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INDIA-EU WATER PARTNERSHIP

Compendium of Business Models on Safe Reuse of Treated Water

Prepared under the India-EU Water Partnership

Implemented by

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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November 2023

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1. Introduction and Objectives

The recently launched National Framework on Safe Reuse of Treated Water (SRTW) in India, developed by NMCG within the India-EU Water Partnership, guides states in creating consistent water reuse policies and projects.

This Compendium on SRTW business models and the **Solution Document for SRTW in Panipat, Haryana** (sister document) shall serve as good practice documentation to support the National Framework on SRTW by identifying and assessing viable business models for SRTW.

This Compendium includes the following 10 SRTW case studies from India and Europe:

	India	**Europe**
Chapter 2: Industrial reuse	2.1. Surat (Pandesara Industrial Estate) 2.2 Chennai (petrochemical industries/ SIPCOT) 2.3. Mathura (Indian Oil Corporation)	
Chapter 3: Agricultural reuse	3.3. Aurangabad (Purple pipes)	3.1. Alicante, Spain 3.2. Milan, Italy
Chapter 4: Urban reuse		4.1. Barcelona, Spain
Chapter 5: Environmental reuse	5.1 Kolar, India (Lake recharge)	
Chapter 6: In-house reuse	6.1 Delhi, India (Airport)	
Chapter 7: Industrial symbiosis		7.1 Kalundborg, Denmark

For each case study, the following aspects and questions are addressed:

- City Context and Background: *What is the history of the water reuse case study? What was the main driver for its implementation?*
- Wastewater Treatment and Water Reuse Infrastructure: *What is the treatment train with its unit processes?*
- Business Value Chain and Business Model: *Which value propositions are delivered by whom to whom and how?*
- Institutional Environment: *Who are the main stakeholders, and which legal frameworks drive or hinder the business model?*
- Funding and Financing: *Which investment and operational costs arise, and how are they covered?*
- Impacts, Scalability and Replicability: *Which socio-economic benefits and costs are involved? How scalable (in size) and replicable (in numbers) is the business model?*
- Summary assessment – SWOT: *What are the business models' main strengths, weaknesses, opportunities and threats?*
- References and further reading materials

The final **chapter 8** highlights cross-cutting issues related to SRTW business models and lessons learned from the selected case studies.

2. Business Models for Industrial Reuse

2.1. Surat, India

The city of Surat is a representative case of the safe reuse of tertiary treated used water in India. The city uses more than 32% of treated used water from its sewage treatment plants to meet industrial, urban, and recreational water demand (*Table 1*). This case study describes the business model of tertiary treated used water from the Tertiary Treatment Plant (TTP) Bamroli to Pandesara Industrial Estate, Surat.

Table 1: Key characteristics of case study Surat, India

City: Surat, Gujarat, India		Case study: Tertiary Treatment Plant Bamroli	
Population (Urban Agglomeration) (2022)	7.3 million	**Treatment capacity**	40 MLD (expandable to 75 MLD)
Annual population growth rate	4.4%	**Treatment**	Tertiary
Water scarcity	water scarce region / high seawater intrusion in groundwater	**Operator**	M/s Enviro Control Associates (I) Pvt. Ltd.
No. of municipal WWTPs	11		
% of total reused water from the WWTPs in Surat	30% (2019) 40% (planned by 2021)	**End users**	Pandesara Industrial Estate

City Context and Background

Surat, the diamond and textile city, is strategically located on the western coast of India in Gujarat. It is the second-largest city in the state and the eighth-most populous metropolis in the country. Surat is known for its thriving diamond industry, with the world's largest diamond cutting and polishing centres. Due to its industrial prowess, the city attracts people from various parts of the country seeking employment opportunities. Thus, the population growth rate increased to 4.4% (2011-21), much higher than the national urban average of 2.4%. These trends have significantly increased water demand from 480 MLD in 2001 to 1548.51 MLD in 2021. The demand is expected to grow to 2350 MLD by 2041. The textile industrial units in Surat consume more than 450 MLD of water obtained from various sources, including potable water supply from **Surat Municipal Corporation (SMC)**. Ground water, which forms the essential basis of water supply to meet daily needs, is highly affected in Surat due to seawater intrusion. River Tapi, the sole source of fresh water for the city, depends on seasonal rains. Therefore, SMC initiated the reuse of treated used water to meet the increasing water demand and reduce the dependence on conventional sources.

With over 7 million population, the city has 11 STPs operational with a total design capacity of 1072 MLD. Currently, 933 MLD are treated, from which > 30% of treated is reused. About 115 MLD undergo tertiary treatment at three Tertiary Treatment Plants (TTP) - two in Bamroli (adjacent to Bamroli Sewage Treatment Plant (STP)) with a design capacity of 75 MLD and another in Dindoli with 40 MLD capacity. The tertiary treated water is sold to Pandesara and Sachin Industrial Estates. SMC systematically plans to reuse 70% of wastewater after treatment by 2025 and 100% by 2030.

Wastewater Treatment and Water Reuse Infrastructure

The first treated water reuse project in Surat was part of the Bamroli STP, which is a 100 MLD plant based on Upflow Anaerobic Sludge Blanket (UASB) technology, which was commissioned in 2003 (Single stage biological treatment) and Extended Aeration technology (Two Stage Biological / Secondary Treatment[1] commissioned in 2008). To supply 40 MLD of industrial-grade treated water (*Table 2*) to Pandesara Gujarat Industrial Development Corporation (GIDC), tertiary treatment based on Ultrafiltration (UF) and Reverse Osmosis (RO) was commissioned in 2014. The unit processes for tertiary treatment are Sand Filtration / Disc Filtration, Ultra Filtration (UF), Reverse Osmosis (RO) and Activated Carbon Filtration (ACF). The quality of treated water attained in comparison to desirable drinking water standards is presented in the table below:

Table 2: Effluent quality of TTP Bamroli STP

Indicators	**Inlet of TTP**	**Outlet of TTP**	**Desirable limits as per Drinking water standard IS-10500**
Color (Hazen units)	55	<5	5
pH	6.5-7.5	6-7.5	6-8.5
Total Hardness as CaCO3 (mg/L)	750	<300	300
Iron as Fe (mg/L)	0.63	<0.25	0.30
Manganese as Mn (mg/L)	0.12	<0.10	0.10
Total Dissolved Solids (mg/L)	2100	<500	500
BOD (mg/L)	20	<5	No standard
COD (mg/L)	100	<50	No standard
Suspended Solids (mg/L)	30	<2	5.0(turbidity)
Total Nitrogen as N (mg/L)	14	<10	10.20
Total Phosphorous as P(mg/L)	8	6-10	-
Residual Chlorine (mg/L)	0.5	0.5	<0.25

Source: (SMC, 2019)

[1] The Secondary treatment consists of Up-flow Anaerobic Sludge Blanket Process + Integrated Fixed Film Activated Sludge process + Extended Aeration.

Business Value Chain and Business Model

SMC built its first TTP of 40 MLD capacity in 2014 at Bamroli STP. The tertiary treated used water from the Bamroli TTP is distributed through a network of pipelines to various industrial units located in Pandesara industrial estate within 5 km from the plants. The industrial estate is home to about 119 water-intensive textile and chemical industries and had about 100 MLD of water demand, with 55 MLD supplied by SMC. The remaining demands are met through tankers and groundwater. The reuse model of treated used water for Pandesara industrial estate was identified in 2007 by SMC when the industrial estate demanded an additional 40 MLD of potable water. Initially, it was planned to establish a TTP under a PPP model with an operating agency also making the capital investment along with O&M and generating revenue through user charges, partly shared with SMC. Realizing long-term monetary benefits for SMC and considering the availability of in-house technical experience in handling much higher capacities of treatment plants, SMC decided to divide it into two contracts – i) Engineering Procurement and Construction (EPC) contract where the entire funding would be sourced from state government and ii) Operation and Maintenance (O&M) contract with a self-sustaining operational model where revenue generation would recover the costs, presented in *Figure 1*. The winning bidder for the EPC contract is automatically awarded an O&M contract per the prevailing practice in SMC. On a turnkey basis, both contracts were allotted to **Enviro Control Associates Pvt. Ltd**. for ten years. Gujarat Pollution Control Board (TNPCB) monitors the STPs and effluent from the industries to meet the required discharge standards.

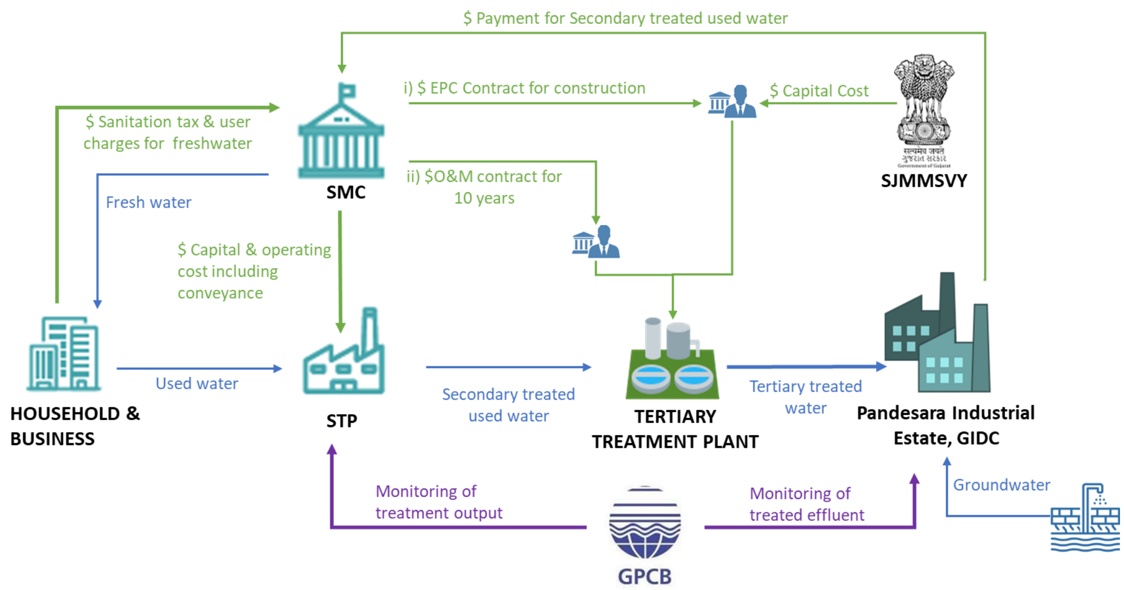

Figure 1: Industrial reuse of treated used water in Pandesara Industrial Estate, Surat

The operation model is that used water, generated by households, is sent to Bamroli STP and further treated at TTP to produce industrial-grade water. This tertiary treated water is distributed to Pandesara industrial estate. The role of the SMC is to ensure the supply of secondary treated used water and land allocation to the private operator. At the same time, the private operator is responsible for treating and supplying tertiary treated used water at the desired quality to the industries. Commitment from Pandesara industrial users is assured through contractual agreements. The industrial estates agree to purchase a guaranteed quantity of treated used water at a fixed price with an annual increase based on an increase in O&M costs as per RBI (Reverse Bank of India) indexation. *Table 3* presents the business model and highlights its key elements.

Table 3: SMC's business model Canvas for reuse of treated used water in Pandesara Industrial Estate, Surat

<table>
<tr>
<td rowspan="2">Key Partners

• Gujarat Industrial Development Corporation (GIDC),
• Private operator (Enviro Control Associates Pvt.Ltd) (customer of SMC)</td>
<td>Key Activities

• Treatment of used water at STP
• Conveyance of treated used water to private operator
• Tertiary treatment of used water
• Conveyance of tertiary treated wastewater to industries</td>
<td rowspan="2">Value Propositions

• Assured quality and quantity of secondary treated water to private operator
• Assured quality and quantity of tertiary treated used water for reuse in industries</td>
<td>Customer Relationships

• O&M contract with private operator
• Contractual agreement with the industries</td>
<td rowspan="2">Customer Segments

• Pandesara Industrial Estate</td>
</tr>
<tr>
<td>Key Resources

• Land
• Wastewater
• Funding for the investment
• Assured O&M from SMC to private operator</td>
<td>Channels

• Contracts between SMC, Industries and private operator to assure quantity and quality of supply</td>
</tr>
<tr>
<td colspan="2">Cost Structure

• 100% capital (excluding land) funding by the state and operating costs by private operator.</td>
<td colspan="3">Revenue Streams

• O&M contract (private operator)
• Fees from sale of tertiary treated used water to industries (paid to SMC)</td>
</tr>
<tr>
<td colspan="2">Social & environmental costs

• High energy requirement to operate facility resulting in GHG emissions</td>
<td colspan="3">Social & environmental benefits

• Reduced pressure on freshwater demand from industries, resulting in freshwater access for domestic consumption
• Avoiding groundwater depletion
• Elimination of water availability risk for industries resulting in better sustainability for them and employment provision</td>
</tr>
</table>

This water reuse business model enabled SMC to free up potable water and reduced the dependency of industrial units on private water tankers and borewells. The project's success created more demand for treated used water among other industries in SMC. It led to the constructing of an additional 40 MLD capacity TTP at Dindoli and a second 35 MLD TTP at Bamroli STP. Both the plants mentioned above were set up in a similar structure where two different contracts were floated for construction and O&M. Both the TTPs are awarded to Enviro Control Associates Pvt.Ltd.

Institutional Environment

Aligned with the national vision, the Government of Gujarat has taken up many initiatives to promote the reuse of treated wastewater. Under the State Government's flagship program 'Swarnim Jayanti Mukhya Mantri Shehri Vikas Yojna' (SJMMSVY) started in 2009, Gujarat has promoted water reuse. It has set a target to reuse 70% of treated wastewater by 2025 and 100% by 2030. The policy provides incentives and subsidies for industries that use recycled water. Under the State Reuse Policy, it is promoted that all GIDC estates, industrial units in Special Investment Regions, industrial parks and large industrial units that i) consume a minimum of 100,000 (one lakh) litre of fresh water per day for non-potable purposes and ii) are situated within 50 km distance from the STP or city limits, to use treated used water. The policy also outlined that urban local bodies in the State are responsible for laying down conveyance pipelines for treated used water in institutional areas, business districts or areas to cater to their water demands. Rules for the enforcement by the State Irrigation Department, which gives permissions for fresh water supply, are also outlined in the policy. The State Reuse Policy also mandated that users shall not be given an allotment of fresh water/reservation of fresh water except as per provisions of the policy. Further, the existing allotment/reservation of fresh water shall stand cancelled within one year from the date of treated used water being made available. The Gujarat Pollution Control Board (GPCB) has also issued guidelines on the permissible uses of treated used water.

At the city level, urban local bodies (such as SMC) are held responsible for all water and sewage management activities under the Gujarat Provincial Municipal Corporation Act. SMC has already executed several treated used water projects before the State Government Policy initiatives came into place. In 2019, SMC prepared an Action Plan for Reuse and Recycle of wastewater in Surat.

Funding and Financing

SMC has set up the first TTP (40 MLD capacity) in Bamroli under SJMMSVY initiative, Government of Gujarat, for a project capital cost of Rs.85.10 crore and O&M cost of Rs.80 crore for 10 years. The project was commissioned in 2014, and the base rate charged for selling treated used water to industries was 18.20 ₹/m^3. This is lower than freshwater costs supplied to industries at 23 ₹/m^3. With an annual increase based on RBI indexation, the price charged for treated used water as of 2020 is 32 ₹/m^3. The funding for the construction of the other two TTPs at Bamroli (extension) and Dindoli is from the Government of India under the Smart Cities initiative, the Government of Gujarat under SJMMSVY and SMC. The operational costs at TTP Bamroli are as follows: ₹ 56 lakhs /month of fixed costs (₹ 5.6 million/month), ₹ 40 lakhs/month of electricity charges (₹ 4 million/month), ₹ 1,860/MLD per month of variable cost and other additional costs to ensure quality in terms of alkalinity, TDS and color depending on the inlet quality. The Bamroli TTP made an annual profit of ₹ 1.3 crores (₹ 13 million) from selling treated used water in 2020. SMC generates a yearly revenue of ₹ 140 crores (₹ 1.4 billion) from the sale of treated used water.

Impacts, Scalability, and Replicability

Due to arid, semi-arid and saline conditions, Gujarat is highly water-stressed. Persistent water scarcity necessitated diversification to alternative water supplies and led to the exploration of reuse of treated used water. The success of treated water reuse in Surat has reduced the dependency on fresh water from the Tapi River; hence, more fresh water is available for domestic consumption. Additionally, a reduction in surface and groundwater abstraction and increased sewage treatment will improve the region's environment and water security. The Pandesara industrial estate (estimated annual turnover of ₹ 4,000 crore, i.e. ₹ 40 billion), experiences high quality and uninterrupted water supply. The total revenue estimated through industrial-grade water sales from Bamroli TTP up to 2017 is around ₹ 74.77 crore (₹ 0.74 billion). As most ULBs in India struggle for funds and are highly reliant on funding from state and central government, the augmentation of their revenues through the sale of treated water (and other products such as energy generated, sludge, etc.) will help ULBs be more self-reliant as well as be able to plan and expand their activities based on more reliable funds now available with them. To identify the demand for treated used water in industries, SMC has zoned the city into three main clusters (Bhesan, Dindoli and Bamroli Cluster). With capacity augmentation plans of increasing sewage treatment capacity to 1,655 MLD, Surat is estimated to reuse about 40% of treated used water (both secondary and tertiary) for various purposes, including industrial reuse in 2021, about 8% more than in 2019. SMC has initiated the set up of TTPs at Kavi Kalapi Garden for gardening purposes, toilet flushing, and gardening in the economically weaker housing sector.

Summary assessment - SWOT

Strengths	**Weaknesses**
• Water stress has created a demand for used water, and industries are willing to pay for treated used water. • SMC's strong role in liaising with stakeholders ensured strategic alliance with Industrial Associations and assured a guaranteed quantity of treated used water at a fixed price with an annual increase. • The ability to mobilise funds under Government schemes for project investment and in-house technical capacities enabled SMC to maximise the monetary benefit from the project and ensure complete cost recovery of investment. • State and city have created a strong enabling environment through policy and law to incentivize and encourage reuse.	• Capital cost funding dependency on the government for setting up TTP will limit scaling and replication. • The price paid for treated used water can be a concern for smaller industries whose ability to pay might be lower.
Opportunities	**Threats**
• Acceptability of treated used water for industrial usage and large-scale water-intensive industries presents an opportunity to increase water sustainability in economic systems. • With only 41% of the SMC area having a sewer network, increasing sewer coverage can promote higher collection, treatment and reuse of treated wastewater and address water-demand challenges. • Reusing treated used water in industries will augment revenue sources for SMC and balance overall water demand in the city. • Strong relations with industrial stakeholders enhance the city's industrial processes with reliable and uninterrupted water supply. Scaling up the initiative to other industrial units offers a great opportunity to maximise environmental and economic benefits in the region.	• Presently, the tariff for treated wastewater is higher than for fresh water. In the long run, adequate incentive mechanisms or reducing tariffs by increasing operations must be ensured for industries to continue using treated wastewater. • If groundwater usage is not monitored properly, industries may not feel the need to use treated used water as the cost incurred to access groundwater can be lower in the longer term. • Periodic monitoring of the quality of treated used water supplied is critical as this has implications of industries' acceptance of treated used water. • Breakdown in conveyance or treatment system will impact the quality and quantity of treated used water supplied to industries. Regular monitoring must be ensured to avoid these issues; if not, industries will lose interest in purchasing treated used water.

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2.2. Chennai, India

The city of Chennai is a representative case of safe reuse of treated used water in India. The city uses more than 10% of treated used water from its wastewater treatment plants to meet industrial, urban and recreational water demand (*Table 4*). This case study describes two reuse business models in the industries by Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB): i) supplying secondary treated used water to petrochemical industries; and ii) supplying tertiary treated used water to State Industries Promotion Corporation Tamil Nadu (SIPCOT).

Table 4: Key characteristics of case study Chennai, India

City: Chennai, Tamil Nadu		Case study: Petrochemical industries		Case study: Koyambedu & Kodugaiyur	
Population (Urban Agglomeration) (2020)	10.9 million	**Treatment capacity TTRO**	30 MLD at CPCL, 10 MLD at MFL and 1.5 MLD at MPL	**Treatment capacity TTRO (Koyambedu & Kodugaiyur)**	45 MLD (2 treatment plants
Annual population growth rate	2.3%				
Water scarcity	18% to 39%	**Treated quality**	Secondary treatment	**Treated quality**	Tertiary treatment
No. of STPs	13	**Operator**	CPCL, MFL and MPL (in-house)	**Operator**	Wabag – IDE BGR Energy Systems Ltd
% of total reused water from the WWTPs in Chennai	10% (year: 2020)	**End users**	CPCL, MPL and MFL	**End users**	SIPCOT

Abbreviations: CPCL, MFL and MPL = names of petrochemical industries, SIPCOT = State Industries Promotion Corporation Tamil Nadu, Wabag -IDE = Wabag and IDE technologies consortium

City Context and Background

Chennai, the capital of Tamil Nadu, is the fourth most populous metropolitan area in India with a population over 10 million, and has experienced severe water shortage, leading up to Day Zero[2] in June 2019. The city being synonymous for floods was a victim of drought in 2019 due to unparalleled urbanisation. The population increased more than 50 percent in the last two decades, the per capita availability of water reduced from 1,816 m^3 in 2001 to 1,545 m^3 in 2020. Due to extreme weather events, the supply of water in 2019 was reduced to 525 MLD against regular supply of 830 MLD which is significantly lower than the actual demand of 1200 MLD. To manage its demand for water, the Government has embarked on several projects to maximise the value of water. One such initiative that was identified is the reuse of secondary and tertiary treated wastewater.

Chennai hosts 13 functional Sewage Treatment Plants (STPs) with a total treatment capacity of around 745 MLD of sewage. CMWSSB has established two Tertiary Treatment and Reverse Osmosis (TTRO) Plants of 45 MLD capacity each. The treated wastewater is sold to industries, construction purposes, landscape, etc., in and around Chennai. Overall, about 30 MLD of secondary treated wastewater and

[2] Day zero is a forecast of water scarcity and no water available in the municipal water storage facilities to supply to its residents

90 MLD of tertiary treated wastewater is reused for industrial uses in the city. As a leading industrial city with prominent presence in automobile manufacturing, textiles, healthcare, hardware manufacturing, etc., the potential of treated used water supply to industries is expected to reduce the water stress situation in Chennai and adapt to climate vulnerabilities. Towards this, CMWSSB is systematically planning to increase the wastewater reuse operations by piloting two more additional plants of 10 MLD capacity and targets to scale the wastewater reuse operations to 240 MLD and supply to industries, lakes rejuvenation, irrigation, and other urban uses.

Wastewater Treatment and Water Reuse Infrastructure

Both the models use ultrafiltration and reverse osmosis technology to achieve industrial grade water as per design values (*Table 5*). The three stages involved in both the models are:

- Primary treatment stage: Pre-chlorination, Rapid Sand Gravity Filters
- Secondary treatment stage: Basket strainers, Ultrafiltration system
- Tertiary treatment stage: Cartridge filters, Reverse Osmosis system and Ozonation

Table 5: Performance Indicators of Secondary and Tertiary Treatment Plant in Chennai, India

Parameters	**Secondary Treatment Plant**			**Tertiary Treatment Plant**		
	Sewage inflow	Design value	After treatment	Sewage inflow	Design value	After treatment
Biological Oxygen Demand (mg/l)	250	460	<20	250-350	350	<3
Chemical Oxygen Demand (mg/l)	780	1570	<250	325-450	450	<10
Total suspended solids (mg/l)	430	690	<30	300-500	430	<1
Total Nitrogen (mg/l)	-	-	-	40-60	50	10
Total Phosphorous (mg/l)	-	-	-	5-8	8	2
Faecal Coliform (MPN/100ml)	$2.5x10^6$	-	$<10^4$	$2.5x10^6$	-	<1

Note: [1] Influent refers to inflow of sewage
[2] Design value refers to system handling capacity
[3] Effluent refers to treated wastewater

Business Value chain and Business Model

CMWSSB initiated its first reuse project in 2005 with Chennai Petroleum Corporation Limited (CPCL) by supplying 24 MLD of secondary treated used water. Shortage of water supply has led to closure of the CPCL plant for 35 days. The success of reuse by CPCL led to demand for secondary treated used water from Madras Fertilizer Ltd. (MFL) and Manali Petrochemicals Ltd. (MPL) who purchased 10 MLD and 1.5 MLD from CMWSSB respectively. Recognising the market for treated used water amongst industries and benefits from saved freshwater in the process, CMWSSB conducted demand assessment for TTRO water in Chennai by other industries. The demand for TTRO water only in North Chennai is estimated to be about 70 MLD in 2020 and is expected to increase to 75 MLD in 2030. Considering this, CMWSSB established TTRO plants between 2015 to 2019. CMWSSB has undertaken industrial reuse of treated used water in two different business models as mentioned below.

a) **Model 1: Secondary treated used water for petrochemical industries:** The used water from the households is treated at the STPs. CMWSSB invests in the conveyance system to supply secondary treated used water to CPCL, MFL and MPL. Each of these industries invest in respective tertiary treatment units to treat the water as per the water quality requirement. These industries have not only invested in the tertiary treatment plant but are also responsible for operating them. CMWSSB has entered into an agreement with each of these industries to supply an agreed quantity of secondary treated used water at fixed price. A schematic drawing of this business model is illustrated in the *Figure 2*.

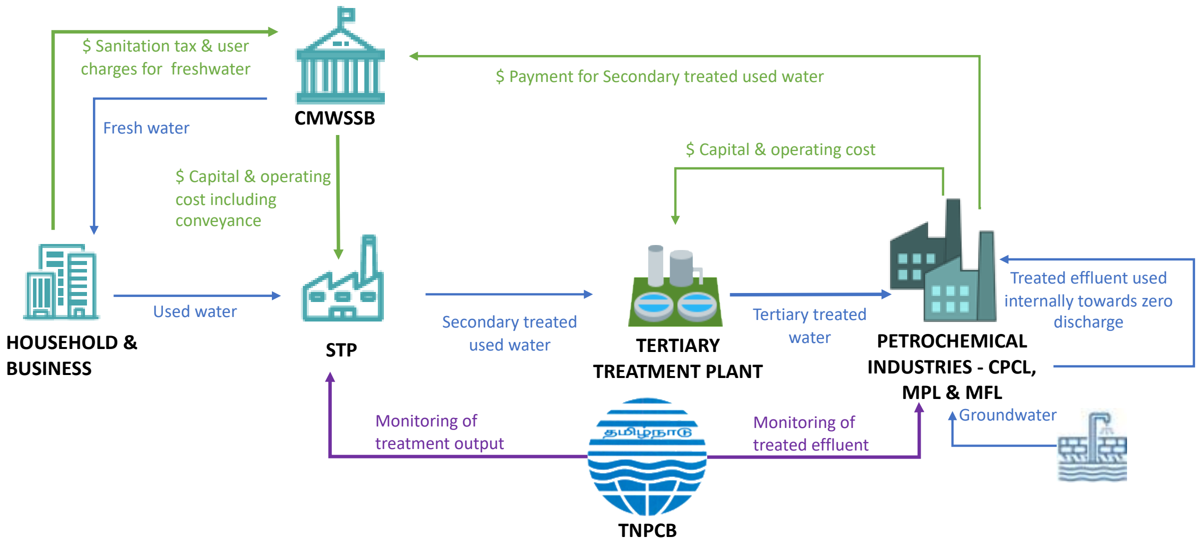

Figure 2: Industrial reuse in petrochemical industries, Chennai – Business Model 1

b) **Model 2: Tertiary treated used water for SIPCOT:** In this model, used water from the households is treated at the STP. CMWSSB transports secondary treated used water to tertiary treatment plant in Koyambedu and Kodungaiyur. The two TTRO plants have been set up under Design, Build and Operate (DBO) contract between CMWSSB and Wabag-IDE consortium and BGR Energy Systems for a period of 15 years. CMWSSB commits to provide assured quantity and quality of tertiary treated water to SIPCOT. A schematic drawing of this business model is illustrated in *Figure 3*.

