance in the water sector. The tariff for NEWater is set at 1.9 SGD per cubic metre and reflects the full life cycle cost of producing and supplying NEWater.

There are four NEWater plants in Singapore with a combined production capacity of 531 million litres per day (MLD). A further 227 MLD is expected to come online by the end of 2016. Two plants are operated by the Public Utility Board (PUB), the public water utility of Singapore, while the other two are operated by private companies under the Design Build Own Operate (DBOO) model. There are some interesting lessons from the way these reuse projects are structured:

- *Technology and performance risks* are largely transferred to the private sector as the private company is responsible for design, construction and operation of the NEWater plants under a long-term contract. This ensures that total expenditure over the contract period is minimised without compromising on the quality or process efficiency.
- *Market risk* is completely managed by PUB as it provides a buy-back guarantee for treated water at defined quality levels. This risk allocation seems reasonable as the utility will be more effective in functions such as managing market demand, tariff setting, and revenue collection.
- *Payment to the private sector* player includes a fixed component or availability payment based on treatment capacity, and a variable component that is linked to the quantity of treated water supplied. Revenue risk is therefore shared by PUB and the private sector player.
- There are *step-in agreements* between the financiers, concessionaire and PUB. In case of default, financial backers can step in to manage or appoint new operators, and PUB can step in to ensure service continuity.

Many of these design insights are relevant to reuse projects in India as well.

4. Public Utilities Board Singapore 2015

Wastewater reuse in Beijing[5]

Since 2008, Beijing has actively invested in water reuse projects and, as a result, reclaimed water accounted for approximately 22% of total water supplied in 2014. Beijing has developed a wastewater reuse network that includes many treatment plants with capacities ranging from 60 kilolitres per day (KLD) to 60 MLD. The larger plants are owned and operated by the local government.

Beijing has also taken the PPP route to develop reuse projects. However, given that the water tariffs are very low, these PPPs cannot be financially viable, but for the generous subsidies and annuity payment that the local government offers. The government has plans to improve the financial viability of reuse projects by increasing tariff in the long run, and until then, capital subsidies will be a prerequisite for inviting private sector participation in such projects.

Driven by resource scarcity, China is marching ahead in terms of adding reuse capacity, and targets to have a combined capacity of approximately 4,370 MLD from its many reuse plants.

Experience in India

Reuse of wastewater is not new to India. Chennai Petroleum Corporation Ltd (CPCL) built a wastewater reuse plant in 1991. However, the idea did not garner mainstream appeal for several reasons:

- There is no clear policy environment to encourage and support reuse projects.
- With low sewerage network coverage and insufficient Sewage Treatment Plant (STP) capacity, there hasn't been much Secondary Treated Water (STW) available for reuse.
- STW is being used for agriculture in many places. Redirecting STW for industrial reuse may face opposition from the public.
- Most cities apply a differential tariff for domestic and industrial water consumers, with the industrial tariff significantly higher than the domestic tariff. Revenue from industrial water supply, in such cases, is used to cross subsidise cost of supplying water to households. By switching to reclaimed water, utilities will have to forego some of this additional revenue
- Surplus freshwater availability in some smaller cities and towns has made utilities complacent and over dependent on freshwater sources.

These conditions that held back the development of reuse of reclaimed water are fast changing. The Government of India has emphasised reuse of reclaimed water in many urban development schemes such as Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Swachh Bharat Mission, Smart Cities Mission and the Namami Gange programme. Sewerage coverage and treatment capacity are consistently improving across urban India. The cost of wastewater reuse technologies is falling. As a result, reuse projects have been undertaken in some cities such as Nagpur, Surat and Visakhapatnam. However, some of these projects are still facing challenges.

One of the challenges faced in this sector is the structure for implementation of wastewater projects through private sector participation. This knowledge paper also outlines what we believe to be potential project structures to attract private investment in the sector and promote water reuse.

At this stage in the development of the market in India, the private sector has a vital role to play in introducing innovative technologies and raising finance. As the market develops, other project structures can be introduced.

The models have been developed based on a review of the policy environment, analysis of technology and market factors, and financial viability analysis. Primary data for the analysis was collected through interviews with technology companies, developers and officials. A financial model for the same was developed using this data. For the model, we assumed a 50 MLD tertiary treatment system that produces Grade III level water as output, built at a capital cost of 26.52 million USD and incurring an operating cost of 0.26 USD per kilolitre of STW. The effective quantity of treated water output is assumed to be 75–80% of the STW input. The capital cost does not include the cost of land, conveyance mains and STP.

Sections 2, 3 and 4 of this paper set out the main findings of the review of the policy environment and the technical and financial analysis respectively. The concluding section highlights some more considerations that could support the development of treated waste-water reuse in India.

5. Jensen, O. & Yu, X.(2016). Wastewater reuse in Beijing: An evolving hybrid system, IJWRD paper

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Policy environment

Treating waste-water started as a social obligation to protect the environment from pollution and prevent outbreak of disease. Currently, it is being accepted as a reliable source of non-potable water that can help address water scarcity issues in cities. To this effect, reuse of reclaimed water has been given an important place in most urban development programmes.

Institutional mechanism and policy environment

Water is a state subject and the provisioning of water and wastewater services to households is a responsibility entrusted to local governments. The regulatory environment for reuse of reclaimed water is influenced by many central, state and local government agencies, as shown in the following figure. The key policy notes that support wastewater reuse are as follows:

- The Water (Prevention and Control of Pollution) Act of 1974 has given discharge norms for sewage and industrial effluents. Industries and local bodies are mandated to treat wastewater to the defined quality level before discharge.
- The National Urban Sanitation Policy (NUSP), 2008, endorses reuse of reclaimed water, and recommends a minimum of 20% reuse of wastewater in every city.
- The National Water Policy (2012) recognises reuse of reclaimed water as an important factor for meeting environmental objectives and suggests preferential tariff to incentivise reclaimed water over freshwater.

Though wastewater reuse is endorsed in many policies and programmes, there is a lack of clear guidelines and frameworks to support the implementation of such projects. As a result, the reuse of reclaimed water for non-potable purposes continues to face challenges. The problem is further exacerbated by limited enforcement of the restriction to extract groundwater for non-potable purposes. More detailed policies and stronger enforcement is needed for wastewater reuse projects to be viable.

Supporting wastewater reuse

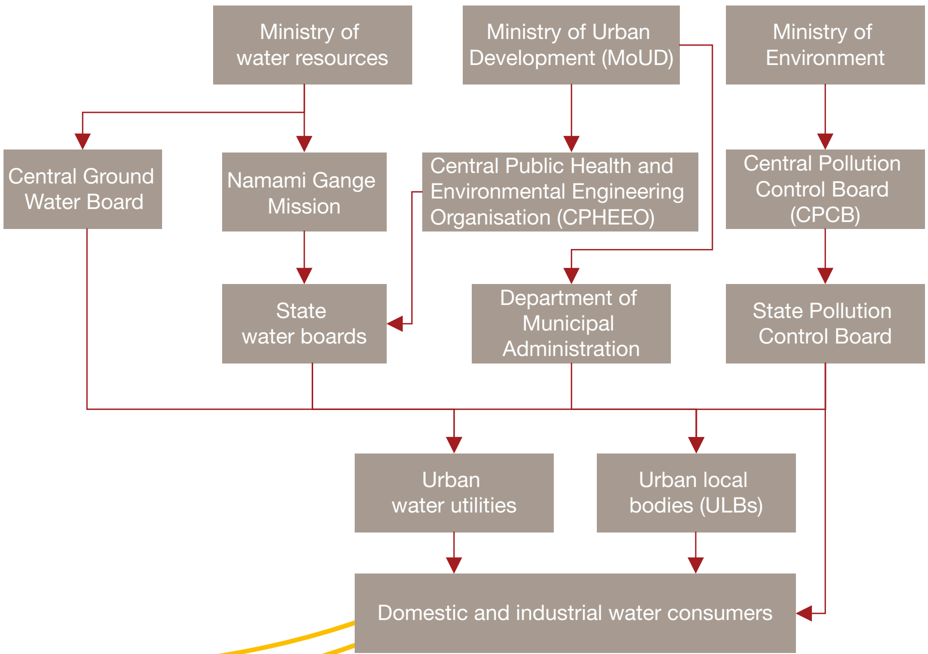
In the last few years, the Government of India has taken many concrete steps to promote reuse of wastewater. It began with regulating industrial water consumption and enforcing mandatory water reuse targets for industries.

