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Reuse of Treated Wastewater in India

Market Potential and Recommendations for Strengthening Governance

Nitin Bassi, Saiba Gupta, and Kartikey Chaturvedi

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The Council on Energy, Environment and Water (CEEW) is one of Asia's leading not-for-profit policy research institutions. **The Council uses data, integrated analysis, and strategic outreach to explain — and change — the use, reuse, and misuse of resources.** The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public.

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Treated wastewater is a highly underutilised resource that offers an avenue to address the scarcity of fresh water and improve the water environment.

Image: iStock

Executive summary

Water security is an imminent issue in India. As per our analysis using the Central Water Commission (CWC) estimates on basin-wise water availability (CWC 2021), 11 out of the 15 major river basins in India will experience water stress by 2025, with annual per capita renewable water availability below 1,700 cubic metres. Hence, it is essential to explore alternative sources of water to address the demand–supply gap.

India treats only 28 per cent of the total sewage it generates per day from the urban centres (CPCB 2021). Out of the 72,368 million litres per day (MLD) of sewage produced in urban centres, the actual treatment is of only 20,236 MLD (CPCB 2021). Class I cities (those whose population is above 1,00,000) and class II cities (with populations of 50,000–99,999), which represent a major share (72 per cent) of the total urban population, produce an estimated 38,254 MLD of sewage, of which only 30 per cent is actually treated (CPCB 2021). The untreated wastewater is then discharged into freshwater bodies, such as rivers.

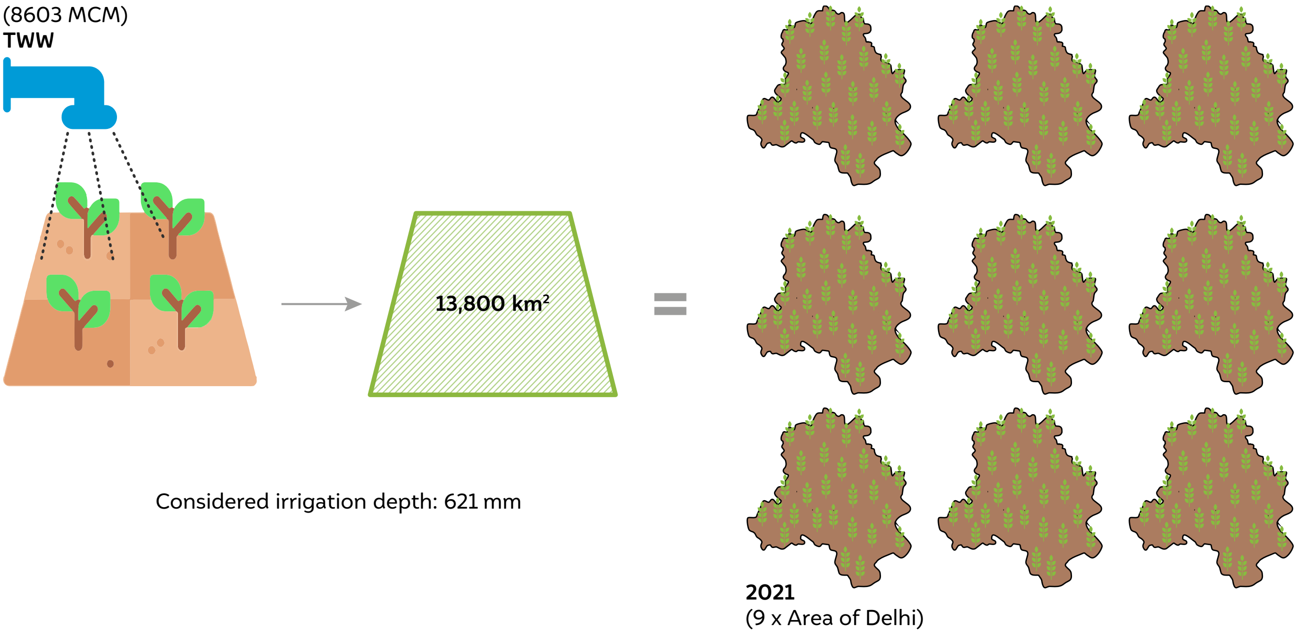
Given the exponential amount of wastewater generated in the country, India has immense potential to meet the growing water demand across different sectors and improve the water environment with proper management. Through this study, we intend to estimate the market potential for the reuse of treated wastewater (domestic sewage) at the national scale and make recommendations to strengthen the existing governance on reuse.

A. Approach

We undertook the following:

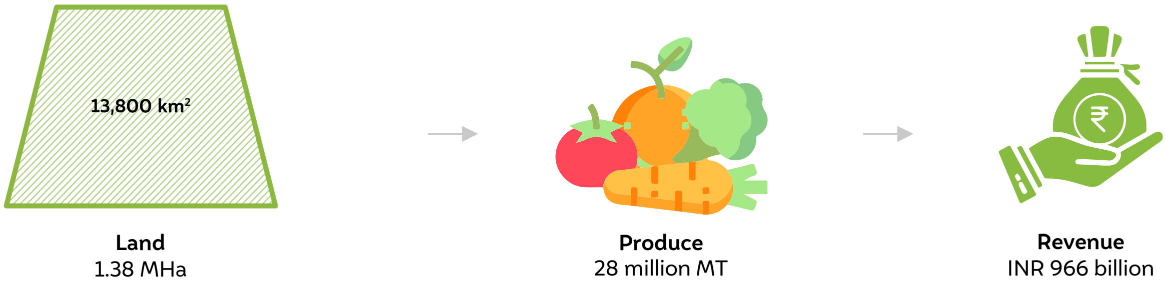
- Estimation of the amount of treated wastewater (TWW) that can replace the equivalent freshwater demand in different sectors for non-potable purposes
- Computation of the economic and market potential for the reuse of TWW with emphasis on the irrigation sector, which is the major consumer of freshwater
- A review and analysis of existing state policies on the reuse of TWW in India with the help of an analytical framework
- An analysis of selected best global practices in the reuse of treated wastewater in terms of the key enablers, drivers, and barriers
- Compilation of recommendations for strengthening the existing governance on the reuse of TWW in India

Figure ES1 1.38 Mha area could have been irrigated using the TWW available in 2021



Source: Authors' analysis using data from the Report of National Commission for Integrated Water Resources Development Plan (1999), Ministry of Water Resources (MoWR), Government of India

Figure ES2 Irrigation using TWW in 2021 could have generated INR 966 billion in revenue

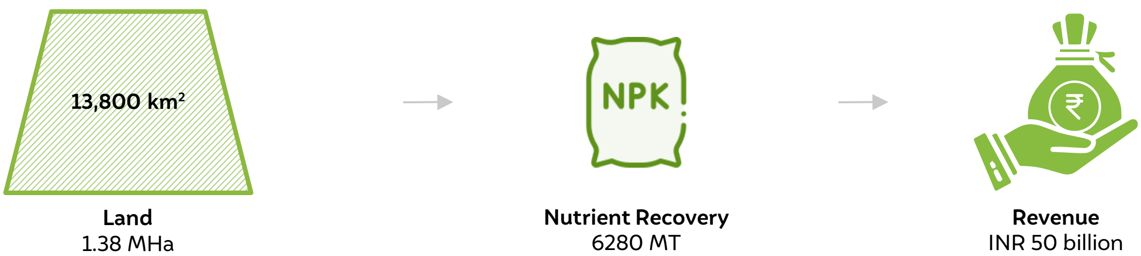


Source: Authors' analysis using data from Horticulture Statistics at a Glance 2018 (Dept. of Agriculture Cooperation and Farmers, GoI); National Horticulture Board 2022

B. Economic and market potential of TWW reuse

- **11,622 million cubic metres (MCM) is the estimated amount of treated wastewater that was available in India for reuse in 2021.** Based on projected sewage generation and treatment capacities in the future, this will become 15,288 MCM by 2025 and 35,178 MCM by 2050.
- **Nine times the area of New Delhi could have been irrigated using the available TWW in 2021.** Based on our analysis, about 8,603 MCM of treated wastewater was available for reuse in the irrigation sector in 2021; this could have replaced the equivalent freshwater demand for irrigation. It had the potential to irrigate 1.38 million hectares (Mha) of land, which is equivalent to about nine times the area of New Delhi (Figure ES1). By 2050, this would go up to about twenty-six times the area of New Delhi.
- **Reusing TWW for irrigation in 2021 could have generated INR 966 billion in revenue.** We estimate that 28 million metric tonnes (MT) of the produce of selected horticulture crops could have been generated using the available treated wastewater for irrigation in 2021. This produce could have further generated revenue of INR 966 billion (Figure ES2).
- **Around 6,000 metric tonnes (MT) of nutrients could have been recovered from the available TWW in 2021, generating savings of INR 50 million.** As per our estimates, the nutrients supplied by currently available TWW (for irrigation use in 2021) amount to more than 6,000 tonnes. Further, considering the market value of the nutrient load, we estimate that the total savings from the reduction in fertiliser use through irrigation using TWW would have been more than INR 50 million (Figure ES3).
- **Reusing TWW in irrigation could have reduced greenhouse gas (GHG) emissions by 1.3 million tonnes in 2021.** Our analysis suggests that the available treated wastewater would have irrigated 1.38 Mha in 2021, which would have reduced pumping in 3.5 per cent of the groundwater-irrigated area. Further, this would have led to a reduction of 1 million tonnes of GHG emissions. Additionally, on account of the inherent nutrient value of TWW, fertiliser consumption would have reduced, resulting in further reduction of GHG emissions by 0.3 million tonnes.
- **INR 630 million would have been the market value of treated wastewater in 2021.** Our analysis suggests that the market value of the treated wastewater available in 2021 (11,622 MCM) would have been over INR 630 million, if we had the mechanism to sell treated wastewater to different sectors for reuse. The market value will substantially increase to over INR 830 million in 2025 and INR 1.9 billion in 2050 at the current market rate.

Figure ES3 INR 50 million could have been saved through the reduction in fertiliser use by using TWW for irrigation in 2021



Source: Authors' analysis using data from Circular Economy in Municipal Solid and Liquid Waste (2021), Ministry of Housing and Urban Affairs (MoHUA), Government of India (GOI)

C. Review of existing state policies on treated wastewater reuse

We undertook this analysis to understand the comprehensiveness of the TWW reuse policies of Indian states and to determine whether they will be able to realise the market potential of the TWW in the future. We found that only 10 states in India have a TWW reuse policy and the following key gaps need to be addressed:

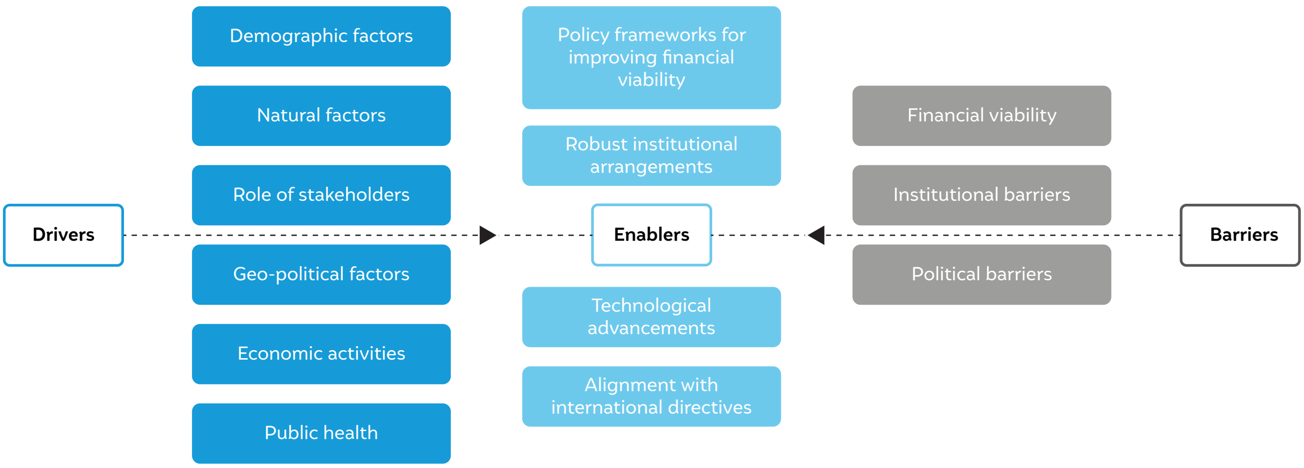
- **Only a few states identify the positive externalities associated with the treatment of wastewater and reuse.** These include improvement in the water quality of receiving natural water bodies and the associated public health impacts.
- **Only a few policies prioritise sectors for reuse.** Also, only a few policies classify TWW into mandatory and non-mandatory reuse.
- **Most policies make only a brief recommendation on the technologies for wastewater treatment.** A majority of the state policies that we reviewed do not provide details on the treatment process and technologies. Further, they make only a brief mention of the tertiary treatment process and technologies.
- **Most policies do not consider the allocation principles for TWW.** They lack the enforcement mechanism that provides a blueprint for their effective implementation.
- **There is no discussion on the incentives to encourage the reuse of TWW.** Most state policies do not have any provisions for incentives for end users, which can promote the reuse of TWW.
- **Most policies do not define the role of external stakeholders, such as community or industrial groups.** Such a description is important from the perspective of community acceptance of TWW for reuse at large.
- **TWW quality standards are not defined for the specific purpose of reuse.** Most state policies provide Central Pollution Control Board (CPCB) or State Pollution Control Board (SPCB) TWW discharge standards. However, they do not define treated wastewater quality standards for specific reuse purposes.
- **Most policies do not define binding provisions to aid effective implementation.** Though majority of the state policies refer to various central and state acts as their regulatory framework, there is very limited mention of the binding provisions required for policy implementation.
- **The criteria for the selection of appropriate business models is not defined.** Almost all state policies call for public–private partnerships (PPP) for developing TWW reuse projects. However, they do not include the criteria for the selection of appropriate business models for effective implementation.