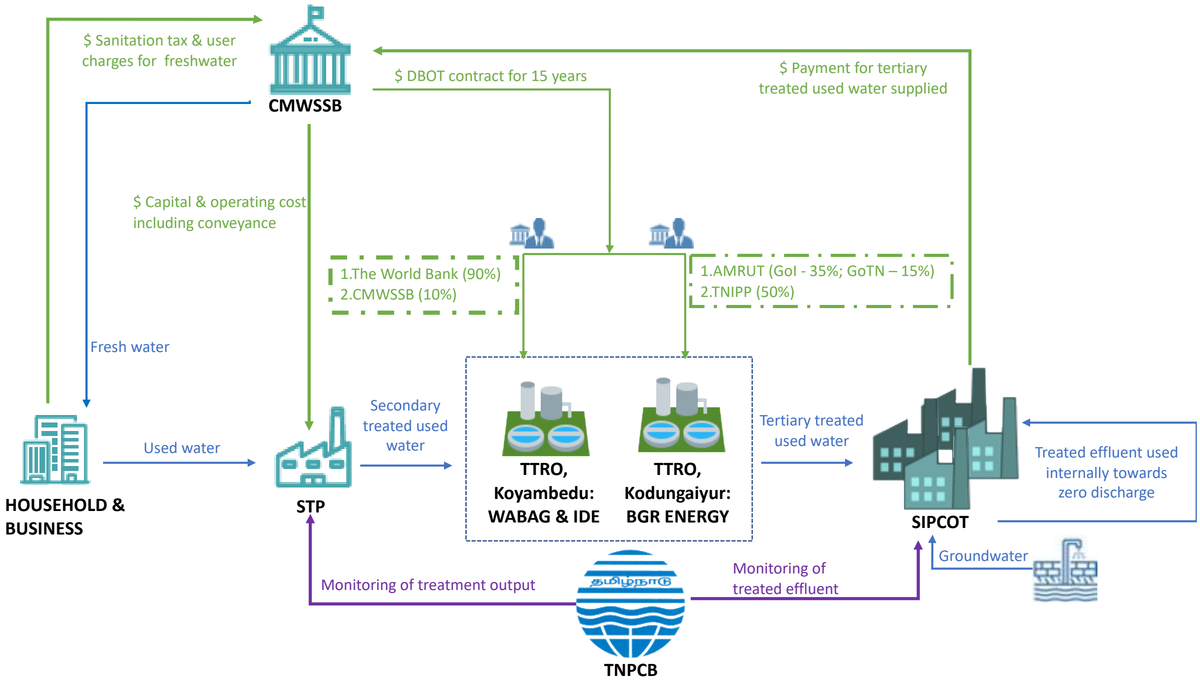

Figure 3: Industrial reuse in Koyambedu and Kodungaiyur, Chennai - Model 2

In both the models, Tamil Nadu Pollution Control Board (TNPCB) monitors the STPs and effluent from the industries to meet the required discharge standards. See *Table 6* on the business model canvas for both the models. The canvas highlights key elements for both the models and unless specified these elements are applicable to both the models.

Table 6: CMWSSB's Business Model Canvas for the reuse of treated used water in industries in Chennai

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
M/s Wabang – IDE consortium for Koyambedu (model 2) M/s. BGR Energy Systems Ltd for Kodungaiyur (model 2)	Treatment of used water at STP Conveyance of treated used water Tertiary treatment of used water	Assured quantity of secondary treated used water (model 1) Assured quantity and quality of tertiary treated used water (model 2)	Contractual agreement with the industries	CPCL, MPL and MFL (model 1) Industries in Sriperumpudur, Oragadam and Irungattukottai from Koyambedu TTRO and Manali-Ennore & Manali-Minjur corridor from Kodungaiyur TTRO (model 2)
	Key Resources Land Used water Funds for infrastructure Operating Cost		**Channels** Contractual agreement with the industries	

Cost Structure	Revenue Streams
Investment cost from CPCL, MPL and MFL for setting up tertiary treatment plant and its operations (model 1) Capital and operating cost for the TTRO under DBOT contract of 15 years. Koyambedu funded by World Bank and CMWSSB and Kodungaiyur funded by AMRUT and TNIPP (model 2)	Sale of secondary used water (model 1) Sale of tertiary used water (model 2) Sale of freshwater saved for domestic consumption
Social & environmental costs	Social & environmental benefits
High energy requirement to operate facility resulting in GHG (greenhouse gas) emissions	Reduced pressure on freshwater demand and reduced groundwater depletion Continued operation of industries ensures local employment creation

Institutional Environment

The Government of India under National Urban Sanitation Policy (NUSP) recognised the potential of used water reuse and recommended all cities to reuse at least 20%. As used water management is a state government responsibility, Government of Tamil Nadu, in line with the national vision, promotes reuse and it mandates industries to be supplied with treated used water. There is push for planning of future water demand by industries and establishing infrastructure to ensure supply of treated used water and treating it to industrial grade quality. Tamil Nadu Combined Development and Building rules, 2019 mandate use of recycled water in buildings over 5,000 m^2 and as well as in existing buildings with a built-up area of 20,000 m^2 or more. Excluding Chennai, about 80 MLD of secondary treated water is reused in Tamil Nadu in 2019 for industrial and agricultural purposes. Chennai city promotes circular economy which is led by CMWSSB. Greater Chennai Corporation has set up a bylaw to maximize reuse of use water by all stakeholders and provides incentives to encourage reuse. CMWSSB has increased the freshwater tariff for industries and implemented a zero-discharge policy making it mandatory for industries and manufacturers to achieve zero-liquid discharge in their operations.

Funding and Financing

Under the model 1, the capital cost for the tertiary treatment plant is incurred by CPCL and is about Rs 760 million and the annual operation costs are around Rs. 378 million, including the purchase cost for secondary treated used water from CMWSSB at Rs 20.25 per m^3 with an annual increase of 1.5 percent (*Table 7*). The investment in the tertiary treatment plant is recovered in 6.4 years as CPCL saves around Rs.126 million annually. The cost of conveyance is borne by CMWSSB.

Under the model 2, the TTRO plants at Koyambedu and Kodungaiyur are established at a capital cost (including conveyance of secondary treated used water to the plant) of Rs. 3.94 billion and Rs. 2.55 billion respectively. The plant at Koyambedu was funded under Government of India sponsored Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and Tamil Nadu Investment Promotion Programme (TNIPP) while the TTRO plant at Kodungaiyur was funded by the World Bank under Tamil Nadu Sustainable Urban Development Project (TNSUDP). The construction and operations for both the plants are contracted to private agencies on Design, Build and Operate (DBO) model for 15 years. The combined annual operational costs for both the plants, including the cost of plant operations and conveyance of the treated water is Rs.972 million. CMWSSB charges Rs 130/ m^3 for the tertiary treated water with an annual increase at 1.5 percent to the industries and achieves a pay back period of 4.9 years on its investment (*Table 7*).

Table 7: Capital and Operating Costs of the wastewater treatment and water reuse plants in Chennai, India

<table>
<tr><th colspan="2">Model</th><th>Capacity
[MLD]</th><th>Conveyance
[km]</th><th>Capital Costs
[billion Rs]</th><th>Annual Operating Costs [million Rs]</th><th>Price of treated water
[Rs/m^3]</th></tr>
<tr><td colspan="2">Model 1 (Secondary treated used water to industries)</td><td>30</td><td>Not Available</td><td>0.76</td><td>378</td><td>20.25</td></tr>
<tr><td rowspan="2">Model 2 (Tertiary treated water to industries)</td><td>Koyambedu</td><td>45</td><td>60</td><td>3.94</td><td rowspan="2">972</td><td rowspan="2">130</td></tr>
<tr><td>Kodaignur</td><td>45</td><td>28</td><td>2.55</td></tr>
</table>

Impacts, Scalability, and Replicability

Chennai city recycles 130 MLD of treated used water which is approximately 30% of the total sewage generated in the city. For industries, reuse of treated used water is providing a cost-effective. The distribution pipeline from the treatment plant to industries are providing continuous high quality and uninterrupted water supply for efficient operations. The sale of TTRO water has generated significant revenue of Rs.82.2 million per month to CMWSSB. The overall operations also benefitted the environment by reducing the discharge of sewage into lakes, rivers and water bodies. CMWSS has set a target to increase the capacity of sewage treatment plants to 600 MLD by 2026 and reuse 50% of the treated sewage for non-potable purposes. Also, TTRO plants set an example for cost-effective alternative in comparison to water supply augmentation technologies like desalination plants. The capital investment required to set up desalination plant (100 MLD capacity) in Chennai is around Rs. 2,357 million while for TTRO (90 MLD both) is only at 649 million, a 72.5% reduction. Realizing the benefits of reuse of treated used water, CMWSSB has proposed two Tertiary Treatment Ultra Filtration (TTUF) projects at Perungudi and Nesapakkam. Each of these plants will have a capacity of 10 MLD each, and will increase supply of water, reducing the stress on existing water resources.

Summary Assessment - SWOT

<table>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>• Treated used water is acceptable to industries for usage
• Water stress situation has created a demand for used water and industries are willing to pay for treated used water
• CMWSSB paying for the investment and operating cost for conveyance of treated used water
• State and city have created a strong enabling environment through policy and by law to incentivize and encourage reuse
• High revenue source for CMWSSB and complete cost recovery of investment</td><td>• Industries may not always be willing to invest in TTRO (Model 1)
• Capital cost funding dependency on government for setting up TTRO will limit scaling and replication (Model 2)
• Price paid for treated used water can be a concern for smaller industries whose ability to pay might be lower
• High capital and operating cost of conveyance can limit in achieving cost recovery of the investment for CMWSSB</td></tr>
</table>

Opportunities	Threats
• Only 10% of used water is reused and CMWSSB can supply treated used water at full cost recovery • State policy and Chennai city by law mandates industries to be supplied with treated used water and price freshwater significantly higher than treated used water • Reuse of used water in industries will augment revenue source for CMWSSB from sale of saved freshwater for domestic purpose. • Rise in city population will result in increased freshwater demand and reuse of used water in industries can help balance this overall water demand by the city	• If the monitoring of groundwater usage is not done properly, industries may not feel the need for using treated used water as cost incurred to access groundwater can be lower in the longer term • Periodic monitoring of quality of treated used water supplied is critical as this has implications of industries acceptance of treated used water in both the models. • Breakdown in conveyance or treatment system will have impact on the quality and quantity of treated used water supplied to industries. If these issues come up frequently, industries will lose interest in purchasing treated used water

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2.3. Mathura, India

The city of Mathura in the state of Uttar Pradesh, India, is a representative case of safe reuse of treated wastewater (Table 8). This case study describes the business model of treated water from the sewage treatment plants (STPs) from the Mathura Refinery of the Indian Oil Corporation (IOC).

Table 8: Key characteristics of case study Mathura, India

City: Mathura city, Uttar Pradesh, India		Case study: IOCL	
Population (2021)	481,000	**Treatment capacity**	20 MLD Tertiary Treatment Plant (TTP)
Annual population growth rate	2.49	**Treatment**	Tertiary Treatment
Water scarcity	Water surplus wrt Water Treatment Plants (WTPs) but ground and surface water quality is degraded	**Operator**	Triveni Engineering & Industries Ltd.
No. of municipal WWTPs			
% of total reused water from the WWTPs in Mathura	7 STPs and almost 39% is being reused	**End users**	IOCL, Mathura

City Context and Background

The Mathura Refinery is the sixth refinery owned by the Indian Oil Corporation. It is situated in Mathura, Uttar Pradesh, around 154 kilometres from the national capital of New Delhi. In the Ganga Basin, sewage production averages 12,000 liters per day, but the available treatment capacity is only about 4,000 MLD. A treatment capacity of 1000 MLD has been developed to date to handle the 3000 MLD of sewage that is released into the mainstream of river Ganga from the Class I and II Cities that are situated along its banks. At its Mathura Refinery, the Indian Oil Corporation (IOC) has signed a contract for the reuse of treated wastewater (*Table 9*). Through this project, National Mission for Clean Ganga (NMCG) and Uttar Pradesh Jal Nigam aim to accomplish the following goals:

- Intercept raw sewage flowing into the river Yamuna and divert the raw sewage to the Sewage Treatment Plants (STPs) of Mathura.
- Treatment of the raw sewage at Mathura STPs
- Treatment of STP effluents for usage at IOCL premises
- Implementation of viable technologies and international best practises for development, operation, and maintenance of Mathura's STPs, Tertiary Treatment Plants (TTPs), and other facilities

Table 9: Project components of Mathura's water reuse scheme

S. no.	Description - Trans Yamuna Zone	Capacity/Length
1	Newly proposed TTP at Lakshmi Nagar based on RO technology	20 MLD

S. no.	Description - Trans Yamuna Zone	Capacity/Length
2	Treated Water Disposal Pipeline	10.11 Km
3	Rehabilitation and restoration of existing Waste Stabilization Ponds (WSP) STP at Lakshmi Nagar	14.5 MLD Average flow
4	Rehabilitation and restoration of existing Anaerobic Sludge Blanket Reactor (UASB) STP at Lakshmi Nagar	16 MLD Average flow
5	Construction of Bengali Ghat MPS, Dhruv Ghat drain I&D works, Ashkunda Ghat Nala I&D works, Vishram Ghat Nala I&D works, Bengali Ghat Nala I&D woks	32.7 MLD
6	Rising main from Bengali Ghat MPS (573m new rising main and 587m old line)	1.16 KM
7	Rehabilitation and restoration of Chintaharan IPS, Chintaharan Nala I&D works, Gaughat Nala I&D, works, Daula Maula I&D works	
8	Gravity Sewer from Chintaharan IPS to Bengali Ghat MPS	1.42 KM
9	Rehabilitation and restoration of Swami Ghat IPS, Ranighat Nala, Swami Ghat Nala	
10	Rising main from Swami Ghat IPS to Bengali Ghat MPS	1.00 KM
11	Rehabilitation and restoration of Dairy Farm MPS, Ambakhar Nalla I&D works, Dairy Farm Nalla I&D works, Mahadev Ghat drain I&D works, Satrangi Nalla I&D works	
12	Rising main from Dairy Farm MPS	
13	Rising main from Cantt IPS to Dairy farm MPS	1.62 kM
14	Rehabilitation and restoration of Cantt Nalla IPS, Cantt Nalla I&D works, Dairy farm drain I&D works	1.22 kM
15	Gravity main from dairy farm drain to Cantt IPS	1.41 kM

Source: NMCG, 2022

The Mathura refinery has several processing units, including an atmospheric vacuum unit (AVU), a fluidized catalytic cracking unit (FCCU), a visbreaking unit (VBU), a continuous catalytic reforming unit (CCRU), a diesel hydro desulphurization unit (DHDS), a once-through hydrocracker unit (OHCU), and a diesel hydrotreater unit (DHDT), amongst others. In addition to sulphur recovery units (SRU) and hydrogen generation units (HGU), it also houses a bitumen blowing unit (BBU) and a petrol desulfurization unit (Prime-G). Following the installation of a once-through hydrocracker unit in July 2000, the refinery's capacity was boosted to 8 million tonnes per annum (mtpa). At the Mathura refinery, a 55,000 tonnes per annum (tpa) octa max unit was put into service in January 2018.

Wastewater Treatment and Water Reuse Infrastructure

The freshwater supply for the IOCL Mathura refinery is obtained from two sources: the Yamuna River and the artificial reservoir Keetham (*Figure 4*). To ensure the raw water quality meets the required standards for the refinery's operations, a Raw Water Treatment Plant (RWTP) was established near

Keetham Lake. The raw water treatment process includes coagulation and flocculation, as well as disinfection treatment near the lake itself. The treatment process involves the use of chemicals such as Poly Aluminium Chloride (PAC), Poly Electrolyte, and Sodium Hypochlorite (the latter replacing chlorine, utilising the Electro chlorination process for disinfection). The IOCL Mathura refinery extracts approximately 390 m^3/hr (9360 m^3/day) of Yamuna River water and 1550 m^3/hr (37200 m^3/day) from Keetham Lake. The total freshwater consumption within the existing IOCL Mathura Refinery complex is 669m^3/hr, and the overall specific water consumption in the facility is estimated at 0.60 m^3 per ton of crude processed. In the existing facility, the wastewater discharge into the river is 176 m^3/hr and the treated wastewater recycling stands at 402 m^3/hr (70%) *(Tables 10 and 11)*.

Table 10: Pollutant treatment methods at the effluent treatment facility

S. No.	Pollutant	Treatment Method	Equipment
1	Free oil	Gravity separation	API, TPI
2	Emulsified oil	Chemical destabilization and flotation	Dissolved Air Floatation (DAF)
3	Sulphides	Chemical oxidation	Reaction Chamber
4	Organics (BOD/COD)	Biological oxidation Sedimentation	Bio Tower, Aeration Tank,
5	Settleable Solids	Sedimentation	Final Clarifier
6	Microbes (Bacteria, Algae, etc.)	Disinfection by Chlorination	Chlorine Treatment
7	Suspended solids	Sedimentation Filtration	Dual Media Filters (DMFs), Activated Carbon Filters (ACFs)

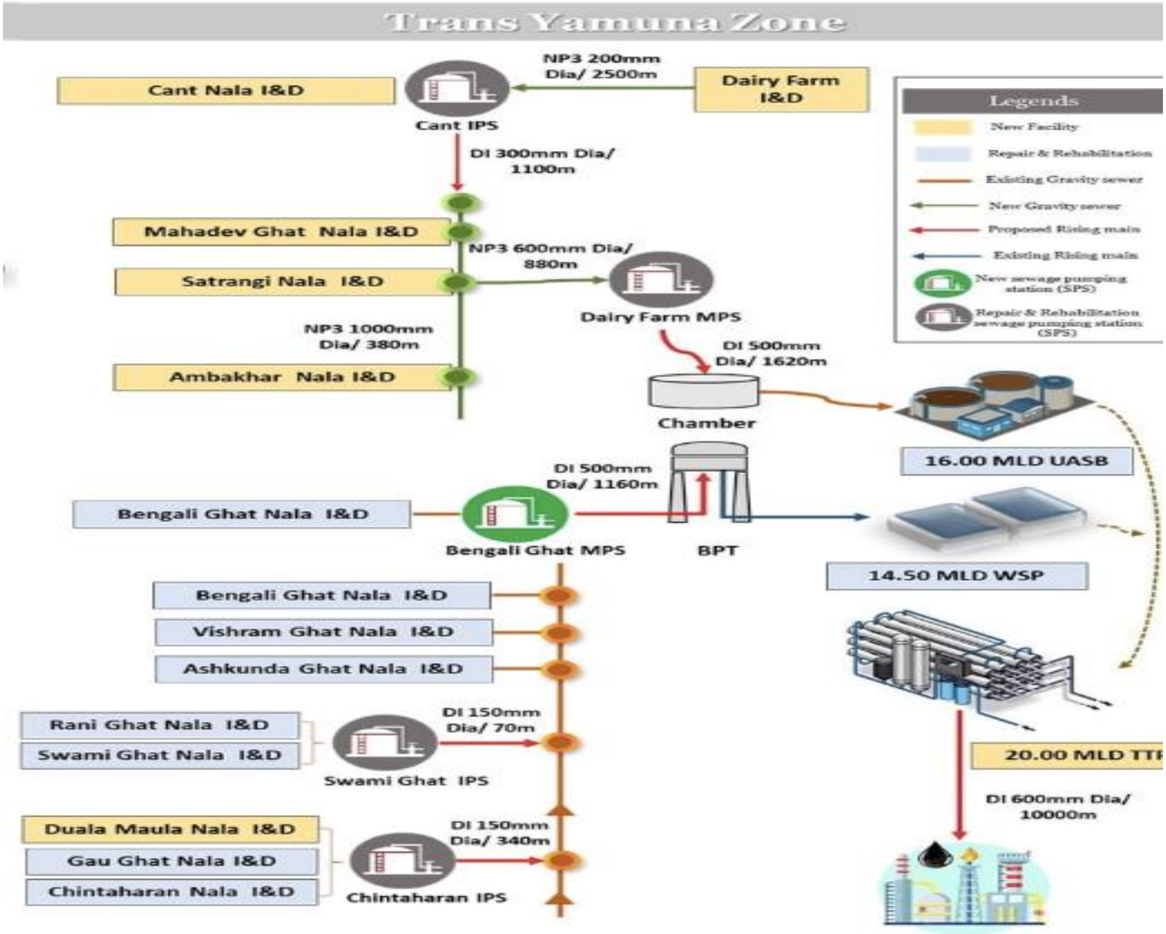


Figure 4: Integrated Sewage Infrastructure Development of STP and Associated Infrastructure under HAM based PP mode at Mathura

Existing Wastewater Treatment System: IOCL Mathura has a comprehensive effluent treatment plant (ETP) to meet CPCB discharge standards. The plant can handle a maximum flow rate of 1050 m^3/hr, especially during the wet season, and employs oil separation methods like API/TPI filters and Dissolved Air Flotation (DAF) for efficient removal of suspended matter and solids. The collected oil sludge undergoes centrifugation and then stored in a PVC-lined pit for bioremediation. The floated water from the DAF system is directed to a biological section comprising a Bio-Tower and Aeration tank, where BOD and COD removal take place. Thereafter, the wastewater goes through a clarification process to eliminate suspended solids introduced during biological aeration. The clarified water is further routed to the guard pond, polish pond, firewater systems, and greenbelt maintenance. A portion of the treated water, 176 m^3/hr, is discharged into the river. Another 460 m^3/hr of treated water is subjected to Dual Media Filter (DMF) and Activated Carbon Filter (ACF) to remove fine suspended solids and colour.

Reverse Osmosis (RO): The IOCL Mathura employs the RO system to enhance the removal of Total Dissolved Solids (TDS) and increase the reuse and recycling of treated wastewater for refinery operations. The RO plant based on treated effluent from ETP as feed has been commissioned in November 2008. It takes an ACF outlet as feed and produces low TDS RO permeate water as a product which is used as feed to the DM plant in TPS. The RO plant consisting of three sections (Pre-Treatment, Ultrafiltration and RO) is designed to produce 150 m^3/hr of RO permeate.

Table 11: Treated Wastewater Quality

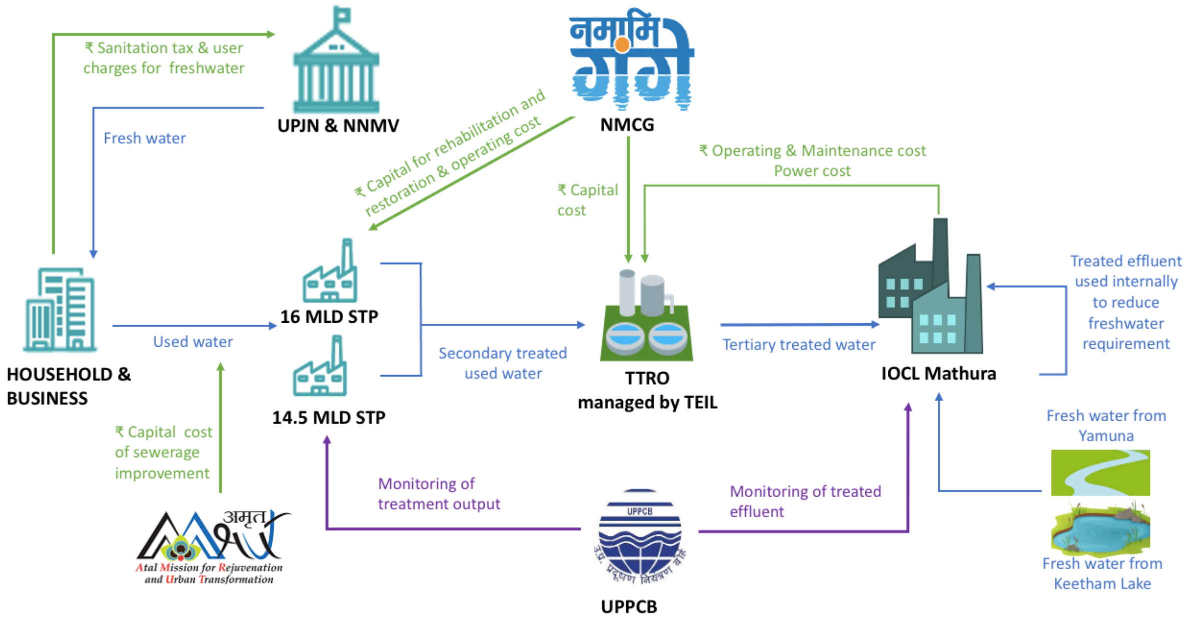
Parameters	Quantity of pollution generated			
	mg/lit except for pH		Kg/100 MT crude oil	
	Standard	Actual	Standard	Actual
pH	6.0 – 8.5	7.7	-	-
BOD	15	13	6	2.2
COD	125	123	50	20
Suspended Solids	20	18	8	3
Phenols	0.35	0.1	0.14	0.02
Sulphides	0.5	0.4	0.2	0.1
CN	0.2	ND	0.08	ND
Ammonia as N	15	6.6	6	1.6
Pb	0.1	0.03	0.04	0.01
Hg	0.01	ND	0.004	ND
Zn	5	2.5	2	0.6
Cu	1	0.1	0.4	0.04

Source: IOCL, 2017

Business Value Chain and Business Model

The Mathura treated sewage reuse project *(Figure 5; Table 12)* is special for three reasons. This is the country's first **Integrated Sewage Infrastructure project based on the One City–One–Operator concept**, which means that the project integrates the building of new STPs and the maintenance of the existing infrastructure under one operator for the whole city. Secondly, under this project, the **treated sewage water is planned to be reused by IOCL.** Thirdly, the project is based on the **Hybrid Annuity Model**, the third-of-its kind in this sector after the HAM–based (Hybrid Annuity Mode Based) STPs being developed in Haridwar and Varanasi. The introduction of the *HAM-PPP (public–private partnership) model"* and the "*One City One Operator (OCOP) model*" have given a much-needed push to PPPs in the sector.