Cities have set their own, more stringent targets. For example, Delhi has adopted aspirational reuse targets to treat and reuse 25% of total sewage produced by 2017, and increase the same to 50% by 2022, and to 80% by 2027.

Against this background, municipalities across India have started to pursue reuse projects. Some of these utility-led reuse initiatives in the recent past are as follows:

- Surat Municipal Corporation (SMC) built a 40 MLD reuse plant in 2014 to supply reclaimed water to Pandesara Industrial Estate.
- Chennai Metro Water Supply and Sanitation Board (CMWSSB) awarded a PPP-based reuse project contract in 2016 to develop 45 MLD reuse capacity on the design, build, and operate (DBO) model to supply non-potable water to industries.

Figure 2: Schema of the municipal wastewater reuse



- Bengaluru's water utility has built a 10 MLD tertiary treatment plant at Yellahanka that supplies reclaimed water to Bengaluru International airport.
- Maharashtra Generation Company (MAHAGENCO) and Nagpur Municipal Corporation (NMC) have jointly invested in a reuse project where treated water from an STP is further treated and used as cooling water.
- A review of these and other existing reuse projects reveals some common design features:
- Most successful PPP-based reuse projects involve a single large consumer (end user).
- The cost of treatment is bundled with cost of conveyance.

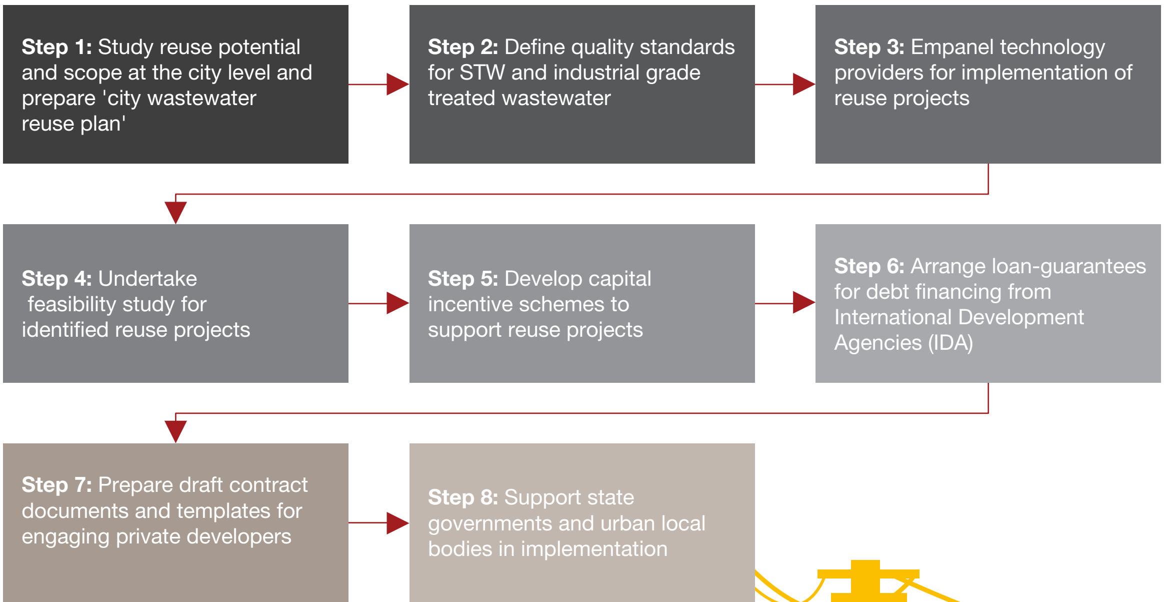
Successful reuse projects, such as the Nagpur Tertiary Treatment Reverse Osmosis (TTRO) plant, and the Bamroli TTRO, needed significant capital subsidies to become viable.

The initiation of these projects suggests that businesses are interested in this sector and that reuse projects can be viable if prepared and structured correctly and backed by supportive policies and institutions.

Many other municipalities, however, have limited interest in reuse. This may be partly because they are not familiar with the innovative technologies and project structures involved and lack the resources to develop these projects on their own. The central government could boost the roll-out of water reuse by putting in place a national-level scheme, like the one illustrated in Figure 2. The first step would be to provide support for city-level scoping studies, leading to more detailed feasibility studies and assistance in contract preparation.

A key purpose of the feasibility studies will be to establish the technology and market parameters of the project. Getting these parameters right will be critical to its success. The next section highlights some of the key considerations.

Figure 3: Government scheme to support urban wastewater reuse



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Technology and market considerations

Defining levels of treatment

Before discussing the design of reuse projects, it is important to clearly define the processes involved in producing reusable water from sewage. For the purpose of this paper, we have assumed that municipal wastewater will consist of effluents from households and is homogeneous in composition.

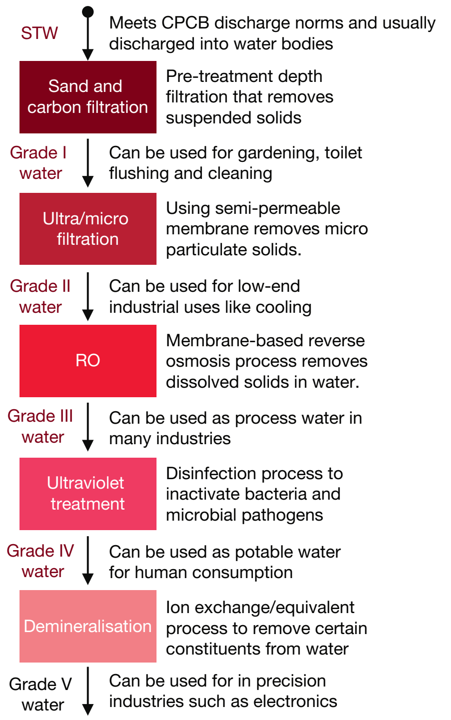
The conventional process for sewage disposal involves transportation of sewage from households through a drainage network to a central STP where it undergoes primary and secondary treatment. The objective is to sufficiently remove contaminants so that the effluent (referred to as STW) can be safely discharged into waterbodies.

Reuse projects shall further treat the STW to remove residual particles and microorganisms and make reclaimed water fit for industrial use. The secondary and tertiary treatment technologies and the targeted quality at each level is given below.[6]

The three alternative technologies for secondary treatment produces three quality variants of STW. The activated sludge process (ASP) produces water that just meets the discharge norms defined by the CPCB. Sequential batch reactor is an advanced secondary treatment process better at removing nutrients such as nitrogen and ammonia from sewage.[7] Membrane bio reactor technology is further advanced and efficiently reduces TSS level. The quality of output from MBR is better than SBR but still cannot be directly used by industries.

The STW is used for agriculture in many peri-urban areas. However, for our defined purpose of industrial reuse, STW has to be tertiary treated to produce industrial grade water. The stages of treatment and the corresponding grades of industrial water produced are shown below:

Figure 4: Classification of treated wastewater



Source: Inputs from Eco Protection Engineers Pvt. Ltd, Chennai.