We must note that though the national framework on the safe reuse of treated water that was launched in January 2023 provides guidelines on some of the identified gaps, the state policies were launched much before and need revision to address these gaps comprehensively.

D. Learning from the global best practices

Based on our analysis of three selected countries (Spain, Israel, and Singapore) that are at an advanced stage in their reuse of treated wastewater, we identified key drivers, barriers, and enablers, which we present in Figure ES4.

Figure ES4 Globally, strong governance was the key enabler for the effective implementation of the TWW reuse policy



Source: Authors' analysis

E. Recommendations

On the basis of the review of existing state policies and learnings from global best practices, we make the following recommendations to strengthen the existing governance on the reuse of treated wastewater in India:

- **Make a paradigm shift in ideology:** Wastewater needs to be considered an integral part of water resources and hence addressed in all water management related policies, plans, and regulations. Also, the potential of TWW as an alternative source of water needs to be recognised.
- **Define water quality standards:** Water quality standards for both safe discharge and reuse need to be well defined with a risk-reducing approach and a periodic review mechanism in place for regular monitoring and assessment.
- **Set robust institutional mechanisms:** Urban local bodies should be empowered to formulate and adopt long-term, city-level wastewater reuse plans, with roles and responsibilities clearly defined. Further, the institutional arrangement should incorporate the engagement of end-user groups for the successful implementation of reuse projects.
- **Improve financial viability:** Targeted performance-based incentives for the operators/end-users of wastewater treatment plants, and an effective pricing mechanism based on the market potential of the TWW and considering different categories of end-users and their paying abilities, can act as catalysts to improve the financial viability of reuse projects.
- **Leverage technological developments:** Need-based and demand-driven technological advancements are essential to upholding the efficiency and effectiveness of wastewater treatment. For this purpose, we need dedicated funds for the research and development of such technologies, which can optimise resource efficiency. Indian states need to come out with a clear strategy for research and development in this sphere, especially focusing on low-cost, highly energy-efficient technological innovations that could be in cooperation with other relevant global actors.
- **Invest in public outreach:** Indian states should develop effective public outreach plans to build public confidence and nudge behaviour for the successful implementation of wastewater reuse projects.

> Public acceptance is a crucial factor for successful implementation of reuse policies and projects.

1. Introduction

Managing freshwater demand should be India's foremost priority. In many river basins, the demand for water, especially for crop irrigation, far exceeds the available renewable supplies. Demand management interventions are particularly important for river basins in western and peninsular India, which offer limited scope for increasing supplies of freshwater (Amarasinghe et al. 2004). With the demand for cereals (mainly rice and wheat), fruits, vegetables, and milk products on the rise, and irrigation water being an essential input for optimal yields (Rosegrant, Ringler, and Zhu 2009), any unmet water demand will affect the overall production, thereby compromising the food security of millions of people. Further, due to the rise in the population and economic growth, the freshwater demand for domestic and industrial sectors is on the rise as well.

While several studies highlight the potential of various water–demand management interventions (Chakraborti, Kaur, and Kaur 2019), one area that researchers have begun to explore only of late is the reuse of treated wastewater (Goyal and Kumar 2022). It is receiving increasing traction given that India generates about 72,368 million litres of wastewater per day in urban areas alone (CPCB 2021); if treated (to the desired quality standard) and reused, this offers tremendous potential in addressing the water supply and demand gap on one hand and reducing the pressure on freshwater resources on the other.

However, the reuse and recycling of treated wastewater has still not become mainstream in India. Only a few Indian states have framed policies and guidelines to promote the reuse of TWW (Goyal and Kumar 2022). Further, a national-level framework on the safe reuse of treated water that provides guidelines on preparing reuse policies was launched only as recently as January 2023. Therefore, the existing state policies might also require a thorough revision to make them comprehensive and channel the financial and technical support available through national programmes, such as the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and *Namami Gange*. While the augmentation and rehabilitation of the existing sewerage systems and recycling of water for beneficial purposes, including the reuse of TWW, are important components of AMRUT, creating additional sewerage treatment capacity in the states sharing the Ganga river basin is a priority under the *Namami Gange* programme.

In this context, we estimate the current and future availability of TWW for various sectors (agriculture, industry, and energy generation) in India; assess the economic and market potential of reusing treated wastewater in the agriculture sector, which is a major consumer of freshwater; identify the gaps in the existing state policies on treated wastewater reuse; and derive key learnings from the global best practices on wastewater management. We used the findings from these analyses to suggest pointers to improve the governance of wastewater management in India.

2. Approach

First, we prepared a quick estimate of the amount of TWW available in India in 2021 and a projected estimate for 2050, and that which can be readily made available for reuse in different sectors in India. This estimation was based on the actual wastewater treatment capacity installed in India in 2021, the projected treatment capacity in 2050 on the basis of the compound annual growth rate in installed capacity from 2014–2021 (which is 6 per cent per annum), and its apportioning as per the ratio of current water demand for irrigation, industrial, and other non-consumptive purposes. While we accessed the latest data on state-wise installed sewage treatment capacity from the Central Pollution Control Board, Government of India (CPCB 2021), we computed the sectoral water demand ratio using the water demand growth estimates of the National Commission for Integrated Water Resources Development, Government of India (MoWR 1999). Further, we assessed the potential area that can be irrigated using the estimated treated wastewater available for the agriculture sector. For this we considered the weighted irrigation delta, i.e., the total depth of the water required by a crop during its entire growing period, for a cropping pattern consisting of wheat, winter maize and other fodder crops, and vegetables. We assumed the weighted delta to be 621 mm based on the estimate that 541 BCM of water is required for a gross irrigated area of about 87 MHa (NITI Aayog 2019). The chosen crops are considered more amenable to the use of treated wastewater (Sane, Nagarkar, and Shinde 2020).

Second, we estimated the economic and market potential of reusing the treated wastewater, mainly focusing on the irrigation sector, since it accounts for the majority of freshwater water demand in India. For this purpose, we estimated the following:

- The economic value of treated wastewater (TWW) in terms of revenue that can be generated from its use in the irrigation of the estimated land area
- The economic benefits from the use of TWW for irrigation, including savings from the reduction in fertiliser use, reduced groundwater pumping and electricity consumption for irrigation, and reduced greenhouse gases (GHG) emissions
- The revenue that can be generated from the sale of total available TWW to different sectors for reuse

For better clarity, we present the methodology to estimate this data in the same section where its results are discussed, i.e., section 5 of this report.

Third, we undertook a review of the selected Indian states' existing policies and guidelines on wastewater management and its reuse. Among others, the review covered the states of Gujarat, Haryana, and Maharashtra, which were the first to formulate and adopt such policies or guidelines. Other states that we considered include Punjab, Rajasthan, Jharkhand, Chhattisgarh, Karnataka, Andhra Pradesh, and Madhya Pradesh. Overall, we reviewed the policies and guidelines with reference to their overall objectives, targets, planning and implementation of treated wastewater reuse systems, water allocation mechanisms, treated wastewater quality standards, funding mechanisms, and governance and management. We specifically explored the mechanism proposed for allocating treated wastewater to various uses, including the institutional arrangement and the proposed financial models. We compared the findings of the review of state policies and guidelines with those provided under the recent National Framework on Safe Reuse of Treated Water.

Fourth, we analysed selected global best practices on wastewater management and reuse for their governance mechanism. This included policies and practices in Israel, Singapore, and Spain, which are at the forefront of wastewater management. The analysis focused on identifying the key drivers, barriers, and enablers through consultations with the key experts.

Lastly, on the basis of these analyses, we suggested pointers for strengthening the governance of wastewater management and its reuse. This covers aspects related to the planning of wastewater treatment and conveyance infrastructure; allocation mechanism for the treated wastewater, especially for areas/river basins with water scarcity; use-based treated wastewater quality standards;

> **Despite its potential, the reuse of treated wastewater has still not become mainstream in India.**

financial feasibility of reuse systems; and institutional arrangements for managing such systems.

Furthermore, we held a convening of relevant stakeholders from governmental and non-governmental organisations to discuss the key findings from the study. We address some of the feedback from the stakeholders in the report and will take up the rest in subsequent studies.

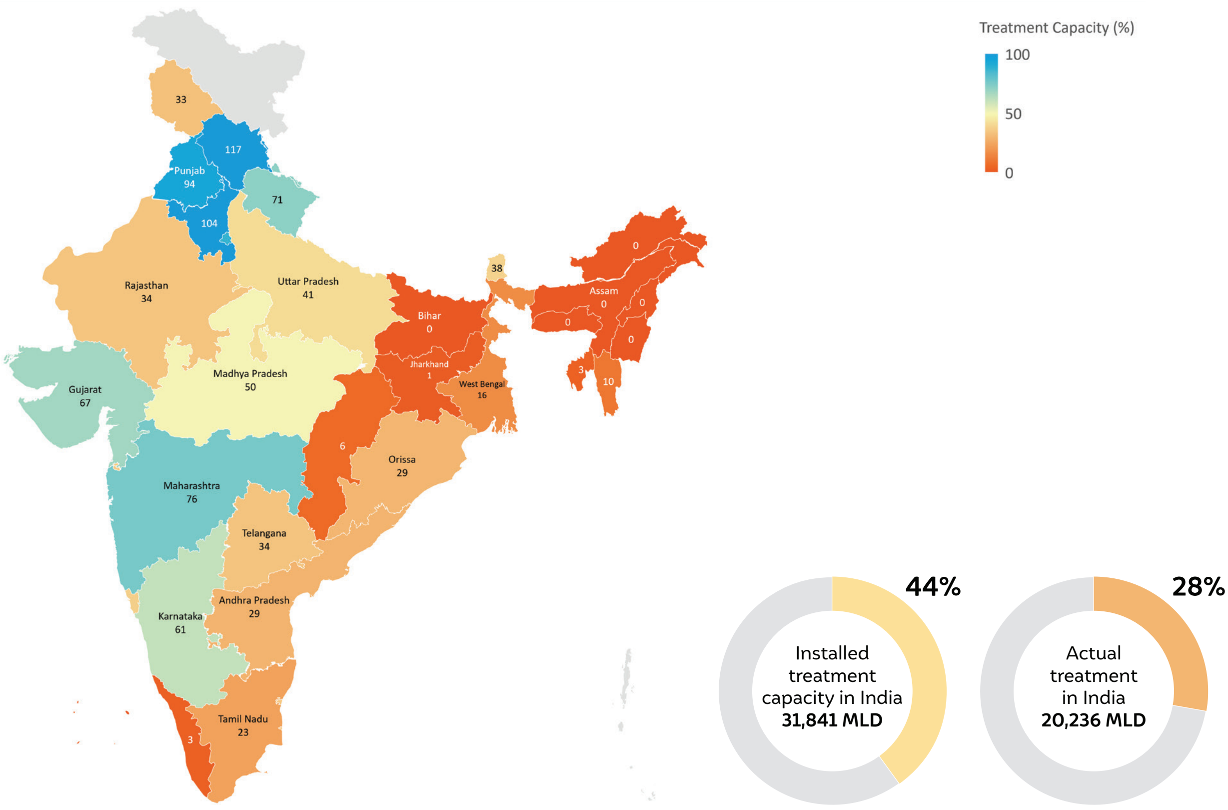
3. Status of wastewater generation and treatment

In India, water stress has become a perennial concern owing to the rapid and unregulated rise in the water demand for domestic, agricultural, and industrial needs (Chakraborti, Kaur, and Kaur 2019; Goyal and Kumar 2022; Bassi et al. 2022; CPHEEO 2021). It is projected that more than 50 per cent of the country's population will be urban by 2050 (Niti Aayog 2019). This would complicate the task of managing water, as the exponential rise in demand will lead to a huge additional burden on already scarce freshwater resources.

