Circular Economy Pathways for Municipal Wastewater Management in India

Technical Report · July 2017

DOI: 10.13140/RG.2.2.31745.45926

3 authors, including:

Rudresh Kumar Sugam
Council on energy, environment and water

Kangkanika Neog
Council on Energy, Environment and Water

2030 Water Resources Group

INDIA

Circular Economy Pathways for Municipal Wastewater Management in India: A Practitioner's Guide

OCTOBER 2016

With the support of

Government of Hungary

Disclaimer, Rights and Permissions

About 2030 Water Resources Group

The 2030 Water Resources Group is a unique public-private-civil society partnership that helps governments to accelerate reforms that will ensure sustainable water resource management for the long term development and economic growth of their country. It does so by helping to change the "political economy" for water reform in the country through convening a wide range of actors and providing water resource analysis in ways that are digestible for politicians and business leaders. The 2030 WRG was launched in 2008 at the World Economic Forum and has been hosted by the International Finance Corporation (IFC) since 2012.

Acknowledgments

This report is supported by the 2030 Water Resources Group (2030 WRG), in conjunction with knowledge partner, Council on Energy, Environment and Water (CEEW) (http://www.ceew.in/). We wish to acknowledge the following individuals for their contributions to the document:

With the support of the Government of Hungary

GOVERNMENT OF HUNGARY

Contributors

Dr. Arunabha Ghosh (Council on Energy, Environment and Water)
Bastiaan Mohrmann, (2030 Water Resources Group)
Rochi Khemka (2030 Water Resources Group)

Authors

Rudresh Kumar Sugam (Council on Energy, Environment and Water) Abhishek Jain (Council on Energy, Environment and Water)
Kangkanika Neog (Council on Energy, Environment and Water)

Experts Consulted (see Annex II for details)

Shyam Asolekar (IIT-B), Rajesh Biniwale (NEERI), Kartik Chandran (Columbia University), Ranjana Ray Chaudhuri (TERI), Frank Heemskerk (Research and Innovation Management Services), A K Jain (independent), Priyanka Jamwal (ATREE), Ravikumar Joseph (World Bank), Suneetha D. Kacker (World Bank), Uday G. Kelkar (NJS Engineers), K Vijaya Lakshmi (Development Alternatives), Patrick Rousseau (Veolia), Rubinder Singh (PDCOR), Suhas P Wani (ICRISAT)

Peer Reviewers

Sudhi Mukherjee (IFC), Anand Jalakam (independent), Nadeem Khalil (Aligarh Muslim University)

Foreword

With rising spatial and temporal scarcity of water, municipalities are confronted with the challenge of identifying innovative yet cost-effective solutions to meet rising demands of urban, industrial, and agricultural communities.

Structured as a practitioner's guide and supported by the 2030 Water Resources Group, this publication aims to highlight the challenges and opportunities for stakeholders to develop circular economy solutions, targeting optimal utilization of scarce water resources. It provides a framework for urban local bodies, businesses, and communities to identify and optimize the nexus between water, energy, and agriculture.

The document builds upon global case studies to distil lessons relevant to the Indian context, including possible options for energy and resource recovery and wastewater reuse, among others. Drawing upon factors such as institutional and regulatory contexts, business cases, scale, participatory approaches, finance, and technologies, it provides a decision-making framework for prioritization of resource-efficient solutions.

The 2030 Water Resources Group (2030 WRG), hosted by IFC, is a unique public-private-civil society collaboration. We facilitate open, trust-based dialogue processes to drive action on water resources reform in water stressed countries in developing economies. The ultimate aim of such reforms and actions is to close the gap between water demand and supply by the year 2030.

2030 WRG wishes to acknowledge the inputs of all experts and reviewers, who have contributed to this document. We hope you find it of value.

Anders Berntell
Executive Director
2030 Water Resources Group/International Finance Corporation

Contents

EXECUTIVE SUMMARY 3

INTRODUCTION 6

METHODOLOGY 8

FINDINGS FROM CASE STUDIES AND EXPERT INTERVIEWS 10

Drivers for initiating wastewater management 10
Policies and regulations 10
Access to technology and finance 11
Scale of intervention 11
Management strategy and institutional framework 11
Consumer/public perception 12
Phases of deployment of wastewater management initiatives 12
Framework for participatory and integrated approach 12

TECHNOLOGY CHOICES: A TECHNOLOGY AND ECONOMIC ASSESSMENT TOOL 14

CONCLUSION 15

ANNEX I: Summary of Case Studies 16

ANNEX II: List of Experts Consulted to Develop this Guide 21

LIST OF FIGURES AND TABLES:

Figure i: Global cases demonstrating multiple utilization of wastewater 3
Figure 1: Spatial distribution of case studies continent-wise 8
Figure 2: Multiple utilization of wastewater 8
Figure 3: Categories of experts interviewed 9

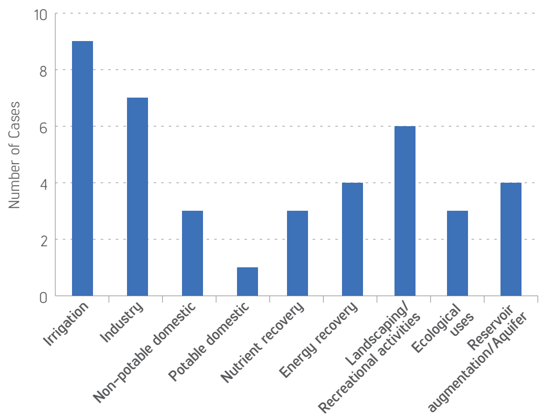
Executive Summary

Decreasing per-capita water availability and increasing pollution of fresh-water resources are huge challenges as India continues to grow economically. In urban areas especially, water resources are under significant pressure due to high water-demand patterns. The situation is worsening with rising demand due to increasing urbanisation. Almost 80 percent of water supply to municipalities flows back into the ecosystem as untreated wastewater, which is a critical environmental and health hazard.

According to a 2009 report by the Central Pollution Control Board (CPCB), India has the capacity to treat approximately 20,000 million liters per day (MLD), against a daily sewage generation of approximately 57,000 MLD. Moreover, most wastewater treatment plants do not function at maximum capacity and do not conform to the standards prescribed under the environmental (protection) rules for discharge into streams. Small and big towns, alike, are yet to appreciate the importance of separating storm water from sewerage networks, let alone separation of municipal sewage from industrial effluents. There are social, political, technical, and financial challenges, which have impacted efficient management of these plants and the wastewater sector.

However, with rising water scarcity and increasing water prices, wastewater treatment has the potential to mature as a profitable intervention. Instead of treating it as a waste to be disposed of, wastewater should be considered a resource for recycle and reuse. A paradigm shift from "use and throw" to a "use, treat, and reuse" approach is required. Such closed loop systems, and an approach that considers waste as a resource, also known as circular economy, when applied to the wastewater sector in India could yield significant positive impacts towards better water management in the country. That said, it should be emphasized that untreated wastewater use for irrigation is a common practice in India. But this practice comes at a cost. According to a scientific study (Grangier, Qadir, and Singh, 2012), the annual health cost per child in an untreated wastewater irrigated environment is around Indian rupees 4000/annum (~$60), which is 73 percent higher than for freshwater irrigated areas (Grangier, et al., 2012). This is in itself enough motivation to push for the cause of wastewater treatment and reuse.

Figure i: Global cases demonstrating multiple utilization of wastewater



Water-use patterns in cities are complex and the quality of water required for a particular use is unique. Along with the residential population, cities host industries and commercial sectors, which already pay higher tariffs for water, even with limited supply assurance. As much as 60 percent of major industries are impacted due to water scarcities. In addition to water supply augmentation, wastewater treatment offers new economic opportunities for energy and fertilizer recovery. That said, investment in wastewater treatment has associated risks as well. It is important to understand the underlying factors that will drive, facilitate, and sustain wastewater management interventions in India.

This practitioner's guide identifies relevant practices for India, based on the status of global thinking (17 global cases studied, see figure i above) on the adoption of a circular economy pathway in the wastewater sector. At this point, India is still to recognise and exploit the opportunity for wastewater circular economy. In several areas, untreated wastewater is used for irrigation, although there are cases of exemplary wastewater reuse and energy recovery. Nutrient recovery, again, is a practice that has not yet been attempted at recognizable scale in India.

Decision-making Framework

Based on the research findings and interviews, the authors have put together a series of factors that are critical to determine the feasibility of a successful circular economy intervention for wastewater management. The factors are arranged in a descending order of priority, as analyzed by the authors based on research and interviews. The factors have been summarized as a set of questions, which the practitioners (utility managers) need to explore. These questions will lead to a holistic overview of the context under which the wastewater reuse and recovery project can be considered.