Used Water Reuse Business Operations to IOCL Mathura



NMCG- National Mission for Clean Ganga; UPJN- Uttar Pradesh Jal Nigam; NNMV- Nagar Nigam Mathura-Vrindavan; STP- Sewage Treatment Plant; MLD- millions of liters per day; TTRO – Tertiary Treated Reverse Osmosis; IOCL- Indian Oil Corporation Limited; TEIL- Triveni Engineering & Industries Limited; UPPCB- Uttar Pradesh Pollution Control Board

Figure 5: Business value chain of Industrial reuse in IOCL Mathura

An estimated cost of Rs. 437.95 crore on HAM-based model has been assigned to Triveni Engineering & Industries Ltd. for the building, operation, and maintenance of a 30 MLD STP in Masani, as part of the Mathura project. A total sewage treatment capacity of 67.3 MLD will be achieved by upgrading and rehabilitating the two existing STPs (14.5 MLD and 16 MLD) in the Mathura region of the Trans-Yamuna, and by developing and rehabilitating the Masani Sewerage Infrastructure. The existing Masani STP has a capacity of 6.8 MLD. A 20 MLD Tertiary Treatment Plant (TTP) will also be built to provide the IOCL Mathura Refinery with treated effluent. The TTP would cost Rs. 162.38 crore to create and operate over 15 years. IOCL would be responsible for paying all operating and maintenance expenses for the TTP for 15 years, which totals to Rs. 82.38 crore. Additionally, IOCL will contribute Rs. 8.70 per kiloliter towards the partial capital cost of developing the TTP. This would reduce the amount of water that IOCL formerly utilised (from the water-stressed Yamuna River) by 2 crore litres per day. Promoting the market for recycled/reused treated wastewater in India would aid in maintaining the infrastructure's functionality, which is urgently needed in the sewage industry. Treated effluent streams are reused or recycled for various purposes in refineries, like make-up for fire water, cooling towers, coke cutting in delayed cokers, etc. The following steps have led to 80–95% of treated water being reused in the refineries, which has resulted in a substantial reduction in freshwater consumption.

- Sour water generated in various units is stripped of contaminants such as ammonia and H_2S and recycled in de-salters, besides being used for process flushing requirements.
- Advanced treatment systems like ultrafiltration, Reverse Osmosis, etc. are used to convert treated effluent to demineralised water or for use in cooling towers as make-up water.
- Rainwater harvesting structures have been put up in all refinery townships, marketing and pipeline installations, and the R&D Centre for recharging groundwater.

Table 12: Mathura's IOCL Business Model Canvas for reuse of water

<table>
<tr>
<td rowspan="2">Key Partners
NMCG
UP Jal Nigam
Indian Oil Corporation
Ministry of Jal Shakti
Ministry of Petroleum & Natural Gas
Mathura-Vrindavan Development Authority
Mathura-Vrindavan Nagar Nigam
Mathura Wastewater Management Pvt. Ltd.
Triveni Engineering & Industries Ltd. or Mahindra Consulting Engineers, Chennai</td>
<td>Key Activities
Water Treatment and Purification
Water Reuse System Design and Infrastructure</td>
<td rowspan="2">Value Propositions
To reduce the dependency of freshwater for refinery operations
Enhanced Water Security
Circular Economy Approach</td>
<td>Customer Relationships
Contractual agreement with the industries</td>
<td rowspan="2">Customer Segments
IOCL Mathura</td>
</tr>
<tr>
<td>Key Resources
Water Treatment Infrastructure
Water Storage and Distribution Infrastructure</td>
<td>Channels
Contractual agreement with the industries</td>
</tr>
<tr>
<td>Cost Structure
Total expenditure (NMCG & NWMPL) 143.44 crore</td>
<td colspan="4">Revenue Streams
Sale of tertiary treated water to IOCL Mathura</td>
</tr>
<tr>
<td>Social & environmental costs
Infrastructure Investment
Operational Challenges
Water Availability Concerns</td>
<td colspan="4">Social & environmental benefits
Social Acceptance
Infrastructure Investment
Water Availability Concerns</td>
</tr>
</table>

Institutional Environment

As a part of the *Namami Gange* programme, the Ministry of Jal Shakti aims to promote the reuse of treated water from STPs situated on both sides of Rivers Ganga and Yamuna for non-potable purposes for the different establishments of the Ministry of Petroleum and Natural Gas. This approach will minimise water withdrawal for non-potable use through efficient utilisation of water resources and reduce river water pollution. For this purpose, the Mathura refinery completed an upgrade project to create transportation fuels complying with BS-VI in January 2020. Additionally, an agreement was signed between NMCG and IOCL to reuse 2 crore liters of treated sewage water per day at IOCL's Mathura refinery, which up until this point had been drawing water from the already overburdened Yamuna River.

Funding and Financing

The project on Rehabilitation/Renovation of the Mathura sewerage scheme in UP state under the Namami Gange Programme at an estimated cost of Rs. 460.45 crore (*Table 13*) under hybrid annuity-based PPP mode with 100% central funding has the following components:

a. Nala tapping arrangement including gravity header: 20 numbers, covering 4.775 km
b. Construction of a 20 MLD TTRO plant, rising main, and pumping station for supply of treated wastewater to the Mathura refinery of IOCL.
c. Operation and maintenance for 15 years

Table 13: Summary of the cost of the project proposal for rehabilitation or renovation of the Mathura sewerage scheme in Uttar Pradesh under the Namami Gange Programme

S. N	Description	Approved cost (In Rs. Lakhs)
I	**Mathura STP Component**	17,067.00
	Capital Cost inclusive of all taxes	5,428.80
	O & M Cost for 15 year including GST	5,061.80
	Power consumption charges	27,557.60
	Total	**27,557.60**
II	**Mathura TTRO – IOCL Component**	
	Capital Cost inclusive of all taxes	8,000.00
	O & M Cost for 15 year including GST	3,972.60
	Power consumption charges	4,264.87
	Total	**16,237.47**
	Total (I+II)	**43,795.07**
III	**Work on which no centage admissible**	
	Original Cost of Project preparation	439.08
	Original Cost of Project supervision	439.08
	Sub total	878.16
	Power connection	485.48
	ESAMP	219.54
	Communication and public outreach (GAAP)	219.54
	Governance and accountability	219.54
	Payments to other departments	228.14
	Total (III)	**2,250.40**
IV	**Grand Total (I+II+ III)**	**46,045.47**

To meet the industrial raw water quality standards, a Concession Agreement for the development of a STP for Mathura was signed. It is anticipated to be finished in 24 months and will use technologies including membrane-based bioreactors (MBRs). The Mathura Refinery will utilize 20 MLPD of this plant's treated effluent. Even though NMCG is covering the plant's capital expenditures, IOC will be responsible for electricity and operations and maintenance (O&M) costs as well as paying Rs. 8.70 per kilo for the treated water for the first 15 years the plant is in operation.

Impacts, Scalability, and Replicability

The IOCL Mathura Refinery has received several awards and accolades for its water management practices, including the "Water Efficient Unit" award from the Confederation of Indian Industry. The IOCL Mathura Refinery's emphasis on the safe re-use of treated water serves as an excellent example of sustainable water management practises that other industries and organisations may employ to reduce their adverse impacts on the environment and local water resources.

Summary assessment – SWOT

• **Strength** • Treated wastewater is reused for cooling tower makeup, firefighting, and gardening. • The refinery maintains rainwater harvesting system to supplement water supply. • SRTW in the refinery aids in reduction of freshwater requirement, minimises wastewater discharge into local water bodies, and reduces the environmental footprint of the refinery.	**Weakness** • High capital expenditure can pose a problem in the future; financial sustainability of running the treated wastewater reuse system must be ensured. • Lack of a proper O&M plan can endanger continued functioning of the system.
Opportunity • The refinery operations will reuse treated effluent (20 MLD) from a STP being built in the Mathura-Vrindavan area for various applications (like irrigation). • The existing 6.25 MLD CETP in Mathura is being upgraded, and another for a 7.5 MLD CETP is being planned in Gorakhpur. • A new textile park with a 1.5 MLD CETP is planned in Farrukhabad. The Textile Cluster Association has accepted the proposals for CETPs with a ZLD (Zero liquid discharge)-based system.	**Threats** • From time to time, potential risks of treated water on public health may be monitored and appropriate actions may be taken. • The social and cultural barriers to acceptance of treated water may be investigated, and any occurrence of public grievance may be addressed accordingly

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3. Business Models for Agricultural Reuse

3.1. Alicante, Spain

The city of Alicante is a representative case of safe reuse of treated used water (SRTW) in Spain. The city uses more than 40% of treated used water from its two wastewater treatment plants (Rincón de León WWTP and Monte Orgegia WWTP) to meet urban, recreational and agricultural water demand (*Table 14*). **This case study describes the SRTW business model from the Rincón de León WWTP-water reclamation plant (WRP) to agriculture. The business model involves a private operator who runs the WRP and sells tertiary treated water to irrigation associations.**

Table 14: Key characteristics of case study Alicante, Spain

City: Alicante, Valencia, Spain		**Case study: SRTW from Rincón de León WWTP-WRP for agriculture**	
Population (2021)	337,304	**Treatment capacity Rincón de León WTP**	60'000 m^3/day
Annual population growth rate	0.26%	**Treatment**	Tertiary (double network)
Water scarcity/demand vs. supply	Highly water scarce region	**Operator**	AMAEM ('Aguas Municipalizadas de Alicante', Empresa Mixta)
No. of municipal WWTPs (with used treatment capacity)	2 (28 million m^3/year: year: 2018)	**% of treated water reused in agriculture**	27% (year 2012)
% of total reused water from the WWTPs in Alicante	43 % (year: 2018)	**End users**	Irrigation associations

City Context and Background

Alicante city in southern Spain faces water shortage given its rapid urban and industrial development and the high tourism activities during summer. Rainfall is highly variable, with average precipitation between 230 – 900 mm/year. The province of Alicante is found among the regions with the highest groundwater overexploitation rates worldwide. Therefore, the region is also known for its high levels of desalination and water reuse (ca. 50% of total generated wastewater in the region is reused). Alicante City Council (ACC) has promoted the use of treated used water since 2006 by funding and implementing the tertiary treatment plant (WRP) at Rincón de León. Aguas Municipalizadas de Alicante, E.M. (AMAEM) is contracted to operate the water reclamation plant and deliver tertiary treated effluents for urban, recreational, and agricultural purposes. The key users are two Irrigation Associations, i.e., Alicante Irrigation Association (AGRICOOP) and High Vinalopó Irrigation Association (ARALVI). The agriculture and golf course irrigation demand in Alicante city is around 12 million m^3/year (43% of treated used water is reused).

Wastewater Treatment and Water Reuse Infrastructure

The Rincón de León WWTP has a treatment capacity of 75,000 m^3/day (average capacity utilization of 52,644 m3/day in 2012). It collects water from the south of Alicante city and the nearby town of San Vincente de Raspeig. It is a conventional secondary activated sludge and anaerobic digestion (AD) treatment plant. The produced biogas is used for heating the sludge in the AD reactor and for electricity production (2.5 MWh/year) that is fully utilized within the wastewater treatment plant to cover 25% of the plant's energy needs.

The WRP in Rincón de León treats secondary effluent using alternative treatment lines since 2006. This allows water production depending on water quality requirements for different uses. Corresponding water qualities are obtained by mixing treated used water from the three treatment alternatives:

- Alternative A: (“CFF UV water”) Coagulation (ferric chloride) + flocculation + sand bed filtration (CFF, 6 filtration lines with a capacity of 10,000 m^3/day). Part of the filtered water (up to 8,000 m^3/day) is subsequently disinfected with UV and then goes to a mixing receptacle, which mixes with ultrafiltered water (Alternative B).
- Alternative B (“UF water”): The remaining filtered water (up to 42,000 m^3/day) enters three self-cleaning 500 µm filters and then the ultrafiltration (UF) membranes (6 modules, each with UF submersible hollow fiber membranes).
- Alternative C (“RO water”): UF water passes into five 5 µm filters and then into five racks of reverse osmosis (RO) membranes. Up to 25,000 m3/d of desalinated water (<100 µS/cm) can be provided.

Treated used water quality from the treatment alternatives A-C is shown below (Quality parameters, mean values, year 2012). Treated used water from treatment alternatives B and C complies with all agricultural and recreational reuse categories under Spanish law (Royal decree 1620/2007, *Table 15*). E.coli values in treated used water from treatment alternative A are not compliant with the irrigation of fresh crops for human consumption.

Table 15: Treated effluent qualities of Rincon de Leon WRP and Spanish water reuse standards

	Treatment alternatives			**Royal Decree standards for agricultural and recreational reuse**			
Quality parameters as per Spanish Royal Decree 1620/2007	**A**	**B**	**C**	**Quality 2.1*** fresh crops for human consumption	**Quality 2.2*** crops for human consumption	**Quality 2.3*** ligneous crops	**Quality 4.1*** Recreational uses
Suspended solids, **SS** (mg/L)	11.3 ± 2.3	0.91 ± 0.72	0.33 ± 0.63	20	35	35	20
Turbidity (NTU)	3.20 ± 0.98	0.43 ± 0.06	0.20 ± 0.03	10	no limit	no limit	10
E. coli (CFU/100 mL)	73.5 ± 42.0	33.74 ± 16.24	0	100	1000	10000	200
Intestinal nematode eggs (egg/10L)	n.a.	n.a.	n.a.	1	1	1	1
Conductivity 20°C (µS/cm)	n.a.	2,311.0 ± 187	57.09 ± 13.22	n.a.	n.a.	n.a.	n.a.
Chemical oxygen demand, **COD** (mg/L)	41.9 ± 5.72	27.1 ± 2.27	3.43 ± 1.75	n.a.	n.a.	n.a.	n.a.
Biochemical oxygen demand, **BOD** (mg/L)	6.9 ± 2.71	3.08 ± 1.93	0.92 ± 0.51	n.a.	n.a.	n.a.	n.a.

* **Quality 2.1** = Agricultural use- irrigation of fresh crops for human consumption; **Quality 2.2 =** Agricultural use- irrigation of crops for human consumption; **Quality 2.3 =** Agricultural use- localized irrigation of ligneous crops; **Quality 4.1 =** Recreational uses - irrigation of golf courses

Business Value Chain & Business Model

RO and UF Water are distributed in pipelines of 650- and 350- mm diameter (dual network) to several water tanks owned by the Irrigation Associations (IAs). The quantity supplied by each is regulated according to the conductivity conditions (water quality) required by the IAs AGRICOOP and ARALVI (*Figure 6*). AGRICOOP uses treated used water to irrigate 1,104 ha and a golf course. The main crops, irrigated by drip irrigation, are almonds, tomatoes, citrus fruits and pomegranate and olive trees. ARALVI uses treated used water to irrigate 2,040 ha and also a golf course. The main crops are almonds, grapes, nectarines, oranges and olives.

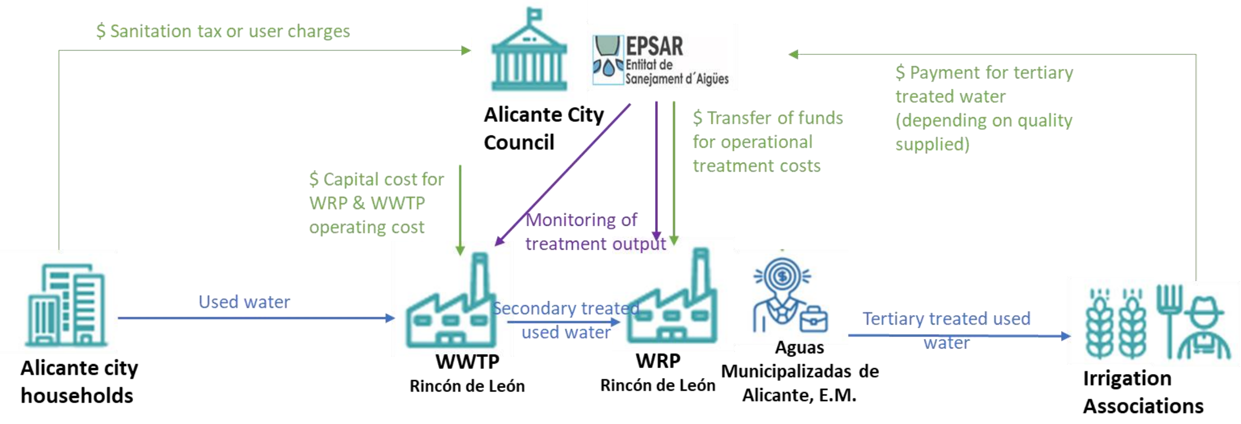

Figure 6: AMAEM's Business value chain of Rincon de Leon water reuse scheme with stakeholders

AMAEM distributes the treated water using different charges ranging from 0.23 -0.36 EUR/m^3 (see funding and financing). The IAs have concessions on yearly reclaimed water allocations granted by the Watershed authorities, i.e., Water Master Plan of the Jucar Basin Authority (*Table 16*). AGRICOOP get 5 million m3/year and ARALVI 6.7 million m^3/year. Roughly 30% of those water demands are met with RO water.

Table 16: AMAEM's business model Canvas of water reuse from Rincon de Leon WWTP-WRP

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
Jucar River Basin Authority Alicante City Council (ACC)	Treating wastewater to tertiary quality (WRP Rincon de Leon) depending on demands and quality requirements from end users **Key Resources** Land Wastewater WRP infrastructure Cost-covering O&M of WRP and distribution network	Distribution of tertiary treated used water adapted to quality requirements by end users.	With Irrigation Associations to assure steady demand of treated used water With ACC to foster urban and recreational reuse (e.g., park irrigations etc.) **Channels** Contractual agreements of AMAEM with ACC and Irrigation Associations to assure quantity and quality of water supply	Irrigation Associations (AGRICOOP and ARALVI)

Cost Structure	Revenue Streams
Capital cost of tertiary treatment plant (borne by ACC) Operations of tertiary treatment plant: - Staff, electricity, reactants O&M and distribution costs charged to end-users	Revenues from sale of treated used water to Irrigation Associations (cost-covering)

Social & environmental costs	Social & environmental benefits
High energy requirement to operate facility resulting in GHG (greenhouse gas) emissions	Reduced pressure on freshwater demand and groundwater depletion Affordable and acceptable alternative water source for farmers

Institutional Environment

The European Water Directives, i.e., the Water Framework Directive (WFD) 2000/60/EC and Urban Wastewater Treatment Directive 91/271/EC require secondary treatment for all towns having more than 2,000 inhabitants. Non-compliance is punished by fines. In Spain, the Royal Decree 1620/2007 is the legal binding framework for the reuse of treated used water. It contains quality parameters for different types of water reuse, i.e., urban, agricultural, industrial, recreational and environmental. Moreover, regional policies in watershed planning, i.e., the Jucar River Basin Plan 2014, or the Master Plan of Sanitation and Purification 2003 for the communities of Valencia favored water reuse in Alicante city.

Funding and Financing

Cost recovery from wastewater treatment is mandatory by the European WFD 2000/60/EC and was therefore introduced in the Spanish legal system in 1985 (amended Water Act 62/2003). AMAEM charges operation costs of wastewater treatment to every user of the Alicante water supply. The Wastewater Treatment Regional Act 2/1992 introduced a specific tax for primary and secondary wastewater treatment cost recovery. Water users pay according to the quantity of water they use. The sewage taxes and the water supply tariff in Alicante city ensure an almost 100% cost recovery for the secondary treatment at Rincon de Leon WWTP.

To reach full cost recovery at the Rincon de Leon WRP, the cost of tertiary treatment and distribution is directly charged to IAs. The construction and operating costs (as of year 2013) of the WRP are displayed in *Table 17.* Operating costs include staff costs, electricity and reactants. The average energy consumption for each alternative is CFF= 0.047 kWh/m^3, UV = 0.056 kWh/m^3, UF and RO = 0.236 kWh/m^3 and 0.869 kWh/m^3. Maintenance costs, overheads and business profit are further added to the price charged to IAs. The IAs agreed with EPSAR (public sanitation agency of Valencia Region) to pay additionally for the water distribution infrastructure to the irrigation tanks. ALARVI are charged 0.124 EUR/m^3 for treated water from CFF-UV mixed with UF and 0.36 EUR/m^3 of RO treated water. AGRICOOP pays 0.23 EUR/m^3 and 0.28 EUR/m^3 respectively. Prices are updated in accordance with the consumer price index. The funds are further transferred by EPSAR to AMAEM to cover for operational costs of the Rincon de Leon WRP. The irrigation districts cover the costs of conveyance and distribution of tertiary treated water from the irrigation tanks to the irrigation fields.

Table 17: Construction and operation costs of Rincon de Leon WRP

WRP treatment	**Construction costs (million EUR)**			**Operating costs**			
	Equipment	**Civil works**	***Total***	**Staff** (distribution of costs)	**Electricity** (distribution of costs)	**Reactants** (distribution of costs)	***Total*** **(EUR/m^3)**
CFF - UV	3.6	1.2	**4.8**	n.a.	9.5% (CFF) 2.5% (UV)	21% (CFF)	0.0142 (CFF) 0.0067 (UV)
UF	10.9	4.8	**15.7**	n.a.	36%	9%	0.0337

RO	n.a.	52%	70%	0.2098

Impacts, Scalability and Replicability

The reuse of treated used water diversifies available water supplies at relatively low additional costs and mitigates the pressure on overexploited freshwater resources. The business model is economic efficient and cost-covering, as the treated effluent can be produced according to end users' requirements and thus comes with different production and distribution costs charged to the end users. The charges for IAs and farmers are affordable even if they are higher than charges for surface water or groundwater for agricultural use. The scarcity and thus unavailability of surface and groundwater in the region render the reuse of treated used water viable and acceptable for the end users. Scalability of the existing business model in Alicante is somewhat threatened by the seasonal demands of end users. Demands are communicated at short notice and not planned according to long-term irrigation needs. Also, water storage infrastructure would need to be enlarged to ensure steady operation of the WRP. Frequent stops and starts of operation make the treatment process unnecessarily expensive (e.g., leads to damaged membranes, more cleaning reactants needed). Yet, the replicability of this business model is assumed high in water-stressed regions with high agricultural water demands for salt sensitive crops (e.g., almonds, citrus), where no alternative irrigation sources exist.

Summary Assessment - SWOT

Strengths	**Weaknesses**
• Diversification of available water supplies with affordable and acceptable prices for end users • Treated effluents are adapted to end user's needs (dual network), especially for salt sensitive crops • Cost-covering operation and maintenance of the WWTP due to urban taxpayers • Cost-covering operation and maintenance of the WRP directly charged to Irrigation Associations	• Operation strongly dependent on seasonal demands – unsteady operation leads to higher operation and maintenance costs • Not enough storage capacity to keep steady operation • Not all of the reclaimed water is used so far
Opportunities	**Threats**
• Water-scarce area with high urban development and tourism • Legal frameworks for cost-covering wastewater treatment on European level: e.g., Water Framework Directive, Urban Wastewater Treatment Directive • Legal frameworks for water reuse on national and regional level: Royal Decree 1620/2007, Jucar River Basin Plan 2014, Master Plan of Sanitation and Purification 2003 • Cost-recovery of wastewater treatment mandatory by EU/Spanish law (Water Act 62/2003)	• High salinity in freshwater sources increases treatment costs

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3.2. Milano, Italy

The water reuse scheme in Milan is a representative case of safe reuse of treated used water (SRTW) in Europe. It is the largest European water reuse scheme for agricultural irrigation and environmental enhancement and restoration of water bodies. Milan is one of the most fertile regions of Italy. The city uses >35% of treated used water from its two wastewater treatment plants (San Rocco WWTP and Nosedo WWTP) to meet agricultural water demand (*Table 18*).

This case study describes the SRTW business models from the San Rocco and Nosedo WWTPs for large-scale water reuse in agriculture. The business model contains a private operator of the WWTPs without contractual agreements with the farmers.

Table 18: Key characteristics of case study Milano, Italy

City: Milan, Lombardy, Italy		**Case study: SRTW from San Rocco and Nosedo WWTPs for agriculture**	
Population (2021)	3’155’000	**Treatment capacity WWTPs**	350’000 - 1’050’000 m^3/day (San Rocco) 430’000 - 1’300’000 m^3/day (Nosedo)
Annual population growth rate	0.19%	**Treatment**	Secondary + disinfection
Water scarcity/ demand vs. supply	Not a water-scarce region	**Operator**	MM Spa (MilanoDepur S.p.A)
No. of municipal WWTPs (with used treatment capacity)	3 (290 Mm^3/ year)	**% Of treated water reused in agriculture**	> 35% (86 ± 6 Mm^3/year)
% Of total reused water from the WWTPs in Milan	n.a.	**Treated water users**	Farmers

City Context and Background

The city of Milan in northern Italy is located in one of the most water-rich regions of Italy, close to the rivers Po, Adda and Ticino and the lakes Como and Maggiore. The use of water (including the reuse of wastewater) for agricultural purposes has a long history in the region. During the Middle Ages, various monasteries have built an irrigation network (irrigation ditches) from the main rivers to ensure water supply for their fertile lands. Those small canals and streams also collected urban wastewater which was subsequently discharged by the Po River to the Adriatic Sea.

In the 20th century the amount of Milan’s wastewater increased largely and led to significant pollution of the environment (e.g., massive eutrophication of the Adriatic Sea in the late 1980s) and a decline in agricultural productivity. The European Urban Wastewater Directive from 1991 and the Italian Water Act (Law n°36/94) 1994 were formed, forcing European cities to treat their wastewaters. The Municipality of Milan, therefore, started a large-scale water treatment program for treating and re-using its whole urban wastewaters. Three wastewater treatment plants (WWTPs) were planned, namely, Milan San Rocco (1,2-million-person equivalent (p.e)), Milan Nosedo (1 million p.e.), and Peschiera Borromeo (0.25 million p.e). Facing strong opposition, the construction of the facilities was delayed and only finished in 2003/2004.

Wastewater Treatment and Water Reuse Infrastructure

Nosedo WWTP, operational since 2003, and San Rocco WWTP, operation since 2004, have similar treatment trains: 1. Pre-Treatment (screening, oil, and sand removal). 2. biological treatment (activated sludge process with nitrification-denitrification), 3. Rapid sand filtration (phosphorus and suspended solids removal) and four. Disinfection (peracetic acid at Nosedo WWTP and ultraviolet (UV) disinfection at San Rocco WWTP). During the irrigation period (April to September), a high UV dose is used at San Rocco WWTP to achieve agricultural reuse standards. During winter, a low dose UV is applied when discharging the water in the Lambro River.

Effluent qualities achieved comply with the Italian target limit values (*Table 19*). The analytical laboratories of the two WWTPs are equipped with advanced tools for routine monitoring. All parameters are monitored daily.