Further, inadequate and limited wastewater treatment facilities pose a threat to water quality and public health. In India, the total installed capacity to treat wastewater (domestic sewage) from the urban areas is 44 per cent, that is, 31,841 million litres per day (MLD) against a daily sewage generation of approximately 72,368 MLD (CPCB 2021). The actual treatment is only 28 per cent, that is 20,236 MLD (Figure 1). Even in class I (whose populations are above 100,000) and class II (whose populations are in the range 50,000–100,000) towns – which represent 72 per cent of the urban population – only 30 per cent of the wastewater is treated, i.e., 11,787 MLD against the 38,254 MLD that is generated (Kaur, et al. 2012). The remaining untreated wastewater is discharged into natural water bodies, such as rivers and lakes, which leads to pollution and impacts the water quality, especially for the communities in the downstream areas.

Nevertheless, India has made substantial progress in strengthening its operational treatment capacity, from only 18,883 MLD in 2014 to 26,869 MLD in 2020, which is an increase of over 40 per cent (CPCB 2021). But a lot more remains to be done to manage wastewater and address the challenges imposed by water scarcity. We require a paradigm shift to a circular approach in wastewater management that mainstreams wastewater treatment and reuse in the broader water management context.

Figure 1 Sewage treatment capacity in most states is below 50% of sewage generation



Source: Authors' analysis, data from CPCB (2021)

Note: In Himachal Pradesh and Haryana, the installed sewage treatment capacity surpasses the sewage generation.

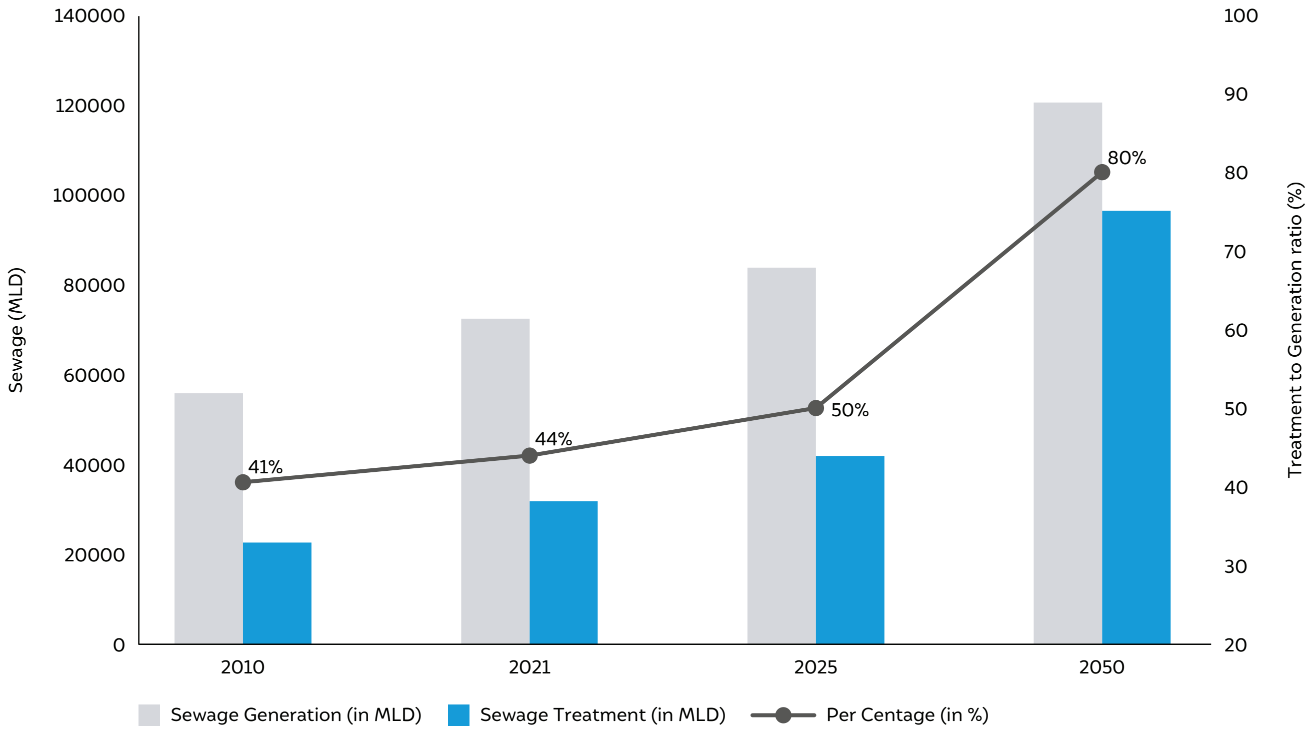
4. Treated wastewater availability for reuse in different sectors

The severity of the water crisis in India is increasing with each passing day. The reuse of treated wastewater can act as a crucial resource to meet the rising demands across different sectors while reducing the pressure on freshwater resources (Kim et al. 2018). However, TWW reuse is very low even in the major urban agglomerations of the country. For instance, it is 49 per cent in Chennai, 19 per cent in Delhi, and 6 per cent in Hyderabad (IWA 2018). Although India's sewage treatment capacity has seen an increase of over 40 per cent in the last few years, there is still a significant gap in terms of mainstreaming treated wastewater reuse across different sectors.

According to our analysis based on urban population projections (using data from MoHUA 2019) and considering that 80 per cent of water supplied to domestic users in urban areas returns as wastewater (CPCB 2021), sewage generation is estimated to increase from 55,812 MLD in 2010 to 1,20,472 MLD in 2050. Given the addition to the sewage treatment capacity in India over the last few years (2014–20), we estimate that treatment capacity as a percentage of total sewage generation will rise from 41 per cent in 2010 to 80 per cent in 2050 (Figure 2). Thus, we estimate that 96,378 MLD (or 35,178 million cubic meters per annum) of treated wastewater will be available for reuse by 2050.

This presents major opportunities for the reuse of treated wastewater for non-potable purposes in various sectors. To further our analysis on its reuse potential, we prepared an estimate of the amount of TWW that can be readily made available for reuse across different sectors in India (Table 1). This estimation is based on the actual wastewater treatment capacity installed in India, apportioned as per the ratio of (current and projected) water demand over the years in three major sectors – irrigation, industries, and energy. As part of this analysis, we have studied the reuse potential of treated wastewater specifically for non-potable uses, i.e., water not meant for direct human consumption.

Figure 2 In 2050, sewage treatment capacity in India is estimated to be 80 per cent of sewage generation



Source: Authors' analysis, data from Niti Aayog Demographic Scenario 2025 (Niti Aayog 2019) and CPCB (2021)

(Projected Sewage Generation = Urban population × 185 × 0.8)

Table 1 About 28,560 MCM of treated wastewater will be available for reuse in 2050

Year	Sectoral water demand projection (MCM)			Sewage treatment capacity (MCM)	Estimated TWW available for reuse (MCM)		
	Irrigation	Industry	Energy		Irrigation	Industries	Energy
2021	5,96,108	57,188	28,482	11,622	8,603	922	459
2025	6,11,000	67,000	33,000	15,288	11,081	1,215	598
2050	8,07,000	81,000	70,000	35,178	24,058	2,415	2,087

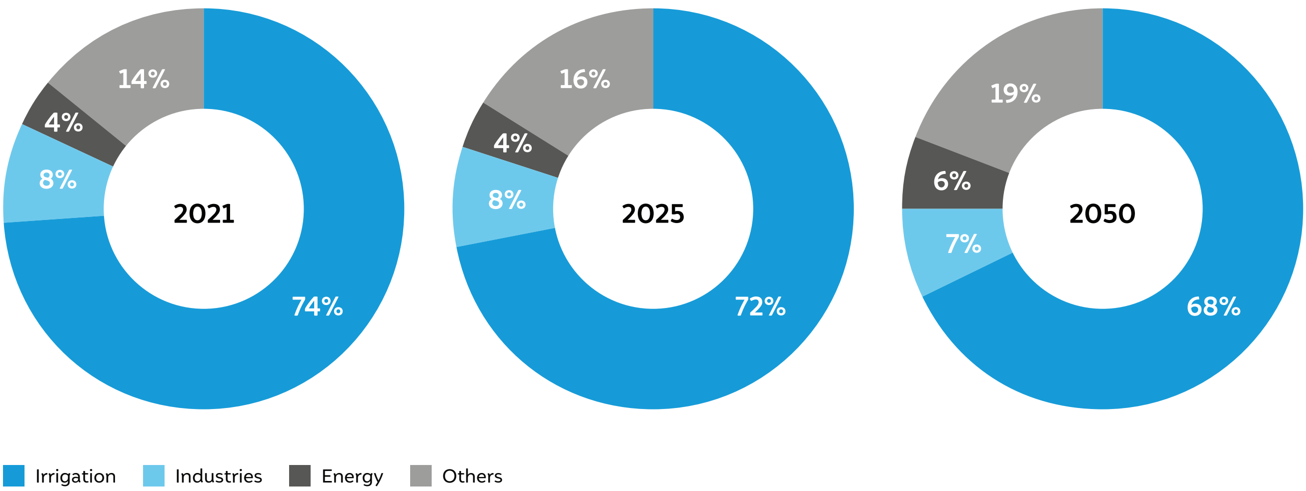
Source: Authors' analysis, data from EnviStats India 2018 (CSO 2018)

Based on the estimates presented in Table 1, about 8,603 MCM of treated wastewater was available for reuse in the irrigation sector in 2021. This volume of treated wastewater has the potential to irrigate about 1.38 Mha of land, which equals nine times the area of Delhi (Figure ES1). Further, this will substantially increase to over 3 Mha by 2050 given the projected levels of treatment capacity. The irrigation depth assumed here is 621 mm.

Further, our analysis suggests that the water demand for the irrigation sector, in proportion to the total water demand, will witness a gradual fall, and that that of the industrial sector will steadily rise. Such changes in the future can be attributed to factors such as efforts towards improving water-use efficiency in irrigation and increasing water demand from the growing economic sub-sectors. Nevertheless, the agriculture sector retains its relative dominance, accounting for 68 per cent of total water demand in 2050 (Figure 3). Thus, the reuse of treated wastewater for irrigation presents an opportunity to reduce pressure on groundwater, which is a major resource for irrigation, and also to minimise fertiliser use on account of the inherent nutrient value of wastewater. Here, we assume that secondary treated wastewater will be used for irrigation. Further, this water will be treated using the following treatment technologies that are prevalent in India: activated sludge process (ASP), membrane bioreactor (MBR), and sequencing batch reactor (SBR).

Furthermore, when the land being irrigated uses treated wastewater, it will generate revenue from its agricultural produce along with additional benefits, such as the economic value of nutrients recovered from wastewater and energy savings from reduced groundwater pumping. Hence, there is immense un(der)tapped potential of reusing TWW that can promote circularity in urban wastewater management.