Challenges	Opportunities/Solutions
1. Drivers for initiating wastewater management	
a. Is water scarcity a recurring problem in the area? b. Is non-compliance to water pollution standards causing nuisance and health impacts? c. Is water shortage limiting water equity in the area? d. Is water shortage limiting industrial growth in the area?	Water scarcity is the major driving factor triggering wastewater reuse. Water allocation for industries is currently on least priority in India, thus impacting industrial growth. Reclaimed water may thus be seen as a continual source of water supply for industries. There is also an opportunity to recover water for peri-urban agriculture.
2. Policies and regulations	
a. Are there supporting policies and regulations for developing wastewater management? b. Are there regulations that mandate industries to meet a certain portion of their water demand by using treated wastewater? c. Are there stringent regulations to curb pollution caused by wastewater?	Cities where regulations and policies concerning water pollution and wastewater reuse have been adopted could be targeted as suitable to undertake wastewater management interventions.
3. Access to technology and finance	
a. Is there enough land available to develop wastewater treatment infrastructure? b. Are there suitable funders for the initiative? If yes, how can finances be raised for the project? c. Are there suitable technology providers in the area? If yes, who? How have they performed in the past? What is the technology maturity level, and what is confidence level in the performance of technology? d. Are there potential buyers of treated wastewater in the region? If yes, who? And at what price? e. Is the project feasible? What is the net present value of the project? f. Is it possible to extract additional resources, energy, and fertilizer from the wastewater? If yes, at what cost? Is the additional cost justified against additional revenue from these resources?	Initial resources, land and finance, to set up a wastewater management system are high. Also, resource requirement would vary with the choice of technology, which depends on the demand and expected benefits. Therefore, in a city where there is dedicated funding and land allocated to develop a wastewater system, there is a strong case for a practitioner or utility to enter into wastewater management. Government budgets assigned for river rejuvenation, water resources augmentation, and pollution abatement should be seen as a potential source of funding for such initiatives. Moreover, wastewater treatment can be seen as a revenue stream. Treated wastewater, fertilizer, and electricity recovered from sludge are potential sources of income.
4. Scale of intervention	
a. What would make a better business case: operating in a small area or across the entire city? b. Is there a possibility of multiple small-scale interventions across the city? c. Will working at a decentralized level, for instance with resident welfare associations (RWAs) or ward commissioners, lessen financial and technical challenges?	Centralized systems work better as they have more opportunities to meet economies of scale. However, such systems are not easy to operate given the complexity of political and regulatory systems prevailing in India. Therefore, decentralized systems should be targeted as the starting points to enter into the sector. Of late, due to regulatory mandates and water shortages, decentralized wastewater management is being adopted at a fast pace in large apartments and commercial establishments. In the longer run, India should look forward to developing more decentralized solutions for commercial establishments and, at the same time, strengthen centralized systems.
5. Management strategy and institutional framework	
a. Who could be the main stakeholders to support such initiative? b. Can involving a private partner under PPP help achieve the objectives of the intervention?	According to the requirements of the interventions, there might be a need to involve an array of stakeholders. Government intervention would be crucial in providing land and other clearances as well as market regulations. Private sector will have to support public utilities in financing, revamping and constructing new infrastructure, and sustainable operation and maintenance. Involvement of NGOs and CSOs would be crucial in advancing awareness about wastewater-related negative health impacts and the benefits of treating and reusing. Industrial associations should be kept in the loop when negotiations on establishing wastewater reuse systems are happening, as they could be potential buyers.

Challenges	Opportunities/Solutions
6. Consumer/public perception	
a. How do people in the area culturally relate to the use of treated wastewater?	Scaling-up potential is high in places where wastewater is already being utilized for secondary purposes. As is the case most often, a new technological or social initiative survives only when the public is fully aware of its nuances. In places where awareness is lacking, the utility will have to keep aside a certain portion of investment towards building trust and awareness. The government can itself, or through a third party, mandate setting up of monitoring devices at the outlets of wastewater treatment plants to reassure consumers.
b. Has there been any such intervention in the area or nearby locality in the past? How did people perceive it? Why was it successful/unsuccessful?	
c. What is the mix of industries in the area? Is there a significant variation in water-quality demands?	
d. Does industry rely completely on external water supply? Have there been cases of intermittent/permanent closure of any industrial unit in the past due to failure in getting enough water?	
e. What is the perception among commercial units/peri-urban farmers on the use of treated wastewater?	
7. Phases of deployment of wastewater management initiatives	
a. Would it be better to start with smaller intervention and gradually scale in order to build trust among consumers and assess feasibility?	A thorough study should be made to analyze who could be the first consumers of reclaimed water, water quality, water scarcity/stress, and tariffs of the area, and the perception of the community towards wastewater reuse. According to global case studies, most often industries are seen as the most suitable consumers of reclaimed water as treated wastewater is a continual source of water supply, even in the event of 'business interruptions' due to cut down of fresh water sources. Industries that have been subjected to such situations would find it suitable to buy treated wastewater instead of risking supply cut-downs for days or months. Thereafter, depending on feasibility, irrigation, landscaping, non-potable domestic purposes like toilet flushing can be targeted in subsequent phases.
b. In case there is lack of public acceptance, should operations start with industries/commercial units and farmers, while generating awareness in parallel?	
8. Framework for participatory and integrated approach	
a. Are there water-user associations or industrial associations in the area?	An agreement should be drawn up only after analyzing the strengths of each stakeholder. This will achieve optimum participation from all stakeholders. If a water-user association is already in place, it should be used to gain maximum public participation. A special-purpose vehicle comprising of representatives from relevant government departments can be constituted to expedite implementation. Involvement of other important departments such as irrigation, fertilizer, municipal corporations, power, and public health is necessary to develop a market for extracted resources from the wastewater treatment processes.
b. Why not directly collaborate with them, instead of with individual users?	
c. What are the roles of different government institutions?	
d. Does the private-sector developer have know-how of his assets and the operating status of existing public infrastructure?	
e. Is there a possibility of creating a participatory structure or special-purpose vehicle to bring together relevant government and private entities?	

A supporting tool has been developed in Microsoft Excel, which will guide the choice of wastewater treatment technology, as well as conduct a basic economic-feasibility analysis. The tool has options to input area-specific populations (and growth rates) to project generation of wastewater. Further, the cost of treatment technologies (CAPEX, OPEX, and land rates), collection networks, and technologies for energy and nutrient recovery are provided in the tool. Based on inputs from the user, the tool provides a net present value (NPV) analysis of the potential wastewater treatment and recovery.

This practitioner's guide is the first step towards inspiring and guiding the circular economy pathways for wastewater management in the country. The authors hope utility managers will make the best use of the guide, decision-making framework, and the associated tool to find feasible approaches towards treatment and recovery of wastewater.

Introduction

Wastewater sector in India—A strong case for circular economy

- **1545 m^3:** Low per-capita water availability
- **20 percent:** Groundwater blocks critical or over-exploited
- **55 percent:** Households have no or open drains
- **91 percent:** of 302 river stretches polluted, high health impacts
- **37,000 MLD:** Untreated sewage flows
- **8.5 percent and 10.1 percent:** Freshwater abstraction by industries in 2025 and 2050, respectively
- **23 percent:** Industries do not get water easily or at high costs
- **30 percent:** Global phosphate imported by India.
- **Water, Energy, Biogas, Phosphates** could be extracted from wastewater

The per-capita availability of water in India has declined from 1,816 cubic metres in 2001 to 1,545 cubic metres in 2011 (Press Information Bureau, 2012). The United Nations defines any region with annual water availability below 1,700 cubic metres per person as a water-stressed region (UN, 2014). The water resources in urban areas are under huge pressure due to intense demand and pollution. India's urban population grew by 31.8 percent in the last decade to reach 0.37 billion, compared with the national average of 17.64 percent (GOI, 2011). Almost 80 percent of water supply to municipalities is disposed back into the ecosystem in the form of wastewater (CRISIL, 2013). Wastewater is a highly critical environmental and health hazard (Amerasinghe, Scott, Jella, and Marshall, 2013). Unfortunately, a large number of Indian cities/towns either do not have a sewerage system or have sewerage systems that are overloaded or working at lower than optimum efficiencies (Trivedi, et al., n.d.). According to a recent report by the Central Pollution Control Board, there exists a wide gap between sewage generation (57,000 MLD) and treatment capacity (20,358 MLD) (Mohan, 2015). Also, most treatment plants do not conform to the standards prescribed by the Environmental (Protection) Rules for discharge into streams (CPCB, 2009).

Urban wastewater treatment has received less attention compared to the supply and treatment of drinking water (Jhansi & Mishra, 2013). Rising costs and growing fresh water-supply challenges make it essential to treat municipal wastewater for reuse and recharge to water bodies (Sethi, 2013). With water scarcity—due to availability, access, or pollution issues—being reported from several parts of the country, planners need to strategize on the utilization of all water resources, including untreated, partially-treated, and fully-treated wastewater, for different productive purposes (Amerasinghe, et al., 2013). Wastewater management has to be regarded from an environmental/ecological viewpoint, and also socio-political, microbiological, and hydro-economic perspectives.