Table 19: Treated effluent qualities of Nosedo and San Rocco WWTP and Italian water reuse standards (adapted from Lazarova et al., 2013)

Parameter	Effluent qualities Nosedo WWTP (2004 – 2011)	Effluent qualities San Rocco WWTP (2004 – 2011)	Legal discharge limits (Leg. Dec. 152/06)	Legal irrigation limits (Min. Dec. 185/2003)
pH	7.5	7.6	5.5 – 9.5	6.5 – 9.5
Suspended solids (mg/L)	< 2 (1 – 4)	< 2 (1 – 5)	35	10
COD (mg/L)	10 (6 – 20)	16 (5 – 38)	125	100
BOD (mg/L)	2 (1 – 6)	1.6 (1 – 9)	25	20
Total N (mg/L)	7 (4.1 – 9.1)	5 (3 – 8.7)	10	15
Total P (mg/L)	0.8 (0.3 – 1.1)	0.7 (0.4 – 1.3)	1	2
E.coli (CFU/100mL) (80%)	5 (80th percentile 8, max 25)	4 (80th percentile 7, max 9)	-	10

Business Value Chain & Business Model

The WWTPs are currently operated by MM Spa a private company contracted until 2037 (*Figure 7*). MMA Spa pumps treated and disinfected water to close by main irrigation channels. From there it is distributed (gravity-driven) to the fields through the already existing extensive network of irrigation canals and ditches (> 300 km).

Neither MMA Spa as private operators of the WWTPs nor the Municipality of Milan have any contractual agreement with the farmers. The build and operation contracts of the WWTPs with the Municipality of Milan lay down that two Irrigation Consortia oversee the delivering of the recycled water and control water allocation and use by the farmers. Thus, the Vettabbia Irrigation Consortium manages treated and disinfected water from the Nosedo WWTP and the Consortium di Bonifica Est Ticino-Villoresi is responsible for the San Rocco WWTP effluents. There are 3,700 ha irrigated with Nosedo WWTP and 24,630 ha with San Rocco WWTP effluents (both areas grow corn, rice, and grassland). The average annual water demand is 1,000 m3/ha for the Consortium of Vettabbia and 5,000 m3/ha for the consortium die Bonifica Est Ticino Villoresi, given its large area of rice production.

During the peak irrigation period, irrigation demands cannot be fully met because a minimum flow rate of the Lambro River needs to be maintained.

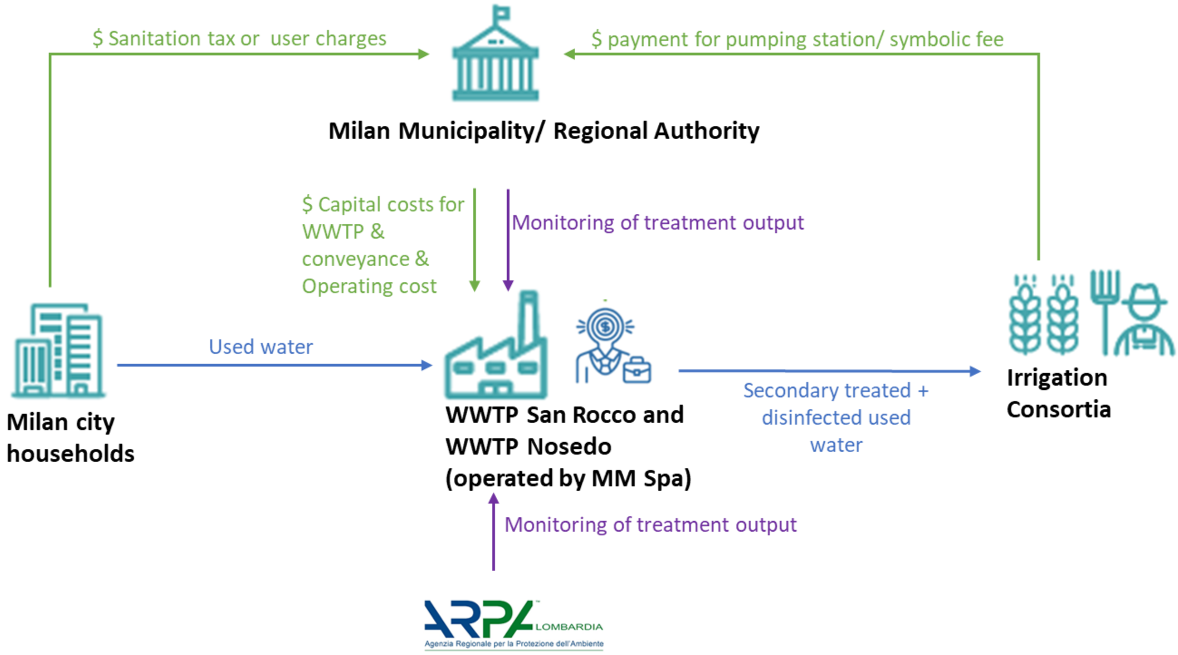

Figure 7: Business value chain of WWTP San Rocco and WWTP Nosedo water reuse with stakeholders

Farmers in both irrigation areas use the disinfected effluents for free. A small symbolic payment (ca. 2,000 €/year) is done for Nosedo WWTP effluents and the pumping costs to the main irrigation channel (1.3 km) are paid by the farmers using the San Rocco WWTP effluents (ca. 27,000 €/year).

Next to internal quality monitoring from the private operators, the Milan town administration (Metropolitana milanese) as well as the public regional control authority ARPA (Agenzia Regionale Per L'Ambiente Lombardia) both autonomously verify the water quality and penalise any non-conformity of the water quality. In case *E. coli* thresholds of 10 E. coli/100 mL are exceeded, the water supply is interrupted.

Since no economic relationships bind the Municipality of Milan with the farmers, periodic meetings organised with the business model's stakeholders are key to mitigate any challenges related to the water reuse scheme. The business model further benefits from transparent and on-going collaborations with the public, academia, and non-profit organizations to highlight the socio-environmental benefits of the water reuse projects (*Table 20*).

Further, it needs to be stressed that qualified staff is required to guarantee the operation and maintenance of the WWTPs.

Table 20: Municipality of Milan's business model Canvas of water reuse from Nosedo and San Rocco WWPs

<table>
<tr>
<td rowspan="2">Key Partners
Consortium Vettabbia (Nosedo WWTP)

Consortium di Bonifica Est Ticino Villoresi (San Rocco WWTP)

MM Spa

Ministry of Historic Heritage and Ministry of Environment (during design phase of the WWTPs)

Agenzia Regionale Per L'Ambiente Lombardia</td>
<td>Key Activities
Treating and pumping treated and disinfected wastewater to irrigation channel network</td>
<td rowspan="2" colspan="2">Value Propositions
Environmental protection (Rivers and Adriatic Sea); sustaining and promoting agricultural productivity through secondary treated and disinfected irrigation water</td>
<td>Customer Relationships
With Irrigation Consortia and indirectly with farmers) to discuss any problems related to water reuse schemes

Together with academia and non-profit organisations tackling households of Milan (the public) to foster environmental awareness and education</td>
<td rowspan="2">Customer Segments
Households of Milan (paying for wastewater treatment services)

Irrigation Consortia (Vettabia and di Bonifica Est Ticino Villoresi)</td>
</tr>
<tr>
<td>Key Resources
Land
Wastewater
WWTP infrastructure
Existing irrigation network
Cost-covering O&M of WWTP and distribution network
Highly skilled personnel</td>
<td>Channels
Contractual agreements with Irrigation Consortia

Regular events for information exchange and environmental education with farmers, academia, the public</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Capital cost of WWTPs (borne by Municipality of Milan, and private funders)

Operations WWTPs: - Staff, electricity, reactants

O&M and distribution costs of WWTPs charged to polluters (Milan households and businesses)</td>
<td colspan="3">Revenue Streams
Revenues from sanitation and water supply taxes (cost-covering)

Small contributions from Irrigation Consortia (pumping costs, symbolic fee)</td>
</tr>
<tr>
<td colspan="3">Social & environmental costs
Very stringent water reuse standards require almost total disinfection for agricultural reuse. This results in high energy requirement to operate facility resulting in GHG (greenhouse gas) emissions and high chemical consumption for disinfection (Nosedo WWTP)

Energy consumption for pumping of water to main irrigation channels.</td>
<td colspan="3">Social & environmental benefits
Environmental protection
Significant improvement of water quality of surface water bodies, restoration of biodiversity
Valorisation of historical heritage
Supply of good quality irrigation water for farmers free of charge
Amelioration of soil permeability
Supporting and collaborating with organisations and associations for environmental education and social rehabilitation of people at risk of social exclusion</td>
</tr>
</table>

Institutional Environment

The European Water Directives, i.e., the Water Framework Directive (WFD) 2000/60/EC and Urban Wastewater Treatment Directive 91/271/EC require secondary treatment for all towns having more than 2,000 inhabitants. Non-compliance to the target limits is punished by fines and cost-recovery of WWTPs is mandatory. In Italy, the Legislative Decree No. 152 of 2006 sets out the legislative framework applicable to all matters concerning environmental protection (including discharge standards of WWTPs, *Table 19*). In 2003, the national water reuse standards where revised (Ministry Decree, D.M., n°185/03) setting new *E. coli* limits for unrestricted irrigation (i.e., 10 E. coli/100 mL in 80% of the samples).

Funding and Financing

The investment cost (CAPEX) of 150 million € was paid partially by the Municipality of Milan (40%) and private funding. The CAPEX of 136 million € for San Rocco WWTP was fully provided by the

Municipality of Milan. The operational and maintenance costs (OPEX) of Nosedo and San Rocco WWTPs amount to 0.138 €/m^3 and 0.115 €/m^3 (as of 2011) respectively. Nosedo has a slightly higher OPEX, given the high chemical consumption for disinfection (peracetic acid) (*Table 21*).

Table 21: Construction and operation costs of Nosedo and San Rocco WWTPs

WWTP	**Construction costs (million €)**	**Operating costs (€/m^3)**					
	Total	Staff	Energy	Chemicals	Maintenance	Sludge & grit disposal	**Total (€/m^3)**
Nosedo	**150**	0.029	0.027	0.041	0.021	0.021	**0.139**
San Rocco	**136**	0.013	0.048	0.013	0.016	0.025	**0.115**

The Milan Service Fee, paid by households and industries, ensures cost-recovering operation of the WWTPs in Nosedo and San Rocco. The Service Fee in Milan includes an annual fee for provided water supply (0.2 – 0.5 €/m^3) and an annual fee for the collection (0.15 €/m^3) and treatment of wastewater (0.38 €/m^3). Farmers are using the treated and disinfected water for free. Small symbolic amounts are paid by the Irrigation Consortia for the supply and pumping of the treated water to the main irrigation channels.

Impacts, Scalability and Replicability

Multiple benefits have been demonstrated in Environmental Monitoring Plans since the on-set of the two water reuse schemes, including environmental enhancement of surface water bodies and biodiversity and improvement of agricultural production and amelioration of soil permeability. Also, the water reuse schemes increased employment opportunities in the regions (*Table 20*). The business model is economic efficient as the operation of the WWTPs is cost-covering from service fees collected. The main driver for the business model was environmental protection which was enforced by EU, national, regional and local policies and laws. Scalability of the existing business model for agriculture is limited, given the minimum flow rates for rivers that also need to be, mandatorily, met. The replicability of this business model is assumed high in regions where environmental pollution is to be tackled by law and wastewater treatment is running at high cost-recovery. A barrier could be the high up-front investment costs for disinfection units to meet stringent national or contractual water reuse standards.

Summary Assessment - SWOT

Strengths	**Weaknesses**
• Significant improvement of water quality in surface waters, restoration of biodiversity • Valorization of historical heritage • Improvement of agricultural production and amelioration of soil permeability	• During irrigation periods, demand from irrigators is higher than possible supply since environmental flows in rivers are to be met

• Cost-covering operation and maintenance of the WWTPs charged to Milan's households and industries • Fostering environmental awareness through guided visits at the WWTPs	• High water reuse standards (E. coli) that require total disinfection of effluents (high investment and operation costs)
Opportunities	**Threats**
• For wastewater treatment infrastructure build-up: Untreated wastewater polluting rivers of Po Valley and the Adriatic Sea as well as agriculture resulting in loss of soil permeability • Clear legal frameworks for cost-covering wastewater treatment on European level: e.g., Water Framework Directive, Urban Wastewater Treatment Directive • Clear legal and institutional frameworks for water reuse on national and regional level: Italian Water Act (Legislative Decree No. 152 and No. 185) • Environmental Monitoring Plan for impact assessment	• Oppositions against construction of WWTPs

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3.3. Aurangabad, India

Located in Aurangabad tehsil of Aurangabad district in Maharashtra, Zalta village is 12 kilometers from the district headquarters. It has long struggled with water scarcity with frequent droughts. As a result of rapid urbanization and climate change, water depletion has intensified, resulting in a significant demand-supply gap of 100 million litres per day (MLD). The multi-stakeholder partnership aimed at reusing wastewater in agriculture for collaboration on sustainable water management was attempted by Aurangabad Municipal Corporation (AMC) with the support of the Zalta Gram Panchayat and its farmers (*Table 22*). Recycling water for agriculture was initiated by painting pipes purple, following the global uniform colour code.

Table 22: Key characteristics of case study Aurangabad, India

City: Aurangabad, India		**Case study: Purple Pipes**	
Population ((2022)	1,642,000	**Treatment capacity**	35 MLD per day of domestic sewage
Annual population growth rate	2.63%	**Treatment**	20 MLD per day
Water scarcity	Drought-prone, Contaminated water for irrigation, feed & fodder shortages, Impacts on soil, health, and communities	**Operator**	Aurangabad Municipal Corporation (AMC)
No. of municipal WWTPs	5 (Zalta, Kanchanwadi, Padegaon, Salim Ali Lake and Banewadi)		
% of total reused water from the WWTPs in Aurangabad	81.5 MLD	**End users**	Zalta Village (farmers)

City Context and Project Background

Aurangabad in Maharashtra is one of the fastest growing cities in Asia. The city is renowned for its rich cultural heritage, magnificent architecture, economic landscape, and engineering feats. It also has a remarkable and sophisticated system of subterranean water supply canals that its founder Malik Amber created in 1617 and which formerly provided the city with water security. In addition to being the fifth most populated metropolitan region in the state, Aurangabad offers almost a million job opportunities for residents and migrants along the Delhi-Mumbai Industrial Corridor, which attracts investment in a continuous stream. A lack of sewer disposal poses a major challenge to the residents of Aurangabad. With an estimated population of 16.42 lacs and sewerage generation of 107 MLD, there is less than 10 MLD of sewage treatment capacity much of the sewage flowing into the Kham and Sukhana river. The proposed tertiary sewage treatment plant with the capacity to treat 161 million litres of sewage per day, at the sewage treatment plant at Kanchanwadi. There are two basins of the city, Kham & Sukhana, with an 80:20 distribution of the population. In the Kham basin, seven main sewers will generate 240.67 MLD of sewerage, while the Sukhana basin will generate 60.83 MLD of sewerage. Increasing urbanization and climate change have resulted in a 100 MLD mismatch between supply and demand in the metropolis. Despite recurrent droughts and a moderate level of climate change vulnerability, AMC consistently ranks highly on the Ease of Living (EOL) and Quality of Life indexes (MoHUA, 2021) among Indian cities with a population greater than one million.

Wastewater Treatment and Water Reuse Infrastructure

Sukhana and Kham are the leading irrigation supplies in Aurangabad's peri-urban districts. AMC runs a cutting-edge STP in the town of Zalta *(Figure 8)*, which is located around 15 kilometers from the city. It can handle 35 MLD of household sewage per day, but only treats 20 MLD on average per day, discharging the cleaned water directly into the Sukhana River.

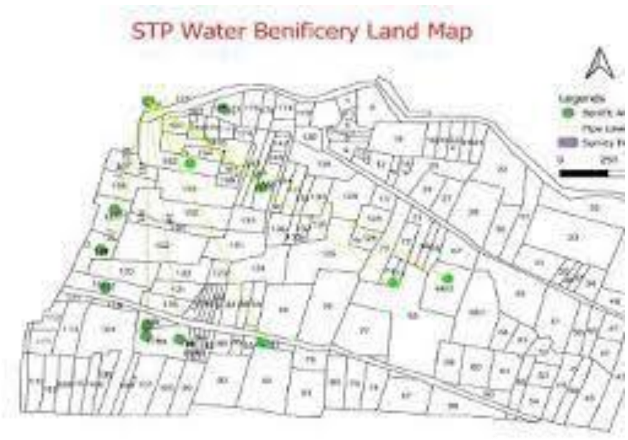

Figure 8: STP Water Beneficiary Land Map

This Recycled Water Supply Scheme for agriculture uses purple pipes for carrying recycled water to the farms, the purple color being chosen in accordance with the universally recognized color scheme. Recycled water is distributed through a parallel distribution system (separate from other water infrastructure). To make the recycled water system readily recognizable and avoid cross-connections between other systems, the Purple Pipe infrastructure is used internationally as a public education tool.

Business Value Chain & Business Model

The key components of the Purple Pipes Project in Aurangabad are as follows (*Figure 9, Table 23*):

Community and Multi-Stakeholder Approach

- Formation of the First of its kind Wastewater Reuse Association (WUA) Sukhana Jalkranti (Jan 2020)

ULB and Regulatory Support

- MoU between AMC and Zalta GP (Jan 2022)
- Allocation of 2 MLD water by the AMC (Feb 2022)
- Tariff structure guidelines by GoM, MWRRA, Draft GO on water allocation

Finance- Farmers Contribution

- Infrastructure: ~ 40% Contribution by the farmers

- Water: INR 1000/annum/farmer – paid by farmers (Mar 2022)

Special Infrastructure

- Dedicated Wastewater Conveyance system from STP to farmlands

Leveraging Technology

- Integration of Solar Energy
- Sensors to detect contaminants in the soil and crops.
- Flow meters to monitor water use

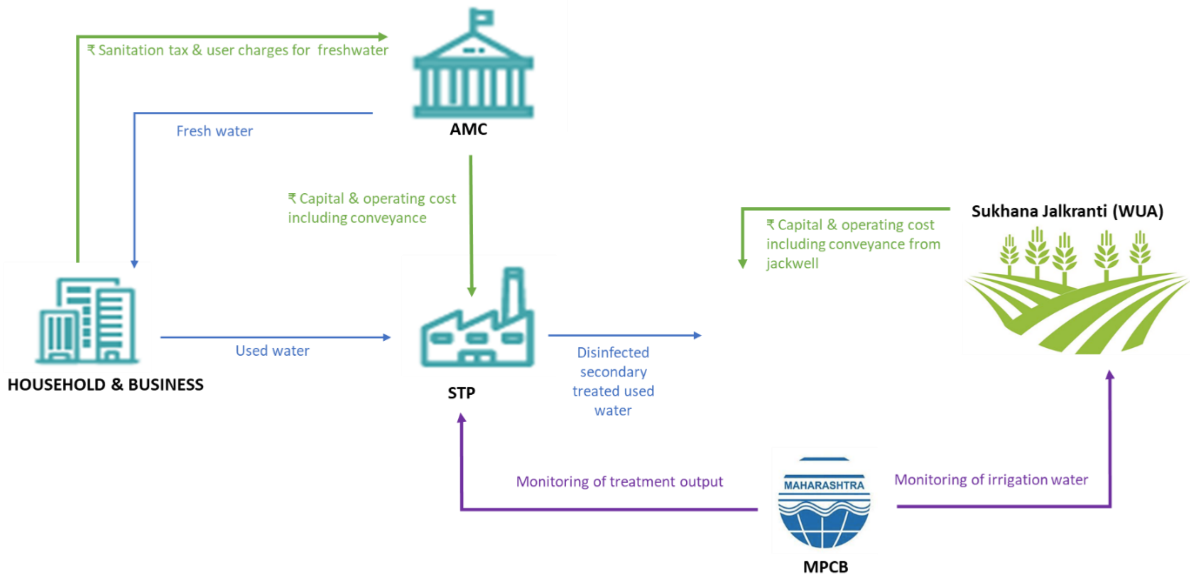

Figure 9: Business value chain of the purple pipes water reuse

Table 23: Business model for purple pipes project for wastewater reuse in Aurangabad

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
Zalta Gram Panchayat Wastewater User Association Research Institutions (IIT-B) Project on Climate Resilient Agriculture MWRRA, GoM Aurangabad Municipal Corporation (AMC)	Wastewater treatment Dedicated Wastewater Conveyance system from STP to farmlands Wastewater reuse for irrigation Annual Monitoring of Water reuse Stakeholder Engagement	Sustainable Water Management Water Conservation Enhanced Agricultural Productivity Economic Growth and Employment Opportunities	Resolution of the Zalta GP to form a WUA MoU Between WUA and AMC Allocation of 2 MLD water by AMC and setting the Tariff Plan	Wastewater User Association (WUA) Zalta Gram Panchayat
	Key Resources Water Sources Wastewater Treatment Infrastructure Land and Property Financial Resources		**Channels** MoU between AMC and Zalta GP (Jan 2022)	

	Technical Expertise and Knowledge			
Revenue Streams *Infrastructure:* ~ 40% Contribution by the farmers *Water:* INR 1000/annum/farmer – paid by farmers	**Cost Structure** CAPEX of sewage treatment plant and conveyance system for treated water OPEX of sewage treatment plant and conveyance of treated water to agricultural farmlands (irrigation)			
Social & environmental costs Social Acceptance and Participation Health and Sanitation Water Discharge and Pollution	**Social & environmental benefits** Transformed Value Chains Higher Productivity and Farmer Incomes Lower Carbon-Water Footprint			

Institutional Environment

A Government Order in 2017 established a Multi-Stakeholder Partnership platform (MSP) on water in order to promote the implementation of multi-stakeholder-driven collective actions supporting water security. Under the direction of the state governments, the MSP platform, sponsored by the 2030 Water Resources Group (2030 WRG), has provided partnership-based solutions. MSPs, led by the Chief Secretary to the State government, have accelerated technological and financial advances in the water sector by encouraging group action. *Figure 10* represents the multistakeholder and community driven Approach of the Purple Pipes Project in Aurangabad.

Figure 10: Multistakeholder and Community Driven Approach of the Purple Pipes Project in Aurangabad

Funding and Financing

Aurangabad invested an average of 80 million USD yearly between 2017 and 2019 to alleviate the severe water constraint. AMC successfully implemented the 2030 WRG project in Zalta with support from Zalta Gram Panchayat, its farmers, and the State government. Farmers' willingness to pay for both the water costs and the electricity needed for pumping it indicates the growing need for treated wastewater for irrigation, allowing for tariffs to be introduced for this ground-breaking change. Several focused group meetings and discussions of the MSP with farmers culminated in the formation of the ***Sukhana Jalakranti*** – a first-of-its-kind Wastewater User Association (WUA) in September 2021. The members signed a formal request letter addressed to AMC requesting allocation of treated water and agreed to the following:

- *Pay tariff as per regulatory guidelines of MWRRA for their consumption of treated water.*
- *Make their own infrastructure arrangements for the conveyance of recycled water from the STP to farm gates, which includes pipelines, pumps, and electricity connections.*
- *Allow qualitative testing of soil, water, and crop samples pre and post-use treated water.*
- *Maintain a record of crop productivity and socio-economic impacts of the pilot project.*

A MoU signed by the AMC and ***Sukhana Jalakranti WUA*** in March 2022, outlines the terms and conditions agreed upon between the AMC and the farmers. Pursuant to this, the farmers have started sourcing water from a common reservoir set up within the Zalta STP premises. The estimated cost of the project is about Rs 8 lakhs – with the farmers having spent about 60% of the cost on pipes, pump sets, electricity, and the cost of the water itself. The AMC has spent money on infrastructure development and is assured of maintaining quality through regular testing. The farmers have agreed to pay Rs 1000 p.a. for treated water from *Zalta* STP and have agreed to install flow meters to help monitor usage on an annual basis.

The establishment of autonomous Special Purpose Vehicles (SPVs), capacity building on designing and financing water recycling projects for city administrations, innovative financial models that enhance private sector capital mobilization, and the emission reduction of recycled water are a few examples of the new spaces being opened up by the growing demand for recycled water in farming, industries, and for non-potable uses in cities. Zalta is an outstanding illustration of how multi-stakeholder collaborations may be used to co-create solutions that result in several benefits via a circular water economy.

Impacts, Scalability and Replicability

This case study demonstrates the effective utilization of recycled water through infrastructure development, stakeholder engagement, and sustainable water management practices, resulting in several social, environmental, and economic benefits. The intended outcomes of the project are as follows:

- Enhance water security, circularity, climate resilience and carbon neutrality
- Improve feed and fodder availability for enhancing livestock productivity
- Reduce freshwater abstraction and hence improve water security

- Reduce contamination of food and water for prevention of food- and water-borne illnesses
- Reduce carbon emissions to address climate crisis
- Mitigate heavy metals from effluents and manage heavy metal accumulation
- Multistakeholder partnerships in co-creating solutions specifically considering local issues

The scaling-up strategy may include the following aspects:

- Policy Reform through issuing Government Order for Wastewater Reuse for Agriculture
- Capacity Building initiatives such as generation of public awareness on reuse of treated water as well as institutional capacity building
- Leveraging innovative financing through Corporate Social Responsibility (CSR), blended finance, blue bonds, Development finance institutions (DFIs), and institutional / private investors
- Leveraging Central and State government policies like Atal Mission for Rejuvenation and Urban Transformation (AMRUT), National Framework for Safe Reuse of Treated Water, and State Level Water Reuse Policies

Summary Assessment - SWOT

Strengths	**Weaknesses**
• Formed the first-of-its-kind Wastewater User Association Sukhana Jalkranti. • Offers a towering example of using multi-stakeholder partnerships to co-create solutions that achieve multiple social welfare and development dividends through a circular water economy.	• Bioaccumulation of contaminants in wastewater is a problem, and the quality of treated effluents needs to be monitored closely. • Since the treated wastewater will be used for irrigation, status of soil health, crop residue and the corresponding impacts on human health must be monitored. • Climate vulnerable district is a drawback that might lead to emerging challenges
Opportunities	**Threats**
• The city administration has drawn up plans of collecting and treating more than 540 MLD of wastewater by 2024 which could be reused and recycled for various secondary applications. • Growing demand for recycled water in farming, industries, and for non-potable uses in cities is opening new spaces for financial and institutional innovation • Participatory water conservation activities already ongoing in the district	• A growing demographic pressure, erratic rainfall, declining groundwater table, and competing demands from industries have put the water distribution system and services under considerable strain, holistically. • Monitoring the quality of treated used water supplied on a periodic basis is essential especially to maintain the social acceptance continue the willingness to pay.