Figure 3 The irrigation sector offers major opportunities for reusing treated wastewater



Source: Authors' analysis, data from EnviStats India 2018 (CSO 2018)
Note: 'Others' refers to the drinking water which is potable use and hence not considered for our analysis

5. Economic and market potential of treated wastewater reuse

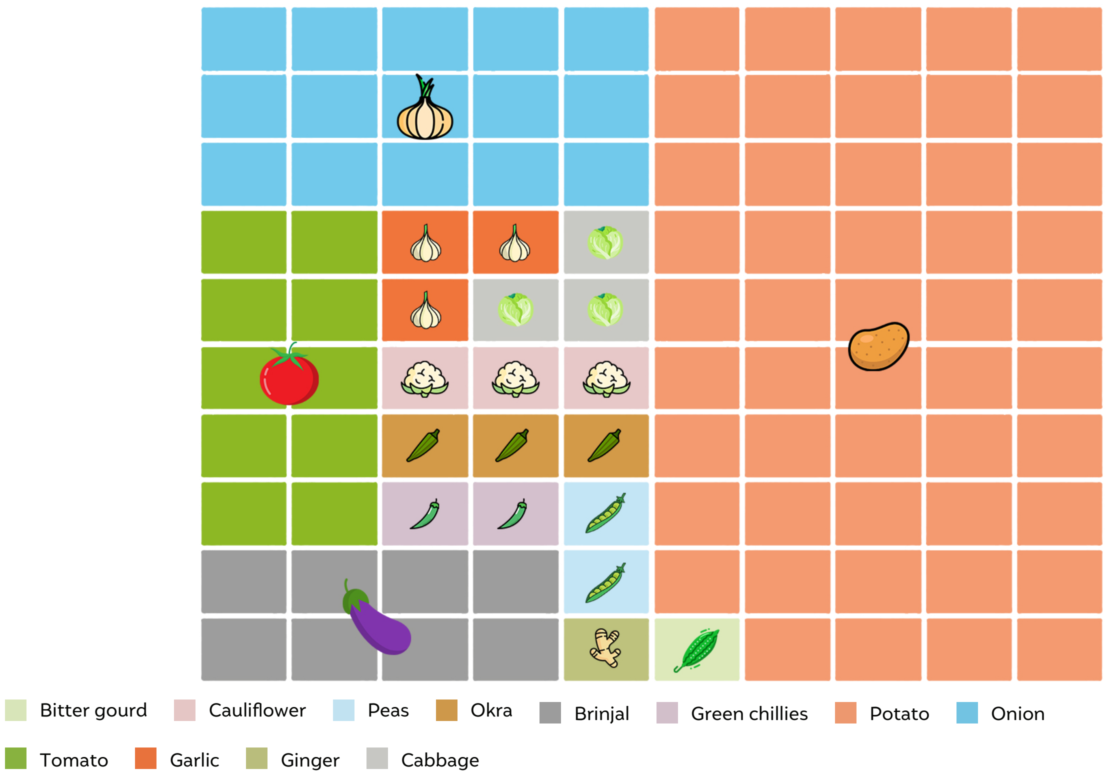
Circular economy principles, from the perspective of water resources management, involve optimal resource recovery by treating wastewater (UNESCO 2020) and further harnessing the economic benefits that can be generated from its reuse. In this section, we analyse the economic and market potential of the reuse of treated water in the irrigation sector, which accounts for a majority of the water demand in India.

5.1 Economic value of treated wastewater

The economic value of TWW refers to the revenue that can be generated from irrigating crops using it. We assumed that the 1.38 Mha land area that can be irrigated using TWW (Figure ES1) will be under 12 horticulture crops (Figure 4) that are commonly grown in sub-urban and peri-urban areas. These account for more than 90 per cent of the total vegetable area under irrigation at the pan-India level (Horticulture Statistics Division 2018). The area irrigated using TWW under each crop was decided on the basis of the proportion of the total irrigated area under each crop in India. The selection of vegetable crops is in alignment with the National Framework on Safe Reuse of Treated Water 2022, which advocates the use of treated wastewater for the irrigation of horticulture crops. Moreover, in sub-urban and peri-urban areas, untreated wastewater is used for irrigation. By providing the option of TWW, the negative risks associated with using raw wastewater in irrigation – such as soil contamination and potential exposure of farmers and consumers to pathogens and emerging contaminants – can be minimised.

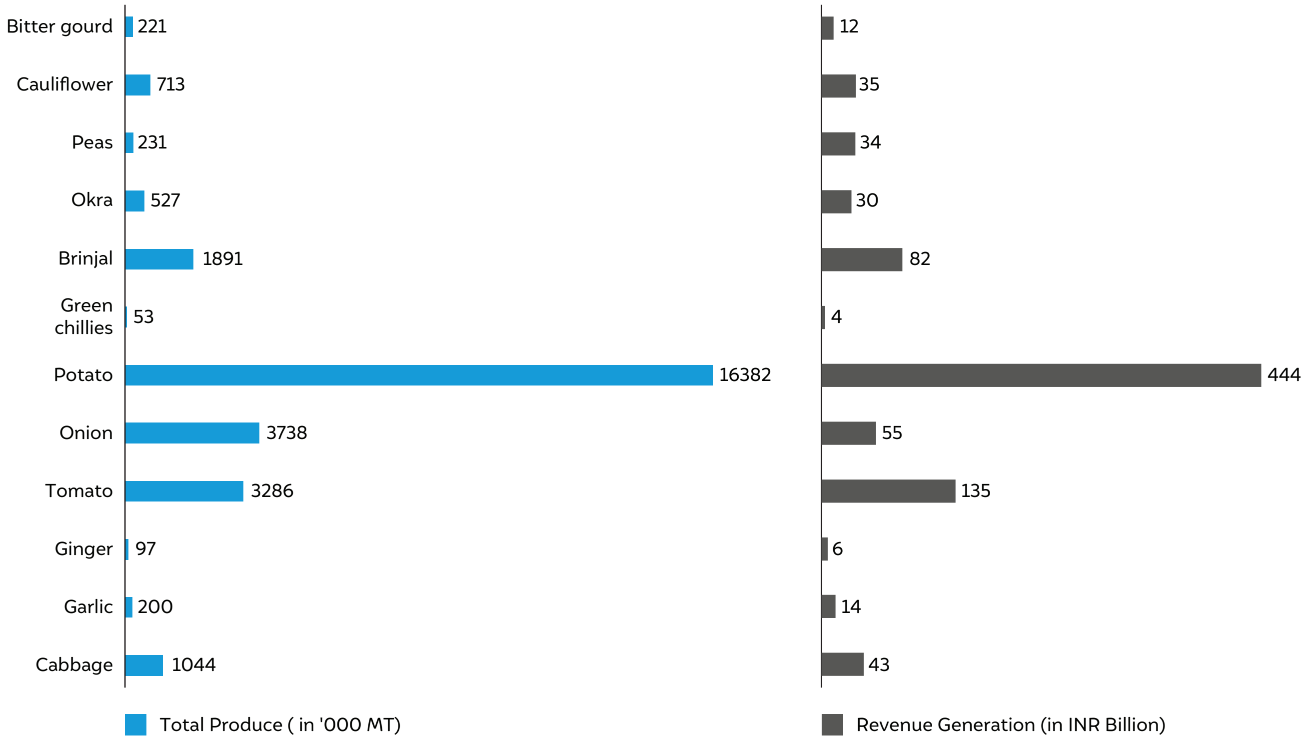
The total production of vegetable crops from the 1.38 Mha of land irrigated using TWW is estimated to be over 28 million metric tonnes (MT). The revenue that can be generated from the sale of this produce is about INR 966 billion (Figure 5). This is the average revenue based on the production and retail prices released by the National Horticulture Board on a per-unit basis (quintal in this case) across 21 centres in India (National Horticulture Board 2022).

Figure 4 Among the 12 vegetable crops, potato will have the highest proportion of irrigated area with TWW



Source: Authors' analysis, data from Horticultural Statistics at a Glance (Horticulture Statistics Division 2018)

Figure 5 An estimated INR 966 billion was generated as revenue from the sale of selected vegetables irrigated using TWW in 2021



Source: Authors' analysis, data from Horticultural Statistics at a Glance (Horticulture Statistics Division 2018), NHB Interactive: Month wise Annual Price and Arrival Report (National Horticulture Board 2022)

5.2 Additional economic benefits from reuse of treated wastewater for irrigation

Reduction in fertiliser usage

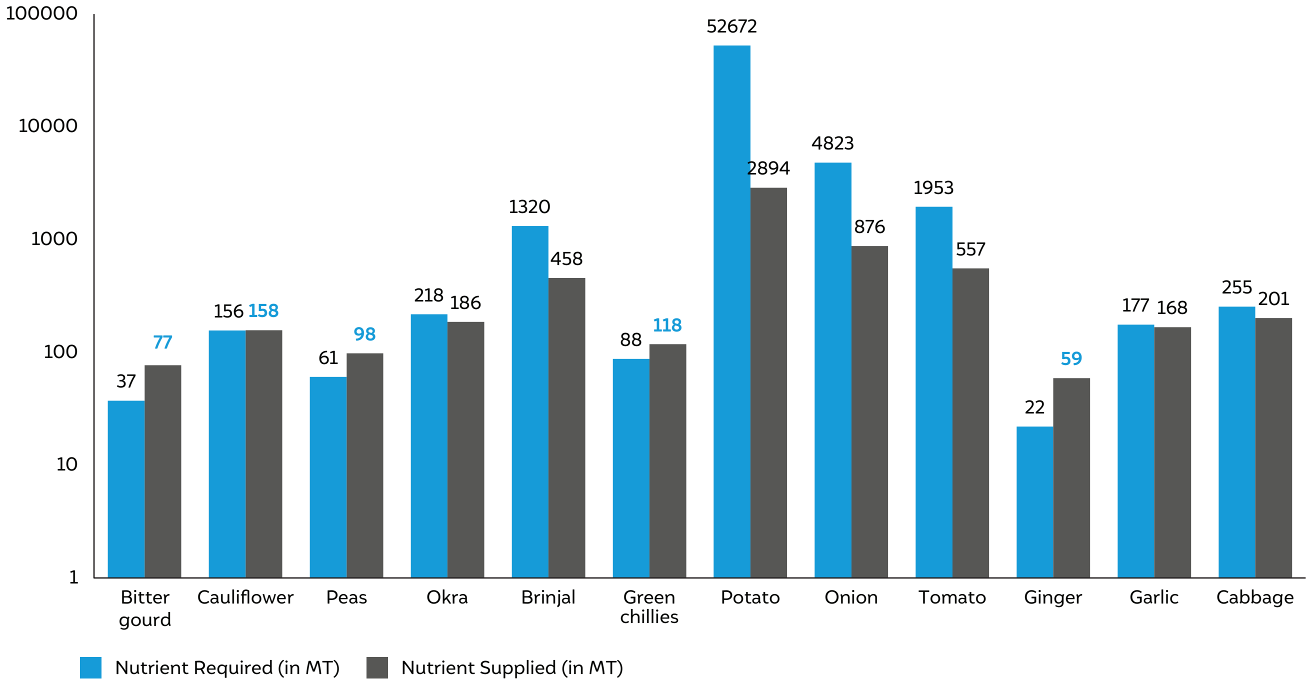
Wastewater contains valuable nutrients (nitrogen, phosphorus, and potassium, or NPK). Thus, reusing treated wastewater for irrigation can aid crop growth and reduce the demand for synthetic fertiliser use. This can lead to both environmental and economic benefits.

For the estimation of reduction in fertiliser usage on account of using TWW, we analysed the same 12 vegetable crops we mention in section 5.1. As per various estimates, there are about 0.63–0.73 tonnes of nutrients in each MLD of treated wastewater (Kumar, Raman, and Jain 2014). Further, these vegetable crops require approximately 156 kg of fertiliser per hectare of land (MoHUA 2021). We used them to estimate the fertiliser reduction potential of irrigation with TWW.

As per our estimates, the nutrients from currently available TWW for irrigation amount to more than 6,000 tonnes. On account of this inherent nutrient value, irrigation using TWW has the potential to reduce fertiliser usage by 9–10 per cent. Moreover, in the case of five vegetables out of the 12 (marked in blue), the nutrient supply from TWW exceeds their requirement and hence does not require an additional dosage of fertiliser (Figure 6).

The market value of nutrients (a mix of NPK) is about INR 8,000/tonne (MoHUA 2021), based on which we estimate that the total savings on account of the reduction of fertiliser use through irrigation using TWW is more than INR 50 million per annum (Figure ES3). The reduction in the use of synthetic fertiliser will consequently reduce the requirement and input subsidy of fertiliser that the government provides farmers. The resultant financial savings can be used to strengthen the wastewater treatment infrastructure.

Figure 6 TWW use in irrigation can supply about 9–10 per cent of the nutrients required by the vegetables



Source: Authors' analysis, data from WastewaterRrecycle and Reuse: an Economical and Sustainable Option (Kumar, Raman, and Jain 2014; Circular Economy in Municipal Solid and Liquid Waste (MoHUA 2021) (Data: Fertiliser Requirement – 156 kg/ ha (MoHUA 2021), Nutrient Load: 0.63–0.73 tonnes/ MLD (Kumar, Raman, and Jain 2014)

Reduction in area irrigated by groundwater and GHG emissions

India has a net irrigated area of 68.2 Mha, of which 60 per cent (about 39 Mha) is irrigated through groundwater (Jain, Kishore, and Singh 2019). The available treated wastewater would have irrigated 1.38 Mha in 2021 and has the potential to irrigate 3 Mha by 2050. This would have reduced pumping in 3.5 per cent of the groundwater-irrigated area in 2021, which will increase to 8 per cent by 2050.