Globally, a shift is occurring from a linear to a more circular economy. The current "take-make/use-dispose" economic model is changing to a more circular one to relieve escalating pressures on our resources—water, energy, materials, and food. An integrated "nexus" approach to supply, conserve, and save water, energy, and materials is necessary and is possible across all sectors. Innovative technologies allow for revenue generation—for example, from waste to energy, wastewater to fertilizer, etc. This holds especially true for the Indian wastewater sector.

Wastewater market opportunities must be created and cities have the unique opportunity to lead the effort to integrate, link, and close the loops as they host industries, households, and public infrastructure (Veolia, 2014). These new opportunities will result in financial, environmental, health, and community-related benefits; including new economic opportunities for different users (for example, fertilizer for farmers, biogas to meet energy demand, water for power plants, water to clean railway stations, nature development for citizens, etc.). The negative externalities of using untreated water, even for irrigation, are significant. According to a scientific study, the annual health cost per child in untreated wastewater-irrigated environments is around Indian rupees 4000/annum (~$60), which is 73 percent higher than the annual health cost per child in freshwater-irrigated areas (Grangier et al., 2012).

There is a need for a rapid assessment tool to help urban local bodies and agencies involved to identify such local opportunities. Nevertheless, this approach may face technical, financial, and governance-related risks as well as implementation barriers such as land acquisition constraints and operation and maintenance deficits, which require a mitigation strategy up front.

This research work presents the status of global thinking on circular economy in the wastewater sector and identifies relevant practices or components of these practices for India. The study has analyzed 17 global good practices in the wastewater sector, which have different driving, facilitating, and sustaining factors. These practices have been studied to assess technological innovation, role of different stakeholders, CAPEX and OPEX, funding and operational nuances, policy initiatives, etc. The researchers have also interviewed experts from India and abroad to understand their perceptions and get their feedback on the findings.

As an output of the research work, this practitioner's guide has two components: one component highlights critical factors that have to be assessed to come up with a wastewater management strategy; the second component provides cost-benefit analysis of various technology choices.

The first component is derived from the case studies and expert feedback. Broadly, the following factors are crucial to making investments in the wastewater sector:

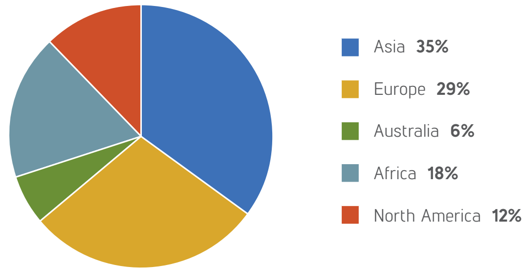
- *Drivers for initiating wastewater management*
- *Access to technology and finance*
- *Public perception*
- *Scale of intervention*
- *Management strategy and institutional framework*
- *Phases of deployment of wastewater management initiatives*
- *Policies and regulations*
- *Framework for participatory approach.*

The second component is a Microsoft Excel-based technology assessment tool. It can be used to assess the merits and shortcomings of different technology choices that could be adopted by the utilities/decision-makers based on local resources availability and user demand.

Methodology

An extensive literature review was done to understand the risks, benefits, challenges (technical, financial, governance, public perception), and scientific advances in the field of wastewater treatment and resources extraction. The literature reviewed comprises published research papers, government reports, legal regulations, non-government-led project reports, newspaper articles, etc. Clearly, the wastewater management sector has seen a lot of progress, but most findings are limited to research laboratories. However, countries that suffered severe water pollution or water scarcity have successfully adopted many of these scientific findings and technologies. Based on the literature review and understanding of the sector, eight factors/filters emerged as essential to be analyzed to test the viability of any wastewater management initiative.

Figure 1: Spatial distribution of case studies continent-wise



Review of good international practices

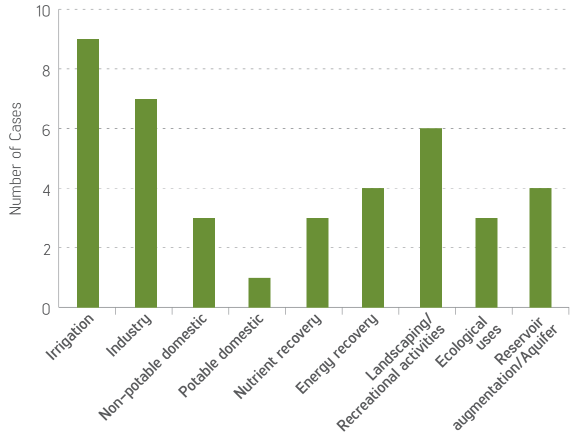
Seventeen cases were selected from all over the world where circular economy was adopted, totally or partially, in the wastewater sector. Cases that demonstrated different uses of treated wastewater as well as innovative practices such as fertilizer extraction, energy recovery, etc. were given preference. These cases were selected keeping in mind an even spatial spread (figure 1), governance structure, rate of success, scale of implementation, and diverse benefits derived.

Figure 2 shows the classification of these case studies based on resource extraction and utilization of wastewater for several purposes. Most of the 17 case studies used wastewater for multiple purposes.

Factors that make them successful cases were noted and outlined and learnings for India were documented for each case study. The cases were also categorized on the basis of the stage of circular economy progression in terms of end use. The categories are, **Basic:** treated wastewater distributed to only agriculture, and/or no energy or fertilizer recovery; **Medium**: treated wastewater used by industries and agriculture, and/or energy recovery only; and **Advanced**: treated wastewater for high-end uses such as drinking, and/or energy and phosphorus/nitrogen recovery.

This classification is case-specific and might not reflect the scenario in the entire country.

Figure 2: Multiple utilization of wastewater



Analysis of interviews

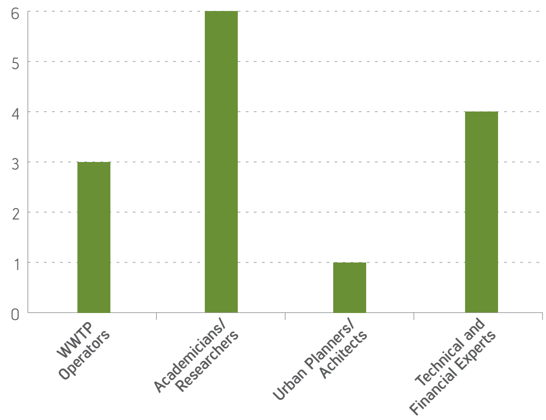
Analysis of global cases helped us identify factors that are indispensable for adoption of a circular economy pathway. However, it was essential to understand India-specific challenges and gauge the response of experts on viability of such initiatives in India. Fourteen national and international experts in the field of wastewater and urban water management were interviewed. These experts were from a range of backgrounds, including academicians, researchers, technical experts, financial experts, private operators, urban planners, technological experts, and engineers. (See figure 3 below. Annex II provides the names, designations, and organizations of the experts).

All experts have substantial working experience in the wastewater sector. They were asked to give their opinions on the viability of wastewater management, including nuanced understanding of the sector based on their on-ground experiences.

The case studies and interviews led us to create a decision-making framework with most feasible/probable options against each of the eight factors selected initially. For example, for the first factor, which is the presence/absence of drivers to initiate wastewater management, it was found that water scarcity is the most important driver that led to adoption of wastewater management across the globe. The decision-making framework developed henceforth is a logical checklist that would help the user/decision-maker to understand whether or not there exists an opportunity to undertake a project for the adoption of circular economy in the wastewater sector at a given location.

In addition to analysis of the socio-economic and political factors, a more in-depth analysis was conducted to help decision-makers choose technologies based on availability of resources and demand. A technology-assessment tool was prepared on Microsoft Excel, which would help the utilities understand the financial/economic feasibility of the project.

Figure 3: Categories of experts interviewed



Findings from Case Studies and Expert Interviews

These are India-specific recommendations based on expert views on the socio-economic and political situation in India. Also, technological and financial solutions suggested are based on their understanding of the advancement and availability of technological solutions, pricing mechanisms, subsidy arrangements, currently-running government programs, and reasons behind the success or failure of wastewater treatment initiatives in India.

Drivers for initiating wastewater management

These factors pertain to the drivers responsible for the initiation/adoption or development of a particular practice. They may be factors that initiate the adoption of certain practices or create a suitable environment for their development.

Water scarcity as a result of erratic or low rainfall, inaccessibility, and increasing demand (also increasing tourism, like in Cyprus) is the major driver in most global cases that pushed the adoption of circular economy pathways in the wastewater sector. Dependence on imported water could also act as a driver at state or national levels.