The treatment stages and their specific uses are not rigidly structured as it will depend on factors such as quality of the influent (concentration of minerals, etc.) and treatment technology used at previous levels. For some of the treatment stages, more than one technology option is available. In such cases, reuse projects must choose the most cost-effective technology option,

Table 1: Treatment technologies and output quality

Level	Secondary			Tertiary
Influent	Raw sewage			SWT
Technology	ASP	SBR	MBR	UF/MF+RO
BOD	<30	<5	<5	<2
COD	<250	<50	<50	<50
TSS	<50	<10	<1	<1
N	~45	<10	<10	--
PH	~5	<1	<1	--

BOD: Biological oxygen demand
COD: Chemical oxygen demand
ASP: Activated sludge process
MBR: Membrane bio reactor
SBR: Sequential batch reactor
TSS: Total suspended solids
PH: Potential of hydrogen
N: Nitrogen
UF: Ultra filtration
MF: Micro filtration
RO: Reverse osmosis

6. Hingorani, P.(2011). Economics of municipal sewage water recycling and reuse in India, India Infrastructure Report
7. Kader, A. (2009). Comparison study between SBR and ASP, a paper presented at the IWT Conference

given the quality of the influent, to produce the desired quality of output. The demand profile for industrial water in the region and corresponding technology choices will determine the treatment cost. For the purpose of this paper, we have considered sand filtration, microfiltration, and reverse osmosis as major stages in the tertiary treatment process to produce industry grade reclaimed water.

Supply-side potential

About 80% of water supplied for domestic use should ideally come back as wastewater for further treatment and reuse. However, this assumption does not truly reflect the reuse potential in India as only a small fraction of wastewater generated by households is treated and available for reuse. There are 522 operational sewage treatment plants (STPs) in India with an installed treatment capacity of 18,883 MLD as on 2013–14. The wastewater generated and treatment capacity across urban centres are shown below:

Table 2: Wastewater treatment capacity in India

	Wastewater generated (MLD)	Wastewater treated (MLD)	%
Metros	15,644	8,040	51%
Class I	19,914	3,514	18%
Class II	2,697	234	8%
Total	**38,255**	**11,788**	**31%**

Source: CPCB report on performance of STPs 2005–06[8]

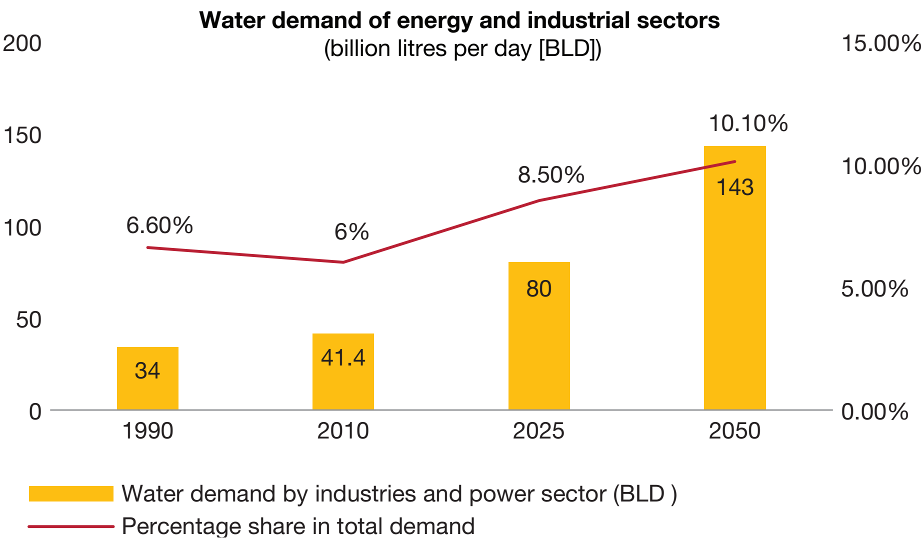
The STP capacity in 2005–06 was only sufficient to meet 31% of treatment required. The capacity has increased by 60% to 18,883 MLD by 2015. Given the rate of urbanisation, the demand-supply gap in sewage treatment capacity will continue to be two-thirds of total demand.

The average utilisation ratio of the STPs in India is less than 60%. Inadequate sewerage network and power shortages are major reasons for this low utilisation. This in effect reduces the quantum of wastewater available for reuse by almost 50%. There are other viability factors such as vicinity to industrial clusters, quality of output, and availability of competing alternatives to reclaimed water, that affect the treated water reuse potential.

Market potential for reuse

India is transitioning from an agrarian economy to an industrial and services-based economy and two major trends of this era are industrialisation and rapid urbanisation. As the industrial footprint expands, the demand for energy and water grows. It is estimated that, between 2010 and 2050, the energy sector's water demand will grow by 3.7 times and that of manufacturing sector will grow by 2.2 times. The projected growth in industrial water demand is presented below:

Figure 5: Industrial water demand in India



Source: India Infrastructure Report, 2011, Chapter 18

If the annual utilisable freshwater remains the same over the next 34 years, water available for the industrial and energy sectors, after accounting for the growing human demand, will drop from 491 billion cubic metre to 135 billion cubic metre in 2050. Reuse of reclaimed water will then be the most reliable source of water for these sectors.

However, this entire water demand will not translate into demand for reclaimed water. In order to service this demand using reclaimed water, there is a need to address certain key design considerations that impact the viability of reuse projects. These include availability of treated water in the vicinity of industrial areas, access to alternative water sources, water tariff, and conveyance distance, which will add to the capital and operations and maintenance (O&M) cost of reuse projects and also impact water tariff at the industry gate. Some of these key viability are discussed in the following section

8. CPCB report on 'Performance evaluation of sewage treatment plants', August 2013.

4

Viability considerations

For reuse projects to be successful, the following are some of the key viability factors that need to be considered during project design and structuring:

1. Water tariff competitiveness

For reuse projects to be viable, the treated water should be cost-competitive when compared to alternative options available to industries.

The conventional sources of water for industries include municipal water supply, private tankers, and direct extraction from freshwater sources. The least cost option is direct groundwater extraction which is regulated in most cities. Thus, the most reliable option for industries is municipal water supplied by utilities. The industrial water tariff in most metropolitan cities and industrial towns range from 0.29 USD per kilo litre (KL) to 2.21 USD per KL. The weighted average of industrial water tariff is approximately 0.68 USD per KL

In times of water scarcity, when municipal water is in short supply, industries resort to buying water from private water tankers which are priced at 0.83 USD per KL and above.

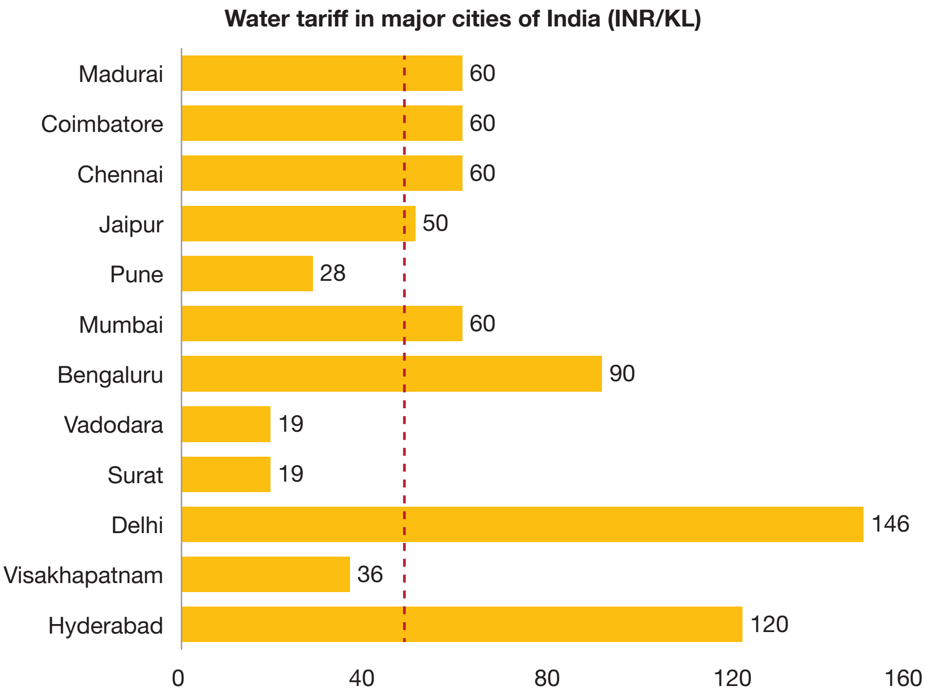
Design input

Given the price range for water from alternative sources, treated water at the end user point has to be priced at less than 0.76 USD per KL in order to be competitive.