Further, the reduction in area irrigated using groundwater will lead to less GHG emissions, as there would be a reduction in energy usage to pump out groundwater. In India, nearly 30 million irrigation pumps (diesel and electricity) are used for groundwater extraction (Agrawal and Jain 2018). Thus, each pump irrigates about 1.3 ha of land – this is based on the ratio of groundwater-irrigated area to the total number of pumps. Considering the irrigation potential of TWW in 2021 (1.38 Mha), the required number of pump sets would have been reduced by 1 million. The substitution of 1 million irrigation pumps would have reduced CO_2 emissions by 1 million tonnes. By 2050, this would be 2.2 million tonnes of CO_2 emissions under the business-as-usual scenario. These estimates are based on a two-fold assumption. First, a 5HP diesel pump runs for 2.5 hours per day for a total of 200 days per year, consumes 0.75 litres of fuel per hour of operation, and releases 2.64 kg of CO_2 per litre of diesel consumption (Bassi 2017). Second, wastewater treatment plants derive their energy from renewable sources that minimise their carbon footprint from treatment operation.

Additionally, the inherent value of nutrients (NPK) in TWW (Hashem and Qi 2021) has the potential to reduce the use of synthetic fertilisers, as it will provide a certain amount of nutrients that are otherwise supplied synthetically. The corresponding reduction in consumption of fertilisers can reduce GHG emissions further. According to our analysis, on account of the usage of the available TWW for irrigation in 2021, GHG emissions could have been further reduced by 0.3 million tonnes (Dolejsi and Bull 2010). This estimation considers the GHG emission reduction potential of the following three fertilisers – urea (0.75 tonnes CO_2/tonne), di-ammonium phosphate (0.29 tonnes CO_2/tonne), and murate of potash fertilisers (0.095 tonnes CO2/tonne), which are the key sources of the nutrients N, P, and K respectively. The reduction in GHG emissions can contribute towards achieving India's Nationally Determined Contributions, which aim at reducing its emission intensity by 2030 (MoEFCC 2022).

Figure 7 INR 630 million is the estimated market value of TWW that was available in 2021

Source: Authors' analysis, data from EnviStats India 2018 (CSO 2018), Circular Economy in Municipal Solid and Liquid Waste (MoHUA 2021) (Data: Revenue sale of TWW is INR 20/kilolitres)

5.3 Market value of treated wastewater

Wastewater treatment plants functioning at optimum capacities can provide opportunities for urban local bodies to cover their operation and maintenance (O and M) costs through revenues generated by selling TWW of prescribed quality to different categories of users. In India, there is evidence from cities like Chennai and Nagpur, where local urban bodies are selling secondary treated wastewater to industrial users.

As per the estimates of the Ministry of Housing and Urban Affairs, Government of India, the standard market rate for treated wastewater is INR 20 per kilolitre (MoHUA 2021). Based on this, we estimate that the market value of the treated wastewater available in 2021 (11,622 MCM) is over INR 630 million (Figure 7). This can be realised if there is a mechanism to sell TWW to different sectors for reuse at its full market price.

We further estimate that the market value will substantially increase over the years, to over INR 830 million in 2025 and INR 1.9 billion in 2050, at the current market rate.

> We estimate the market value of the currently available treated wastewater to be over INR 630 million. This will substantially increase to over INR 1.9 billion by 2050.

6. Review of TWW reuse policies in selected Indian states

To realise the economic and market potential of TWW, it is important that the necessary governance structure exists in terms of policy and institutional support that can enable TWW reuse in various sectors. We found that only 10 out of 28 states in India have a TWW reuse policy. They include Andhra Pradesh (AP), Chhattisgarh (CG), Gujarat (GJ), Haryana (HR), Jharkhand (JH), Karnataka (KA), Madhya Pradesh (MP), Maharashtra (MH), Punjab (PB), and Rajasthan (RJ). Further, a National Framework on Safe Reuse of Treated Water was launched very recently – in January 2023.

In this section, we review the existing TWW reuse policies of Indian states (except for MH, whose policy could not be obtained); using a framework consisting of nine components. These include i] the need for policy, ii] identified sectors for reuse, iii] technologies for treating wastewater, iv] TWW allocation mechanisms, v] the pricing of TWW, vi] institutional arrangements, vii] quality standards and performance benchmarking, viii] supporting legal frameworks, and ix] business models for developing TWW reuse projects. We present the summary of the review in Table 2.

6.1 Need for policy

India is witnessing high pressure on its limited freshwater resources. As per our analysis using the Central Water Commission (CWC) estimates on basin-wise water availability (CWC 2021), 11 out of the 15 major river basins in India will experience water stress by 2025, a situation where the annual per capita renewable water availability will be below 1,700 cubic metres. Further, 351 river stretches on 323 rivers are polluted with biological oxygen demand (BOD) above the desired criteria, i.e., 3 mg/l (CPCB 2018). Also, as per the Composite Water Management Index of India, about 70 per cent of India's water supply is contaminated (NITI Aayog 2019). Thus, both the quantity of freshwater available and its quality are of concern. In the urban context, the situation is likely to get worse with rapid unplanned urbanisation and industrialisation putting pressure on stressed freshwater resources and an existing inadequate wastewater treatment system.

For most states, water scarcity and inequitable distribution of water are the key driving factors for the adoption of the TWW reuse policy. Only two states, Rajasthan and Chhattisgarh, highlight the key role that such a policy can play in improving water quality and public health at large (GoR 2016; GoC 2017). Haryana also considers the policy a foundation to prepare a tangible action plan for the effective recycling and reuse of water (GoH 2019).

Inferences

- Most state policies acknowledge the TWW reuse as a response to growing water scarcity.
- Only a few policies highlight the positive externality associated with the treatment of wastewater and reuse in terms of improvement in the water quality of receiving natural water bodies and on public health at large.

6.2 Identified sectors for reuse of TWW

Climate change-induced global warming will impact all components of the freshwater system (Cisneros et al. 2014). The reuse of reclaimed water (or TWW) provides an opportunity to mitigate the rising water crisis by reducing the burden on freshwater resources, especially for non-potable uses across different sectors.

Agriculture and industries are the two main sectors that most states identify for the potential reuse of TWW. Additionally, wetland restoration, river/streamflow augmentation, and environmental recreation are acknowledged by Karnataka and Andhra Pradesh as potential areas for TWW reuse (GoK 2016; GoAP 2016).

In terms of the priority of TWW reuse among identified sectors, Punjab, Rajasthan, and Jharkhand give priority to the agricultural reuse of TWW for unrestricted irrigation (GoP 2017; GoR 2016; GoJ 2017). On the contrary, Gujarat and Haryana prioritise the reuse of TWW for industrial and municipal (non-potable) uses with any surplus to be used for irrigation/agriculture (GoG 2018; GoH 2019).

For industrial purposes, nearly all states classify the reuse of TWW in thermal power plants for cooling requirements, boiler-feed water, and power generation. Haryana and Gujarat have gone a step ahead by incorporating mandatory and non-mandatory provisions into their policies (GoH 2019; GoG 2018). For example, in Gujarat, industrial parks or units consuming more than 100,000 litres of freshwater per day for non-potable purposes and thermal power plants situated within 50 km of sewage treatment plants (STPs) or city limits are mandated to use TWW, whereas municipal uses for non-potable purposes are in the non-mandatory category (GoG 2018).

Further, Andhra Pradesh, Gujarat, and Haryana acknowledge the construction sector as one of the potential users of TWW (GoAP 2016; GoG 2018; GoH 2019).

Also, high-end technology manufacturing industries, such as circuit-board manufacturing, are relatively new industries where reclaimed water can be reused. Andhra Pradesh mentions such new industries in their policy as opportunity areas for the reuse of TWW.

Inferences

- The identification of sectors for reuse and setting up priorities is very context-specific (MoJS 2021), as there is huge diversity among the states on various fronts – regional topography, availability of natural resources, level of urbanisation, industrialisation, development priorities, and wastewater treatment infrastructure.
- Non-potable applications are the key focus areas for the reuse of TWW. Sectors such as thermal power plants, which are considered water-intensive sectors (Chaturvedi et al. 2018), are rightly classified under the mandatory category for reusing treated wastewater. Minimising their water demand can have a considerable impact on the availability of freshwater required for potable purposes.
- The reuse of TWW in other sectors that are classified as non-mandatory, e.g., construction activities and municipal uses, are based on local bodies fulfilling certain conditions – for instance, laying special supply lines for TWW and filling tankers with TWW for use in construction sites.
- High-end technology industries are also exploring avenues for the reuse of treated wastewater given the massive growth in digitisation and rise of semi-conductor industries.

6.3 Recommended technologies for wastewater treatment

Sustainable Development Goal 6.3 focuses on improving water quality. Mainstreaming wastewater treatment and its safe reuse is a crucial component in the achievement of this target. The selection of appropriate wastewater treatment technologies is very important for obtaining effluents of desired water quality standards.

The wastewater treatment process ideally has three stages. The first stage, or primary treatment, involves techniques such as screening and equalisation. The second stage is referred to as secondary treatment, and the techniques used are gravel filtration, sand filtration, and chlorination. The third stage involves techniques of broken brick and charcoal-treated greywater. These stages are fundamental to wastewater treatment and are considered a minimum standard process. Even though they are fundamental, only the policies of Madhya Pradesh, Andhra Pradesh, and Jharkhand mention these processes for wastewater treatment (GoMP 2017; GoAP 2016; GoJ 2017).

Further, only some policies (those of Madhya Pradesh and Rajasthan) elaborate on the different types of treatment methods that are on site and off site (GoMP 2017; GoR 2016). They emphasise the need for the right mix of on-site and off-site treatment methods to generate TWW of desired quality. Other policies focus only on off-site treatment methods. Under the off-site method, households are usually connected to a proper sewerage network and the wastewater is collected and transported to centralised treatment facilities. However, due to an inadequate sewerage network and treatment capacity, about one-fifth of urban India is dependent on on-site treatment methods (CSE 2014), where the wastewater storage and treatment takes place within the plot occupied by a dwelling and its immediate surroundings.

Technologies states identified as suitable for on-site treatment include bio-digestors, phytorid technology, and reed bed filters. For off-site treatment, nearly all states underline the need to identify appropriate technologies which are simple to operate, easy to maintain, robust, and most importantly, techno-economically feasible. Haryana lists technologies such as moving bed biofilm reactors (MBBR), membrane bioreactors (MBR), sequencing batch reactors (SBR), and activated sludge process (ASP) (GoH 2019), which need to be explored based on their effectiveness and suitability.

Specific policies also note some innovations. Andhra Pradesh has introduced the concept of demand profiling (GoAP 2016), where the major demand areas are identified at the urban local body (ULB) level, and suitable treatment systems are designed to meet the required quality requirements. Many other states, like

Jharkhand, Karnataka, Rajasthan, and Madhya Pradesh, mention nature-based solutions (GoJ 2017; GoK 2016; GoR 2016; GoMP 2017) for localised treatment through constructed wetlands where the physical, chemical, and biological processes are combined to remove contaminants. This serves twin benefits, enabling groundwater recharge and access to clean water at an affordable cost. Madhya Pradesh even discusses the types and designs of wetlands that can be constructed based on local conditions (GoMP 2017).

Inferences

- Most of the state policies that we reviewed do not provide details on the treatment process and technologies. However, certain policies make a clear pitch for the need for both on-site and off-site technology systems, given that the sewerage network and treatment infrastructure do not cater to the entire urban area.
- The provision for on-site treatment, which certain policies discuss, provides opportunities to reduce the burden on the centralised system by providing treatment at affordable costs, reducing the energy footprint, and promoting local reuse of treated wastewater.
- Most of the policies make only a brief mention of the tertiary treatment process and technologies.
- A majority of the states underline the need for appropriate and innovative technology to enhance wastewater treatment efficiency. Some states also refer to nature-based solutions for wastewater management.

6.4 Mechanism for allocating treated wastewater

The allocation of TWW guided by the principles of sustainability, equity, and fairness will ensure effective distribution and optimum reuse of TWW across the different categories of users. However, among all the policies analysed, only Karnataka explicitly mentions these principles in its policy document.

Nevertheless, states have laid down different criteria for TWW allocation in their policy documents. Gujarat and Haryana categorised their allocation criteria based on the availability of TWW in comparison to the demand (GoG 2018; GoH 2019). Their policy documents mention that if the availability of TWW is more than the demand, after supplying to mandated users, the surplus water shall be allocated to other users or mandatory categories of users outside the supply zone. For instance, surplus water can be supplied to thermal power plants located outside the 50 km mandate. In case the availability of TWW is less than the demand, the allocation shall be as determined by the state government in a manner that favours better revenue generation. Finally, if TWW is completely unavailable, then the focus shall be on creating the infrastructure for the collection and treatment of wastewater, and the requisite supply of fresh water will be made available until this is done.

Under Karnataka's policy, industrial estates/zones within 30 km of STPs are mandated to prioritise treated water. Additionally, the Department of Industries and Commerce will be responsible for establishing a voluntary target according to which TWW was to comprise 20 per cent of the total state-wide industrial water use by 2020 (GoK 2016). As we mentioned earlier, the state of Andhra Pradesh has introduced the concept of 'demand profiling', which will help in identifying and setting up priorities for local reuse contexts at the ULB level.