For example:

- Singapore, which now imports water from Malaysia, has taken several wastewater treatment and reuse initiatives to become self-sufficient.
- The problem of water pollution has acted as driver only for a few countries like China, Morocco, and Namibia.
- Inequitable distribution of water in South Africa acted as driver in promoting wastewater reuse.
- Sustainability principles should ideally act as a driver for ensuring water security but there are only few countries, such as Sweden, which have adopted such initiatives to achieve sustainability goals.

Thus, water scarcity stands out as the major driver for initiating wastewater management.

Interviewees agreed that water scarcity and its associated problems are and would be the major driver to push for the reuse of treated wastewater. The fact that there is unaccounted informal wastewater irrigation in the country can be another push factor as increasing concerns over public health and infected food due to such informal irrigation can be a driver. According to experts, water scarcity is better understood by people, compared to water quality (which at this stage is significant but nothing more than a theoretical concept). **For industries located in a water-scarce area, treated wastewater reuse could be a viable option as it could become a source of continual water supply.** This would lower the risk of business interruption due to cut down of municipal water supply, which is commonplace in areas with water scarcity.

Fertilizer and biogas production from sludge can also be drivers in the development of circular economy for wastewater. Sludge water can be a source of nutrients for agriculture. This can cut down cost of fertilizers as nutrient-rich wastewater fills the gap of nutrients in the soil. Given the fact that phosphorus is usually mined and its sources are dwindling, **wastewater can, therefore, be a ready source of phosphorus as fertilizer.**

Practitioner's takeaway: *A practitioner/utility can identify industrialized areas as potential buyers of reclaimed water where the issues of water scarcity is already frequent.*

Policies and regulations

The existence of supporting policies and regulations contribute towards better governance of reuse schemes. However, existence of ideal policies does not ensure adoption of sustainable practices but act as supporting structures. Most countries studied had supporting institutional frameworks and regulatory mechanisms leading to adoption of circular economy pathways.

For example:

- Code of good agriculture practice in Cyprus ensures that a minimum standard of water quality is maintained for irrigation; there is a sound monitoring system to enforce the code.
- In Morocco, both the National Water Strategy and the Green Morocco Plan consider wastewater reuse an important unconventional water resource and encourage its valuation in the field of integrated water-resource management.
- Existence of strong legal and regulatory frameworks for PPPs, such as the Public-Private Partnership Act (Mexico), designed to promote investments in infrastructure, is key to the success story of the Atotonilco wastewater treatment project.

All the experts agree that policies in India encourage treatment of wastewater but regulation is poor. Increasing water scarcity and degrading water quality, however, would force the government to better regulate over-extraction and pollution. Policies and regulations should be more stringent at the country and state levels, while leadership and interest to adopt wastewater circular economy practice should come from a city or even at smaller decentralized unit levels like societies and apartments. This would require a lot of capacity-development initiatives at local administration levels.

Practitioner's takeaway: *In India, the government is striving to create an enabling environment to encourage reuse of treated wastewater. In the revised (electricity) tariff policy notified by the Government of India on January 28, 2016, there is a provision that requires "thermal power plant(s), including the existing plants located within 50-km radius of sewage treatment plant of any municipality/local bodies/similar organisation, shall... mandatorily use treated sewage water produced by these bodies."*

Similarly, in December 2015, a memorandum of understanding (MoU) was signed between Ministry of Railways and Ministry of Water Resources, River Development and Ganga Rejuvenation, for use of non-potable water released after treatment from sewage/effluent treatment plants located in the Ganga and Yamuna river zones for various non-potable railways purpose. Several cities, like Gurugram and Chandigarh in India have recently been reforming their policies to control water wastage and pollution. These cities, in addition to cities where additional bore well drilling is restricted, could be locations where utilities/practitioners could look to strengthen wastewater reuse systems for industrial use and peri-urban agriculture. The possibility of generating electricity out of biogas and recovering fertilizers can also be explored.

Access to technology and finance

1. Challenges
   - Upfront investment for wastewater treatment is the biggest challenge across all the case studies.
   - Another major challenge is the proper operation and maintenance of the treatment plants, as experienced by Morocco in the earlier days, keeping in mind the long-term sustainability of the project.
   - Since a wastewater treatment plant is financially more demanding than a freshwater treatment plant, the cost recovery is expected to be more. Currently, in most places in India, freshwater is highly subsidized (and therefore, not reflecting actual cost of recovery), which does not endorse the case for reusing wastewater.
   - Another important aspect is that, when treatment systems integrate phosphorus and nitrogen removal, CAPEX can increase up to three to four times, making cost recovery difficult
2. Opportunities/Solutions
   - Few initiatives such as West Amsterdam, Chennai, and South-East Beijing had innovative solutions to financial challenges. They were all able to reduce operational costs by extracting energy, biogas, or phosphate fertilizers from wastewater.
   - In India, which is the world's largest importer of phosphate fertilizer, phosphate recovery practices, as adopted in Amsterdam, could easily be adopted in a decentralized manner. It would reduce imports, reduce soil and water pollution, and increase farmer incomes.

Experts suggest that advances in treatment technologies are way ahead of deployment, thus technology is not seen as a limitation. However, more research is required to reduce the resources requirement in using advanced technologies. That said, just installing high-end technologies will not solve the issues, as currently operation and maintenance of existing plants is really poor, leading to overall insufficient plant functioning. Network losses and commercial leakages, contamination due to cross connection, absence of risk measurements, solid material influx from open channels, and mixing of industrial and municipal wastewater (leading to inefficient treatment) are a few other major technical issues that a typical wastewater treatment and reuse project might face.

Practitioner's takeaway: *Technology would largely be determined by consumer requirements and resources availability. As seen in successful global cases and also suggested by experts, wastewater recycling and resource extraction would be profitable only in a long-term scenario (8–15 years). Therefore, the practitioner should enter into this sector with a firm determination to stay for the long term. Initial years will be tough, as the suggested business model is currently immature in India. Government budgets assigned for river rejuvenation, water-resources augmentation, and pollution abatement could be utilized for this initiative.*

Scale of intervention

The important question to ask before choosing the scale of operation is: Which scale would ensure cost recovery and ease of operation and regulation? It was found that a centralized wastewater management plan worked across the globe; a city-wide scale was more favoured than colony or ward-level treatment systems. All the cases studied had operations at a city or municipality level.

Experts suggested that delinking of politics and water is easier at decentralized levels. Several decentralized sewage treatment plants (STPs) are successfully being run in Mumbai and Bengaluru. Centralized systems, on the other hand, had the least supporters even though technical experts admitted that centralized systems have better chances of meeting economies of scale and are resilient. Experts also pointed out that centralized systems derive advantage if the potential customer for treated wastewater is in the vicinity, as that would nullify the transportation costs that might otherwise be incurred.

Practitioner's takeaway: *Centralized systems are always recommended as they have a better chance of meeting economies of scale than decentralized systems. However, decentralized systems are currently popular as practitioners do not have to deal with governance, regulatory, and political system complexities. That said, the long-term goal should be to establish city-level wastewater treatment systems to realize maximum benefits. Setting up decentralized systems in regularized colonies or housing complexes could be seen as a currently available opportunity, especially where mandating wastewater reuse and fixing a rational tariff is feasible. In upcoming housing complexes, such systems could be made an integral part of the land-use design.*

Management strategy and institutional framework

A city-level centralized institutional structure for wastewater management is largely favoured. It is important to outline the stakeholders involved to understand the division of responsibility for a particular project. The centralized units are mostly governed by a central governing agency. Public Utilities Board (Singapore), Mekorot Water Company (Israel), South Australian Water (Australia), eThekwini Water Services (South Africa), Water Development Department (Cyprus), City of Stockholm and Stockholm Vatten (Sweden), Orange County Water/Sanitation District (California), and CONAGUA (Mexico) are the public-sector agencies that took the lead in carrying out the management of projects. The World Panel on Financing Water Infrastructure, also called the Camdessus Panel, active from 2001 to 2003, recognized that public funding in the water sector needed to be augmented by private capital. This could take the form of public-private partnerships (PPPs), making water a more attractive investment opportunity.

PPPs require good regulation and legal systems, transparent contracting procedures, reliable cost recovery, and public acceptance. (Winpenny, 2003). Blended finance, which involves combining grants with loans, equity or other risk-sharing mechanisms, from other public and private financiers could be one of the vehicles to mobilize greater private-sector participation. PPP is operational across the globe, mostly under the Build, Own, Operate, and Transfer (BOOT) mechanism. However, cost recovery is not seen as the prime motive; key goals were, rather, pollution management and water augmentation. Government subsidies were directed towards these operations to meet private-sector requirements.