2. Quality of reclaimed water

The quality of water required by industries varies significantly as discussed in the previous chapter.

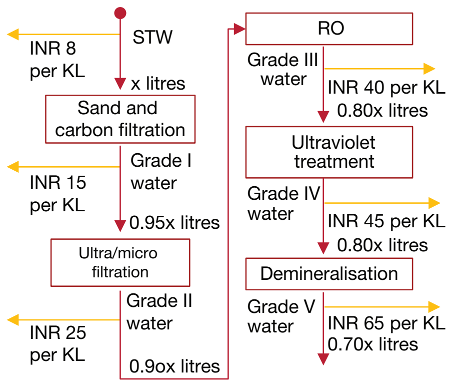
Figure 6: Water tariff in major Indian cities



Market demand will be a key determinant for choosing treatment level and technology. It is important to assess the industrial profile and the quality of water demand at a location before designing the wastewater reuse plants.

An estimated variation in costs of reclaimed water based on levels of treatment is presented below.

Figure 7: Cost of producing treated wastewater



Source: Inputs from Eco Protection Engineers Pvt. Ltd, Chennai.

These estimates include capital and operating costs of the treatment facility but do not include cost of conveyance. In addition to the incremental costs associated with higher levels of treatment, the volume of reclaimed water decreases as we move through the stages and this affects the revenue potential of reuse projects. For example, for 100 litres of STW supplied, up to 80 litres of Grade III water is produced after reverse osmosis.

It is not economical to lay multiple pipelines to supply different grades of water. A single treatment level must therefore be chosen upfront when designing reuse projects with multiple users, and demand for water at this quality level should be assessed. If conveyance costs are covered by end users, or if water is purchased at plant gate, then it may be viable to produce different grades of water quality.

Design input

Reuse projects must study the market demand profile and choose a specific grade of water that will provide maximum financial returns. In this regard, Grade III water produced after RO stage seems to be the most feasible option for reuse systems.

3. Cost of conveyance

The conveyance of STW to reuse plants and reclaimed water to industries requires underground pipelines. It is estimated that, on a non-undulating surface, laying these pipelines would cost approximately 0.46 million USD per km.[9] In addition, further costs will be incurred for the O&M of the pipelines. These high costs erode the cost advantage of reclaimed water over standard piped water supply from the utility. Land gradation between the treatment plant and customers is another determinant of the overall cost of conveyance of reclaimed water to industries.

It is difficult to recover conveyance costs through customer tariff while keeping the tariff lower than the standard rate for industrial piped supply. Despite these issues, there are advantages in bundling treatment and conveyance components, as it is easy to design and manage, and helps ensure quality and continuity of service.

Design input

Conveyance can be bundled with treatment in reuse projects, but the risk involved in building and operating conveyance infrastructure is steep. Therefore, this conveyance cost has to be subsidised either upfront or through annuity payments to the private operator.

4. Quality of STW

The composition of sewage generated and collected by a secondary treatment plant, and the quality of secondary treatment process is another variable that affects the viability of reuse projects.

Under ideal conditions, municipal sewage collected from households is a homogeneous influent. But given the inadequate sewerage network, sewage is collected through open drains where it is often mixed with industrial waste from small-scale industries such as tanneries and dyeing units. This adds high chemical load to sewage and affects the composition of the influent to STPs. This necessitates more expensive treatment at the tertiary level to produce industry grade water. The quality of secondary treatment process in municipal plants is also not consistent. Most STPs are not designed to manage peak flows, leading to overflows and contamination of treated water by untreated sewage. Poor design, power shortages, and mismanagement by operators also lead to STP downtime, resulting in variable effluent quality. This in turn has cost implications for the reuse plant, which uses the STW as an influent, with knock-on effects on operating and potential capital costs.

Design input

Reuse project contracts could be bundled with STP O&M contracts.

One way of ensuring more consistency in STW quality would be to bundle O&M of the secondary plant into the reuse contract. This also entails risks—variability in the composition of raw sewage, legacy design issues—and the difference in capacity between the STP and the reuse plant will mean that it is difficult to recover the STP O&M cost through the reuse tariff. A separate O&M fee could be paid instead to the company that operates both STP and the reuse plant.

5. Disposal of residual effluent

The residual wastewater produced after reverse osmosis process accounts for 12–15% of total STW treated and has very high concentrations of unwanted compounds and microbial load. This residual output does not meet environmental discharge norms of the CPCB. The safest method of disposal is through a marine discharge or evaporative watering. The cost of disposing residual effluent from the RO plant will in turn depend on the distance from the marine discharge area and dewatering technology used. The viability of reuse projects in non-coastal cities will depend on cost of disposal of residual effluent.

Design input

Capital subsidies may be required to support reuse projects where cost of disposal of residual water and sludge is very high.

Taking into account the viability considerations discussed here, we have identified three potential transaction models for wastewater reuse projects

9. IDFC quarterly report on 'Wastewater reuse', 2011

5

Engaging private sector for reuse

Rationale for private participation

Wastewater reuse projects are technically complex, and require huge capital investments. Considering this, engaging private sector environmental firms to design, build and operate plants could be a good option and the same has two major advantages:

- **Technology migration:** Membrane-based tertiary treatment technology is new to India. There is potential for significant efficiency gains from technology and process innovations which can be better delivered by private sector firms.
- **Capital Investments:** Tertiary treatment and reuse projects require huge capital investments. Given the high opportunity cost of public funds, private sector participation will lead to inorganic growth in wastewater treatment capacity.

PPP project structures can be defined based on how roles and risks (design, finance, asset ownership, construction, operation, revenue, etc.) are shared between public and private entities. Based on the viability considerations discussed earlier, there could be three project structures for implementing reuse projects under the PPP mode.

The PPP structures we set out here could be designed to produce Grade III water for industrial use. In these models, the O&M of source STP and the conveyance cost of STW and reclaimed water are not recovered from the water tariff.

I. Three party fixed price (TPFP) model

This model is designed to use STW from existing STPs (owned by utilities) and would treat it to produce industry grade water for a single entity, which could be one industry or an industrial zone. These three players—utility, developer, and industrial entity—enter simultaneously into long-term contracts, assuring supply of STW and reclaimed water at predetermined rates and quality levels. The key stakeholders in this project design are as shown in Figure 8:

1. **Water utility/ULB:** Provides land either within existing STP or outside for installation of tertiary treatment modules. The utility is the enforcer of the contract terms and will also ensure quality compliance and oversee operations. The utility makes a net annuity payment to the private developer to ensure a guaranteed minimum revenue for the developer. Utility also has rights to levy penalties on the private developer for delays, quality non-compliance, and breach of contract.
2. **Private sector developer:** Invests in building treatment and conveyance infrastructure to the customer gate, and operates the same for a fixed period, after which it transfers the assets to the utility. The developer could also be given responsibility for the operation of the STP.