Furthermore, it is important to have clear enforcement mechanisms to ensure the effective implementation of TWW allocation criteria and define the roles and responsibilities of different institutions. Despite that, only Gujarat and Haryana have defined enforcement mechanisms (GoG 2018; GoH 2019) in their policy document.

Inferences

- Though several state policies define the criteria for allocation of TWW for different purposes, the foundational principles for water allocation (equity, sustainability, etc.) were lacking in most state policies.
- Most state policies that we reviewed were lacking in an enforcement mechanism that provides a blueprint for effective implementation.

6.5 Pricing of treated wastewater

Pricing principles tend to be a deciding factor in generating demand, especially for non-conventional products (Bassi et al. 2022). Nearly all states have defined pricing principles to cover the operation and maintenance (O and M) costs of wastewater treatment systems. States such as Punjab, Jharkhand, Rajasthan, and Karnataka mention the 'polluter (or generator) pays principle', where a charge is levied on generators for wastewater services (GoP 2017; GoJ 2017; GoR 2016). For instance, Bangalore levies a fee amounting to 25 per cent of the water consumption charges.

In addition to pricing principles, all states, with the exception of Chhattisgarh, mention the factors and criteria used to determine the prices of TWW. Gujarat and Haryana have identified the following factors for price determination – cost of capital, O and M of STPs, distribution networks, and tertiary treatment (GoG 2018; GoH 2019). They also define the parameters of price variation: prices will be fixed for the first year, with the incorporation of a suitable price escalation clause in the agreement, and there will be provisions for a review every five years by the State Level High Power Committee (SLHPC). In the case of Punjab, Rajasthan, and Jharkhand, the price variation clause is based on geography, end use, effluent quality, and socio-economic conditions (GoP 2017; GoR 2016; GoJ 2017). The state policy documents of Jharkhand and Rajasthan suggest aligning the pricing mechanism with urban reforms (under various schemes such as AMRUT), which intends to recover 100 per cent of the cost of O and M from the consumers, with cost criteria depending on the system/technology adopted, administration costs, updated infrastructure (MIS and customer data on GIS), power charges, and costs of spare parts. Karnataka and Madhya Pradesh mention the introduction of cross-subsidies to make pricing pro-poor (GoK 2016; GoMP 2017).

Furthermore, many states allocate the responsibility of managing revenues for services rendered in wastewater treatment and reuse projects to ULBs. Rajasthan and Gujarat, envision a purchase agreement between the users and the implementing agency, along with the creation of an escrow account managed by ULBs (GoR 2016; GoG 2018). Also, all the states mention the role of the private sector in the management of wastewater treatment and reuse infrastructure.

Inferences

- Most state policies elaborate on the pricing principles and factors taken into account for price determination, and some have also briefly accounted for price variation.
- The state policies are silent on the incentives given to end users to promote the reuse of TWW.

6.6 Institutional arrangements

Institutional arrangements provide clarity regarding roles and responsibilities and ensure effective coordination and implementation. The suggested institutional structures for wastewater treatment and reuse vary widely across states. Gujarat and Haryana have a three-tier institutional structure (GoG 2018; GoH 2019) consisting of (i) a SLHPC, the apex body for implementation; (ii) a State Level Technical Committee responsible for technical approval, monitoring of projects, and preparation of guidelines for O and M; and (iii) a TWW cell headed by a chief engineer responsible for the smooth implementation of projects and ensuring interdepartmental coordination at the local level.

The Karnataka government's institutional structure includes primary departments (such as the Urban Development Department) and secondary departments (such as the Water Resources Department) (GoK 2016) based on their extent of involvement and role in wastewater treatment and reuse. The responsibilities of ULBs are delineated separately and include coordination with the Waste Water Reuse Resource Centre, which is responsible for capacity building and project assistance to ULBs through the preparation of the Integrated Urban Water Resource Management Plan, and identification of viable wastewater reuse projects.

Jharkhand has a two-tier institutional structure (GoJ 2017) consisting of a special-purpose vehicle at the state level, known as the Jharkhand Urban Infrastructure Development Corporation (JUDICO), which is responsible for assessing the citywide performance of wastewater treatment (WWT) and reuse projects, and putting in place a monitoring and evaluation (M and E) framework. JUDICO consists of a cell that is responsible for the formulation of project guidelines and M and E of projects (GoJ 2017).

Furthermore, provisions for coordination and dispute resolution among stakeholders form an integral part of most state policies. Many states recognise that active civil society participation and regulation by ULBs at the grassroots are key factors in the effective operationalisation and implementation of the WWT and reuse projects. Furthermore, Chhattisgarh mentions that academicians and researchers (GoC 2017) should be involved in carrying out primary research and developing models for safe and sustainable wastewater treatment and reuse to support on-ground implementation.

Inferences

- Most state policies have a well-defined institutional structure, and roles and responsibilities are clearly delineated.
- Many state policies also define the roles and responsibilities of ULBs as part of their institutional structure.
- The policies of most states identify different stakeholders in wastewater management; however, their roles are not well defined.

6.7 Quality standards and performance benchmarking

State policies highlight public health as the prime objective behind the standardisation and regulation of TWW quality. All states have made CPCB/SPCB norms for the safe disposal of TWW mandatory (CPCB 2008). They make references to the World Health Organization (2017) and CPHEEO (2013) manuals in the discussion regarding the reuse of treated water for specific purposes, such as agriculture and industries. But state policies do not define reuse-specific TWW quality standards.

Performance-linked disposal and reuse norms ensure effective implementation and foster a spirit of competition among states to achieve quality standards. Most state policies mention performance monitoring under the "quality standards and benchmarks" section. As per the policies of Gujarat and Haryana, a separate TWW cell (GoG 2018; GoH 2019) is to be established; it will be responsible for maintaining a real-time database to assess the performance and prepare monitoring formats for wastewater generation, technology adopted for reuse, and characteristics of treated effluents. The policies of Jharkhand and Chhattisgarh have provisions for developing an M and E framework to assess citywide performance, aligned with performance-linked incentives to receive the relevant grants of the 14th Finance Commission (GoJ 2017).

Inferences

- Water quality standards in state policies are limited to CPCB/SPCB-based discharge standards.
- Treated wastewater quality standards for specific reuse purposes are not defined.

6.8 Supporting legal and regulatory instruments

Wastewater recycling and reuse are among the most feasible solutions to the critical problem of water resources. They can help ensure future water security in an affordable, inclusive, and sustainable manner. The idea is enshrined in constitutional principles, such as Article 48A of the Directive Principles of State Policy, according to which the "state shall endeavour to protect and improve the environment," (GoI 2021) and is operationalised through various legal and regulatory instruments.

Gujarat, Haryana, and Chhattisgarh explicitly mention the constitutional provisions in the form of Fundamental Rights (Article 21), Directive Principles of State Policy (Article 48A), Fundamental Duties (Article 51A), and Role of Local Self-Governments (73rd and 74th Constitutional Amendment Act) (GoG 2018; GoH 2019; GoC 2017), which form the basis for the policy framework for wastewater recycling and reuse. All states refer to national policies and legislations on environmental protection, solid waste management, and sustainable building codes. Key policies and legislations include the National Urban Sanitation Policy (2008), Guidelines for *Swachh Bharat* Mission (2014), Environment Protection Act (1986), Water (Prevention and Control of Pollution) Act (1974), and Municipal Solid Waste Management (MSW) Rules (2016). Additionally, Chhattisgarh has referred to the National Building Code to govern the installation, design, and maintenance of septic tanks (GoC 2017).

Inferences

- States refer to numerous central and state acts, rules, and guidelines in their wastewater treatment and reuse policies. However, there is very limited mention of binding provisions, leading to a lackadaisical approach towards policy implementation.
- They do not identify a single agency (MoJS 2021) that can be responsible for the effective implementation of the WWT and reuse policy on the ground.

6.9 Business models for developing treated wastewater reuse projects

To mainstream the reuse of wastewater, states need to determine priorities for sanctioning reuse projects. Generally, the key priorities for sanctioning include the quantity of sewage generated, location of STPs, status of existing infrastructure, and strategic location. However, some states do not mention project-sanctioning priorities at all, whereas others only partially mention them. For instance, the policies of Gujarat and Haryana do not explicitly mention sanctioning priorities but underline the need to profile local bodies in their detailed project reports.

All state policy documents mention the provision for exploring appropriate public–private partnership (PPP) models. Gujarat and Haryana highlight various PPP models, such as design-build-operate (DBO), design-finance-build-operate-transfer (DFBOT), build-operate-transfer (BOT), the hybrid annuity model (HAM), and so on (GoG 2018; GoH 2019). States like Rajasthan, Jharkhand, and Madhya Pradesh also have provisions for the development of city wastewater plans over the next 20–30 years (GoR 2016; GoJ 2017; GoMP 2017), which should be aligned with the master plans for the respective cities to avoid any conflicts with current and future urban development.

Inferences

- Although all the policies mention the PPP models that could probably be used for the development of wastewater treatment and reuse projects, none of them discuss the appropriate business models for such projects, which would involve time-bound creation of treatment facilities, conveyance systems, distribution of treated wastewater, provision for smart metering for transparent pricing mechanisms, and arrangements for sustainable O and M.
- Some state policy documents align the treated wastewater reuse projects with existing city master plans, which is a welcome step especially from the planning perspective.

Table 2 Comparative analysis of existing wastewater treatment and reuse policies in various states in India

Parameter	States								
	PB	RJ	GJ	HR	JH	CG	KA	MP	AP
Need for policy									
Address water scarcity and distributional inequity	✓	✓	✓	✓	✓	✓	✓	✓	✓
Improve water quality and public health	✓	✓	✓	✓	✓	✓	✓	✓	✓
Develop a tangible action plan	✗	✗	✗	✓	✗	✗	✗	✗	✗
TWW reuse options									
User categories defined	✓	✓	✓	✓	✓	✗	✓	✓	✓
Priorities among users defined	✓	✓	✓	✓	✓	✗	✗	✓	✓
Mentions specific industries and industrial purposes for reuse	✓	✓	✓	✓	✓	✗	✗	✓	✓
Lists mandatory and non-mandatory provisions	✗	✗	✓	✓	✗	✗	✗	✓	✗
Technology recommendations									
Mentions process for wastewater treatment	✗	✗	✗	✗	✓	✗	✗	✓	✓
Suggests technologies for treatment	Partial	✓	✗	✗	✗	✗	Partial	✓	✗
Has provisions to explore and identify innovative technologies	✓	✓	✓	✓	✓	✗	✗	✓	✓
Focuses on nature-based solutions	✗	✓	✗	Partial	✓	✗	✓	✓	✗

Parameter	States								
	PB	RJ	GJ	HR	JH	CG	KA	MP	AP
TWW allocation mechanism									
Mentions principles guiding the allocation of treated wastewater	✗	✗	✗	✗	✗	✗	✓	✗	✗
Mentions criteria to decide allocation priorities	✗	✗	✓	✓	✗	✗	✓	✗	✓
Has a layout enforcement mechanism	✗	✗	✓	✓	✗	✗	✗	✓	✗
TWW pricing									
Defines pricing mechanism	✓	✓	✓	✓	✓	✗	✓	✓	✓
Mentions pricing criteria	✓	✓	✓	✓	✓	✗	✓	✓	✗
Identifies authority for managing revenues	✓	✓	✓	Partial	✓	✗	✓	✓	✓
Institutional arrangements									
Suggests institutional structure	✓	✓	✓	✓	✓	✓	✓	✓	✓
Has provisions for interdepartmental coordination	✗	✓	✓	✓	✓	✓	✓	✓	✓
Has provisions to involve stakeholders	✓	✓	✓	✓	✓	✓	✓	✓	✓
Quality standards and performance benchmarking									
Mentions standardising TWW quality	✓	✓	✓	✓	✗	✓	✓	✓	✓
Lists key objectives behind standards and regulations	✓	✓	✗	✗	✓	✗	✓	✓	✓
Has provision for performance monitoring	✓	✓	✓	✓	✓	✓	✓	✓	✓
Provides quality standards for TWW reuse	✗	✗	✗	✗	✗	✗	✗	✗	✗
Supporting legal framework									
Enshrines constitutional principles	✗	✗	✓	✓	✗	✓	✗	✓	✗
Mentions national policies and acts	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mentions state policies and acts	✓	✓	✓	✗	✗	✓	✓	✓	✗
Makes reference to CPHEEO manual, 2013	✓	✓	✓	✓	✗	✓	✓	✓	✓
Business models									
Sets priorities for project sanctioning	Partial	✓	✗	✗	✓	✗	✓	✓	✗
Discusses scope for PPP	✓	✓	✓	✓	✓	✓	✓	✓	✓
Makes linkages with sustainable infrastructure	✗	✓	✗	✗	✓	✗	✗	✓	✗