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4. Business Models for Urban Reuse

4.1. Barcelona, Spain

The city of Barcelona is a representative case of the safe reuse of treated used water (SRTW) in Spain. The metropolitan area uses around 30% of treated used water from its wastewater treatment plant (WWTP) El Prat de Lobregat to meet environmental, recreational, agricultural and urban water demands (*Table 24*). **This case study describes the SRTW business model from the El Prat de Llobregat WWTP following a flexible wastewater-freshwater swap.** The business model includes s a **typical European urban reuse application as a side reuse option** next to a larger reuse purpose (such as agriculture, industry or environmental flows). Urban water reuse, i.e. irrigation of green areas and street cleaning, is only a small part of the total reuse in this case study (< 1 %). The biggest part (> 80%) is used to re-establish the Llbobregat River flow.

Table 24: Key characteristics of case study: Barcelona, Spain

City: Barcelona, Catalonia, Spain		**Case study: SRTW from El Prat WWTP for urban reuse**	
City Population (2016)	1,608,746 (metropolitain area ca. 5.6 million)	**Treatment capacity El Prat WWTP**	300’000 m³/day
Annual population growth rate	0.51%	**Treatment**	Tertiary
Water scarcity/demand vs. supply	Highly water-scarce region	**Operator**	EMSSA
No. of municipal WWTPs (with used treatment capacity)	7 (1.2 million m3/day: year: 2018)	**% of treated water reused for urban applications**	< 1% (year 2008)
% of total reused water from the El Prat WWTP i	30 % (year: 2008)	**End users**	Tanker supplies (irrigation of green areas, street cleaning)

City Context and Background

Barcelona is the capital city of Catalonia in northeastern Spain. It is Spain's second most populous city, with 5.6 million people living in the metropolitan area. Barcelona has a Mediterranean climate characterized by mild winters and hot summers. Therefore, the region experiences relatively dry summers with limited rainfall, which pressures the water resource availability. The metropolitan area of Barcelona relies on the lower Llobregat River as one of its primary sources of water supply.

To address its increasing water demands, the Metropolitan Area of Barcelona Environmental Authority MAB- EMA (Area Metropolitana de Barcelona – Entitat del Medi Ambient) includes the reuse of treated urban wastewater as part of its water supply portfolio. MAB- EMA has established multiple wastewater treatment plants to ensure the efficient and sustainable management of its water resources. The two WWTPs (El Prat Baix de Llobregat and St Feliu de Llobregat) in the district of Baix Llobregat (*Figure 11*) were designed to support directly or via water exchange a range of demands (agriculture, environmental flow, wetland ecosystem services, seawater barrier through managed aquifer recharge, urban water supply, recreation and industry) by the Catalonian Water Agency (ACA; Agencia Catalona de l’Aigua).

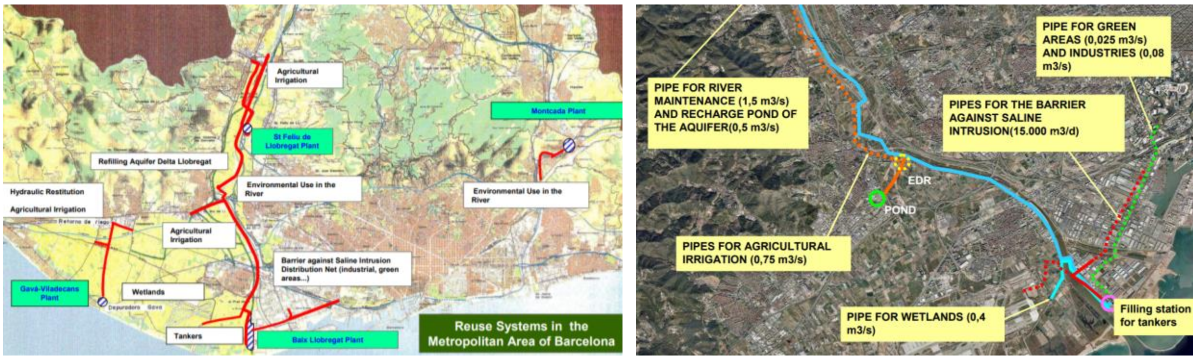

Figure 11 Reuse purposes from different WWTPs in the Metropolitain Area of Barcelona (left) and from EL Prat WWTP (right)

Wastewater Treatment and Water Reuse Infrastructure

The WWTP El Prat de Llobregat is an activated sludge system with a treatment capacity of 320'000 m^3/day. It is operating since 2004 and receives municipal and industrial wastewater. About two-thirds of the secondary treated water is discharged into the Mediterranean Sea. One-third could undergo, depending on demand, tertiary treatment for reuse. The plant has three different treatment trains to achieve three water qualities with increasing physico-chemical and microbiological levels:

(Quality A) water for in-stream river flow substitution, restoration of wetland areas. The treatment train consist of coagulation-flocculation and lamella settling, filtration through a microscreen followed by UV disinfection. Oxygen supplied from a cryogenic tank is injected into the pipelines conveying reclaimed water flows for environmental use, ensuring a saturated dissolved oxygen concentration.

(Quality B) water for agricultural irrigation and urban applications. Same treatment train as Quality A plus additional reverse osmosis (RO).

(Quality C) water for supplying the seawater intrusion barrier. Same treatment train as Quality A plus an additional desalination step that uses membranes for electrodialysis reversal (EDR).

Treated effluent qualities (Quality B) meet the Royal Decree standards for agricultural and environmental uses. Quality C effluents fulfil the standards for direct injection into the aquifer (*Table 25*)

Table 25: Treated effluent qualities of El Prat de Llobregat WWTP and Spanish water reuse standards

	Treatment alternatives			Royal Decree standards for agricultural and recreational reuse			
Quality parameters as per Spanish Royal Decree 1620/2007	**Quality A**	**Quality B**	**Quality C**	**Quality 2.1*** fresh crops for human consumption	**Quality 2.2*** crops for human consumption	**Quality 2.3*** ligneous crops	**Quality 5.2*** Aquifer recharge by direct injection
Suspended solids, **SS** (mg/L)	< 35	< 20	< 10	20	35	35	10
Turbidity (NTU)	n.a.	< 10	< 2	10	no limit	no limit	2
E. coli (CFU/100 mL)	n.a.	< 100	0	100	1000	10000	0

Intestinal nematode eggs (egg/10L)	n.a.	< 1	< 1	1	1	1	1
Conductivity 20°C (µS/cm)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Chemical oxygen demand, **COD** (mg/L)	< 125	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Biochemical oxygen demand, **BOD** (mg/L)	< 25	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total nitrogen (mg/L)	< 10	n.a.	< 10	n.a.	n.a.	n.a.	10
Total phosphorous (mg/L)	< 2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

* **Quality 2.1** = Agricultural use- irrigation of fresh crops for human consumption; **Quality 2.2** = Agricultural use- irrigation of crops for human consumption; **Quality 2.3** = Agricultural use- localized irrigation of ligneous crops; **Quality 5.2** = Aquifer recharge by direct injection

Business Value Chain & Business Model

The water reuse scheme of EL Prat WWTP is promoted by MBA-EMA and ACA (*Figure 12; Table 26*). The operator is the private company EMSSA (l'Empresa Metropolitana de Sanejament). It is estimated that the annual demand for tertiary treated water is 50 million m^3/year for the following reuse purposes: re-establish Llobregat river flow (80%), stabilized wetlands of ecological inerest (11%), agricultural irrigation (6%), avoid salt water intrusion in the aquifer (1%), other purposes like industrial and urban reuse (2%).

The water swap business models from El Prat WWTp works as follows: 1. High quality treated water (Quality B and C) is recovered from El Prat WWTP. 2. Some of it is sold directly to industrial and urban users (Quality B) and some is returned to aquifers to avoid seawater intrusion (Quality C). This saves freshwater resources. 3. Farmers use the tertiary treated used water (Quality B) in times of droughts, which secures freshwater for other urban water uses. They pay for freshwater/treated wastewater via the urban water bill (conveyance of tertiary treated wastewater is paid by farmers). The water swap is thus financed through the re-allocation of freshwater for higher valued uses.

Figure 12: MBA-EMA's Business value chain of El Prat de LLobregat WWTP

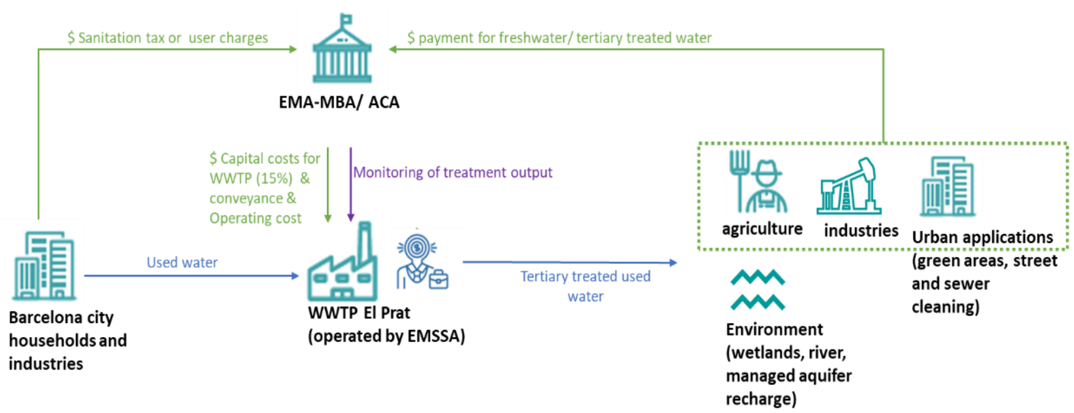

Table 26: MBA-EMA's business model Canvas of water reuse from El Prat de Llobregat WWTP

<table>
<tr>
<td rowspan="2">Key Partners
EMSSA (private operator)

ACA (water authority)

Environmental protection agencies</td>
<td>Key Activities
Treating wastewater to tertiary quality (El Prat WWTP) depending on demands and quality requirements from end users

Negotiate water swap with farmers, urban users and industry

Exchanged freshwater to be sold to households and industries</td>
<td rowspan="2">Value Propositions
Distribution of tertiary treated used water adapted to quality requirements by end users as an exchange with allocated freshwater

Drought mitigation (and related costs) through the re-allocation of freshwater</td>
<td>Customer Relationships
With farmers, industries and urban users to assure steady demand of tertiary treated used water</td>
<td rowspan="2">Customer Segments
Farmers
Industries and urban water users</td>
</tr>
<tr>
<td>Key Resources
Land
Wastewater
WWTP infrastructure
Cost-covering O&M of WWTP and distribution network</td>
<td>Channels
Roundtables for negotiations

Automated billing

Distribution canals for irrigation with tertiary treated water</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Capital cost of tertiary treatment plant (borne by ACA and European Coheison funds)

Operations of tertiary treatment plant: - Staff, electricity, reactants

O&M and distribution costs charged to end-users</td>
<td colspan="2">Revenue Streams
Urban households pay ACA for freshwater, and farmers for high-value crops and the conveyance of water

Selling of tertiary treated wastewater to industries and urban users (tanker supplies)

Indirect revenues through drought mitigation (socio-economic damage)</td>
</tr>
<tr>
<td colspan="3">Social & environmental costs
High energy requirement to operate facility resulting in GHG (greenhouse gas) emissions

Potential health impacts on consumers from the consumption of wastewater irrigated wastewater (acceptance issue)</td>
<td colspan="2">Social & environmental benefits
Reduced pressure on freshwater demand and groundwater depletion, hydraulic barrier against sea water intrusion

Continuous supply of local fruits and vegetables</td>
</tr>
</table>

Institutional Environment

The European Water Directives, i.e., the Water Framework Directive (WFD) 2000/60/EC and Urban Wastewater Treatment Directive 91/271/EC require secondary treatment for all towns having more than 2,000 inhabitants. Non-compliance is punished by fines. In Spain, the Royal Decree 1620/2007 is the legal binding framework for the reuse of treated used water. It contains quality parameters for different types of water reuse, i.e., urban, agricultural, industrial, recreational and environmental. Moreover, regional policies and laws such as the Catalonian Drainage Plan (Plan de Saneamiento de Catalunya) and Water Reuse Program or the Integral Drainage Master Plan of Barcelona address new challenges related to climate change (such as flood mitigation measures) to sustain the success of the water reuse schemes.

In the case of the Llobregat delta, the farmers are prohibted to use common irrigation channels during drought periods. Thereby they are obliged to use the tertiary treated used water from the El Prat WWTP.

Funding and Financing

The initial budget for the El Prat WWTP was set at 102 million €. The funding came primarily from the European Union Cohesion Funds, contributing 85% of the total, while the ACA provided the remaining 15%. However, the final construction costs exceeded the initial budget up to 142 million €.

The construction costs were divided into different segments, including 15.6 million € for nutrient removal, 23 million € for the water reclamation plant, 66.8 million € for the water distribution network, 15.9 million € for the reversal electrodialysis plant, and approximately 20 million € for the seawater intrusion barrier. Regarding O&M costs, the estimated costs are as follows: Quality A at 0.05 €/m^3, Quality B at 0.23 €/m^3 and Quality C at 0.36 €/m^3.

In general, the additional wastewater treatment is paid by the urban water users and wastewater producers (urban water bill) as well as the costs of conveying irrigation water by the farmers.

Impacts, Scalability and Replicability

The main impact is the reduction of direct and indirect costs related to future droughts. The exchange of water towards higher value allows economic gains for MBA-EMA and ACA. The water quality of the Llobregat aquifer has widely improved and energy savings associated with the reduction of pumping groundwater were quantifed.

So far, the MBA-EMA relies on voluntary water swap by farmers (except during drought periods), industries and urban users. Similarly to Alicante, the scalability of the existing business model is somewhat threatened by the seasonal demands of end users. Demands are communicated at short notice and not planned according to long-term irrigation needs. Also, water storage infrastructure would need to be enlarged to ensure steady operation of the WRP. Frequent stops and starts of operation make the treatment process unnecessarily expensive (e.g., leads to damaged membranes, more cleaning reactants needed). To scale the swapped water quantities, the business model needs regulatory support, e.g. by surface or groundwater abstraction limits (volumes, time periods) which different users have to adhere to, in exchange of a reliable supply of tertiary treated used water.

The model is replicable in water-stressed regions, as treated wastewater can be designed for any reuse and then allocated to the type of use which allows the highest returns for the respective water quality. Monitoring crop and water qualiy is needed to prevent any rejection on produce markets.

Summary Assessment – SWOT

Strengths	**Weaknesses**
• Government support and EU funds to invest in WWTP infrastructure • Dialog with farmers and other users and the offer of a reliable alternative water supply • Cost-recovery of wastewater treatment mandatory by EU/Spanish law (Water Act 62/2003) • Flexible water qualities supporting all water user's quality needs (including ecosystems)	• In times of sufficient freshwater supply, expensive infrastructure (RO, EDR) is unused and prone to damage • Missing incentive or regulatory system to use more tertiary treated wastewater • Market reservations (farmers, consumers)
Opportunities	**Threats**
• Water-scarce area with high urban development and tourism • Legal frameworks for cost-covering wastewater treatment on European level: e.g., Water	• Public perception on the use of treated used water • Alternative freshwater source appear more reliable (long-distance transfer, desalination)

Framework Directive, Urban Wastewater Treatment Directive • Legal frameworks for water reuse on national and regional level: Royal Decree 1620/2007, Programs and policies related to Sanitation and Purification, and Water Reuse	

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5. Business Models for Environmental Reuse

5.1. Kolar, India

The city of Kolar in the state of Karnataka, India, is a representative case of safe reuse of secondary treated used water to meet agricultural water demand *(Table 27)*. This case study describes the business model of secondary treated water from the sewage treatment plants (STPs) operated by Bangalore Water Supply and Sewerage Board (BWSSB) for the Koramangala-Challaghatta Valley Project (K.C. Valley Project).

Table 27: Key characteristics of case study: Kolar, India

City: Kolar district, Karnataka, India		Case study: K.C. Valley Project	
Population (2011)	1,536,401	**Treatment capacity**	440 MLD
Annual population growth rate (2001-2011)	1.0%	**Treatment**	Secondary treated wastewater
Water scarcity	Stage of groundwater development 211% (All over exploited blocks) Freshwater scarcity	**Operator**	Bangalore Water Supply and Sewerage Board
No. of municipal WWTPs	3		
% of total reused water from the WWTPs in Bangalore	440 MLD water is directed to Kolar district.	**End users**	Farmers

Source: City Population, N.d.

City Context and Project Background

Kolar district is eastern most district of southern Karnataka, and is known as the "Golden Land" of India due to the presence of gold fields. Kolar district experiences a partial rain shadow effect, resulting in limited rainfall. Due to its topography and physiography, the district lacks perennial water sources such as rivers. The soil composition in the area ranges from red loamy to red sandy, with some areas having lateritic soil. Agriculture occupies approximately 60% of the district's geographical area, resulting in a significant demand for water. The groundwater level in Kolar District has experienced a drastically plummeted by 64.97% from 14.06 metres below ground level in 2018 to 4.93 metres below ground level in 2019.

The Koramangala & Challaghatta Valley (K.C. Valley) Project in Kolar District was launched in November 2016 with the aim of supplying treated sewage water to 126 irrigation tanks located in various clusters across Kolar and Chikkaballapur districts, implemented in a phased manner. The authorities of Bengaluru Metropolitan and the Karnataka State Government have been grappling with the escalating challenges posed by sewage management. Consequently, the K.C. Valley Project has been designed to yield mutually beneficial outcomes. On the one hand, it addresses the persistent drain and sewage water issues in Bangalore city, while on the other hand, it rejuvenates the declining groundwater table in the vicinity of the irrigation tanks in Kolar district.

It is important to acknowledge the role of the scientific community in addressing the key issues such as presence of heavy metals and chemicals of concern in the treated water. The call for improved treatment systems and a robust monitoring of water that is transferred into the lakes is a key component of SRTW. Farmers have also taken note of this and have demanded for tertiary treated water. In August 2021, the Karnataka State Pollution Control Board (KSPCB) ordered the Chief Engineer of Minor Irrigation Department, to install tertiary treatment plants at major tanks (out of the 126 tanks targeted) using the treated sewage water from the STPs operated by BWSSB. There has been slow developments and no significant changes in this regard, as per recent reports.

Wastewater Treatment and Water Reuse Infrastructure

In the K.C. Valley scheme, approximately 440 MLD (Million Litres per Day) of secondary treated wastewater (TWW) is utilised from various STPs located in the K.C. Valley region (*Table 28*). This includes 310 MLD from Belur Nagasandra/K.C. Valley STP, 40 MLD from Kadubeesanahalli Ph-1 STP, and an additional 90 MLD from Bellandur STP. Wastewater treatment plant (WWTP) near the Kolar district K.C. Valley has a capacity of 440 MLD, and it consists of several units (Screening & Grit chamber, Aeration tanks, Secondary Clarifier, Storage Tank) for treatment. Specifications studied and examined for the performance appraisal of the WWTP are Total Solids, Oil & Grease, Chlorides, Sulfates, Nitrates, Nitrites, COD, and BOD5@ 20° C. The studies done in the recent times states that removal efficiency of COD at a WWTP was around 88.07% and efficiency of BOD5 at a WWTP was around 95.67%. As excess sludge is produced in these wastewater treatment plants, they are further used as a fertiliser.

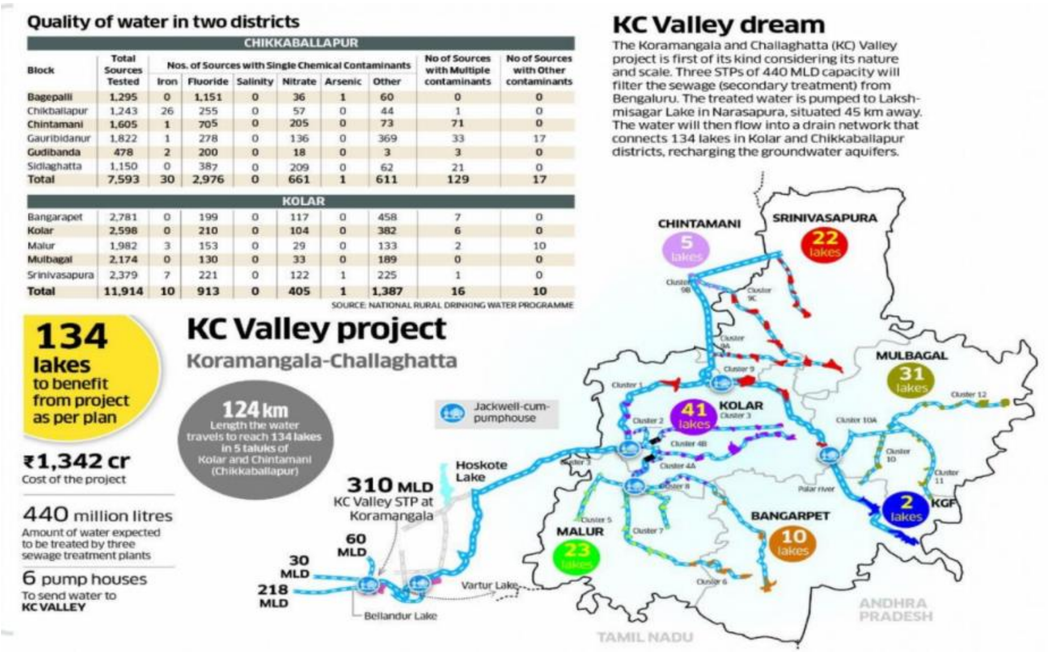
Table 28: Overview of K.C. Valley scheme in Kolar

Name of scheme	**Allocated water (MLD)**		**Proposed tanks for Filling**	**Tanks filled till date (July 2021)**	**Water pumped (MLD)**
	Irrigation	**Industries**			
Koramangala & Challaghatta valley (K.C. Valley) for Kolar	400	40	134	82	310

Considering the availability of large volumes of treated wastewater and its potential for agriculture reuse in the drought prone districts of Kolar, the Government of Karnataka (GoK) has launched ambitious lift irrigation project to transfer secondary treated wastewater from Bengaluru for groundwater recharge in drought affected areas. Lakshmisagara lake, located approximately 45 km away from the Bellandur STP, remained dry for several years due to drought has been replenished with treated water during the past two years. Previously, the land surrounding the lake was predominantly occupied by eucalyptus plantations, and agricultural activities were minimal. Only a single crop, such as Ragi and Maize, could be cultivated during the monsoon season, primarily for household consumption. The area faced challenges with inadequate water resources, as the existing borewells, dug to depths of more than 800-1000 ft, often failed. The positive changes have enticed many farmers who had previously left their lands due to drought to return and resume agricultural activities. They have transitioned away from eucalyptus plantations and can now cultivate 3-4 crops annually. Adopting modern drip irrigation systems, farmers now focus on commercially viable crops such as tomatoes, beans, cauliflower, chillies, and flowers like Marigold and Jasmine. The extended agricultural cultivation period has not only boosted farm productivity but also created more employment opportunities for wage labourers, both men and women, including those who were previously landless.

Business Value Chain & Business Model

With an estimated cost of Rs 1,270 crore for the first phase, the first-of-its-kind K.C. Valley project treats wastewater from Bengaluru and uses it to build lakes in the adjacent districts of Bengaluru Rural, Kolar, and Chikkaballapur (*Figure 13 & 14*). As per the erstwhile Rural Development and Panchayat Raj (RDPR) Minister Krishna Byre Gowda, about 20 lakes were filled up in 2019 in the first phase, and the targeted 126 lakes were planned to be covered by the end of the year. For the second phase, Rs 455 crores was allocated by the State Cabinet to fill 250 tanks.

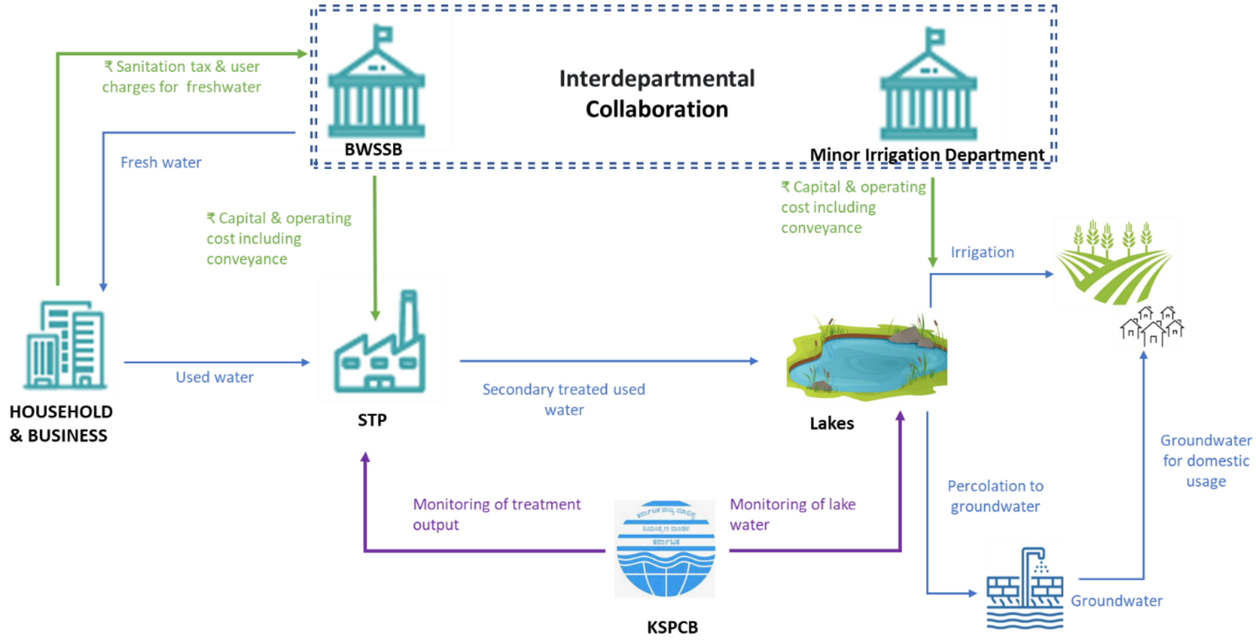


Quality of water in two districts

Block	Total Sources Tested	Nos. of Sources with Single Chemical Contaminants: Iron	Fluoride	Salinity	Nitrate	Arsenic	Other	No of Sources with Multiple contaminants	No of Sources with Other contaminants
CHIKKABALLAPUR									
Bagepalli	1,295	0	1,151	0	36	1	60	0	0
Chikballapur	1,243	26	255	0	57	0	44	1	0
Chintamani	1,605	1	705	0	205	0	73	71	0
Gauribidanur	1,822	1	278	0	136	0	369	33	17
Gudibanda	478	2	200	0	18	0	3	3	0
Sidlaghatta	1,150	0	387	0	209	0	62	21	0
Total	7,593	30	2,976	0	661	1	611	129	17
KOLAR									
Bangarapet	2,781	0	199	0	117	0	458	7	0
Kolar	2,598	0	210	0	104	0	382	6	0
Malur	1,982	3	153	0	29	0	133	2	10
Mulbagal	2,174	0	130	0	33	0	189	0	0
Srinivasapura	2,379	7	221	0	122	1	225	1	0
Total	11,914	10	913	0	405	1	1,387	16	10

SOURCE: NATIONAL RURAL DRINKING WATER PROGRAMME

Figure 13: Map Showing K. C. Valley project (Chaithrashree and Shivalingaiah 2022)



BWSSB- Bangalore Water Supply and Sewerage Board; STP- Sewage Treatment Plant; KSPCB- Karnataka State Pollution Control Board

Figure 14: Business value chain of the Koramangala-Challaghatta Valley Water Reuse Project

Table 29 represents the business model canvas for reuse of treated used water in agriculture in Kolar District.