Experts also suggest that the government will have to act as a nodal agency as there are several clearance requirements that would need government interventions. However, Indian utilities are currently short of financial and technical resources, making a strong case for PPPs. The private sector will have to support public utilities in financing, revamping, constructing new infrastructure, and sustainable operation and maintenance. Involvement of NGOs and CSOs would be crucial in advancing awareness about wastewater-related negative health impacts and the benefits of treating and reusing it. Industrial associations should be kept in loop during negotiations on establishing wastewater reuse systems, as they would be potential buyers. Consumer requirements would largely drive decisions on technology choices. Also, financial institutions would have to play an important role in such initiatives.

Practitioner's takeaway: *Two groups, financial and operational management, are required to manage such initiatives. The private-sector partner would be the lead in operational management, well supported by the expertise available in the government. The government, on the other hand, will have to take the lead in reforming financial strategies to meet the cost requirements of running wastewater treatment plants and cost recovery. Once the market is developed, the private sector would generate benefits from the initiative and government's role would become more of a regulator. It is essential that a third-party independent audit is done annually and a public feedback mechanism is in place.*

Consumer/public perception

Public perception is a major challenge in the case of wastewater reuse. Most case studies show that people use it for non-potable purposes like domestic and industrial. According to a public perception case study in Kuwait (which produces potable quality water), an overwhelming 77.91 percent of respondents objected to the use of reclaimed water for drinking.

Good advertising or branding goes a long way to convince people about reusing treated wastewater. In California, public non-acceptance was a major reason for scrapping a reuse plant in the 1990s. However, with renewed efforts to educate the public, certain reservations were overcome. In fact, the governing agency of NEWater of Singapore Public Utilities Board (PUB) stresses on the use of terms such as 'used water' and 'water reclamation' instead of 'wastewater' and 'sewage treatment'. Inclusion of politicians, public figures (Singapore), government intervention through financial subsidies to enhance end-user confidence (in Australia), and positive messages from successful pilot projects (in Cyprus) were other important efforts to bring about a change in public perception.

Practitioner's takeaway: *Government and NGOs will have to play a huge role in making such initiatives a success. The utility will have to keep aside a certain portion of investment towards building trust and awareness. Government can itself or through a third party mandate setting up of monitoring devices at the outlets of wastewater treatment plants to ensure consumer confidence.*

Phases of deployment of wastewater management initiatives

A general agreement was seen among interviewees that industries could be targeted for the first phase of treated wastewater reuse projects. There is growing demand in industries for water. Also, industrial water tariffs are higher than domestic water tariffs. Wastewater could easily be a low-cost option, provided initial infrastructure development is partly supported by public funding. In terms of recovery of cost, there is better guarantee of payment from industries. Use of treated wastewater for irrigation, landscaping, and non-potable domestic purposes like flushing, etc. can be targeted in the second phase of the project. By that time, both government and private sectors would have developed a better understanding and people will have greater confidence in the operators.

Other areas that should be targeted are places where water is scarce; water tariffs are high; groundwater is depleting or salinized or of poor quality; and where high-priced desalinated water is being used. Villages and other areas that face problems of water availability could also have decentralized plants to treat and reuse water, wherein the government can subsidize the tariffs.

Potable water reuse may be a long-term goal that requires preparation in all areas (technology, quality, public perception, etc.).

Practitioner's takeaway: *There should be a clear analysis of potential consumers in an area. This should entail clear understanding of water quality, water scarcity/stress, tariffs, and perception of the community towards water reuse. Industries in water-scarce areas, which often pay huge tariffs for water, might be potential consumers of reclaimed water.*

Framework for participatory and integrated approach

Australia, South Africa, and almost all successful cases, work as there is integration and harmony among all stakeholders. The success and sustainability of the Australian case was possible as the Virginia Pipeline Scheme (VPS) under BOOT was a well-designed PPP with enhanced participation among stakeholders through a contractual agreement. The VPS conceptualization was a result of collective action by irrigators determined to find solutions for the issue of water scarcity. According to a study by Keremane in 2011, the push for collective actions had deep roots in strong community feelings, willingness to help and participate, and trust in public entities.

In the South African Durban Water Recycling (Pvt.) Ltd. (DWR) case, DWR, which holds a concession agreement with e-Thekwini Water Services (EWS), formed a successful consortium with five other companies. The 20-year concession agreement was a first of its kind and was possible because of the alliance brought in by both DWR and EWS. Under this system, the private sector was responsible for capital investments, designing, building, and operations, while the public sector was responsible for setting performance standards, asset ownership, and user-fee collection. Therefore, the PPP was successful as it managed to exploit the strengths of both the private and public sector. Integrated management of resources is essential, especially for the new cities that India is planning to develop. The Hammarby model is a perfect example of integrated approach at a small scale. The integration of sustainable resource use, ecological design, low-carbon transport, and waste management is encouraging circular economy in Hammarby Sjöstad.

Practitioner's takeaway: *The first aspect that should be looked into while trying to adopt a systemic approach is that water and wastewater should be seen in an integrated manner. Secondly, harmony and coordination among all stakeholders is important. It is crucial to encourage stakeholder participation, preferably mandated through comprehensive contracts outlining responsibilities. While designing the stakeholder participation model, it is better to analyze the strengths of each stakeholder and divide responsibilities accordingly. Another important aspect is to include community participation to best use its possible contribution in the scheme. A special-purpose vehicle comprising representatives from relevant departments such as urban development, pollution control, land revenue, and industries development corporations would be required to expedite the process by providing single-window clearance. Involvement of other important departments such as irrigation, fertilizer corporations, power, public health, etc., is necessary to develop a market for extracted resources from wastewater treatment processes.*

Technology Choices: A Technology and Economic Assessment Tool

A whole set of technologies exist today to treat wastewater and recover water, energy, or nutrients. While it provides diversity of choice of technologies suitable to a local context, it also increases the complexity for practitioners to make decisions. This practitioner's guide is accompanied by a Microsoft Excel-based economic assessment tool to facilitate decision-making as to which technology is suitable.

The tool includes the capability to project municipal water demand and, correspondingly, wastewater generation in the city. It further incorporates the potential demand for recycled water by initial adopters such as industrial and agricultural users. The tool provides a set of wastewater treatment technology choices, including wastewater stabilization ponds, activated sludge process, moving bed biofilm reaction, membrane bioreactor, and upstream anaerobic sludge blanket, along with their CAPEX, OPEX (energy cost, chemical cost, manpower cost, repair cost), and land requirements. It further provides the option to use these technologies along with a tertiary treatment process, according to the demanded quality of recycled water.

In terms of recovery of energy and nutrients, the tool includes options for electricity generation from biogas, using a combined heat and power unit, and phosphorus and nitrogen recovery, using the struvite[1] crystallization process.

Practitioners have the option to select a suitable treatment technology depending on the local context. Practitioners can provide their desired payback on investment as an input, and the tool can determine the potential tariff at which the recycled water can be sold to the industry. The tool also provides the net present value (NPV) of the intervention. The tool is designed to have sufficient flexibility for users to input values as per their local contexts. However, it uses default values in case the user wants to retain benchmark numbers.

Further, the tool provides the capability to conduct sensitivity analysis to understand how various technology options are sensitive for various parameters determining the economics of the intervention. A reference sensitivity analysis case is conducted and provided in the tool, users may create new scenarios (as detailed in the tool) to assess sensitivity of various parameters, depending on the local context. It is evident from the sensitivity analysis that the land cost becomes a highly sensitive parameter for technologies such as waste stabilization ponds (WSPs), whereas electricity tariffs and the annual growth in electricity tariffs become highly sensitive parameters for energy-intensive technologies such as membrane bioreactors (MBRs). Further, the tariff at which the recycled water is sold, as well as the quantity of recycled water being sold to the industry, is a highly sensitive parameter, quite justifiably so.

The tool provides practitioners a quick economic assessment of the intervention. It does not replace the need for a detailed budgeting exercise, which will determine the final cost of the project. However, it provides an initial understanding of the potential tariff and whether there is a business case for the intervention or not.

A demonstration case for a 50-MLD wastewater treatment plant has been presented in the table below.

Further, based on the estimates, utilities will require to set a tariff of Indian rupees 47 and Indian rupees 26 per kl to recover the cost in a timeframe of 5 and 15 years (payback period), respectively.

WW Treatment Capacity	Manually Planned	50 MLD
		Million Indian rupees
Total CAPEX		794
ASP with tertiary treatment		740
Biogas-to-electricity unit		7
Cost of supply infrastructure		47
Annual OPEX (year 1)		63
Power cost		20
Repairs cost		12
Chemical cost		27
Manpower cost		4
Annual revenue (year 1)		161
Annual water sold to agriculture	19.2 MLD	–
Annual water sold to industry (40 percent of treated water being sold)	12.8 MLD	144
Annual electricity generated/sold	8000 kWh/d	18
Annual MAP equivalent fertilizer recovered	0 metric tonne	–
Payback period (years)		10
Tariff for water resale to industry (Indian rupees per kl)		31

1 Struvite, also referred to as MAP, is formed when there is a mole to mole to mole ratio (1:1:1) of magnesium, ammonia and phosphate in the wastewater.