Source: Authors' analysis

Note: Acronyms - PB, Punjab; RJ, Rajasthan; GJ, Gujarat; HR, Haryana; JH, Jharkhand; CG, Chhattisgarh; KA, Karnataka; MP, Madhya Pradesh; AP, Andhra Pradesh

6.10 Key gaps identified

Based on our review of the existing state policies, we summarise the gaps we identified under each component of the framework used for analysing the policy:

- **Need for policy**: State policies recognise the need for reusing TWW to address the problem of water scarcity and to reduce the pressure on freshwater sources. However, only a few policies highlight the positive externalities associated with the treatment of wastewater and its reuse – namely, improvement in water quality of receiving natural water bodies and the associated public health impacts.
- **Identified sectors for reuse**: Not all state policies have provisions for prioritising sectors for TWW reuse, with only a few policies providing a classification of mandatory and non-mandatory uses. Furthermore, in most cases, the reuse of TWW for non-mandatory purposes – for example, construction activities and municipal uses – is subject to local bodies fulfilling certain conditions: for instance, laying of special supply lines for TWW and filling tanks with TWW for use in construction sites.
- **Recommended technologies for wastewater treatment**: A majority of the state policies that we reviewed do not provide comprehensive details on the treatment process. Furthermore, most of the policies make only a brief mention of the tertiary treatment process and technologies.
- **Mechanism for allocating treated wastewater:** Some policies have defined the criteria for allocation of TWW based on the uses. But almost none of the state policies consider allocation principles, and they do not provide a clear enforcement mechanism that serves as a blueprint for the effective implementation of the policy.
- **Pricing of TWW:** Most state policies have defined the criteria for determining the price for TWW reuse for different sectors. However, they do not include any provisions for incentives for the end users that can promote the reuse of TWW.
- **Institutional arrangement:** Most state policies set out a well-defined institutional structure with delineation of roles and responsibilities. However, the role of external stakeholders (the community, industrial groups, etc.), which is important from the perspective of acceptance of TWW for reuse, is not well defined.
- **Quality standards and performance benchmarking:** Quality standards in the state policies are limited to CPCB/SPCB discharge standards. However, the quality standards for TWW reuse as a function of the specific purpose of use are not defined.
- **Supporting legal and regulatory instruments:** Although most state policies refer to various central and state acts as their regulatory framework, there is very limited mention of binding provisions required for policy implementation.
- **Business models for developing treated wastewater reuse projects:** State policies discuss the scope of exploring PPP models for the development of wastewater treatment and reuse projects. However, they do not specify the criteria for the selection of appropriate business models for effective implementation. This includes the time-bound creation of treatment facilities, conveyance systems, distribution of TWW, provision for smart metering for transparent pricing mechanisms, and arrangements for sustainable O and M.

7. Global best practices on the reuse of treated wastewater

In this section, we present an analysis of the policies on the reuse of TWW employed by selected countries that have successfully implemented the reuse model. The objective is to draw lessons from countries that are frontrunners in the reuse of TWW and derive actionable pointers for strengthening the relevant policies in India. We selected reuse models employed by Spain, Israel, and Singapore, and identified the key drivers, barriers, and enablers based on an analysis of their policy instruments and consultations with key experts.

7.1 Brief background of selected countries

Spain witnesses a regional imbalance between water resource demand and annual rainfall, especially between the north-west and south-east regions (Jodar-Abellan, López-Ortiz, and Melgarejo-Moreno 2019). The former region has higher rainfall and lower water demand than the latter. The Spanish Water Law, established in 1985, focused on pollution control through wastewater discharge regulations and abstraction control. However, with Spain joining the European Economic Community (EEC) in 1986, it needed to broaden its approach to focus on urban wastewater treatment and reuse. Hence, to align with the EEC directive, Spain formulated the Spanish Royal Decree, 2007, which provides a legal framework for the reuse of TWW (Government of Spain 2011). Furthermore, the National Investment Plan (NIP) of 2020 focused more on improving governance to align and comply with the objectives of the EEC. It involved setting up of priorities, strengthening administrative cooperation, improving financing mechanisms, promoting the reuse of wastewater, and improving the efficiency of wastewater treatment plants. As a result, the south-east region of Spain (with relatively low rainfall), consisting of regions such as Murcia and Catalonia, has one of the highest desalinated water and wastewater reuse rates in the world.

Israel suffers from chronic water shortage problems, with frequent droughts. Furthermore, rapid urbanisation, increased water consumption by different sectors, and a large amount of sewage generation pose the threat of polluting already scarce water resources. Israel defined sewage as an integral part of its water resources way back in 1959 with its first Water Law (Marin, Tal, and Yeres 2017). The Israel Water Authority (IWA) was established in 2007 as an autonomous government agency with planning and regulatory responsibilities for all the elements in the water chain (Marin, Tal, and Yeres 2017). A centralised institutional framework that took into account the country's size and population provided a strong footing for mainstreaming wastewater treatment and reuse in the country. In the current scenario, almost 90 per cent of wastewater is reused in Israel.

Singapore has a high annual rainfall of 2,340 mm. However, because of limited availability of land area for constructing reservoirs and the absence of proper aquifers, it had to rely on the water imported from Malaysia to meet its demand (Tortajada and Bindal 2020). After its separation from Malaysia in 1965, Singapore developed a long-term water security strategy focusing on comprehensive water resource management. The objective was to diversify the water supply options to meet the rising demands, put the principles of a circular economy into practice, and most importantly, reduce import dependency. The Water Master Plan, 1972, defined a strong institutional and legal framework with clear roles and responsibilities (Tortajada and Bindal 2020). It led to the institutionalisation of the Public Utilities Board (PUB), the primary statutory agency responsible for Singapore's water supply and drainage networks, the construction and maintenance of reservoirs, the development of pricing mechanisms for different categories of users, the collection and treatment of wastewater, and the regulation of treated effluent discharge. Currently, the reuse of TWW accounts for about 40 per cent of total water demand, which is likely to become 55 per cent in 2060 (Tortajada, Biswas, and Joshi 2013).

7.2 Key drivers leading to mainstreaming of TWW in water supply

Demographic factors

Given the growing population in Singapore, the water demand is expected to double by 2060 in comparison to 2020 (Tortajada and Bindal 2020). This pushed the government to augment the reuse and desalination capacity to meet the likely increase in water demand in the future. Similarly, in Israel, increasing levels of water consumption owing to rapid urbanisation led the government to prioritise mainstreaming the reuse of TWW to reduce the dependence on already scarce freshwater resources.

Natural factors

Climatic variability and geographical topography have acted as key drivers for the adoption of wastewater management strategies. In Spain, rainfall distribution varies immensely across different regions. The north-west region receives an average annual rainfall of 1,000–1,500 mm, whereas the south-east region receives only 300–400 mm (Jodar-Abellan, López-Ortiz, and Melgarejo-Moreno 2019) and, hence the availability of freshwater is low. In Singapore, although there is adequate rainfall, the absence of aquifers and shortage of land area for constructing reservoirs (Tortajada, Biswas, and Joshi 2013) made water storage a challenge. Thus, both these countries took up the reuse of TWW as a viable alternative to augment the available supplies.

Role of stakeholders

Active stakeholder participation and the proactive role of citizens have been crucial in driving the shift towards circular wastewater management to meet the growing water demand in different sectors. For instance, Israel's farmer associations and Spain's golf-course promoters and hotel and resort owners played a significant role in enabling wastewater reuse (Jodar-Abellan, López-Ortiz, and Melgarejo-Moreno 2019). In Singapore, a good understanding of the problems associated with water scarcity among the citizens led the national government to prioritise the water security agenda, and one of the options was to adopt the reuse of reclaimed water.

Geopolitical factors

The geopolitical dynamics of the regions emerged as another key factor leading to the mainstreaming of TWW reuse. Spain joining the EEC in 1986 led to the broadening of its national mandate to include wastewater management (Varela-Ortega and Hernandez-Mora 2010) in order to comply with the Community's regulations. In the case of Singapore, the major geopolitical factor was the need to achieve self-sufficiency (Tortajada, Biswas, and Joshi 2013) after separation from the Federation of Malaysia in 1965.

The changing nature of economic activities and allocation priorities

Spain engaged in intensive agricultural practices and also witnessed a boost in its tourism industry (Jodar-Abellan, López-Ortiz, and Melgarejo-Moreno 2019). Hence, water allocation priorities were set according to these increasing demands. As a result, owners of hotels, resorts, and golf courses lobbied for the allocation of TWW to meet their water demands for non-potable uses. In the case of Israel, water allocation for the agricultural sector witnessed a dip due to the increasing demand–supply gap of freshwater resources (Marin, Tal, and Yeres 2017). This led to the demand for TWW reuse for irrigation, which emerged as the sector with the highest use of TWW in the country.

Safeguarding public health

Public health concerns arising from the use of untreated wastewater motivated governments to address this issue. For instance, the 1970 cholera outbreak in Jerusalem (Juanico 2008) due to the irrigation of vegetables with untreated wastewater prompted the Ministry of Health to take control of the situation and ensure that only TWW was reused for irrigating crops.

7.3 Key barriers to the sustainability of TWW projects

Financial viability

In Spain, golf courses that are predominantly publicly owned (local government ownership) are major users of TWW that is supplied through municipal networks. Hence, the local authorities end up covering all the costs involved in the treatment and conveyance of TWW (Varela-Ortega and Hernandez-Mora 2010). Furthermore, in the absence of a well-developed market for the other uses of TWW, keeping such projects financially viable is a challenge. In the case of Singapore, investment in TWW reuse projects and desalination plants, post its separation from Malaysia meant that finances were needed for the requisite infrastructure, and it also led to an increase in energy use.

Institutional barriers

In the case of Spain, there were significant variations in the level of enforcement of TWW reuse across regions (Jodar-Abellan, López-Ortiz, and Melgarejo-Moreno 2019). The plan was more effectively implemented in regions such as Catalonia, which suffer from water scarcity, but it did not get much traction from the agencies and communities in relatively water-abundant regions. On the other hand, Israel faced the barriers of multiple institutions, overlapping jurisdiction, and ambiguity in roles and responsibilities, which often led to coordination failure.

Political barriers

In Spain, waiving the water tax has been high on the election manifesto. The lack of a proper pricing mechanism emerged as a major deterrent to the effective management of wastewater. It resulted in poor recovery of the cost that was needed to support the capital and O and M expenditures associated with the reuse projects. Hence, it created a major barrier to the development of a market for TWW and impacted the financial viability of the reuse projects.

> **Rapid urbanisation and increase in water demand are key drivers for mainstreaming wastewater reuse globally.**

7.4 Enablers that led to scalability of the TWW reuse projects

Policy frameworks for improving the financial viability

The presence of a national policy framework with clear guidelines and legal provisions for the reuse of TWW is a fundamental enabler. Spain had an early start with the Water Law of 1985, followed by a legal framework for the reuse of TWW – the Spanish Royal Decree 2007 (Government of Spain 2011). The NIP, which was adopted in 2019, created an enabling environment to mainstream the reuse of TWW projects and improve their financial viability. It provides adequate concessions and subsidies for the water operators, which facilitated private sector participation in the treatment and reuse of reclaimed water and the investment of private companies in building wastewater treatment infrastructure (Jodar-Abellan, López-Ortiz, and Melgarejo-Moreno 2019).

Israel acknowledged sewage as an integral part of its water resources in its Water Law, 1959 (Juanico 2008), which is still in place and acts as the cornerstone for water and wastewater management in the country. Furthermore, to ensure financial viability, the urban and rural sectors have a complementary relationship, with several shared reuse schemes. TWW from the municipality-owned treatment plants is sold to the rural areas to meet their irrigation needs, thereby earning revenue as well (Juanico 2008).

Singapore came up with a comprehensive water policy that aims to ensure water supply for all, with emphasis on meeting water demand through non-conventional sources of water (desalination and reuse of TWW) and an effective pricing mechanism.

Robust institutional arrangements

Robust institutional arrangements constitute the foundation of effective implementation. Singapore and Israel developed a centralised system for effective planning, execution, and monitoring of their respective reuse models. Singapore's PUB is the national water authority for managing water supply, sanitation, sewerage, and drainage networks (Tortajada, Biswas, and Joshi 2013). Similarly, in Israel, the IWA is the national regulator for the entire water sector, including potable water supply and wastewater services, irrigation services, and water resources management (Marin, Tal, and Yeres 2017).