Figure 8: Schema of the TPFP model

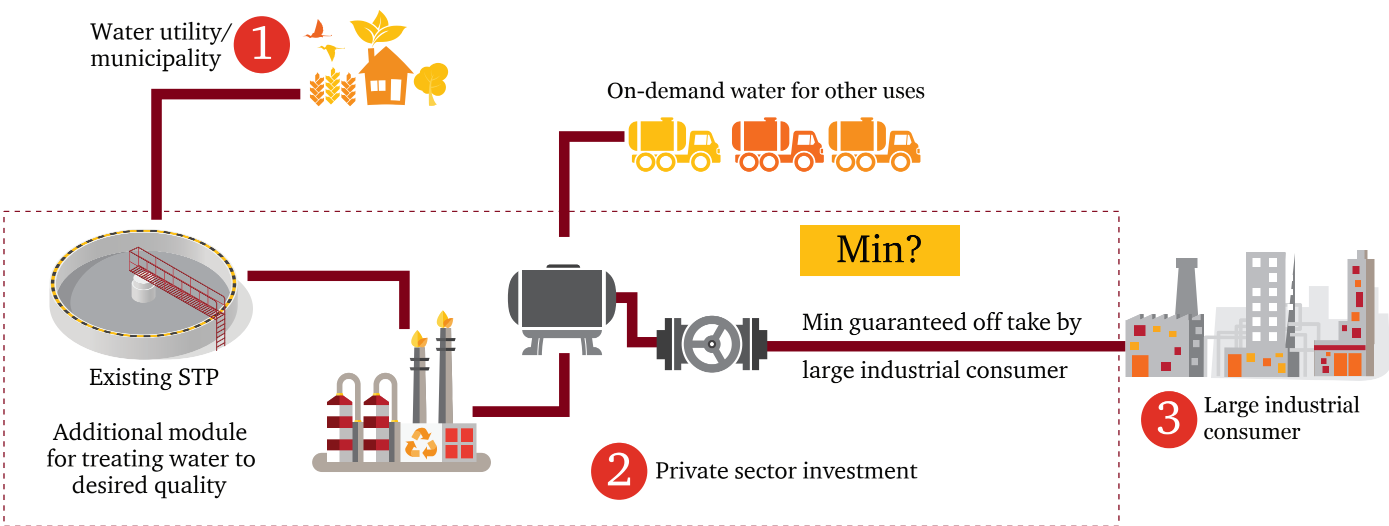
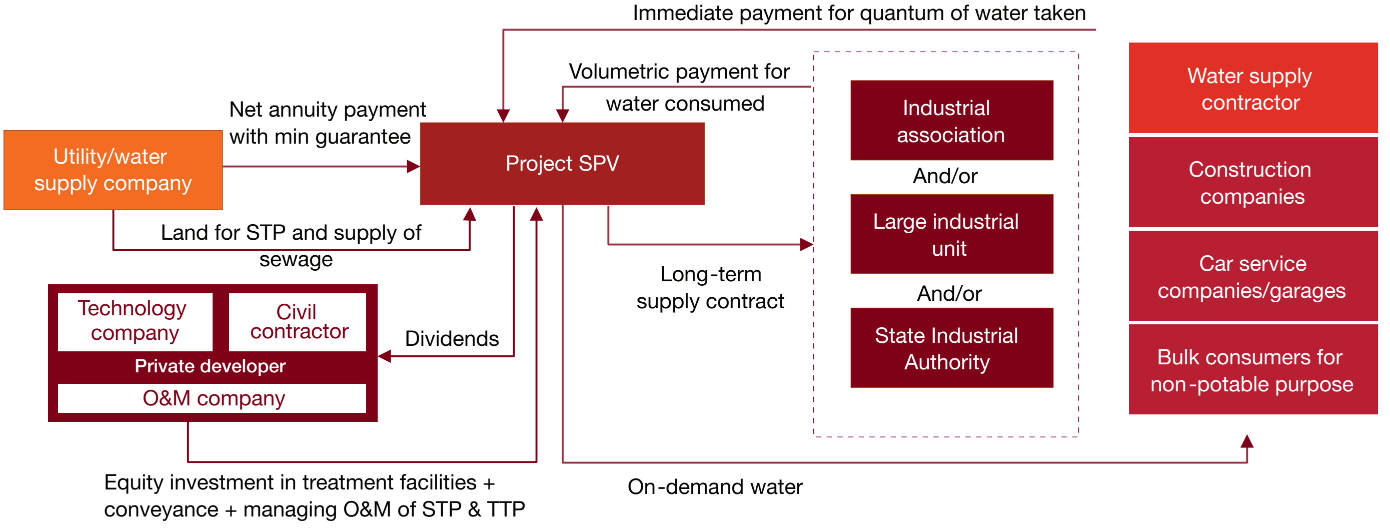


Figure 9: Project structure of the TPFP model



3. **Industrial bulk consumer:** A single entity with large water requirement that provides assured purchase guarantee for reclaimed water at a predefined quality, quantity, and tariff.

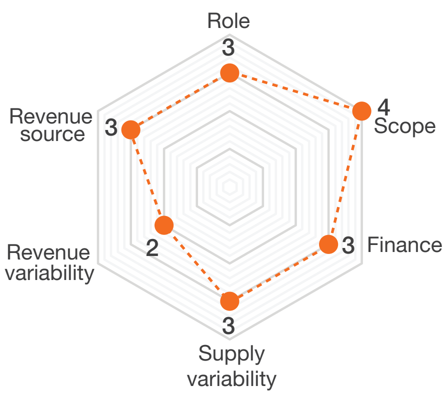
The private developer would study the quality of STW from existing STP and would choose the most appropriate technology mix for the treatment plant based on the need of the bulk consumer. A Special Purpose Vehicle (SPV), fully owned by the private developer, will be established. The utility will provide land for reuse plant and transfer operational responsibility to the SPV. The private developer will operate the TTRO plant and will supply the agreed quantity of treated water to the bulk consumer, and will also sell additional treated water available in bulk or retail to other consumers. After the end of the term period, the SPV shall transfer all assets back to the utility.

Bid parameter: The minimum guaranteed annuity payment can be the bid parameter.

Payment terms: The industrial consumer will pay volumetric charges to the utility at a predefined tariff rate. The utility will pay only the differential between minimum guaranteed revenue (bid parameter) and water charges collected from bulk and other consumers, as shown in Figure 9.

Risk allocation: With a water purchase guarantee from bulk consumers and minimum guaranteed revenue from the utility, the revenue risk and revenue source risk are low for the private developer, as shown in Figure 10. Given that the developer also operates the STP, its supply quality and variability risk is moderate. The finance risk rests with the private player but is moderate as the project remains viable without heavy subsidies.

Figure 10: Risk profile of the TPFP model



Advantages and challenges: In addition to the benefits of reuse discussed earlier, this project structure offers specific advantages to all stakeholders involved:

- Leverages existing infrastructure and improves quality of treatment by engaging private sector for end-to-end treatment process
- Reduces revenue risk of private developer as there is assured purchase commitment from the bulk industry consumer
- In a fixed price model, the private developer has incentives to improve efficiency by investing in technology upgrades.

The key challenge in this model will be in clearly defining the contract terms between all three stakeholders. The price discovery process for determining reclaimed water tariff must adopt a long term view and should sufficiently address cost escalation risk. Dependence on a single buyer also poses revenue risk which is hard to mitigate in this model.

Financial viability analysis: For a 50 MLD reuse plant that produces Grade III industrial water to become viable without any capital subsidy, the reclaimed water tariff may need to be a minimum of 0.73 USD per KL.

This three-party fixed price model could be successful when there is a utility with an operational STP and a large industrial water consumer but neither has the capacity to build and operate a tertiary treatment system. The utility then engages a treatment company to invest in tertiary treatment and supply industry grade water to the large industrial consumer at the lowest price.