Conclusion

The study establishes that direct benefits through recovered resources from wastewater could make an economically attractive case for practitioners to adopt circular economy pathways to manage wastewater. However, beyond economic attractiveness of the intervention, the study highlights a set of factors that need to be considered and aligned to achieve long-term sustainability of the intervention. Moreover, beyond economics, wastewater management should be looked at from a sustainability viewpoint, as it has multi-dimensional benefits. As observed in all the case studies, a proactive approach and leadership from the government and public sector is essential towards successful intervention. **Providing financial and land resources and creating an enabling environment would be the major roles for the government.** The Government of India has been incurring significant expenditure towards river rejuvenation, water augmentation, health facilities, irrigation facilities, etc. Much of this expenditure could be reduced or eliminated by adequately managing wastewater. Thus, there is a strong case for considering wastewater management from a holistic viewpoint.

Based on the research findings**, the study strongly recommends that utilities and local governments integrate water and wastewater management at strategic planning and implementation levels.** The existing consumer subsidy on freshwater could to be transferred to wastewater management, which would not only lessen the debt on water utilities but also support wastewater treatment. The wastewater regulations in India clearly mandate treatment of wastewater to a certain level before discharging into rivers. Enabling on-ground action within the purview of this regulation needs participation from various stakeholders. **NGOs can positively influence public at large through awareness-building initiatives; government can help in designing socially acceptable solutions, certification, and authorization; entrepreneurs can help in designing technological interventions according to the needs; and financial institutions can support the initiatives through long-term patient capital.**

With regards to successful institutional frameworks, viability gap funding or blended finance model could boost public-private partnerships, where the private sector could work under BOOT mode, sharing equal risks. Wastewater management needs long-term investment, providing multi-fold benefits in the long run. Given the limited financial resources to tackle the humongous problem of wastewater management, it is difficult for local governments to tackle the challenge across an entire city at once. Instead, local governments could initiate decentralized wastewater treatment with the support of the private sector and other relevant stakeholders as the first phase. Once the market for recycled resources matures, upscaling phases can follow.

This practitioner's guide is the first step towards inspiring and guiding circular economy pathways for wastewater management in the country. The authors hope that the utility managers will make the best use of this guide, decision-making framework, and the associated tool to find feasible approaches towards treatment and recovery of wastewater in India.

ANNEX I: Summary of Case Studies

*Renewal internal freshwater sources per capita per year = RIFSPCPY
**Population= P

Stage of circular economy progression:
Basic – Treated wastewater distributed/sold to agriculture, and/or no energy or fertilizer recovery;
Medium – Treated wastewater sold to industries, and/or energy recovery only;
Advanced – Treated wastewater used for drinking, and/or energy and phosphorus/nitrogen recovery.

Disclaimer: This classification is case-specific and might not reflect the scenario in the entire country.

Countries	Details of practice	Application	Cost/Tariff per m^3	Stakeholders	Learnings
SINGAPORE (Advanced) *RIFSPCPY* = 111 m^3 *P* = 5,469,700	In order to become self-sufficient in terms of water supply, Public Utilities Board (PUB) produces high-grade reclaimed water called NEWater, which contributes to 30 percent of Singapore's water needs. NEWater is produced through an advanced cleaning process: Conventional wastewater treatment in a water-reclamation plant; followed by microfiltration/ ultrafiltration; and, finally, reverse osmosis. At this stage, the water is of potable quality; UV disinfection to ensure that all organisms still left are inactivated.	Industry, Reservoir augmentation	Water tariff = $1.22	Public Utilities Board, Keppel Seghers, Sembcorp	Effective branding for public awareness (for instance, the use of phrases like 'used water' not 'wastewater' and 'water reclamation' not 'sewage treatment'), involvement of media and political leaders for endorsement of NEWater, transparency in terms of data, stringent quality checks to maintain high standards, initiative to decrease per-capita water consumption, and exemption of water conservation tax in tariffs to encourage use of NEWater were helpful in making the NEWater project successful.
ISRAEL (Medium) *RIFSPCPY* = 93 m^3 *P* = 8,215,300	The Dan Region Wastewater Treatment Plant in Shafdan, the largest and most advanced in the Middle East, treats almost 130 MCM of wastewater per year. Funding is fully public and treatment is carried out using soil aquifer treatment processes. The treated water is distributed to agricultural fields. Purification of the wastewater is performed through conventional pre-primary (removal of suspended particles) and primary methods (gravitational settling) followed by secondary treatment consisting of natural biological processes. Tertiary treatment involves filtering the effluents through a deep sterilization granular (particulate) bed. Effective endorsement of water stress and other explanatory actions are carried out extensively and this alone may have helped reduce 10-15 percent of the domestic water consumption.	Irrigation, Industry	Water tariff = $1.08 for Industry $0.35 for Agriculture	Israel Water Authority, Mekorot, association of seven municipalities	The project is highly publicized and therefore has gained wide acceptance. A powerful ad campaign had popular models and actors talking about the 'years of drought' while their features started peeling off due to lack of moisture. The Water Authority also put up posters in strategic locations like public washrooms and toilets, resulting in generating consciousness in people about the state of water resources. Also, lower tariffs for reused water, networking among the seven municipalities, which enhanced both technical and financial capacity, were other reasons for success.
AUSTRALIA (Basic) *RIFSPCPY*= 21,275 m^3 *P* = 23,893,726	The Virginia Irrigation/Water Recycling scheme was established in 1999 and is the first and largest recycled water scheme of its type in Australia, distributing about 20 Giga litres (GL) per year of highly treated reclaimed water to 400 connections/irrigators in Virginia and Angle Vale districts north of Adelaide through a large network of pipes. This water is produced by a dissolved air floatation/filtration (DAFF) plant fed by treated effluent from the Bolivar Wastewater Treatment Plant, increasing the reuse from the Bolivar plant from about 29 percent to 35 percent	Irrigation	Water tariff = $0.095	South Australian (SA) Water, Water Reticulation Systems Virginia (WRSV), TRILITY	Incentives in the form of pricing, education, and training programs were important measures to promote user confidence. A user association played a crucial role in managing an education program for irrigators on advantages of using reclaimed water over groundwater and also implementation of a proper pricing mechanism (signing contracts with the water company). In the Virginia Pipeline Scheme, the government initially subsidized farmers that adopted recycled water. With an increase in customer confidence, the pricing was altered to reflect true cost of reclaimed water. Since 2007, the pricing is linked to consumer price index.
SOUTH AFRICA (Medium) *RIFSPCPY*= 843 m^3 *P* = 5,770,560	Durban Water Recycling (Pvt.) Ltd. was awarded a 20-year build own operate and transfer (BOOT) contract to treat 10 percent of the city's wastewater for the production of high-quality reclaimed water. The plant was commissioned in May 2001 and treats 47.5 MLD of domestic and industrial wastewater to a near-potable standard. This is sold to industrial customers for direct use in their processes. The operation and maintenance contract was given to VWS for 20 years. The two largest customers so far are the Mondi Paper Mill in Merebank (consumes 30-39 ML/day) and the Sapref Refinery (3.3-8.9 ML/day), owned by Shell and BP.	Industry	Water tariff = $0.34	e-Thekwini Water Services, VWS, Mondi Paper, and SAPREF.	One of the most important aspects of the e-Thekwini Water Services (South Africa) case study is the management of water through the entire value chain and coordination among the four key stakeholders: EWS, VWS, Mondi Paper, and SAPREF. Also, it is interesting as it changed wastewater, which was a burden for local government, to an asset, as the operator pays for the wastewater it gets, which is a win-win situation.