Table 29: Business model canvas for reuse of treated used water in agriculture in Kolar District.

Key Partners	**Key Activities**	**Value Propositions**	**Customer Relationships**	**Customer Segments**
Government of Karnataka (GoK) Karnataka Urban Water Supply and Drainage Board (KUWSDB) Bangalore Water Supply and Sewerage Board (BWSSB) Karnataka Lake Conservation and Development Authority (KLCDA) Bangalore Development Authority (BDA) Karnataka State Pollution Control Board (KSPCB) Bruhat Bengaluru Mahanagara Palike (BBMP) Local Communities and Residents	Wastewater Treatment Water Transfer Infrastructure Development Rainwater Harvesting Monitoring and Management Stakeholder Engagement	Sustainable Water Management Water Conservation Enhanced Agricultural Productivity Economic Growth and Employment Opportunities	Agreement of BWSSB with Industries / Farmers Associations / Lake Management Authorities	Lake Management Authorities Industries/ Industry Associations Farmer associations
	Key Resource Water Sources Wastewater Treatment Infrastructure Land and Property Financial Resources Technical Expertise and Knowledge Regulatory Framework and Permits		**Channels** Contract between BWSSB, Industries, farmer associations, and private operator to assure quantity and quality of treated water	

Cost Structure	Revenue Streams
CAPEX of sewage treatment plant and conveyance of secondary treated water (secondary treated effluent to agricultural farmlands/industries) OPEX of sewage treatment plant and conveyance of secondary treated water to agricultural farmlands/industries	Fees from sale of treated used water to industries, farmer associations, and to BWSSB
Social & environmental costs Social Acceptance and Participation Health and Sanitation Water Discharge and Pollution	**Social & environmental benefits** Improved Water Availability Agricultural Development Rural Revitalization Groundwater Recharge Ecosystem Restoration Water Pollution Mitigation

Institutional Environment

Government Agencies: The local municipal corporation, state environmental departments, and national water resource management authorities are responsible for formulating policies, issuing permits, and enforcing regulations related to the lake's use, conservation, and development.
Lake Management Authorities: These authorities may be established for implementing strategies for lake conservation, pollution control, and sustainable use of lake resources, coordinating with other agencies, research, and facilitating public participation for improved lake management.
Community and Stakeholder Groups: Local communities, resident associations, and environmental organisations may be engaged in advocacy, generating awareness, and participating in decision-making processes related to the lake's management.
Research and Academic Institutions: Research institutions, universities, and academic organisations may conduct research on the ecological, hydrological, and social aspects of Kolar Lake, and provide valuable scientific knowledge for informed decision-making about effective lake management.
Regulatory Framework: The fregulatory framework for encompass laws, policies, guidelines, and permits related to water quality, pollution control, land use, and conservation.

Funding and Financing

The funding and financing of the K.C. Valley project for Kolar involves a combination of sources. The project is supported by the Government of Karnataka through its various departments and agencies. Financial assistance is provided by Karnataka State Natural Disaster Monitoring Center (KSNDMC) Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC), National Bank for Agriculture and Rural Development (NABARD) and the Ministry of Housing and Urban Affairs (MoHUA), Government of India. Public-private partnerships (PPPs) play a crucial role in the project's financing. Private entities and corporations contribute through investments, grants, and collaborations to support the implementation and operation of the K.C. Valley project. Furthermore, the project may also secure funds through external sources, such as multilateral development banks, bilateral agencies, and international organisations.

Impacts, Scalability and Replicability

The K.C. Valley project in Kolar has addressed the issue of dry borewells and declining groundwater levels. Groundwater levels have risen significantly, resulting in increased yields from borewells and abundant water in open wells throughout the year, including overflow during the monsoon. The utilisation of secondary treated wastewater contributes to water conservation, and supports the revival of water bodies in the Kolar and Chikkaballapur districts. The transformation at Lakshmisagara lake following its rejuvenation and the introduction of treated wastewater has led to a thriving local economy. It has successfully provided irrigation facilities to farmers throughout the year enabling farmers to cultivate more crops even in limited areas. Diversification of crops is a key outcome wherein farmers have transitioned from eucalyptus plantations to cultivating 3-4 crops such as tomatoes, beans, cauliflower, chillies, and flowers like Marigold and Jasmine. Research on the implementation of the K.C. Valley Project has shown renewed hope in the farming community by enabling the effective utilisation of treated water and creating better livelihood opportunities in the area. However, quality of the treated water has to be ensured to achieve success and scalability of the solution to other areas of the country.

Summary Assessment - SWOT

Strengths	**Weaknesses**
• Provided year-round irrigation facilities, and boosted farm productivity. • Contributed significantly to the rise in groundwater levels, resulting in increased yields from borewells and abundant water in open wells throughout the year. • Promoted the effective reuse of secondary TWW: a) contributed to the revival of waterbodies in Kolar/Chikkaballapur districts b) transformed Lakshmisagara lake and boosted the local economy. • Farmers who had left their lands (due to drought) are motivated to resume agricultural activities.	• The quality of the treated water has been a challenge due to the presence of heavy metals and other chemicals of concern. Improved quality of TWW must be ensured to achieve success and scalability of the project. • The state and city authorities have been grappling with the escalating challenges posed by sewage management. • Despite the government's intentions to install tertiary treatment plants at major tanks, slow development has been noticed so far.
Opportunities	**Threats**
• The State Government has taken the initiative to install tertiary treatment plants at major tanks using the treated sewage from STPs. • The State Government has launched ambitious lift irrigation project to transfer secondary TWW from Bengaluru for groundwater recharge in drought-affected areas of Kolar. • The extended agricultural cultivation period has created a flourishing economy and improved livelihoods in the Lakshmisagara region.	• Kolar, being a drought-prone area, faces a steady depletion of groundwater levels and decline of traditional water tanks, due to changing climate • Earlier, farmers would invest money in drilling borewells, which now often dries up, burdening them with significant debt. • Resource-deficient farmers had to work as labourers due to drought and borewell failures, had experienced livelihood loss, this aspect needs to be monitored.

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6. Business Models for in-house Industrial Reuse

6.1. Delhi, India

An integrated wastewater reuse system has been implemented as part of Delhi Airport's commitment to sustainable development. The system reduces the amount of freshwater used for irrigation, HVAC makeup, and toilet flushing, while sustaining landscaping entirely with recycled water (*Table 30*). As Delhi is suffering from a water shortage, this approach is essential in demonstrating water conservation, biodiversity promotion, cost savings, and the development of green infrastructure.

Table 30: Key characteristics of case study: Delhi Airport, India

City: New Delhi, India		**Case study: New Delhi Airport**	
Population (2021)	20 million	**Treatment capacity**	16.60 MLD ZLD
Annual population growth rate	2.73%	**Treatment**	ZLD
Water scarcity	18%	**Operator**	Delhi International Airport Limited (DIAL)
No. of municipal WWTPs	35 Existing		
% of total reused water from the WWTPs in Delhi	35% (2019) 70% (2024) 80% (2026)	**End users**	Delhi International Airport Limited (DIAL)

City Context and Project Background

Delhi, the capital city of India covers an area of 1486 sq. Km. It is served by Indira Gandhi International Airport (IGI Airport) which is one of the busiest airports in the world, handling millions of passengers (69.23 million airport users in 2018-19) and tons of cargo each year. As a major transportation hub, the airport plays a vital role in connecting Delhi to domestic and international destinations. Delhi faces significant challenges due to its rapidly growing population, urbanisation, and water scarcity issues. The city's demand for water exceeds its available supply, leading to overexploitation of groundwater and reliance on water sources from outside the city.

Delhi Jal Board (DJB) is responsible for the production and distribution of drinking water as well as for the collection, treatment, and disposal of domestic sewage in Delhi. DJB promotes the use of treated effluent to reduce the stress on the demand for potable water supply in the city. Delhi Jal Board supplies around 900 MGD (820 surface water and 80 MGD groundwater). The demand for a population of around 23 million in 2021, is around 1380 MGD.

The Delhi International Airport Limited (DIAL) is a GMR Infrastructure-led consortium that manages the IGI Airport. DIAL's key objectives are sustainable development and management of water resources through continual assessment, conservation, augmentation, protection from pollution, and safe distribution. The water demand of IGI Airport is met primarily from the Delhi Jal Board (DJB) supply. Water efficiency at this airport is continuously monitored through data collection and analysis.

Wastewater Treatment and Water Reuse Infrastructure

Sewage Treatment Plant (STP) of 16.6 MLD capacity is operating to treat the wastewater generated by Delhi Airport. This plant is equipped with all primary, secondary, and tertiary treatment systems with a highly efficient centrifugal sludge ticking unit. It is a biological treatment method with a nitrification and denitrification treatment process. State-of-the-art circular bio reactor (nitrification and denitrification) chamber is energy efficient in the process of being set up. This continuous mixed plug flow bioreactor is selected due to the higher rate of biological conversion than the conventional one. It is equipped with highly efficient porous membrane diffused aerators to achieve the aeration with less residence time and high rate of air diffusion and mass transfer. Treated water is processed with extended aeration before it is used as irrigation water. The clarified wastewater is further processed through Dual Media Filters (DMF). It comprises advanced treatment systems such as ultra-filtration (UF) and Reverse Osmosis (RO) to process the wastewater for HVAC use. State-of-the-art membrane (UF & RO) systems are used to process the biologically treated and filtered water to meet the quality criteria of HVAC system requirements. Entire STP has automated, controlled infrastructure, equipped with energy efficient filters, pump and lightings. Variable Frequency Drives, pumps, sensors and controllers of flow, level and pressure are the main features of this plant. The STP water quality is monitored regularly by MoEF&CC /NABL approved labs. The maximum concentrations observed value of each pollutant during the reporting period (April 2021 to March 2022) were within the limits of the prescribed standard given by Delhi Pollution Control Committee (DPCC) (Table 31 & 32)**.**

Landscaping & Irrigation Systems: IGI Airport has implemented a significant green initiative focused on landscaping and tree plantations. Spanning over 120 acres of land, the airport has undertaken an extensive and dense landscaping project. Thousands of medium to large shrubs and trees, along with a multitude of ground cover, have been planted in accordance with the master plan. Additionally, more than 19,000 trees have been planted and are being maintained by DIAL around various water bodies in New Delhi.

An important aspect of this green initiative is the sustainable water management approach. The entire landscaping project is irrigated using treated wastewater, which is supplied through a drip irrigation system. This water-efficient system ensures that the plants receive an adequate water supply while minimising water consumption. Moreover, an automatic water dispensing system is employed, further optimising the use of water resources.

By utilising treated wastewater for irrigation, the airport demonstrates its commitment to environmental sustainability and responsible water management. This initiative not only enhances the aesthetic appeal of the airport but also contributes to the conservation of freshwater resources and the reduction of wastewater discharge.

Overall, the landscaping and tree plantation project at IGI Airport showcases a proactive approach towards green infrastructure development, promoting biodiversity, and utilising treated wastewater effectively for sustainable irrigation practices.

Table 31 Performance Indicators of Tertiary Treatment Plant

RO Outlet for HVAC (CT Makeup)		
Parameter	**Unit**	**Report**
pH	-	5.5 - 6.8
Turbidity	NTU	ND
TDS	ppm	25
Chloride (Cl^-)	ppm	<10
T-Hardness	ppm	<10
Ca-Hardness	ppm	<10
Alkalinity	ppm	<10
O-PO_4^- as 'P'	ppm	ND
Silica (SiO_2)	ppm	ND
Total Iron as Fe	ppm	ND
Nitrate -N	ppm	ND
Amm. N_2 as N	ppm	ND
COD	ppm	ND
BOD	ppm	ND
Sulphate -SO_4^{2-}	ppm	ND

* ND: Non detectable

Table 32 Performance Indicators of STP for flushing and landscaping

Horticulture & Flushing		
Parameter	**Unit**	**Report**
pH	-	7.5 to 8.2
Turbidity	NTU	<1
TDS	ppm	<2100
Chloride (Cl^-)	ppm	700
T-Hardness	ppm	400

Ca-Hardness	ppm	250
Alkalinity	ppm	350

Business Value Chain & Business Model

Water is required at Delhi Airport for potable use, firefighting, sanitation, horticulture, and air conditioning, and it is supplied by DJB as well as the use of bore wells for groundwater as a backup (*Figure 15; Table 33*).

Aligned with the national vision of sustainable development, DIAL has undertaken multiple initiatives to promote the reuse of treated wastewater as part of the Operations, Management, and Development Agreement (OMDA). DIAL has implemented robust wastewater treatment systems to efficiently treat and recycle water within the airport premises. These initiatives aim to reduce reliance on freshwater sources and minimise the environmental impact associated with water consumption. By reusing treated water, DIAL demonstrates its commitment to responsible resource management and aligns with the objectives outlined in the OMDA. DIAL's key focus area is the conservation of water with the goal of becoming a water-positive Airport in the near future. To do so, various measures have been undertaken such as rainwater harvesting, efficient faucets and landscape irrigation systems, and recycling and reusing treated water, to reduce the consumption of DJB-supplied water and the wastage of potable water. There is a 7 MLD water treatment plant for potable water requirements at the airports. However, there is a requirement for more water for non-potable uses and this is being met by reusing treated water. To cater to the treatment of sewage generated in the airport as well as the need for meeting other water demands a Zero Liquid Discharge (ZLD) Sewage Treatment Plant (STP) of 16.6 MLD capacity has been established within the airport premises. The treated sewage is then utilised for heating, ventilation, and air conditioning (HVAC) makeup water, sanitation requirements such as flushing, and maintaining the landscape, thereby, reducing and optimising freshwater demand. DIAL has Service Level Agreement contracts in place to manage the operation and maintenance of the water treatment infrastructure, as well as water and treated water distribution for concessioners as per the requirements.

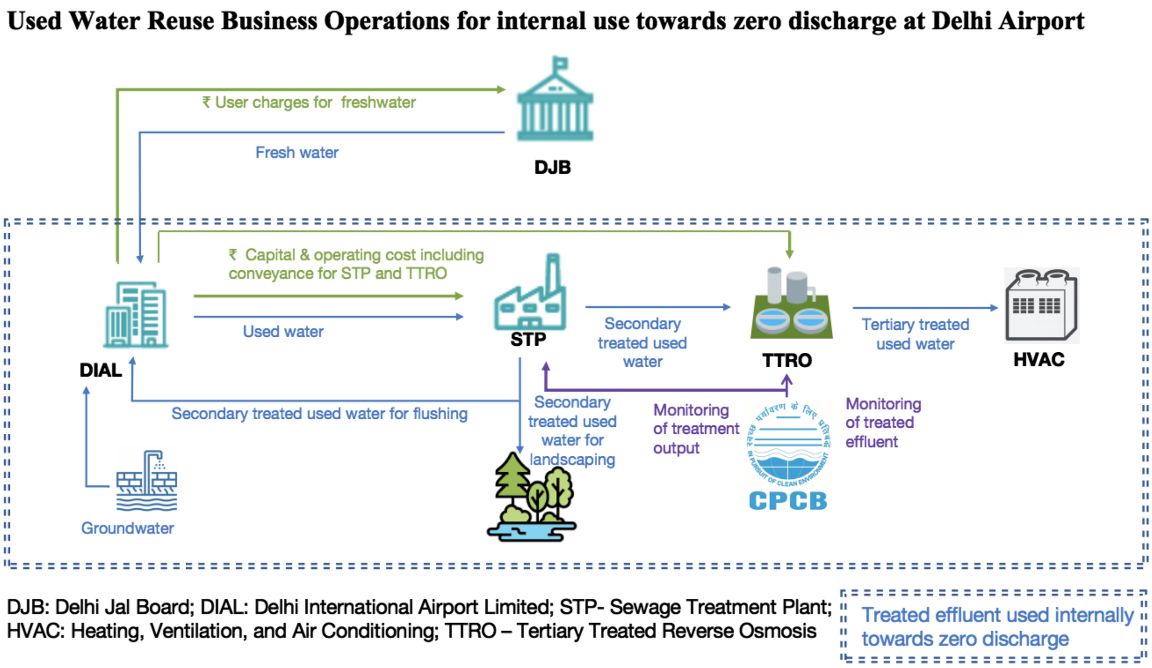

Figure 15: Water Reuse in Delhi Airport

As a result of the implementation of the system at Delhi airport, the dependence on freshwater has been reduced considerably for irrigation of 120 acres of landscaping, for HVAC makeup, and for toilet flushing.

The landscaping is maintained entirely by supplying STP-treated recycled water by drip irrigation and the automatic water efficient water dispensing system. The system also helps DIAL save almost 25 crores per year in terms of the cost of water.

Table 33: Delhi Airport Business Model Canvas for water reuse

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
Delhi Jal Board (DJB) Delhi International Airport Limited (DIAL) Airports Authority of India (AAI)	Treatment of used water at Zero Liquid Discharge Sewage Treatment Plan Conveyance of secondary treated water for horticulture, flushing, and other uses Conveyance of tertiary treated water for cooling	Assured quantity of secondary treated water (RO Plant reject of STP and WTP is also blended) for horticulture, flushing water, and other uses Assured quantity of tertiary treated water treated (UF & RO) used for cooling tower makeup water Freeing freshwater for potable purposes	69.23 million airport users (2018-19) are assured of water resources. DIAL has a sustainable water supply for all operations	Delhi International Airport Limited (DIAL)
	Key Resources Sewage Sewage Treatment Plant Water (Including treated		**Channels** Service Level Agreements based contracts for O & M and distribution	

	water) Distribution Infrastructure			
Cost Structure CAPEX 350 Crores (Approx) OPEX 419.667 lakhs/annum	**Revenue Streams** INR 28.8423 crore or INR 24.64563 crore savings for DIAL (Inclusive of OPEX) by using treated water			
Social & environmental costs High energy requirement to operate facility resulting in GHG (greenhouse gas) emissions	**Social & environmental benefits** Conservation of Freshwater Resources Reduction of Wastewater Discharge to the environment Minimization of Environmental Impact Enhanced Resilience to Water Supply Challenges			

The Delhi Airport 7 MLD water treatment plant utilises raw water from local piped water and bore wells as a backup, which is then treated using reverse osmosis (RO) technology. The rejects from the RO system, along with sewage from both the new terminal building and old infrastructure, are combined to form a pseudo sewage. This pseudo sewage has a higher ammonia to BOD (Biochemical Oxygen Demand) ratio compared to conventional city sewage, primarily due to the predominant use of toilets for urination rather than flushing. The pseudo sewage is then treated in a biological nitrification-denitrification reactor using the MLE (Modified Ludzack-Ettinger) process. The treated sewage undergoes equalisation, followed by filtration through dual media filters (DMF) with the addition of $FeCl_3$ to remove colloidal phosphorus. Subsequently, it goes through ultrafiltration (UF), cartridge filters, and reverse osmosis (RO). The unique shape of the bio-reactor allows for a plug flow configuration, which can be modified if necessary, in the future.

Institutional Environment

The Green Bond Principles (GBP) and Green Loan Principles (GLP) are internationally recognized frameworks that provide guidelines and standards for financing projects with environmental benefits. In the context of Delhi Airport, these principles can be applied to promote sustainable development and support eco-friendly initiatives.

Under the Green Bond Principles, Delhi Airport can issue green bonds to raise capital for projects that have positive environmental impacts. These projects could include investments in renewable energy infrastructure, energy-efficient buildings, low-carbon transportation systems, or initiatives to reduce greenhouse gas emissions. By adhering to the Green Bond Principles, Delhi Airport ensures transparency and accountability in the use of proceeds, providing investors with confidence that their funds are allocated towards sustainable endeavours.

Similarly, the Green Loan Principles offer a framework for financing projects that contribute to environmental sustainability. Delhi Airport can seek green loans from financial institutions to support initiatives such as the implementation of energy-saving technologies, water conservation measures, waste management systems, or nature conservation efforts. The Green Loan Principles help in verifying the environmental credentials of the funded projects and provide guidelines for tracking and reporting on their environmental performance.

By embracing the Green Bond Principles and Green Loan Principles, Delhi Airport demonstrates its commitment to environmental stewardship, sustainability, and responsible financial practices. These principles facilitate the mobilisation of capital towards projects that mitigate climate change, protect natural resources, and contribute to a greener and more sustainable future for the airport and its surrounding areas.

At the city level, the urban local body (ULB) which in this case is DJB, is held responsible for all activities related to water and sewage management under the Delhi Jal Board Act of 1998. DJB has planned and executed several reuses of treated water projects.

Funding and Financing

The Government of India had decided in 2003 to restructure Delhi airport and develop it as a world-class airport by involving the private sector. This was done as significant investments were required to do so. Hence, the Airport Authority of India (AAI), in the capacity of State promoter, signed the Operations, Management, and Development Agreement (OMDA) with Delhi International Airport Limited (DIAL) on April 4, 2006 (Shareholding of AAI is 26% with GMR led investors accounting for 74%). The term of concession granted to DIAL as per OMDA is 30 years, provided that an annual fee of 45.99% of the revenue of DIAL is paid to AAI (CAG, 2011).

The capital cost of the water reuse system is approximately 350 Crores while the operation cost is around 419.667 lakhs/annum. The annual cost of water for 4.5 MLD is almost 29 crore INR and reusing treated water saves DIAL almost 25 crores per year.

Impacts, Scalability and Replicability

Delhi is second on the list of the world’s 20 largest cities under water stress. As of 2020, the water availability from all sources is 935 MGD while the demand is 1140 MGD (19 million population with 60 GCPD demand) indicating a deficit of 141 MGD. However, by 2031 the population is estimated to be 29.1 million and the demand is around 1746 MGD. Additionally, due to Delhi's limited access to raw water, DJB targets for domestic potable water demand need to be rationalised, and gradually reduced to 50 GPCD (225 LPCD) by 2041. This is expected to be done through Integrated Urban Water Management (IUWM) and supplemented by using fit-for-purpose recycled treated water. This will reduce the total water demand to 1455 MGD by 2041. Hence, the efforts taken by Delhi Airport to implement an integrated water management system that addresses freshwater demand, efficient water use, diversifying water sources, reuse of treated water, etc. The limited availability of freshwater supply and the additional demand for water for flushing, HVAC, and landscaping a key driver.

Summary Assessment - SWOT

Strengths	Weaknesses
• The water stress situation has created a demand for used water and DIAL is willing to invest in systems for using treated water. • Ability to mobilize funds under Government schemes for project investment and DIAL's drive to be a water-positive airport. • State and city have created an enabling environment through policy and by law to incentivize and encourage reuse.	• Willingness to invest in capital cost • Cost recovery from joint ventures
Opportunities	**Threats**
• Acceptability of treated used water for airport non-potable uses • The Sustainable Water and Wastewater Management processes upscaling to other airports	• Increased energy usage will impact emissions • Regular monitoring and maintaining water quality is critical • Maintaining wastewater treatment infrastructure since several issues could arise from equipment breakdowns

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7. Business Models for in-between-Industry Reuse

7.1. Kalundborg, Denmark

Kalundborg is one of the most famous and successful examples of a circular economy relying on a close interaction of industries and the municipality (*Table 34*) regarding reusing energy, material, and water flows. Also, Kalundborg is an important example of how wastewater treatment markets can be designed and regulated to optimize Prices, Efficiency and Effectiveness of water treatment.

Table 34: Key characteristics of case study: Kalundborg, Denmark

City: Kalundborg, Zealand, Denmark		Case study: Kalundborg Eco-Industrial Park	
City Population (2016)	16,211	**Treatment capacity Kalundborg WWTP**	50,000 person equivalents
Annual population growth rate		**Treatment**	Tertiary
Water scarcity/demand vs. supply	Water scarce (groundwater)	**Operator**	Kalundborg Forsyning
No. of municipal WWTPs (with used treatment capacity)	1 (50,000 person equivalents)	**% of treated water reused for industy**	n.a
% of total reused water from Kalundborg WWTP in industry	n.a. (ca. 700,000 m^3/year used as cooling water)	**End users**	Municipality, industry

City Context and Background

Kalundborg is a small city with 16,211 inhabitants and is located on the west cost of Zealand in Denmark. Kalundborg evolved as one of the world's most complex and advanced 'Industrial Symbiosis'. In the Kalundborg Eco-industrial park, wastewater, waste materials and energy are shared and distributed between companies for competitive advantage. The Kalundborg Eco-Industrial Park now includes nine private and public enterprises.

The Kalundborg Eco-industrial park was not initially planned for industrial symbiosis but developed over 20 years. The park was established in 1959 with the Asnaes Power Station, which today has material and energy links with the community and other industries. The park has been expanding and sharing a variety of materials and waste products, some for industrial symbiosis and some out of necessity; for example, freshwater scarcity has led to water reuse schemes, i.e., 700,000 m3/year of cooling water is piped from Kalundborg (earlier Statoil) Refinery to Asnaes power station per year.

Wastewater Treatment and Water Reuse Infrastructure

The wastewater treatment in the Kalundborg Eco-industrial park is centralized and operated by Kalundborg Forsyning. Kalundborg WWTP has a treatment capacity of 50'000 person equivalents. The largest amount of incoming wastewater (ca. 60%) is industrial used water whilst the remaining 40% are from the municipality of Kalundborg. Wastewater is pre-treated by some industries. There is for example an advanced WWTP on the Production site of "Novo Nordisk and Novozymes" a producer of technical enzymes for the biopharmaceutical industry. The WWTP is also connected to an internally driven biogas plant producing electricity for the grid and heat for internal use and with-it reducing COD of the effluent (reaching Kalundborg WWTP) significantly.

The Kalundborg WWTP is a Biodenipho™ [3] plant with a side stream hydrolysis. Used water is first mechanically pretreated, pumped into anaerobic pre-tanks, and brought to oxidation ditches. From there, the water is brought into secondary clarifiers, and sludge will be dewatered and then used as agricultural fertilizer. After the secondary clarifiers, the water can be tertiary treated with ozonation or post-treated in an MBBR (membrane bioreactor).

Business Value Chain & Business Model

Kalundborg WWTP is a public company that monopolises wastewater treatment services in Kalundborg. As a monopoly, Kalundborg Forsyning operates under specific regulations regarding its pricing and profit generation.

Freshwater from Lake Tisso is supplied to industrial freshwater users. Afterwards, used water is pre-treated on-site and reused by other companies or further treated in Kalundborg WWTP (*Figure 16, Table 35*). From there, the treated used water is reused by industries (treated to the required quality) or discharged in the Fjord of Kalundborg.