II. Reuse utility buy-back model

This model assumes that the utility shall enter into a buy-back agreement with the private developer and shall offtake the predefined quantity of reclaimed water from the tertiary treatment plant (TTP) at predefined quality levels. The model excludes the end user and has only two key stakeholders, as shown in Figure 11:

1. **Water utility/ULB:** Provides land either within existing STP or outside for installation of tertiary treatment modules. The utility is the enforcer of the contract terms and also ensures quality compliance and supervises operations. The utility supplies STW/sewage, as the case may be, and provides full buy-back guarantee for reclaimed water produced by the developer.
2. **Private sector developer:** Invests in building treatment and conveyance infrastructure to the utility's water storage reservoir, and operates the same for a fixed term, after which it transfers the assets to the utility. The ideal private developer is a technology provider who also has civil construction and O&M capabilities.

Utilities will be responsible for collection of sewage and will build, own and operate the sewers up to the STP. If the project involves new STPs, the construction will be financed by the water utility, either directly or through annuity payments to the private developer. Likewise, the O&M of the STP and conveyance network will be financed by the utility and implemented by the private developer.

This model also assumes that water utility is best suited to engage with industrial consumers and distribute non-potable water. The utility will either use the existing distribution network, or build and operate new distribution mains for supplying reclaimed water to industries. The quality of inflowing sewage and that of the reclaimed water will need to be clearly defined in the contract, which will be the basis for choosing the right technology option for the TTP.

Payment terms: The utility will pay pre-fixed annuity fees to the private developer that will cover the O&M cost of the STPs and conveyance mains, and contribute to the recovery of capital costs of the conveyance mains. The annuity fees can be performance-linked to ensure timely completion of infrastructure works, service levels at STP and TTP plants, etc. The utility will pay volumetric charges to the private developer, as shown in Figure 12.

Bid parameter: The tariff for reclaimed water at the plant gate could be the bid parameter.

Risk allocation

The most significant risk in this model lies with the utility's ability to pay for the reclaimed water without any major delay.

The other important risk comes from dependency on the utility to meet its obligation to efficiently collect and transport sewage from households to the STP.

Advantages and challenges: The key advantages of this transaction model are:

- This model with buy-back guarantee from the utility reduces revenue risks of the private developer as it is not required to identify potential buyers for reclaimed water.
- This model can be easily implemented as an add-on to all new STP projects and also all new large-scale industrial water supply projects;
- As the utility is the final beneficiary, it can subsidise tariff by providing capital subsidies

Figure 11: Schema of the TPFP model

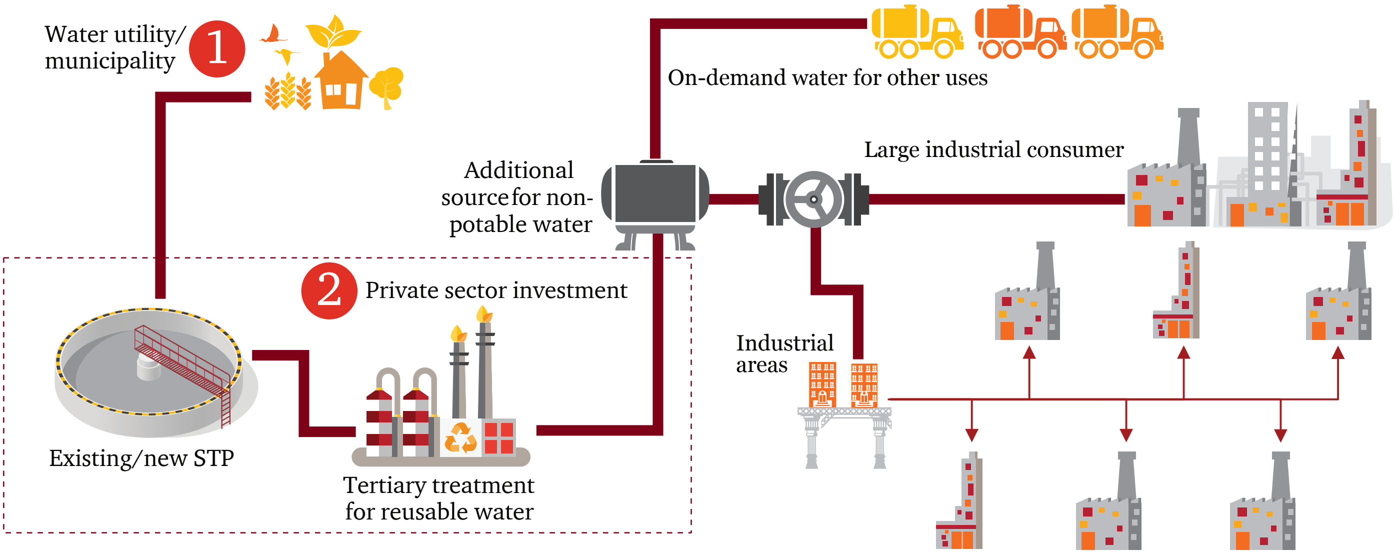
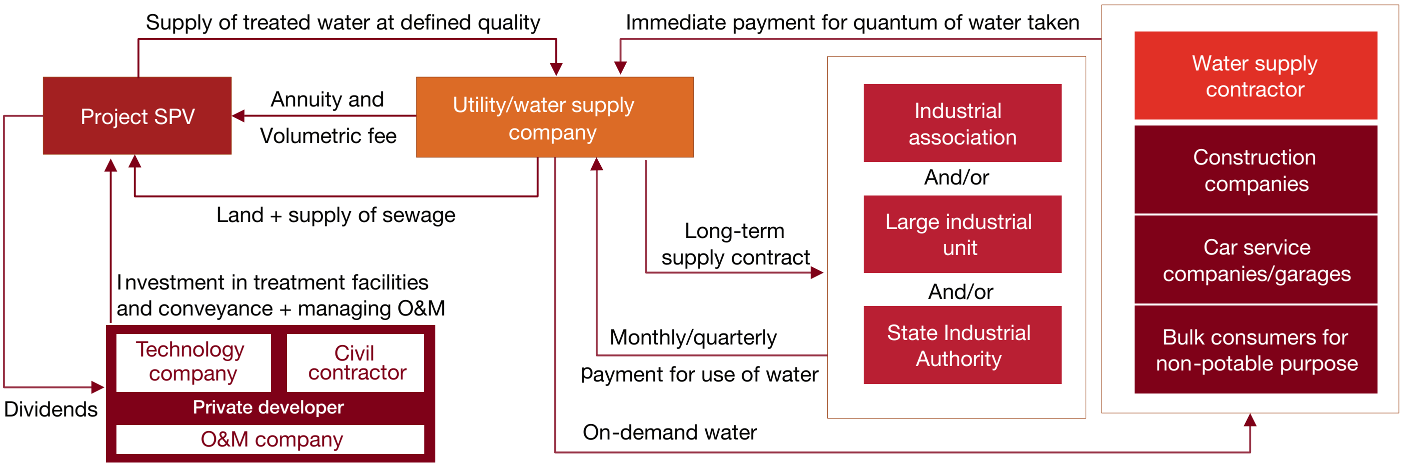


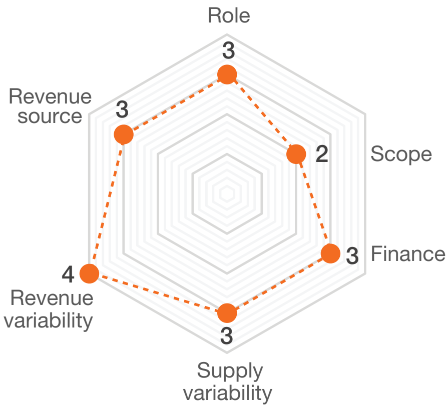
Figure 12: Project structure of the RUB model



The challenges of the model will be:

- Mobilisation of public funds by the water utility/ local government for developing STPs and conveyance infrastructure.
- The financial condition of the water utility and its ability to pay will influence the private sector's willingness to participate in the project. Some form of payment guarantee arrangements may make the project attractive for the private sector.