Countries	Details of practice	Application	Cost/Tariff per m^3	Stakeholders	Learnings
SPAIN (Medium) *RIFSPCPY*= 2,385 m^3 *P* = 46,404,602	Spain has the highest reuse figures in Europe; around 408 Mm^3/year is reused in Spain as of 2004. These water reuse programs were mostly financed through grants from the European Union and investments from the water reuse project proponents and implemented by River Basin District Plans, the National Sewerage and Treatment Plan (PNSD), and the autonomous regions. The primary treatment in most treatment plants includes screens, grit and grease separation, anoxic reactors, and sedimentation, or a combination of a few of these components. The secondary treatment plant includes either trickling filters, activated sludge, or aerated trickling filters. Tertiary treatment in some plants includes natural lagoons.	Irrigation, Industry, Non-potable domestic, Landscaping/ recreational activities, Ecological uses	Not available	River Basin District Plans, the National Sewerage and Treatment Plan (PNSD) and the autonomous regions.	In terms of policy and regulations, the decentralized regulation format for all its autonomous councils is quite useful as this allows the government to outline operation rules according to regional needs. For instance, the Catalan government approved a document in 2003 that specifies the quality parameters for various regenerated water uses. Public education and acceptance are other reasons for high reuse numbers in Spain.
CYPRUS (Medium) *RIFSPCPY*= 684 m^3 *P* = 1,153,058	Cyprus has followed a policy since the 1960s to capture maximum runoff. Cyprus has almost 90 percent rate of reuse of treated effluents. At present, Cyprus has 25 wastewater recycling plants operating. Conventional methods are used for primary and secondary treatments after which the secondary effluent is sent for sand filtration. It is then subsequently transferred to a meandering contact tank for chlorination. The disinfected effluent is then pumped to Water Development Department's storage tanks, which are then distributed. Lately, membrane biological reactors have also been installed apart from sand filters for tertiary treatment.	Irrigation, Landscaping/ recreational activities, Aquifer recharge, Ecological uses	Water tariff = $0.08	Water Development Department (WDD), Ministry of Agriculture Natural Resources and Environment.	Cyprus boasts of a very pro-active government in terms of encouragement of wastewater schemes. The tariff for reused water has been set lower than freshwater. Good regulation in terms of a very strong legal framework with numerous laws including the Environmental Impact Assessment Law of 2005, Water Pollution Control law/regulations, and Code of good agricultural practice are beneficial for implementation of such large-scale water reuse.
HAMMARBY SJÖSTAD, SWEDEN (Medium) *RIFSPCPY* = 17,812 m^3 *P* = 25,000 by 2017 (projected)	Hammarby Sjöstad is an urban development project of 160 ha area to the south of Stockholm's South Island. The wastewater recycling in the system, which is a part of the Hammarby Model, is an integrated closed-loop system where infrastructure for waste, water, and energy are integrated into one system. The municipal wastewater is treated in one of the two wastewater treatment plant (Sjöstaden's and Heriksdal's wastewater treatment plants) after which the biogas is used as biofuel for transportation, stoves, and electricity. Biosolids are used as fertilizers in arable land and the purified wastewater in Hammarby's heat plant. The Henriksdal wastewater treatment plant is equipped to handle 370 MLD and a Biological Oxygen Demand 7 days (BOD_7) load of 63 tons of oxygen per day. The wastewater is treated with conventional mechanical, chemical, and biological methods, after which it is passed through sand filters that filter out the remaining small particles.	Industrial cooling, Nutrients, Energy	Not available	City of Stockholm, Stockholm Water Company, Stockholm Waste Management Administration, KTH, IVL Swedish Environmental Research Institute	The Hammarby Model is based on sustainability principles. It is a perfect example of an integrated approach on a small scale. The integration of sustainable resource use, ecological design, low-carbon transport, and waste management is really commendable. Also, it focuses on raising public awareness. Hammarby Sjöstad has education programs for residents and tourists that are organized in a dedicated facility called the GlashusEtt. These programs speak specifically about the Hammarby model and Hammarby Sjöstad's dedication to sustainability.
CALIFORNIA, USA (Medium) *RIFSPCPY* = 8,903 m^3 *P* = 38,802,500	According to the California Department of Water Resources, the state currently recycles anywhere from 555 MCM to 715 MCM of wastewater annually, which is almost three times the amount recycled in 1970. California is currently cleaning enough wastewater to meet the demands of about 500,000 people through the Groundwater Replenishment System (GWRS), which was developed, funded, and managed by the Orange County Water District and the Orange County Sanitation District. The following steps are applied to treat wastewater: 1) pre-treatment using conventional techniques; 2) microfiltration; 3) reverse osmosis; and 4) ultraviolet light and hydrogen peroxide disinfection. The reclaimed water is first pumped into the county's aquifers, receiving another natural level of filtration before being drawn back to the surface for domestic use.	Irrigation, Landscaping/ recreational activities, Aquifer recharge	Cost = $0.68 Water tariff = $0.2	California Department of Water Resources; Orange County Sanitation District; Orange County Water District	California has shown extreme expertise in terms of preparedness for drought through its groundwater replenishment program. Aquifer recharge after adequate wastewater treatment is a good option as it does not involve direct interaction with users. However, it has two limitations; firstly, it is a risky endeavour as it might lead to pollution of pristine groundwater resources if not done properly; secondly, setting a tariff for treated wastewater would not be feasible making the entire business unviable. That said, it could work well if the operator has a contract with government or if government is willing to provide treated wastewater freely.

Countries	Details of practice	Application	Cost/Tariff per m³	Stakeholders	Learnings
KUWAIT (Basic) *RIFSPCPY*= 0 m³ *P* = 3,479,371	Kuwait generates about 600 MLD of wastewater. About 60 percent of this is treated to an advance level of ultra-filtration (UF) and reverse osmosis (RO) membrane filtration at the Sulaibiya plant, which is the world's largest membrane-based water reclamation facility. The rest of the generated wastewater (40 percent) is treated up to the tertiary level (rapid sand filtration and chlorination) utilizing three other conventional activated-sludge plants. In spite of being heavily dependent on desalination for potable water, the country has not used the reclaimed water for drinking due to cultural reasons.	Irrigation, Landscaping/ Recreational activities, Ecological uses	Al Kharafi Company sells highly treated and purified treated wastewater to Ministry of Public Works for $0.0006 and MPW charges customers (farmers) only $0.0001	Ministry of Public Works, Utilities Development Company (Al Kharafi Group), Ionics	The Sulaibiya plant is an example of a successful public-private partnership.
WINDHOEK, NAMIBIA (Advanced) *RIFSPCPY*= 2,674 m³ *P* = 325,858	For more than 30 years now, the treated water from the Gammons Water Care Works has been fed into Goreangab Water Reclamation Plant (now the New Goreangab Water Reclamation Plant) for further treatment of the treated effluent. The plant produces 21 MLD, safe for human consumption. The technique used for removal of contaminants is the 'multiple barrier' approach, which involves treatment, non-treatment, and operational measures to control any issues in water quality.	Potable water	Cost = $1.08 Water tariff = $0.85 to $2.61 (consumption related)	City of Windhoek Private agencies: Kreditanstaltfür Wiederaufbau, European Investment Bank, DB Thermal, Stocks Structures	Water conservation as a solution to water scarcity in the country has been deeply ingrained in the minds of the citizens. This is a reason why the water reclamation project is working well in Namibia. It also demonstrates the successful nexus between the three leading water utility providers, which seldom happens. The success of such a reclamation project, and especially a direct reuse project, is an exemplary public outreach program. Extensive public education programs including advertisements and education in public schools were undertaken since the beginning of the program. Moreover, consistent maintenance of excellent water quality has contributed to garnering public approval.
MOROCCO (Medium) *RIFSPCPY*= 879 m³ *P* = 33,492,909	The main driver for wastewater treatment in Morocco is the increasing water pollution, apart from water scarcity. As of 2010, the country annually generated a wastewater volume of about 700 MCM. 21 percent, that is, 150 MCM (54 percent of this is treated till tertiary level) of this wastewater is treated per year. Of the treated wastewater, only 12 percent is currently reused. Morocco has a comprehensive political and regulatory framework for wastewater reuse. Among the political machinery, both the National Water Strategy and the Green Morocco Plan consider wastewater reuse an important unconventional water resource and encourage its valuation in the field of integrated water-resource management. There are four projects in Morocco where the reuse of the treated effluents was considered from their inception: Ouarzazate (lagoon), Ben Sergao (filtration-percolation), Benslimane (aerated lagoon) and Drarga (infiltration-percolation). The treatment process involves primary, secondary, and tertiary treatments.	Irrigation, Industry, Landscaping/ Recreational activities, Aquifer recharge	Cost = $0.13 to $0.19 Water tariff = $0.21 (landscaping) $0.05 (irrigation)	State	Morocco's political and regulatory norms for wastewater reuse have encouraged improvement in technologies for water treatment and reuse. These outline strict regulations on water reuse and its quality. The regulatory framework (Water Law 10-95) is comprehensive, detailed, and intensive. This case is evidence of how regulations help in changing practices. This also signifies that acceptance of wastewater reuse is not going to be easy, but the Indian government will have to develop a long-term plan to encourage reuse of treated wastewater.
MEXICO CITY, MEXICO (Medium) *RIFSPCPY*= 3,343 m³ *P*= 123,799,215	The Atotonilco project is the largest wastewater treatment PPP project in Mexico and will provide treated water for irrigation of around 80,000 hectares in the Tula Valley and improve the living conditions of approximately 300,000 inhabitants in the region. By treating 60 percent of the wastewater from the metropolitan areas of Mexico City, the Atotonilco project will significantly improve environmental conditions and raise the city's overall water treatment rate from 8 percent to 60 percent. The plant's total design capacity is around 4,500 MLD. The treatment process will include pre-treatment; primary treatment using Lamella clarifying units; secondary treatment using bioreactors; sludge gravity thickening; anaerobic digestion; sludge dewatering; cogeneration (converting biogas to energy), and power distribution.	Irrigation, Industry, Non-potable domestic	Cost = $0.09	CONAGUA, Aguas Tratadas del Valle de Mexico (ATVM) Financing: Mexico's national development fund - FONADIN private contractors and credit from the National Bank of Public Works and Services	Existence of strong legal and regulatory frameworks for PPPs, such as the Public-Private Partnership Act (Mexico), designed to promote investments in infrastructure is key to the success story of the Atotonilco wastewater treatment project. The situation in the Tula Valley in Mexico could easily be compared to Meerut and Muzaffarnagar districts, etc., in India where irrigation using highly-polluted effluent is causing a lot of health issues. Thus, the drivers exist to initiate wastewater treatment.