There are different water reuse schemes in the Kalundborg Symbiosis. For example, used water from the Kalundborg refinery is supplied to the Asnaes Powerplant as cooling water (700,000 m^3/year).

Besides water reuse, over 20 different waste materials are reused in between companies due to economic advantages. Companies save money by receiving cheaper energy or facilitating production processes by not having their own freshwater supply (e.g., Statoil Refinery receiving steam from Asnaes Power plant) and having less waste to dispose of. The prices of exchanged materials, water, and energy are based on negotiations between companies. Due to the low transportation costs, this is viable even if resources are sold at market prices. The symbiosis's total savings are estimated at around 80 million € annually.

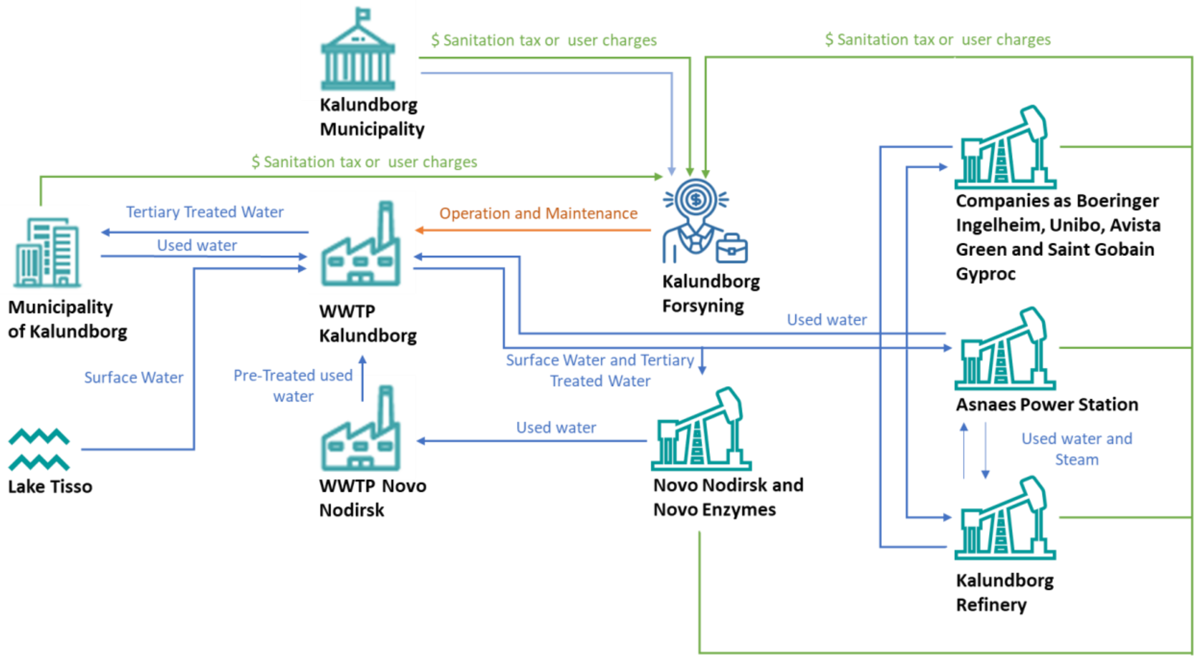

Figure 16: Kalundborg's Eco-Industrial Park's business value chain related to water flows

[3] Bio-denipho processes are biological treatment processes for removal of carbon, nitrogen and phosphorus from wastewater.

Table 35: WWTP Kalundborg's (Kalundborg Forsyning's) Business Model

<table>
<tr>
<td rowspan="2">Key Partners
Kalundborg Municipality

Novo Nordisk & Novozymes

Kalundborg refinery (Statoil)

Gyproc
Orsted
Meliora BIO
Kalundborg Bioenergy
ARGO
Unibio
Remilk
Avista Green</td>
<td>Key Activities
Fit-for-purpose used water treatment

Freshwater supply</td>
<td rowspan="2">Value Propositions
Distribution of tertiary treated used water adapted to quality requirements by industrial (and urban) end users</td>
<td>Customer Relationships
Regular exchange with industries and municipality to discuss and guaranty treatment and quality needs</td>
<td rowspan="2">Customer Segments
Industries
Municipality</td>
</tr>
<tr>
<td>Key Resources
Land
Used water
Freshwater
Steam
WWTP infrastructure
Cost-covering O&M of WWTP and distribution network</td>
<td>Channels
Automated billing</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Capital cost of tertiary treatment plant (borne by companies and municipality)

Operations of tertiary treatment plant: - Staff, electricity, reactants

O&M and distribution costs charged to polluters and users</td>
<td colspan="2">Revenue Streams
Competitive advantage through the use of alternative locally available material, water or energy stream

Urban households pay for freshwater supply and wastewater treatment

Selling of tertiary treated wastewater to industries and urban users</td>
</tr>
<tr>
<td colspan="3">Social & environmental costs
High energy requirement to operate facility resulting in GHG (greenhouse gas) emissions</td>
<td colspan="2">Social & environmental benefits
Reduced pressure on freshwater demand and groundwater depletion</td>
</tr>
</table>

Institutional Environment

The Danish water sector comprises natural monopolies. To ensure effective management of these sectors, the Danish Parliament enacted legislation in 2009, imposing various requirements for economic regulation and organization on the largest and municipally owned water supply companies. Approximately 300 companies are subject to the Danish Water Sector Act regulation. This legislation establishes guidelines for water supply companies to keep their revenues within a specified limit, known as a revenue cap, and sets efficiency requirements. The regulator employs benchmarking techniques to determine individual efficiency improvement targets for each company.

Furthermore, the water sector legislation governs the permissible activities of water and wastewater companies. The Danish economic regulator for water supply companies is the Secretariat for Water Supply, which operates under the Danish Competition and Consumer Authority and falls under the Ministry of Industry, Business, and Financial Affairs. The water sector legislation defines the Secretariat's responsibilities. Payment and delivery terms for water services in Denmark are regulated by legislation. The Water Supply Act and the Act on Payment Rules for Wastewater Supply Companies specify how water supply companies can cover the costs associated with the services they provide to consumers. Most consumers in Denmark are connected to water supply and wastewater companies. In addition to their regular responsibilities, wastewater supply companies in Denmark are also responsible for financing climate change adaptation within their discharge systems. In cases of cloudbursts or heavy rainfall, sewer systems can become overwhelmed. As per the Act on Payment

Rules for Wastewater Supply Companies, these companies may contribute to climate change adaptation projects that serve dual purposes, such as cloudburst on municipal and private property.

Funding and Financing

Kalundborg WWTP was built in 1985 and was financed by the municipality from tax money. Since then, it has been upgraded and extended multiple times. All extensions have been paid by exceptional contributions, investments and donations by companies involved in the Kalundborg Eco-industrial Park. Operation and maintenance costs are covered via fees paid by the people of Kalundborg and the industries. The fee is split into two parts. Transport of used water costs 5.07 €/m3 and treating used water costs 0.95 €/m^3. The fee is divided because some larger industries, i.e., Novo Nordisk, have their wastewater pipes and bring them directly to Kalundborg WWTP and thus pay only for the treatment. Kalundborg WWTP is also cross-financed by the Municipality and Industry for special tasks, e.g. the treatment of rainwater is paid extra by the municipality or the treatment of highly polluted wastewater is charged with a special fee to the polluting companies.

Impacts, Scalability and Replicability

By implementing a circular economy approach, the symbiosis has minimized waste generation and reduced the environmental footprint of participating industries. By sharing resources and optimizing their use, companies within the symbiosis have realized cost savings, improved production efficiency, and increased competitiveness. Moreover, the collaboration between industries and the municipality has attracted investment, created job opportunities, and stimulated economic growth in the region. The symbiosis has also contributed to the community's overall well-being by promoting sustainable practices, protecting public health through effective wastewater treatment, and supporting the development of a resilient and environmentally conscious society.

Despite its various positive impacts, the scalability and replicability of this model are limited as it depends on many context-specific factors, such as the industries involved, regulatory frameworks, and local stakeholder engagement. Scaling up/replicating the model would require substantial infrastructure development and thus significant investment costs for companies and municipalities. The availability of excess resources (e.g., heat, byproducts) varies across industries and regions. The model's scalability depends on the availability of resources and industry diversity so that suitable partnerships for excess resources can be established. Effective and long-term stakeholder commitment is also an important component.

Summary Assessment – SWOT

Strengths	**Weaknesses**
• Competitive advantages for industries by sharing excess resources in between industries • Freshwater scarcity promoting water reuse schemes • Reduced environmental footprints through the reuse of different waste materials • Job opportunities/Economic growth • Public health protection	• Industry diversity and available excess resources limit scalability of the model
Opportunities	**Threats**
• Legal frameworks for cost-covering wastewater treatment on European level: e.g., Water Framework Directive, Urban Wastewater Treatment Directive • Kalundborg Forensyng as monopoly of water supply/wastewater treatment by Danish Law	• Industry diversity and available excess resources limit replicability of the model

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8. Cross - cutting issues

8.1. Climate, resilience

Relevance: Climate resilience is the ability of a system, community, or infrastructure to foresee, plan, respond to, and recover from the adverse impacts of climate change. In the context of reused water management, it involves developing strategies and adopting practices that can withstand and adapt to the increasing uncertainties of climate change, such as unpredictable weather events, erratic precipitation patterns, and rising global temperatures. The changing climate is challenging communities across the world to meet their long-term water needs. Reuse of treated wastewater (TWW) for agricultural, non-potable, or even potable uses provides an excellent and reliable alternative to the traditional water sources and makes a community's water supply more resilient to climate stresses such as persistent droughts or floods or other extreme weather events.

Aspects of TWW contributing to climate resilience: The intersection of the concepts of climate resilience and safe reuse of treated water lies in their potential to address water scarcity and enhance water security in the face of climate change impacts. Some aspects of reuse of treated water contributing to climate resilience are discussed below:

- *Diversification of water sources:* TWW provides an additional water source that is less vulnerable to climatic fluctuations, making communities more resilient to droughts, floods and changing precipitation patterns. Diversification is not just about the availability of an alternative water source, but also about leveraging this source to reduce stress on the more traditional (freshwater) supplies.
- *Resilient agriculture:* Reusing TWW for irrigation helps maintain agricultural production even when freshwater resources are limited due to climate-related stresses. Also, reusing TWW for irrigation helps improve agricultural water use efficiency that could free up adequate amount of water for urban and other uses, especially in water-conflict regions.
- *Drought mitigation and flood control:* Wastewater reuse provides a consistent water source during droughts, ensuring that essential services like agriculture and industry can continue to operate. Also, if properly designed, water management systems can manage excess water during climate-induced heavy precipitation events, by capturing and reusing treated stormwater, thus mitigating the risk of flooding.
- *Reduced carbon emissions:* Climate emissions can be reduced from decreased pumping of freshwater from aquifers or long-distance surface water sources. Multiple climate benefits can arise from the reuse of treated water. Wastewater treatment helps to reduce greenhouse gas emissions (GHG) emissions (like methane). A well-designed wastewater system will result in improved sludge management outcomes (like methane capture and energy generation) that will help mitigate the GHG emissions (emanating from the wastewater management plant's operations).
- *Energy efficiency:* Although wastewater treatment and distribution of reused water require energy, the overall energy usage is often lower than that needed for desalination or long-distance water transport. This reduces the overall carbon footprint of a region, contributing to climate mitigation.

- *Protecting aquatic ecosystems and promoting revival of waterbodies:* The use of TWW for non-potable purposes can reduce the climate-induced stress on freshwater sources (rivers/aquifers). Also, when TWW is put to productive use instead of discharging into sensitive aquatic ecosystems, it can contribute to the restoration of lakes and waterbodies.
- *Climate-resilient infrastructure:* When designing and operating reused water management systems, it must be ensured that the infrastructure is climate-resilient in terms of withstanding extreme weather events and addressing emerging challenges for continued availability of reused water.
- *Public awareness and acceptance:* Both climate resilience and treated water reuse strategies require community awareness and involvement. Educating the public about the benefits and safety of treated water reuse can foster acceptability for these practices.

Implications of GHG emissions and reuse of treated water in India: Recent research in India indicates that 11,622 million cubic metres (MCM) of treated wastewater was available for reuse in 2021 that is predicted to increase to 15,288 MCM and 35,178 MCM by 2025 and 2050, respectively. Consequently, about **1.3 million tonnes (MT)** of GHG emissions might have been avoided by reusing TWW in irrigation in 2021, as discussed below.

- In 2021, by irrigating 1.38 Mha with the available TWW, 3.5% of the groundwater-irrigated area would have required less pumping thereby reducing 1 MT less of GHG emissions (due to reduction in energy usage to extract groundwater). In India, nearly 30 million irrigation pumps are used for groundwater extraction with each pump irrigating about 1.3 ha of land. As a result, the required number of pump sets would have decreased by 1 million, resulting in a 1 MT reduction in CO_2 emissions, which would be 2.2 MT of CO_2 emissions by 2050 (under the business-as-usual scenario).
- Further, as TWW already contains nutrients (NPK), less fertilizer would have been needed, thereby decreasing the GHG emissions by **0.3 MT**, considering urea (N), ammonium phosphate (P), and murate of potash (K) fertilisers (0.75, 0.29 and 0.095 tonnes CO_2/tonnes) are the key sources of the nutrients N, P, and K, respectively.

Therefore, GHG emissions reduction through adequate reuse of treated water can contribute towards achieving India's Nationally Determined Contributions (NDCs), which calls for a reduction in emission intensity by 2030.

Application of safe reuse of treated water to achieve climate resilience: Evidently, water scarcity is a significant concern across many regions in the world, including cities like Alicante and Barcelona in Spain, and Chennai in India. Changing climate, population growth, and unsustainable water management practices have aggravated this problem in these cities that have been addressed by adopting strategies on safe reuse of treated water.

The Intergovernmental Panel on Climate Change (IPCC) forecasts that the Mediterranean (including Spain) will be one of the regions most affected by climate change. Urban growth in Alicante and Barcelona has led to increased risk of flooding and water scarcity, and hence emphasises the need to mitigate urban flooding. In terms of diversification of water sources, both Alicante and Barcelona have taken up desalination projects (removal of salt and other impurities from seawater) for drinking and irrigation purposes that helps reduce the reliance on the already-overexploited traditional freshwater sources.

In Chennai, rapid urbanization and urban flooding has contributed to an acute water crisis. The cyclone-prone water of the Bay of Bengal flows into the city causing its sewage-filled rivers to flood onto the streets. In 2019, the city reached "Day Zero", when reservoirs were left with no water. To build climate resilience and increase water availability, Chennai is diversifying its water supply through desalination and reuse of TWW. The city has mandated rainwater harvesting in all public and private buildings, and is an exemplary city in India to reuse 10% of treated water, with plans to increase the reuse rate to 75%. To achieve this target, several efforts are being made: the factories in Chennai have constructed ponds for rainwater harvesting; the mines and quarries are a potential source for water supply and rainwater harvesting storage ponds, all of which make the city resilient to water stress.

All these three cities have implemented wastewater treatment and reuse strategies that promote climate resilience by reducing their vulnerability to water scarcity. Cities worldwide can replicate such examples and adapt similar strategies to address their own water scarcity challenges triggered by climate change. However, successful implementation of such strategies will require a well-balanced combination of technological, policy, and community-driven approaches.

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8.2. Legislation

Relevance: Evidence indicates that treated wastewater (TWW) has the potential to significantly reduce water stress, reduce pollution, increase agricultural productivity, conserve energy, and contribute to climate adaptation and resilience by decreasing water stress, reducing environmental pollution, and increasing agricultural productivity, economic opportunities, empowering communities, and enhancing their resilience. Considering 72,368 million liters per day (MLD), of sewage, generated in urban India, there is tremendous potential to meet the growing water demand across various sectors using treated wastewater. According to estimates, wastewater generation in the country is expected to increase by 75-80 percent over the next 25 years. Meanwhile, urbanization and economic development have contributed to a rapid increase in water demand. The use of TWW is a sustainable water management practice to address the rising gap in demand and supply for water use. Several states in India have initiated reforms for adopting policies for the use of TWW.

India - The National Framework on SRTW: The safe reuse of treated wastewater (SRTW) is governed by the National Framework on Safe Reuse of Treated Water (SRTW), various related laws and regulations that ensure the protection of public health, the environment, and sustainable water management practices. The SRTW mandates end use criteria, identifying “no freshwater zones”, implementation targets, and determining pricing policy for TUW. In considering the designation of mandatory use and no freshwater zone provisions, the requirement to maintain allocations for potable water and high quality treatment processes for some industries needs to be taken into consideration. Similarly, States will also consider designation of associated ‘no-freshwater’ zones.

A summary of some key legislation and guidelines in this regard is presented below: The Framework for Safe Reuse of Treated Wastewater, 2022, envisions the adoption of a sustainable circular economy approach, thereby reducing pressure on surface and groundwater resources, environmental pollution, and public health risks. The framework provides an overview of the relevant legislation and policies that have been summarised in *Table 37* below.

Table 36 Relevant National-Level Legislations

Laws & Policies	Relevance
The Water (Prevention and Control of Pollution) Act, 1974	Ensure that aquatic resources are kept 'wholesome' by preventing sewage discharge or pollutants
The Ganga Action Plan, 1986	To prevent pollution of the river Ganga, improve the treatment of sewage, and prevent the mixing of industrial wastes with river water.
The Environment Protection Act, 1986	For the protection and improvement of the human environment, as well as the prevention of hazards to people, plants, and property.
National Water Policy (NWP, 2012)	To reduce water pollution
National Water Policy (NWP, 2020) *Draft (revised)*	To reduce water pollution and recycle and reuse water
National Urban Sanitation Policy (NUSP, 2008)	To ensure safe and sanitary disposal of human waste, encourage recycling and reuse
National Environment Policy (NEP, 2006),	To encourage the recycling of sewage and used water from municipal and industrial sources. Action plans should be developed and implemented by major cities to combat water pollution,

Laws & Policies	Relevance
National Water Quality Monitoring Programme	To ensure that urban wastewater treatment is thoroughly monitored
Model Bill for Regulation of Groundwater Development 2016	To regulate ground water quality both in urban and rural areas, including the disposal of waste water to prevent ground water contamination
National Faecal Sludge and Septage Management Policy (FSSM, 2017)	For safe disposal of faecal waste in the urban areas of India, and the establishment of strict environmental discharge standards

The National Action Plan on Climate Change (2008), has addressed the reuse of TWW in order to ensure that a substantial portion of urban water needs can be met by recycling wastewater, along with other interventions for addressing climate change. Goal 3 of the National Water Mission (NWM) emphasizes the recycling of used water to meet the water needs of urban areas. The Ministry of Power, under its 2016 Tariff Policy, the Ministry of Housing and Urban Affairs (MoHUA), and the National Building Code 2016 advocate the reuse of used water. The National Water Quality Monitoring Programme (NWQMP) of India, and the National Guidelines on Zero Liquid Discharge (ZLD) developed by the Central Pollution Control Board relate to wastewater disposal.

Several Government programs and missions specifically for urban areas encompass waste water reuse and recycling including, the service level benchmarking, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Jal Jeevan Mission, and Swachh Bharat Mission. The service level benchmarking initiated in 2006, with the objective of improving services in urban areas, covers performance indicators to measure the extent to which wastewater can be reused and recycled, AMRUT aims to provide basic services (e.g., water supply, sewerage, and urban transport). Water scarcity and security in urban areas are addressed specifically in the mission through the recycling and reuse of TWW. The Jal Jeevan Mission (JJM) 2021-2022, aims to address water security in 500 cities under the Department of Drinking Water and Sanitation, Ministry of Jal Shakti.

The National Green Tribunal (NGT) of India in 2019 notified the State/Union Territories (UTs) to develop action plans for TWW and submit the same to the Central Pollution Control Board (CPCB) for review. Around 15 states have policies for using TWW and aim to improve sewage collection and treatment within a specified time frame based on the size of the cities. The target varies by the size of the city in some states. Gujarat and Haryana target 100% reuse by 2030 and 2033, respectively, while Karnataka prescribes 50% reuse by 2030. Some other states have similar policies that encourage the reuse of TWW, while others are drafting policies in order to encourage the use of TWW. Some Urban Local Bodies (ULBs) have also set targets ranging from 20% to 25% of TUW, replacing freshwater usage initially. *Table 38* outlines the policies for reusing TWW in the states and Union Territories.

Table 37 State-Level Legislations

States	Policies	Reuse
Andhra Pradesh	Policy on wastewater Reuse and recycle for urban local bodies (2017)	Irrigation/landscape irrigation, fire protection, and toilet flushing, recreational opportunities without human contact
Assam	State Wate Policy of Assam (2007)	Reuse of TWW in non-edible crops

States	Policies	Reuse
		water reuse by suggesting a dual piping system, Industrial reuse, especially in thermal power plants, agriculture (non-edible crops)
Bihar	State Water Policy	Water reuse promotion in water-stressed areas
Chandigarh	State Treated Wastewater Policy, 2017	Water recycling and reuse (target reuse 18% TWW) for development of infrastructure
Chhattisgarh	Wastewater Recycle and Reuse policy	
Damman and Diu, Dadar Nagar Haveli	Under the direction of NGT 2023	Reuse of treated wastewater for mainly industrial purposes
Delhi		Promotion of reuse
Goa	State Water Policy, 2021	Reuse in agriculture and industry
Himachal Pradesh	Himachal State Water Reuse Policy, 2013	Consider water reuse in industries
Gujarat	Policy for Reuse of Treated Wastewater,2018	Reuse in Industries, and other non-potable uses
Haryana	Policy on reuse of treated wastewater, 2019	Reuse in agriculture, thermal power plants, industries, construction, and dual water supply systems in houses, offices, commercial establishments and municipal institutions.
Jammu and Kashmir	State Policy For "Wastewater Reuse " For Jammu & Kashmir	Promotes reuse of TWW
Jharkhand	Jharkhand Wastewater Policy, 2017	Non-potable uses
Karnataka	Policy for Urban Wastewater Reuse, 2017	Agriculture/irrigation, industries, non-potable uses
Kerala	The Kerala Water Authority promotes the recycling and reuse of TWW	Agriculture use
Maharashtra	Maharashtra's State Water Policy encourages recycling or reuse of treated wastewater	Target 30% reuse TWW for industries, thermal power plants, and other non-potable purposes
Madhya Pradesh	State Level Policy (2017) for Waste Water Recycle & Faecal Sludge Management (FSM)	Non-potable reuse, mainly in public parks, golf courses, urban green belts, freeway medians, cemeteries, and residential lawns.
Meghalaya	Meghalaya State Water Policy, 2019	Promotes reuse of treated wastewater
Nagaland	Nagaland Water Policy, 2016	Reuse through dual piping systems in new establishments, thermal powerplants
Odisha	Odisha Urban Sanitation Policy 2017	Promotion of water recycling and reuse for non-potable applications including industries
Puducherry	Action plan for utilization of Treated sewage water, 2019	Promotes reuse in Industries
Punjab	Treated Wastewater Policy in 2017	Reuse for agriculture/ irrigation
Rajasthan	State Sewerage and Wastewater Policy, 2016	Reuse for agriculture/irrigation
Tamil Nadu	State Policy for Wastewater Reuse" was formulated in 2017	Reuse mainly in industries and for infrastructure development, city-specific plans- Chennai

States	Policies	Reuse
Telangana	Announced the introduction of a wastewater reuse policy	To encourage water reuse mainly in industries and agriculture, and draft city specific plans for reuse (Hyderabad)
Uttar Pradesh	Draft policy on Waste water recycling and reuse in Urban local bodies, Uttar Pradesh	Reuse in industries, vehicle washing, construction
Uttarakhand	Draft Peoples Water Policy	Promotes reuse for agriculture/ irrigation
West Bengal	Treated wastewater reuse policy of urban West Bengal, 2020.	Reuse in irrigation and agriculture, energy and construction, washing/flushing of community toilets

The regulatory framework governing wastewater reclamation and reuse in India is still in the development stages. Although several states have implemented wastewater policies or have related policies in place, better planning, regulation, and implementation are needed. Good governance xamples are seen in Maharashtra and Haryana State (*Box 1*). Some of the areas that need further attention in other Indian States are listed below.

- Integration with water resource/supply planning and management
- Legislative, Institutional, technical, economic, and social barriers to implementation
- Highlighting impactful actions
- Inadequate Capacities
- Economic feasibility
- Coordination and Integration of National, State, Regional, City level policies
- Prioritization of incentives and legal implications for adherence and non-adherence
- Recognize and address state/ regional level challenges
- Resource materials for support and guidance

Europe – Water reuse legislation: Water reuse practices in Europe are mainly driven by the demand for additional water resources and evolve under quite diverse national legal and policy regimes. Mostly agricultural uses are permitted but some countries also have quality standards for urban, industrial, recreational and environmental applications (e.g. Spain and Italy, s*ee case studies Alicante, Barcelona and Milan*).

Since 2020 the **EU 2020/741 Minimum requirements for water reuse** is enacted (EUR-Lex, 2020). The regulation aims to stimulate the uptake of water reuse by offering a sustainable, alternative water supply for agricultural irrigation by following a strict risk management approach. It will help to ensure that enough water is available for the irrigation of fields, in particular during heatwaves and severe droughts as a result of climate change, so preventing crop shortfalls and food shortages. Because the geographic and climatic conditions vary greatly across Member States, they are free to decide whether it is appropriate to use reclaimed water for agricultural irrigation. Member States may also decide to use reclaimed water for other uses such as industrial water. The regulation contains strict requirements for the quality of reclaimed water and its monitoring to protect human and animal health as well as the environment. It is developed as a permit system which is based on a 'Water Risk Management Plan' that entails compliance checks, monitoring, and information and awareness. The adoption of common environmental and health standards for water reuse across the EU is an essential strategy, with a robust permitting, monitoring and compliance platform, to promote public confidence in agricultural products irrigated with reclaimed water and prevent potential barriers to the free movement of agricultural goods (Cuadrado-Quesada et al., 2020).

Box 1: Enabling governance mechanisms for SRTW in India

Maharashtra Water Resources Regulatory Authority (MWRRA)

The Maharashtra Water Resources Regulatory Authority (MWRRA) is a statutory organisation established under the Maharashtra Water Resources Regulatory Authority Act, 2005, to regulate water resources in the state. MWRRA plays a crucial role in the sustainable management, allocation, and utilization of water resources. They facilitate and ensure judicious, equitable, and sustainable management, allocation, and utilisation of water resources, set rates for the use of water for agricultural, industrial, drinking, and other purposes, and deal with other related issues. The MWRRA comprises a governing council, an executive committee, and an administrative structure. The Governing Council is responsible for policy-making, while the Executive Committee and the Administrative setup implement these policies.