Figure 13: Risk profile of the RUB model



Financial viability: In this model, as the utility enters into a buy-back arrangement, a capital subsidy of 50% can bring down water production cost to approximately 0.56 USD per KL for the utility. Without subsidy, the cost of producing water will remain at 0.73 USD per KL which is the full cost of producing treated water at plant gate.

This model is applicable when there is shortage of industrial water and the utility turns to reclaimed water to augment its water sources. The reuse plant in Surat or Nagpur is an ideal example where reused water is supplied to industrial areas. This model can also be used when a new STP or an industrial area is being developed in a water-stressed region.

III. End user reuse PPP (EURP) model

This model is designed such that the end user industry will purchase STW from utilities at a defined cost and will invest in conveyance mains. The end user industry will then hire the services of a technology provider to build and operate the reuse plant for its internal consumption.

There are two main stakeholders in this model as shown in Figure 14:

1. **Water utility/ULB:** Supplies STW from existing STPs to the end user industry and charges a minimal volumetric charge for the STW supplied at the end user point.
2. **Private sector developer:** Invests in conveyance mains to bring STW to its premises and in TTP to produce industry grade water for its own consumption.

The end user industry will engage one or more technology firms through performance-based service contracts for the construction and operation of the conveyance mains and treatment plants. The design risk here will lie with the end user company that will have to undertake a detailed study of its water demand and technology options available.

Bid parameter: These projects are usually not awarded on a competitive bidding basis and will have to be awarded based on case by case basis. The end user industry will apply for STW supply, and will enter into discussions with the utility to seek approval for supply of STW and determine the charges to be paid for the same.

Payment terms: The end user industry will pay monthly or quarterly volumetric charges for the STW that it takes from existing STPs. The end user will also pay the technology providers a service fee for O&M of the treatment plant and service mains which can be estimated based on the volume of water supplied, as shown in Figure 16.

Risk allocation: There are two significant risks in this model. The first risk is that supply variability both in terms of quality and quantity is high, since the utility will be primarily responsible for the secondary treatment as shown in Figure 15:

Figure 14: Project structure of the end user reuse model

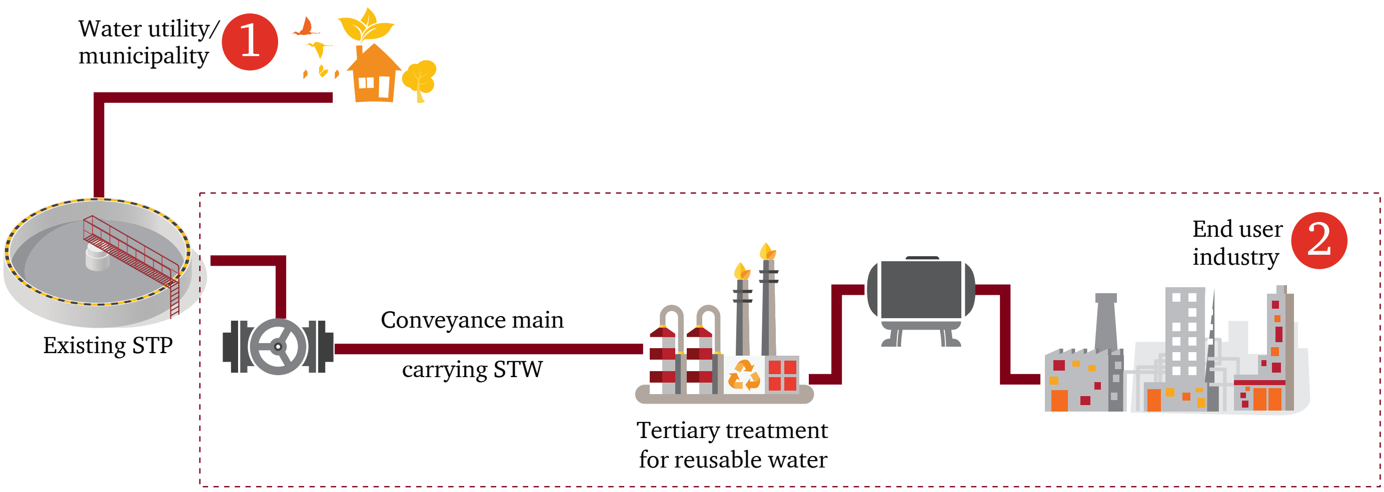


Figure 16: Schema of the EURP model

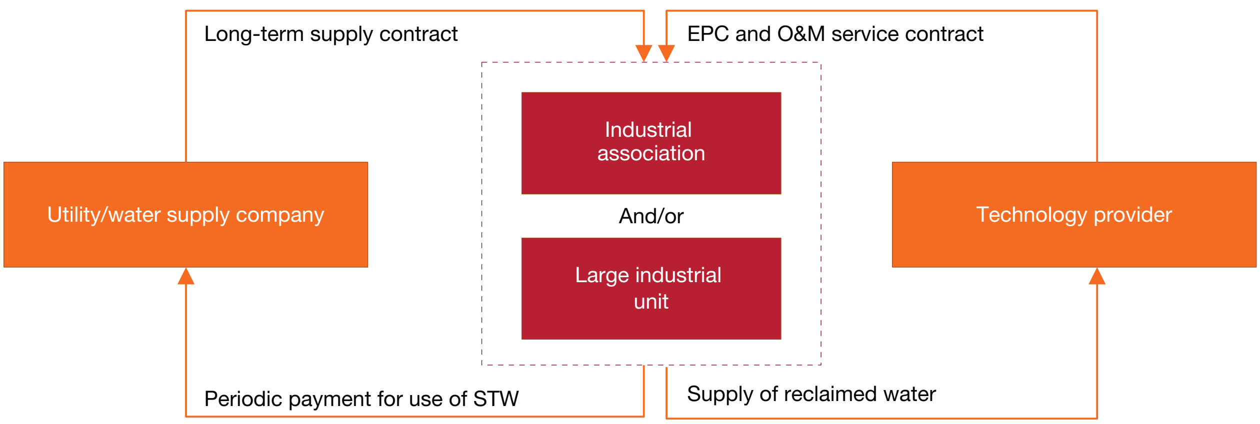
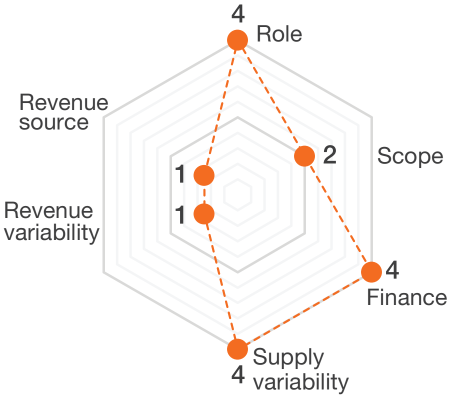


Figure 15: Risk profile of EURP model



The second risk stems from the fact that the end user is responsible for technical design, including choosing an appropriate technology option.

In terms of role definition, the end user takes the responsibility from conveyance to treatment, and, therefore, it is a high-risk effort from the end-user point of view.

Advantages and challenges:

- This model is entirely end user driven in terms of design and financing, therefore mobilising resources will be much faster for the project.
- The model provides greater financial benefit (realised as lower water costs) as there is no intermediary treatment company involved. Thus the reuse projects of this kind are competitive even in places where industrial water tariff is less than 0.76 USD per KL

The most significant challenge will be that such large consumers are limited in numbers and many of them are located further away from cities. This increases conveyance cost and in addition place administrative bottlenecks on execution. The other key challenge is to get the technology design right.