Countries	Details of practice	Application	Cost/Tariff per m³	Stakeholders	Learnings
CHINA (Advanced) *RIFSPCPY*= **2072 m³** *P* = **1,360,720,000**	The northern part of China was the first to adopt wastewater reclamation technologies to recycle municipal wastewater. Beijing has led the nation in implementation and close to 60 percent of the treated municipal wastewater effluent is reused. The improvement work of Beijing's Bei Xiao He wastewater treatment plant was undertaken under a two-year program that began in 2006. The project updated the plant's previous mechanical/biological treatment, by providing a new membrane bioreactor (MBR) system, which almost quadrupled the plant's treatment capacity to 100,000 m³/day from 40,000 m³/day. Improving and increasing the capacity of the plant principally involved addition of an entirely new wastewater treatment line to produce water for non-potable use. Bei Xiao He wastewater TP supplied treated water for the Olympic Park and continues to provide treated wastewater for Beijing's population. Nutrient removal technology comprises simultaneous nitrification and denitrification systems and provides a big boost to Beijing's target of processing 90 percent of its wastewater, with 50 percent for recycle and reuse.	Non-potable domestic, Nutrient recovery, Landscaping/ recreational activities	Water Tariff = $0.15 in urban areas and $0.14 in rural areas (Domestic) $0.22 in urban areas and $0.19 in rural areas (Non-residential)	Beijing administration	Policies by the Beijing government encouraged growth of wastewater reclamation facilities and some plants are even required to upgrade their discharged water quality to meet the Grade IV standards for surface water quality. For example, the Beijing Water Authority has mandated that all wastewater treatment plants in Beijing be required to be upgraded to wastewater reclamation plants by 2015 to meet reclaimed water discharge quality for reuse. Also, the pricing mechanism ensures marketability of treated wastewater, in addition to resource conservation.
ENKÖPING, SWEDEN (Basic) *RIFSPCPY*= **17,812 m³** *P* = **20,000**	The Enköping project is a novel example of industrial symbiosis. The municipality, in collaboration with Ena Energy AB, carried out a phytoremediation-biofuel symbiosis project in which 200,000 m³ of wastewater is used to irrigate short-rotation willow coppice (Salix) plants in a 75-hectare area. The amount of nitrogen and phosphorous in the municipal wastewater was suitable and well balanced for willow plantations. The decant and reject water left after dewatering the sludge in wastewater treatment plants are stored in lined storage ponds in winter. This water, along with conventionally treated wastewater, is then used to irrigate the willow plantations from May to September. It has led to reduced fertilizer costs, increased biomass production (50 percent more than other farms in Sweden), and low-cost wastewater treatment.	Irrigation	Not available	Municipality of Enköping, in collaboration with Ena Energy AB, wastewater treatment plant and local farmers	Managing resources in a cost-efficient and demand-driven way was the key to success in this case. In all cases, high-end wastewater treatment technologies are not required, especially if the intended use is for non-potable purpose. It also suggests that analyzing wastewater quality is essential for its management. The project outlines a successful industrial symbiosis that has showcased exemplary collaboration among stakeholders.
AMSTERDAM, NETHERLANDS (Advanced) *RIFSPCPY*= **655 m³** *P* = **779,808**	The wastewater treatment plant at Amsterdam West is based on primary sedimentation, activated sludge (modified University of Cape Town (mUCT) process), and secondary sedimentation tanks. The treated water is discharged into the nearby harbour. The energy content of the sludge and biogas is very efficiently utilized through co-operation with the neighbouring Waste and Energy Enterprise, Amsterdam (AEB). The digested and dewatered (24 percent dry solids) sludge of the wastewater TP is combusted in the high-efficiency incineration furnaces of the AEB. The biogas from the sludge digestion process is converted into electricity by gas engines at the AEB site, producing approximately 40 percent of the electricity demand of the wastewater TP. Phosphate recovery is carried out through a biological P-removal method.	Phosphate recovery, Biogas generation, Energy recovery	Not applicable	Waternet (City of Amsterdam and Amstel GooiVecht)	This case highlights the efficient recovery of resources from wastewater. The energy content of the sludge was efficiently utilized in the wastewater TP and also in neighbouring industries, thereby exhibiting a novel process of industrial symbiosis. Phosphate deposition, which was proving to be a nuisance for smooth operation, was recovered and used as a fertilizer source.
CHENNAI, INDIA (Medium) *RIFSPCPY*= **1,130 m³** *P* = **4,343,645**	Kodungaiyur wastewater treatment plant in Chennai has a capacity of 110 MLD. The treatment plant is based on conventional activated-sludge process with anaerobic sludge digestion and biogas utilization by means of a power plant based on gas engine of capacity 1317 KVA. The power production per month is 450,000 kWh. The digested sludge is dewatered in centrifuges. The average electrical energy production from biogas is about 2 KWh/m³ of biogas. Energy cost savings through power production per year is Indian rupees 37,350,000 (~$575,000) (nine months/ year).	Industry, Landscaping/ recreational activities, Energy recovery	Water Tariff = $0.13 (industries)	WABAG, Chennai Metro Water Supply and Sewerage Board (CMWSSB)	The energy produced from biogas is utilized in the wastewater treatment plant, which has resulted in energy cost savings.

Countries	Details of practice	Application	Cost/Tariff per m^3	Stakeholders	Learnings
SOUTH-EAST BEIJING, CHINA (Medium) *RIFSPCPY*= **2,072 m^3** *P* = **11,510,000**	The Xiaochongmen wastewater treatment plant in Chaoyang District, in the south-eastern corner of Beijing, is one of China's largest treatment facilities and the largest anaerobic sludge stabilization plant where 600,000 m^3 of wastewater, collected from the nearby Liangshui River basin with a population of over two million, is treated daily. The main plant units consist of mechanical sludge thickening, anaerobic sludge stabilization, mechanical sludge dewatering with phosphorus removal, and biogas recycling. The treatment plant produces 30,000 m^3 biogas/day and energy savings (electricity): € 7,000/day (~$7,850) plus thermal energy.	Energy recovery	Not applicable	WABAG, Beijing Administration Financing: Beijing Administration, World Bank	Energy generation adds up to considerable savings with regard to plant operation costs, as well as a marked improvement in the overall CO_2 balance of the wastewater treatment plant. The stabilized sewage sludge has a dry solids content of around 3 percent Following subsequent sludge dewatering, this content is raised to around 25 percent, which significantly reduces volume and thus saves landfill space for further disposal.

ANNEX II: List of Experts Consulted to Develop this Guide

No.	Name	Organization	Designation
1	Shyam Asolekar	Indian Institute of Technology (IIT) - Bombay	Professor
2	Rajesh Biniwale	National Environmental Engineering Research Institute (NEERI)	Principal Scientist, Cleaner Technology Centre
3	Kartik Chandran	Columbia University	Principal Scientist, Cleaner Technology Centre
4	Ranjana Ray Chaudhuri	TERI University	Lecturer, Department of Regional Water Studies
5	Frank Heemskerk	Research and Innovation Management Services, Belgium	Chief Executive Officer
6	A K Jain	Independent	Architect-Town Planner
7	Priyanka Jamwal	Ashoka Trust for Research in Ecology and the Environment (ATREE)	Fellow, Centre for Environment and Development
8	Ravikumar Joseph	World Bank	Senior Water and Sanitation Specialist
9	Suneetha D. Kacker	World Bank	Water and Sanitation Specialist (Urban)
10	Uday G. Kelkar	NJS Engineers Pvt. Ltd.	Managing Director
11	K Vijaya Lakshmi	Development Alternatives	Vice President
12	Patrick Rousseau	Veolia Water (India) Pvt. Ltd.	Chairman and Managing Director
13	Rubinder Singh	Project Development Company of Rajasthan (PDCOR) Ltd.	Chief Executive Officer
14	Suhas P Wani	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	Scientific Coordinator – India

2121 Pennsylvania Avenue, NW
Washington, DC, 20433 USA

www.2030wrg.org

For further information, please contact
2030wrg@ifc.org