The overarching philosophy is to use an 'integrated multi-sector approach' to river basin planning and management. This approach views water as a shared resource and promotes water reuse and conservation. MWRRA offers a comprehensive framework for water reuse as well as several opportunities for engagement and support. MWRRA also sets the pricing for both bulk and treated water based on a tariff determination process that includes assessing the cost of providing water, including the capital cost, operation and maintenance costs, and the cost of supplying treated wastewater for irrigation purposes.

Additionally, they have introduced legislation around Water Entitlement Transfer (WET), {*a mechanism for trading and transferring water rights between entities, similar to how stocks are traded},* and Wastewater Reuse Certificates (WRC), {*tradable permits that allow the reuse of wastewater, promoting the circular economy*}, which are two of the key components of water management and circular economy initiatives.

Haryana Water Resources (Conservation, Regulation, and Management) Authority (HWRA)

The Haryana Water Resources (Conservation, Regulation, and Management) Authority (HWRA) is a body established under the Haryana Water Resources (Conservation, Regulation and Management) Authority Act, 2020, to regulate, conserve, and manage the state's surface and ground water resources. HWRA is empowered to ensure the judicious, equitable, and sustainable utilisation, management, and regulation of water. This includes the tariff revision for bulk water uses of surface water and treated water.

HWRA promotes the reuse and recycling of treated waste water. They have established a framework for the reuse of treated wastewater and the pricing thereof. The tariff for bulk water users has been established as per 'the principles of economy, efficiency, equity, and sustainability' and based on volumetric measurements of water consumption. The authority has also assessed the current availability of treated water and its reuse. They found the reuse was inadequate and not as per the Haryana 'Reuse of Treated Waste Water Policy 2019' goals (50% reuse by 2025 and 80% by 2030). They found that only 15.09% (62.16 MCM) of treated water from the STPs and 24% (8.17 MCM) of treated water from the CETPs are being reused for non-potable purposes. Therefore, several measures have been planned in the 'Integrated Water Resources Plan Haryana 2023-2026' and the activities supported by the 'Integrated Water Resources Action Plan 2023-2025'. The action plan was formulated based on clear-cut outcomes based on the convergence and cooperation of all departments in the state.

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8.3. Gender equity & inclusion

Relevance: Safe re-use of treated wastewater (SRTW) has a significant impact on gender issues, particularly in areas of water scarcity. In this context, gender refers to the social attributes and opportunities associated with women and men that further define their cultural, economic, and political roles. Disparities in gender roles and water are significant in India and several other developing countries, with women bearing a disproportionate burden. Gender inequalities in water are reflected through property ownership, control, employment, wage distribution, division of labor in households, and access to services. The reuse of treated wastewater can play a significant role in addressing equity and inclusion through improved water management and supply of water for domestic use. The sustainable practice of SRTW can have several positive impacts on communities affected by water scarcity and inadequate access to safe water. Additionally, it has direct and indirect impacts on women who play a primary role in sowing, weeding, and harvesting.

The Dublin Statement on Water and Sustainable Development dated 1992, emphasized the role of women in providing, managing, and safeguarding water. Furthermore, the statement stressed that policies must take into account women's specific needs and ensure that women are able to participate in water resource programs at all levels, including decision-making and implementation, based on their preferences. Despite the intrinsic relationship between gender equality (SDG 5) and the right to water and sanitation (SDG 6), much remains to be achieved.

India's National Framework on SRTW identifies a variety of potential non-potable end uses, which include agriculture (forestry and horticulture), aquaculture, municipal uses (e.g., landscaping, parks, flushing toilets, firefighting), environmental, including discharge into surface water bodies, maintenance of wetlands and environmental flows, construction, etc. Gender is not explicitly mentioned in the national framework, but it plays an important role in cross-cutting issues such as agriculture, aquaculture, landscaping, parks, construction, etc. The implementation of the above-mentioned measures will also have several benefits, many of which particularly benefit women.

Gender implications of safe water reuse in India: Safe reuse of treated water has several benefits indicated in the SRTW framework, such as improved water security, health, and the environment, as well as economic, social, and environmental benefits, especially advantageous to women.

Improved water security: Water scarcity and Gender inequalities are highlighted with estimates, indicating women in India spend 150 million hours collecting water annually and lose approximately INR 10 billion (US$133 million) in income. In addition to saving time and resources, safe water reuse provides women with opportunities for food production and income generation. Access to water can enable young girls to attend schools instead of collecting and fetching water. WASH facilities in schools can reduce school absenteeism and improve the quality of education for girls.

Health: Enhanced WASH practices reduce the risk of waterborne diseases. The availability of water is crucial to maintaining sanitation and hygiene, particularly in schools, hospitals, and households. Supporting sanitation and hygiene needs can also contribute to women's health, security, and well-being. Water is provided by women to households, which places them at a greater risk of exposure to and infection from diseases. Reduced water pollution with TWW also has several health impacts, especially on women.

Perception and acceptance: Research suggests that women with less education (without a university degree) were more likely to experience discomfort with using treated wastewater. Concerns about the health implications (water-borne infections) linked to the reuse of treated wastewater, particularly for potable purpose, had been voiced by both men and women. Men are more inclined than women to choose wastewater reuse options that are riskier, but research on the influence of gender on accepting treated wastewater revealed no significant connection. However, treated wastewater is acceptable for both men and women for usage in sectors such as firefighting, agricultural applications, lawn watering, and car washing (Akpan et al., 2020).

Economic and social benefits: Indian women spend 150 million days collecting water annually, losing an estimated INR 10 billion in incomes. Since women spend most of their productive daily hours getting water from potentially dangerous sources, women in rural communities are particularly susceptible to sanitation-related ailments. When water scarcity forces individuals to change their consumption patterns, water scarcity adversely impacts economic growth. Providing access to basic water and sanitation (and providing an safe alternate water source) is estimated to have a benefit of $18.5 billion every year, and several social benefits including women's empowerment reflecting on increased comfort levels, safety, dignity, status, and overall quality of life.

Reduced Climate emissions: Treated wastewater reuse reduces the dependence on conventional water sources, which can be vulnerable to climate change. Diversifying water resources may help women who collect, and manage, water, work extensively in agriculture, and are responsible for food provision to become more resilient to climate change.

Safe reuse of treated wastewater reuse and gender in India – Lessons learned: TWW offers solutions that could be beneficial to all, few of the gender impacts from lessons learned from India include;

- Based on the case studies from Chennai and Surat, the reuse of TWW in industry has reduced industries' dependence on stressed groundwater resources and potable water, thus reducing the stress on water and ensuring water security for domestic and non-industrial use. A number of studies and reports have documented the impact of water stress on women in these cities, with a reduction of the same having a favorable gender impact.
- The diversion of Bangalore's treated wastewater to Kolar has led to a reduction in the excessive use of groundwater and surface water in tanks for crop irrigation. A number of studies indicate that this has not only improved agriculture and water resources in Kolar, a semi-arid region plagued by prolonged droughts that have led to the depletion of surface water sources as well as a rapid decline in groundwater levels but have also led to improved wastewater management in the area having several gender impacts, especially on women in agriculture.
- Women-led initiatives in the water-scarce Kolar district, have led to the diversion of wastewater to agriculture, along with other measures to conserve water, resulting in the rejuvenation of lakes in the area.
- Active involvement of women in WASH management, including sewage treatment plant management, as part of the Swachh Bharat Mission 2014, led the path for women’s leadership.
- The involvement of women Self Help Groups (SHGs) across the country in wastewater management has demonstrated a positive impact on the social, economic, and political empowerment of women.

Prioritization of Gender Aspects in TWW: Provided below are a few of the recommendations for addressing gender issues in the safe reuse of treated wastewater

- Gender-sensitive policies on TWW
- Gender mainstreaming in planning and management
- Detailed assessment of gender issues in wastewater
- Enhance institutional capacities of women
- Equity in terms of gender representation and participation
- Increased awareness and capacity building of women on TWW
- Gender Parity of resources
- Gender-sensitive risk reduction measures, especially in the agricultural sector, to ensure safety in the food value chain
- Precautionary measures for gender-sensitive health risk reductions

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8.4. Water quality control, monitoring

Relevance: The treatment of used water is critical for protecting human and environmental health when it makes its way back into surface water bodies or groundwater. Water quality standards are crucial for all water-reuse purposes and such standards vary from country to country. Water quality standards for discharging treated wastewater is the basis for developing the evolving guidelines for the reuse of treated water. The COVID-19 pandemic emphasized the potential risk of pathogens and the need for improved water supply, sanitation, hygiene, and safe reuse of treated water, in terms of improved water quality outcomes.

Inclusion of water quality aspect in National Framework on SRTW: The National Framework contributes to the Government's commitment to environmental sustainability and achievement of SDG 6.3 on improving water quality through increased recycling and safe reuse. It specifies applicable water quality standards for industrial, agricultural and aquaculture, non-potable domestic and municipal uses and for release to surface water bodies including environmental use. It ensures that a uniform minimum treatment standard needs to be achieved and WQ standards are meant to be 'fit-for-reuse' based on the purpose of use, and the level and type of treatment depends on its intended re-use purpose. The quality of treated used water (TUW) needs to be monitored for the presence of emerging contaminants, heavy metals, pesticide residues and antibiotic residues with some strict discharge norms on specific water quality parameters (BOD, COD, TSS and TDS). The States are expected to consider adopting suitable and timely end-use standards to provide an enabling environment for SRTW investment. Also, service standards (on reliability of TUW supply to end-users) and process standards (on risk mitigating barriers to ensure usage safety) need to be provided.

Water quality standards in National Framework on SRTW: *Table 39* specifics the existing water quality standards and environmental considerations for some of the important reuse types of treated water in India.

Table 38: Existing water quality standards for various reuse types in India

Reuse type	Water quality standards
Industrial use	The upcoming Treated Industrial Wastewater Reuse guidelines of the CPCB (Central Pollution Control Board) include water quality standards for industrial used water. The guidelines direct SPCBs for developing water quality criteria for reuse of treated industrial water for industries, agriculture, horticulture, and other purposes.
Agricultural and aquaculture use	Meet water quality compliance (to protect food safety) as well as in forestry, and horticulture. CPHEEO (Central Public Health and Environmental Engineering Organisation) Manual 2013 provides water quality safety standards for aquifer recharge, return flows, agricultural use, as well as specifications for Dissolved Phosphorus, Nitrogen and Faecal Coliform. State PCBs have set minimum standards for the treated sewage, specifically for agriculture and other non-potable uses. Development of more specific national end-use standards for agriculture and aquaculture to be coordinated by CPCB.
Non-potable domestic and municipal use	SRTW can be used for municipal uses like landscaping, parks, toilet flushing and firefighting with quality norms advised by SPCB, CPCB and CPHEEO depending on the reuse option.
For release to surface water bodies	The National Water Quality Monitoring Programme (NWQMP) advises State governments and sets standards on water quality in streams and wells. CPCB has prescribed a minimum water quality standard for municipal used water and industrial effluents discharged to surface water bodies. Stricter norms for minimum

Reuse type	Water quality standards
	water quality standards may need to set by SPCBs for lakes and wetlands, or where points of TUW discharge are close to the points of extraction of water for domestic supply.

Roles of key stakeholders in ensuring water quality standards: The roles and responsibilities of key institutions and stakeholders for ensuring water quality standards of treated water (during the implementation of the Framework) at the national and state levels are specified in *Table 40.*

Table 39: Roles of key institutions in ensuring water quality standards.

Institutions	Roles of key institutions
Ministry of Jal Shakti, Dept of Water Resources	Ensure consistency of SRTW interventions with related water quality requirements
Ministry of Environment, Forest and Climate Change (MoEFCC)	Ensure common regulatory standards for water quality and safety of agricultural and aquaculture products, in consultation with Ministry of Agriculture and Farmers' Welfare.
CPCB	Issue SRTW end-use water quality standards for each type of reuse for implementation by SPCBs through coordination with related agencies.
State Pollution Control Board (SPCB)	Regulatory role in water quality assessment and water quality monitoring of groundwater and in rural areas.

Confidence in treated used water- Lessons learned: Some national and international case studies on SRTW are discussed below.

1. *Chennai, Tamil Nadu, India* - Chennai generates 1100 MLD of wastewater, with a 70% installed treatment capacity. The 12 sewage treatment facilities (STPs) treat secondary wastewater (727 MLD) and sell it to major industries, which treat it to tertiary levels before use. Overall, 49% of treated wastewater is reused, allowing the city to meet 15% of its water demand. Industries reuse around 8% of treated wastewater, and approximately 33 MLD of secondary treated wastewater is delivered to industries. However, there are worries about the quality of effluents produced from STPs due to the presence of trace organic chemicals (such as acesulfame, atenolol, caffeine, iohexol, and sucralose), which are likely to increase the treatment cost of wastewater provided to industries.
2. *Surat, Gujarat, India:* Surat Municipal Corporation operates 11 STPs with a total design capacity of 1072 MLD, of which around 930-950 MLD of wastewater is currently treated. Since 2014, the city of Bamroli has been operating a 40 MLD STP, providing industrial quality water and distributing it to Pandesara GIDC (Gujarat Industrial Development Corporation). There were no reported issues or concerns about the quality of treated wastewater, and user industries are said to be satisfied with the quality and quantity of treated water.
3. *Milano, Italy:* The Milano Nosedo wastewater treatment facility provides abundant supply of high-quality treated effluent for reuse in irrigation for a large area stretching from Milan's southern outskirts to the province of Pavia.
4. *Alicante, Spain:* Spain has one of the highest rates of wastewater reuse in the world. Different irrigation entities have received 66 million m^3/year; with golf courses, highway medians, and gardens consuming an additional 4 million m^3/year. Tertiary and even advanced wastewater treatment systems help improve water quality for future usage. The improved water quality

not only protects the natural environment with appropriate discharges, but serves as a model for an integrated reused water cycle system wherein the treated water can be reused for several purposes.

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8.5. Funding mechanisms, tariffs

Relevance: The reuse of treated wastewater has gained significant attention in recent years as a sustainable solution to water scarcity, environmental challenges and increased economic opportunity. Financing projects related to the reuse of treated wastewater is a crucial aspect of ensuring the successful implementation and operation of such initiatives. National SRTW Framework provides guidance on business model for reuse of treated wastewater. The framework lays out different financing mechanisms and incentives for the implementation of reuse. There are a variety of financing mechanisms that can be used to finance wastewater treatment and reuse projects. These include:

- **Public Funding:** Governments at the national, regional, and local levels can play a vital role in financing wastewater reuse projects. Public funds can be allocated for the initial capital investment required to build the necessary infrastructure, such as wastewater treatment plants and reclaimed water distribution networks. Additionally, governments can provide grants, subsidies, or low-interest loans to cover operational costs or encourage private sector participation in such projects. Public funding can help address the high upfront costs associated with implementing wastewater reuse projects and make them more financially viable.
- **Private Sector Investment:** The involvement of the private sector in financing the reuse of treated wastewater brings the advantage of efficiency and expertise. Private companies, including utilities, investors, and technology providers, can contribute financial resources for the construction, modernization, and operation of wastewater treatment and reuse facilities. These entities may seek returns on their investment through user fees or the sale of treated wastewater to industrial or agricultural sectors. Private sector investment can leverage market mechanisms and drive innovation in wastewater reuse technologies and management practices. Some of the other financing mechanisms explored through private sector are:
    - **Debt financing:** Debt financing is where a project borrows money from a lender, such as a bank, to finance its construction and operation.
    - **Equity financing:** Equity financing is where investors buy shares in a project in return for a share of the profits.
- **Public-private partnerships (PPPs):** PPPs involve collaboration between public and private entities to jointly finance, develop, and operate wastewater reuse projects. This model allows for the sharing of risks, costs, and expertise between both the sectors. In PPP structures, the public sector typically contributes its ownership of existing wastewater infrastructure or land, while private partners bring in financial resources, technical know-how, and operational efficiency. PPPs can enhance project bankability, reduce the burden on public budgets, and create long-term sustainable revenue streams, while ensuring the equitable and efficient utilization of water resources. There are different forms of PPP engagement undertaken in reuse of wastewater based on the type of customer targeted for the end use. National SRTW framework describes different PPP structures.
- **Grants:** Grants are financial contributions that are given to a project without the expectation of repayment. While government play a significant role in provision of grants which are part of public funding, local and international donors (including private foundations) are another set of players who can play a significant role in promotion of circular economy concepts. Corporates can also be engaged under corporate social responsibility (CSR) to fund wastewater treatment and reuse infrastructure.

The choice of financing mechanism will depend on a number of factors, including the size and complexity of the project, the availability of public and private funding, and the risk appetite of the investors. In addition to the traditional financing mechanisms, there are a number of emerging financing options for wastewater treatment and reuse projects. These include:

- **Municipal bonds/Government bonds:** Municipal bonds are debt securities issued by municipality, state or other government agency which is used to finance public infrastructure. These bonds are typically used to finance local government projects and are backed by the government's ability to generate revenue through taxes or other sources of income. Investors who purchase municipal bonds essentially lend money to the government entity in exchange for regular interest payments over a fixed period of time.
- **Green bonds:** Green bonds are debt securities that are issued to finance environmental projects, such as wastewater treatment and reuse projects. Investors who purchase green bonds are motivated by both financial returns and the desire to support sustainable projects
- **Water funds:** Water funds are a type of financial instrument that is used to raise money for water projects. Water funds can be public or private, and they can be used to finance a variety of water-related activities, including wastewater treatment and reuse.
- **Carbon markets:** Carbon markets are a system for trading carbon credits. Carbon credits are tradable permits that allow the holder to emit a certain amount of greenhouse gases. Carbon markets can be used to finance wastewater treatment and reuse projects that reduce greenhouse gas emissions.
- **Impact investment:** Impact investing is a mechanism that may attract capital for sustainable development projects like reuse of treated wastewater. It is a type of equity investment with values' alignment to support social or environmentally sustainable investment with intrinsic motives for socially impactful businesses and socioenvironmental sustainable operations. While this mechanism is not yet common in reuse of treated wastewater projects, however it is increasing rapidly in other development sectors that meets environment and social goals.

For a municipality, based on various revenue sources, it could explore one of the above financing mechanisms mentioned and manage the working capital requirement for operating the wastewater treatment and reuse infrastructure. The different revenue sources for the municipality are:

- **Tariff:** Municipality can issue tariffs which is a user fee charged to residents for treatment of wastewater
- **Trade:** Municipality can sell treated wastewater and other byproducts to generate additional revenue
- **Taxes:** Municipality can impose taxes and cess on its residents for providing various urban services. A portion of this tax should be ring-fenced specifically for treatment of wastewater
- **Transfer:** Municipality can receive budget transfers from state of central towards implementation of public infrastructure.

The financing of wastewater treatment and reuse is a complex issue, but there are a number of options available. The choice of financing mechanism will depend on a number of factors, but the goal is to find a mechanism that is sustainable and that will help to ensure the long-term success of the project. Here are some additional things to consider when financing the reuse of treated wastewater:

- **The cost of treatment:** The cost of treating wastewater varies depending on the technology used and the quality of the water that is being treated.
- **The demand for reclaimed water:** The demand for reclaimed water will depend on the availability of other water sources and its price, the cost of reclaimed water, and the environmental benefits of using reclaimed water.
- **The regulatory environment:** The regulatory environment for wastewater treatment and reuse is important to understand before financing a project.
- **The political will:** There needs to be political will to support wastewater treatment and reuse projects including acceptance of using treated wastewater by end customer targeted. Also, understanding existing informal use plays a vital role – it is observed farmers are using untreated wastewater for irrigation; not engaging farmers and planning of reuse project with another end customer creates an issue of competing priorities for scarce resource.

By carefully considering above factors, one can increase the chances of success in financing the reuse of treated wastewater.

Financing lessons learnt from case studies in India and EU

In India, based on the type of end use and the business model conceived, it is observed that the financing mechanism and strategies change significantly.

- **Financing for industrial end use:** In supplying treated wastewater to industries, municipality gains direct economic returns as the willingness and ability to pay by the industries is high. For industries, the need for water has direct implications to their business performance. Both PPP and Private sector investment has been taken up for financing infrastructure for reuse of treated wastewater for provision of treated water to the industries.

  In Chennai, industries have invested in treatment infrastructure to treat secondary treated water to their required water quality. They also manage the operating cost of the treatment facility. However, Chennai Metropolitan Water Supply and Sewerage Board has invested in the pipeline and operate it to supply secondary treated wastewater to industries. Also, Chennai has invested in reuse infrastructure for supplying treated water and required quantity and quality in PPP mechanism as well. Similar is the case for Surat. Even in the case of industries such as airports that are required to have their own wastewater treatment infrastructure, funding can be through PPP mechanism. For construction industries, using treated wastewater should be mandatory and municipality invests in transport facility which is typically a tanker/truck that supplies water to construction site.
- **Financing for agriculture end use:** Farmers hardly pay for water sourced from canals for irrigation. Since there is hardly any direct revenue from sale of water to farmers, financing mechanism should be carefully evaluated. In the few cases that has been formally implemented in India, public funding for infrastructure especially for conveyance of treated water is utilised. The quality of water required should be free from pathogens and hence the capital cost required for disinfection can be part of existing arrangement used for setting up of wastewater treatment facility. Based on the type of business model, the investment source can change. For e.g., if the municipality auctions treated wastewater to an entrepreneur as in

the case of Unjha municipality, who in turn supplies water to farmers, the entrepreneur invested in last mile water supply to farmers in terms of pumps and pipes.

- **Financing for urban end use:** Urban end use doesn't have direct revenues for the municipality. Water saved can be sold to new customers or augment for existing customers. The investment required is for disinfection of treated wastewater and its conveyance. In Odisha, treated wastewater is supplied using tanker to irrigate landscaping and tanker is invested through public funding.
- **Financing for environmental end use:** Similar to urban end use, environmental end use doesn't have direct revenue source. Again, in this case public funding plays a crucial role in financing reuse infrastructure. Corporates under CSR can be engaged in funding of infrastructure as is the case in Bangalore where Bharat Electronics Limited (BEL) has invested in wastewater treatment infrastructure for recharging of nearby lake resulting in promoting flora and fauna along with improving groundwater in the region. BEL also manages the operations of the treatment plant.

Reference:

MoJS. 2022. National Framework on the Safe Reuse of Treated Water. Department of Water Resources, River Development & Ganga Rejuvenation, National Mission for Clean Ganga, Ministry of Jal Shakti, Government of India.

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8.6. Risk management

Relevance: Risk assessment and management provides a systematic approach to identify, evaluate, and manage potential risks and uncertainties associated with water reuse projects. This proactive approach enhances the project's overall success and contributes to protecting public health, the environment and the project's financial viability.

Risk management in water reuse schemes is essential for:

- **Public health and safety:** Any potential contaminant or pathogen present in the treated used water can pose significant risks to public health and safety. Potential hazards can be identified and mitigated through risk assessment to ensure safe water reuse.
- **Environment protection:** If the water contains poorly removed pollutants, they could harm aquatic and terrestrial ecosystems. Risk assessment can identify potential risks and mitigation strategies.
- **Legal and Regulatory Compliance.** Risk assessment helps project managers and regulatory authorities to understand whether a proposed project complies with set risk thresholds and helps to define necessary treatment processes, monitoring protocols and reporting requirements (see chapters 9.2 and 9.4).
- **Operational Efficiency:** Conducting risk assessments allows project planners and operators to anticipate potential operational challenges and develop contingency plans. Identifying potential risks upfront can help implement effective operational strategies during disruptive events, thereby ensuring a smooth project function.
- **Public Acceptance:** Risk assessment can provide transparency and evidence-based information to address opposition and concerns from the public.
- **Financial considerations:** Failing to identify and address potential risks in a water reuse project can lead to unexpected costs, such as required treatment process modifications, regulatory fines, legal actions or remediation efforts in case of contamination incidents.
- **Long-term sustainability:** Water reuse projects access alternative water resources to combat water scarcity. Risk assessments related to water availability, treatment technologies and changing environmental conditions are important to ensure long-term sustainability.

Risk management considerations in the National Framework on SRTW- and Lessons learned from case studies: The framework acknowledges the importance of pro-active risk management with SRTW project, highlighting the need for stakeholder engagement and context-specific risk mitiation measures. According to the framework the following risks are likely for Indian SRTW projects:

- **Likely risk: Limited market acceptance for treated used water**

Lessons learned and Risk mitigation: Acceptance for treated used water is more likely in water stressed areas where no alternative water resource exist (e.g. case studies in Chennai, India, Alicante, Spain). In less water-scarce regions, the information, education and communication campagins on the benefits of treated used water are very important (c.f. case study of Milan, Italy as environmental protection measure).

To increase the demand for treated used water the creation of 'no freshwater' zones and mandatory use of treated used water need to be enforced. This e.g. is seen in Milan, Italy, where farmers are prohibited to use surface water during drought periods and thus need to use treated used water from El Prat WWTP. The national Tariff Policy 2016 which mandates the use of thermal power plants located within 50 km radius of STPs to use treated used water is a first step in the right direction, despite its implementation hurdles (low STP coverage, tweaked accountability between ULBs and power plants to set up pipelines from STP to thermal power plants)

- **Likely risk: Lack of financing to infrastructure development, operation and maintenance and distribution of treated used water. Cost-recovery of used water treatment not achievable**.

Lessons learned and Risk mitigation: Where freshwater is highly subsidized or no water scarcity exist, cost-recovery for water reuse schemes will be low since the end users are not willing to pay for treated used water. In Europe, low value agricultural reuse business models (*i.e., Milan, Italy where treated used water is supplied free of charge and no water scarcity exist, c.f. Business Model Compendium*) are feasible, because cost-covering operation and maintenance of wastewater treatment is mandatory by EU and often also national law. Treatment fees are charged to the polluters, i.e. households and industries. This is hardly seen in India.

Industrial reuse models are more viable (i.e., case studies in Chennai, Surat) since the willingness to pay of industries is higher (see Chapte 8.5).

In areas where cost-recovery is low and financing lacking, there is a need to provide public budget transfers, such as by the EU Cohesion Fund (cf. case study Barcelona, Spain) or any Indian government infrastructure development programme (e.g. case study, Surat). Alternatively the subsidies for freshwater supply to industries could be revised to make treated used water a more attractive water resource.

- **Likely risk: Assured Quantity and quality cannot be supplied. Weak monitoring and enforcement of quality standards can have environment and public health impacts**

Lessons learned and Risk mitigation: The internal quality monitoring at the wastewater treatment/water reuse plants are crucial to detect any distruptive events and to mitigate any health or environmental impacts due to treament malfunctions. E.g., if the E.coli thresholds are exceeded, the water supply to end users shoud be immediately interrupted. Equally important is the engagement with appropriate external institutions for the monitoring of effluent qualities which autonomously verify the water quality and penalise any non-conformity of the water quality (see case study Milan, Italy).

Reference:

MoJS. 2022. National Framework on the Safe Reuse of Treated Water. Department of Water Resources, River Development & Ganga Rejuvenation, National Mission for Clean Ganga, Ministry of Jal Shakti, Government of India.

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