Financial analysis: When an end user industry opts to use reclaimed water (Grade III) and invests in a TTP plant, it can bring down the cost of water to 0.52 USD per KL, after servicing the debt raised for building the TTP plant.

This model is the most easily applicable amongst the three models suggested. It is suitable for industrial units (end users) such as power plants and fertiliser units that are water intensive and can invest in in-house reuse plants to meet their water requirements.

Implementing PPPs for reuse of treated wastewater

PPP models like the ones covered in this paper will need to be refined and tailored to local conditions but with willingness and commitment from the parties involved. There are reasons to believe that projects can be structured to achieve viability. Multiparty ‘upstream’ discussions, well before commercial negotiations on an individual project begin, can be very helpful. However, the immediate goals of closing contracts and commissioning plants should not overshadow the long-term policy objectives. Early consideration of certain issues could contribute to the sustainable development of the sector:

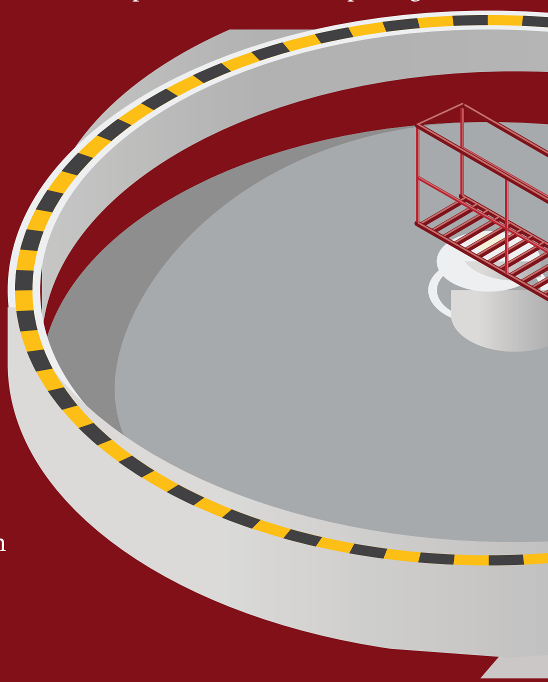
1. The rationale behind engaging in a PPP over traditional procurement must be clear and convincing. Without a strong case, backed up by sound method and reliable data, decisions made today about the use of scarce public funds will be vulnerable to challenges from policymakers and the public in the future. Value-for-money reviews and other studies may require considerable human and financial resources, but these costs are likely to be much lower than the costs of bidding, awarding and cancelling a PPP project.
2. Performance monitoring is essential in long-term PPP contracts to ensure that the benefits of the contract are shared fairly between the parties involved. Setting up effective monitoring mechanisms is challenging and needs to be addressed at an early stage in the PPP project. For example, contracts would ideally include clauses, requiring the private party to report periodically on performance, and trying to introduce reporting requirements ex post is likely to be difficult, if not impossible.
3. The rapid roll-out of wastewater and water reuse PPPs in India provides an excellent opportunity to introduce efficiency benchmarking. This will be particularly important in the early period of market development when most PPPs rely on a government annuity to cover operating and capital costs. With a national benchmarking programme, monitoring authorities will be able to assess efficient operating costs in a fair and transparent manner.
4. Larger PPPs that bundle together construction and operation of multiple assets, offer potentially greater efficiency gains than more limited projects, but there is a trade-off: few firms have the capacity and desire to develop these complex projects but the same radically reduces the number of potential bidders. Competitive tendering is essential to both getting public value from PPPs, and in protecting the company that does win from challenges to the validity of its contract in the future. A careful balance, therefore, needs to be struck between size, complexity and effective competition.

Conclusion

Like other infrastructure subsectors in India, the wastewater sector will be driven by government initiatives based on which the implementation models will be designed. Hence, sound policy and regulatory interventions by the central and state governments are a prerequisite for the launching of innovative reuse projects. Government interventions will need to focus on incentivising the use of reclaimed water and developing institutional support mechanisms. One important regulatory intervention will be to prevent industries from groundwater abstraction at a level that leads to over-exploitation. The current low cost of exploiting groundwater makes reuse unviable and at the same time irrecoverably depletes groundwater resources. In industrial areas where reclaimed water is made available, groundwater extraction has to be strictly regulated by either the water utility or the State Pollution Control Board.

To promote reuse, the central and state governments should jointly issue a national wastewater reuse policy with clear policy targets, setting out the legislative, regulatory and financial measures needed to achieve those targets. Furthermore, the Ministry of Environment and Ministry of Water Resources should together define quality norms for different grades of industrial water which will help standardise design of reuse systems nationwide. National level norms for water safety planning and risk management are also needed to build credibility for reclaimed water as a reliable alternative.

At the city level, a first step would be to produce an urban wastewater reuse plan, followed by detailed feasibility studies for individual projects. Utility-led reuse projects need to be planned with a compelling justification based on detailed industrial water demand assessment. This demand study would also help to define the level of treatment required and other design aspects involved. Utilities should also be required to prepare a financing plan for meeting recurring O&M expenses and a capacity development plan to train utility managers in operating reuse systems. State-level workshops could be organised to sensitise utility managers about water reuse covering technology options, new standards, policy incentives, implementation challenges, and best practices in procurement.



Historically, infrastructure development in the water sector has been fully funded by the Government of India. For PPP structures to evolve in this sector, significant government interventions (including the aforementioned) are required to create a favourable environment for private sector participation. Other fundamental conditions are already in place: strong local water companies interested in this opportunity, interest of international funding agencies in financing reuse projects, and an experienced advisory community. But beyond mere justification based on financial viability, the primary driver for government's support to reuse of wastewater should be rooted in the broader goals of building liveable cities, improving public health, and environmental sustainability.

Given the worsening water crises in many Indian cities, the moment has come for the government to engage efforts and resources in developing wastewater reuse to meet industrial water demand. It may be a tough road ahead for utilities and government to fast-track the necessary interventions, but the long-term benefits of reusing wastewater are substantial.

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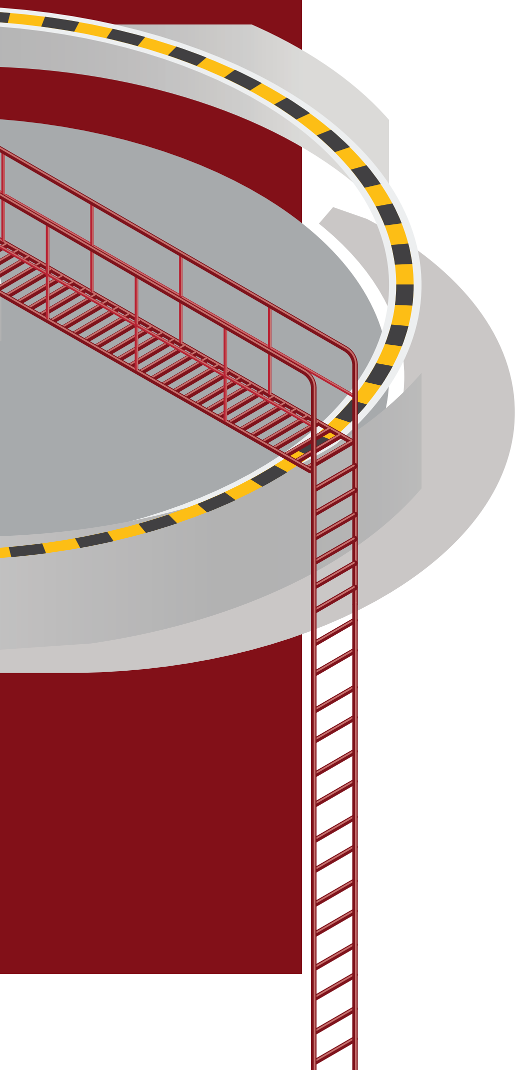

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