In contrast, Spain adopted a more decentralised institutional approach (Varela-Ortega and Hernandez-Mora 2010), with regional governments managing water resources. Although the regional and municipal water utilities are responsible for sewage collection and wastewater treatment, they must adhere to national guidelines. For instance, as per the national legal framework, local authorities are to conduct programmes and come up with plans for the use of reclaimed water in their respective jurisdictions. These plans need to factor in infrastructure requirements to implement reuse projects and also establish a pricing scheme for the same. This would ensure that irrespective of the variable water availability and demand, reuse is considered an option by all the regions.

Technological advancements

Singapore and Israel saw demand-driven technological advancements in wastewater treatment, which were backed by comprehensive need-based assessments. The Changi wastewater treatment plant in Singapore is one of the largest and most advanced reclamation facilities in the world, where the PUB has deployed a membrane bio-reactor. Similarly, Israel's wastewater treatment technologies have also evolved over the years to meet the changing needs and demands – from basic sewerage technologies (anaerobic ponds) to the activated sludge process, to soil aquifer technology (Marin, Tal, and Yeres 2017).

Even Spain's strategy evolved from the Water Law, which initially focussed on wastewater discharge regulations and moved on to reuse-specific treatment after joining the EEC (Jodar-Abellan, López-Ortiz, and Melgarejo-Moreno 2019). Consequently, Spain carried out targeted technological improvements to address the broadened mandate of TWW reuse. Furthermore, the NIP, 2019, led to private companies investing in building wastewater treatment infrastructure (Jodar-Abellan, López-Ortiz, and Melgarejo-Moreno 2019).

> **Active stakeholder participation and the proactive role of citizens are crucial in driving the shift towards circular wastewater management.**

Alignment with international directives

Spain's national framework is aligned with the directives of the European Commission (EC) on urban wastewater treatment and reuse. The directives of the EC define uniform quality standards and benchmarks, include provisions for fines for non-compliance, and provide a prescribed format for reporting on the status of implementation (Government of Spain 2011). Similarly, Israel's quality standards and benchmarks for treatment and reuse were aligned with the directives of the Barcelona Convention (Juanico 2008).

8. Conclusion and recommendations for strengthening governance of wastewater management in India

This research study estimated the economic and market potential of TWW, especially with regard to the agricultural sector, which is the major consumer of freshwater in India. This is the first such attempt in India. The technical feasibility and financial viability of transferring TWW to the point of use need to be explored further.

Furthermore, a review of the existing state policies on TWW and reuse was undertaken to identify the key gaps, and lessons from selected global best practices were assessed. Using this as the basis, we determined key pointers to strengthen the governance of TWW reuse in India, which are as follows.

8.1 Need for a paradigm shift in ideology

Wastewater needs to be considered an integral part of water resources, and all water management-related policies, plans, and regulations need to take it into account. Also, the potential of TWW as an alternative source of water needs to be recognised. Although the state reuse policies in India do recognise the importance of TWW as an important solution for water scarcity, the cases of Singapore, Spain, and Israel demonstrate how a paradigm shift in approaching wastewater as an important resource can ensure efficient water resources management. These countries have transformed from water-scarce nations to leaders in water management.

In India, the reuse of TWW holds immense potential to address the demand–supply gap given that there is large-scale wastewater generation, which is likely to increase exponentially over the years. In India, the National Framework on Safe Reuse of Treated Water was recently launched. The focus can now shift towards effective implementation of the same.

8.2 Define water quality standards

There are two aspects of water quality standards for TWW: first, treating wastewater to discharge-specific standards, so it can be safely discharged into surface water sources, and second, further treating the reclaimed water to use-specific standards so that it can be reused across different sectors. Existing state policies have only addressed the first aspect. Even the National Framework on Safe Reuse of Treated Water only provides guidelines. As protecting public health and safeguarding the environment are the key objectives during wastewater treatment and reuse, quality standards for both safe discharge and reuse need to be well defined, with a periodic review mechanism in place for regular monitoring and assessment. This should include monitoring for emerging contaminants as well. Our analysis of the global cases suggests that in the long term, quality standards can be aligned with international guidelines and regulations.

The EC organises a working group meeting on water reuse every six months to ensure regular assessment of water quality standards and monitoring requirements for water reuse in different sectors. This mechanism could probably be replicated in India as well.

8.3 Set robust institutional mechanisms

Robust institutional arrangements are essential for effective collaboration and coordination between the centre and the states. In India, a three-tier institutional structure is required, with synergy among the centre, state, and city levels (including among the different stakeholders involved) for the effective implementation of wastewater treatment and mainstreaming its reuse. In addition to national and state levels, the city level is also a crucial element of the institutional framework. Urban local bodies should be empowered to formulate and adopt long-term city-level wastewater reuse plans, with roles and responsibilities clearly defined. Our analysis of the global cases highlights how incorporating the end user in the governance and implementation process can go a long way in achieving success.

For instance, the farmers' associations in Israel (Juanico 2008) played a key role in the mainstreaming of TWW reuse in the irrigation sector. The regional farmers' associations contribute to part of the investment required for the conveyance of TWW to the point of reuse. As a result, 50 per cent of the water demand for irrigation is met by TWW. States in India need to engage with external stakeholders as well, and this aspect is mentioned in the National Framework on Safe Reuse of Treated Water.

8.4 Improve financial viability

This includes financing of the projects, principles of pricing to retain project viability, the mechanism for subsidies, and concession to develop a market for TWW. States should carry out feasibility-cum-impact assessments prior to the development of the reuse projects. Furthermore, targeted subsidies and incentives for both operators and end users can act as catalysts. For instance, a private ownership model can be explored through incentives to residents welfare associations/housing colonies for setting up decentralised wastewater treatment facilities within the vicinity of gated colonies. This could promote on-site treatment and reuse.

A key lesson from the experiences of other countries is that ensuring the financial viability of the reuse projects is crucial to developing a market for TWW – which can inspire states in India. Global experiences also suggest that mixed funds are required to ensure financial viability – such as private sector investment, public equity, loans from multilateral institutions, bilateral engagements, and so on. In Singapore, the water reclamation plants are owned by the PUB, with the O and M costs recovered through user fees.

Nevertheless, an effective pricing mechanism for TWW should be put in place based on its market potential and considering different categories of end users and their paying abilities. This will help reduce/recover the wastewater treatment cost and thus contribute towards making reuse projects commercially viable for the implementing authorities. The National Framework on Safe Reuse of Treated Water provides only the guidelines; such a comprehensive pricing mechanism goes a step further.

One other important component in improving the financial viability of TWW is to generate demand for it. In groundwater-irrigated areas in India, farmers receive electricity at a highly subsidised rate. Similarly, freshwater for domestic use in cities is highly subsidised. Thus, to enable a shift towards TWW, especially in areas with water stress, freshwater needs to be priced reflecting its scarcity, which means that its price should be higher than that of TWW. However, some form of subsidy on energy to marginal farmers and on water to the households belonging to the economically weaker sections can continue.

8.5 Leverage technological developments

The global case studies suggest that need-based and demand-driven technological advancements are essential for upholding the efficiency and effectiveness of wastewater treatment. Additionally, dedicated funds for research and development also play a key role in developing technologies that optimise resource efficiency.

Israel has constituted a commission that periodically reviews the status of treatment and reuse, setting the agenda for technological advancements, water standards (Marin, Tal, and Yeres 2017), and so on based on its assessment. Singapore's technological advancements highlight the importance of dedicated research and development in wastewater management (Tortajada, Biswas, and Joshi 2013).

The states in India need to formulate a clear strategy for research and development in this sphere, especially focussing on low-cost technological innovations that are high on energy efficiency. This aspect is not covered comprehensively in the National Framework on Safe Reuse of Treated Water.

8.6 Investment in public outreach

Lack of public acceptance can often act as a barrier to mainstreaming the reuse of TWW. Hence, building public confidence and encouraging behavioural changes are fundamental for the successful implementation of wastewater reuse policies and programmes.

Global experience suggests that stakeholders were one of the key drivers in scaling up TWW reuse. Singapore invested massively in public outreach programmes and designed a comprehensive information, education, and communication programme to gain public trust and acceptance of the TWW reuse projects (WHO 2017). Indian states can draw inspiration from such cases to develop effective public outreach strategies, which can lead to an increase in demand for TWW. This aspect is not covered in the National Framework on Safe Reuse of Treated Water.

> **Reuse-specific quality standards need to be defined for safe reuse of treated wastewater across different sectors.**

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Acronyms

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
ASP	activated sludge process
BOD	biological oxygen demand
BOT	build-operate-transfer
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health & Environmental Engineering Organisation
CWC	Central Water Commission
DBO	design-build-operate
EC	European Commission
EEC	European Economic Community
GHG	greenhouse gas
GIS	geographic information system
HAM	hybrid annuity model
IWA	Israel Water Authority
MBBR	moving bed bio-film reactor
MBR	membrane bio-reactor
MCM	million cubic metre
M and E	monitoring and evaluation
Mha	million hectare
MIS	management information system
MLD	million litres per day
MT	metric tonne
NIP	National Investment Plan
O and M	operation and maintenance
PPP	public private partnership
PUB	Public Utilities Board
SBR	sequential batch reactor
SPCB	State Pollution Control Board
STP	sewage treatment plant
TWW	treated wastewater
ULB	urban local body
WHO	World Health Organization
WWT	wastewater treatment

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Nitin is a Programme Lead for the Water Team at the Council. He is a natural resource management specialist, and his focus areas include river basin water accounting, agriculture water management, institutional and policy analysis in irrigation and water supply management, water quality analysis, climate-induced water risk assessment, and wetland management.

Before joining the Council, Nitin worked with the International Water Management Institute (IWMI) and the Institute for Resource Analysis and Policy (IRAP).

"Promoting the reuse of treated wastewater will lead to several benefits and positive externalities. There is a huge market potential for reusing it for irrigation alone provided financially viable models are developed to scale up WWT and reuse in India."

Saiba Gupta
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Saiba is a research analyst with the Water Team at the Council. Her work focusses on promoting the circular economy in water. She is an urban planner and architect with five years of professional experience. Saiba formerly worked at the National Institute of Urban Affairs (NIUA) as a research associate in the fields of urban policy design and capacity building in the areas of water and sanitation. She holds a master's in urban planning and policy design from Politecnico di Milano, Italy, and a Bachelors in Architecture from Sushant School of Art and Architecture, Gurgaon.

"Given the enormous amount of wastewater generation in the country, its treatment and reuse hold immense potential to open up avenues for financial gains from recovery of this highly underutilised resource."

Kartikey Chaturvedi
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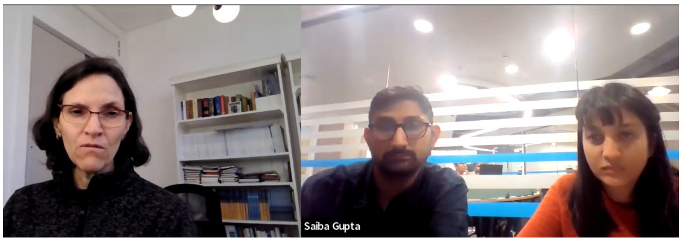
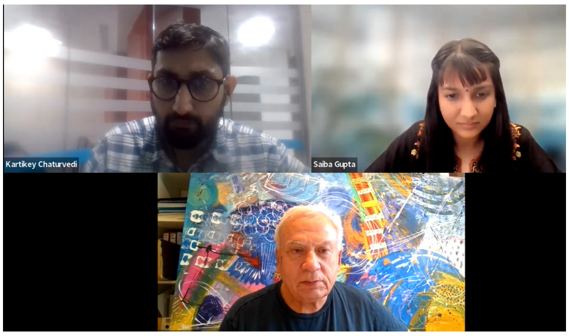
Kartikey is working as consultant in the Water Team at the Council. He is currently focussing on strengthening the governance framework in urban wastewater management. His research interests include the governance of urban wastewater management, circular economy, and sustainable urbanisation. Kartikey has been Capstone Fellow with Global Solutions Initiative – GIZ, Berlin. He holds a postgraduate degree in public policy from Jindal School of Government and Public Policy and a bachelor's in technology in electrical engineering from Government College of Engineering and Technology, Bikaner.

"Wastewater treatment and reuse is one of the most viable water demand management interventions that can reduce the pressure on freshwater resources. However, the effectiveness of the governance framework will be a deciding factor in its successful implementation."

CEEW's Saiba Gupta and Kartikey Chaturvedi in consultation with experts to understand key drivers, barriers and enablers in global wastewater treatment and reuse models.



with **Professor Cecilia Tortajada**
Professor, University of Glasgow

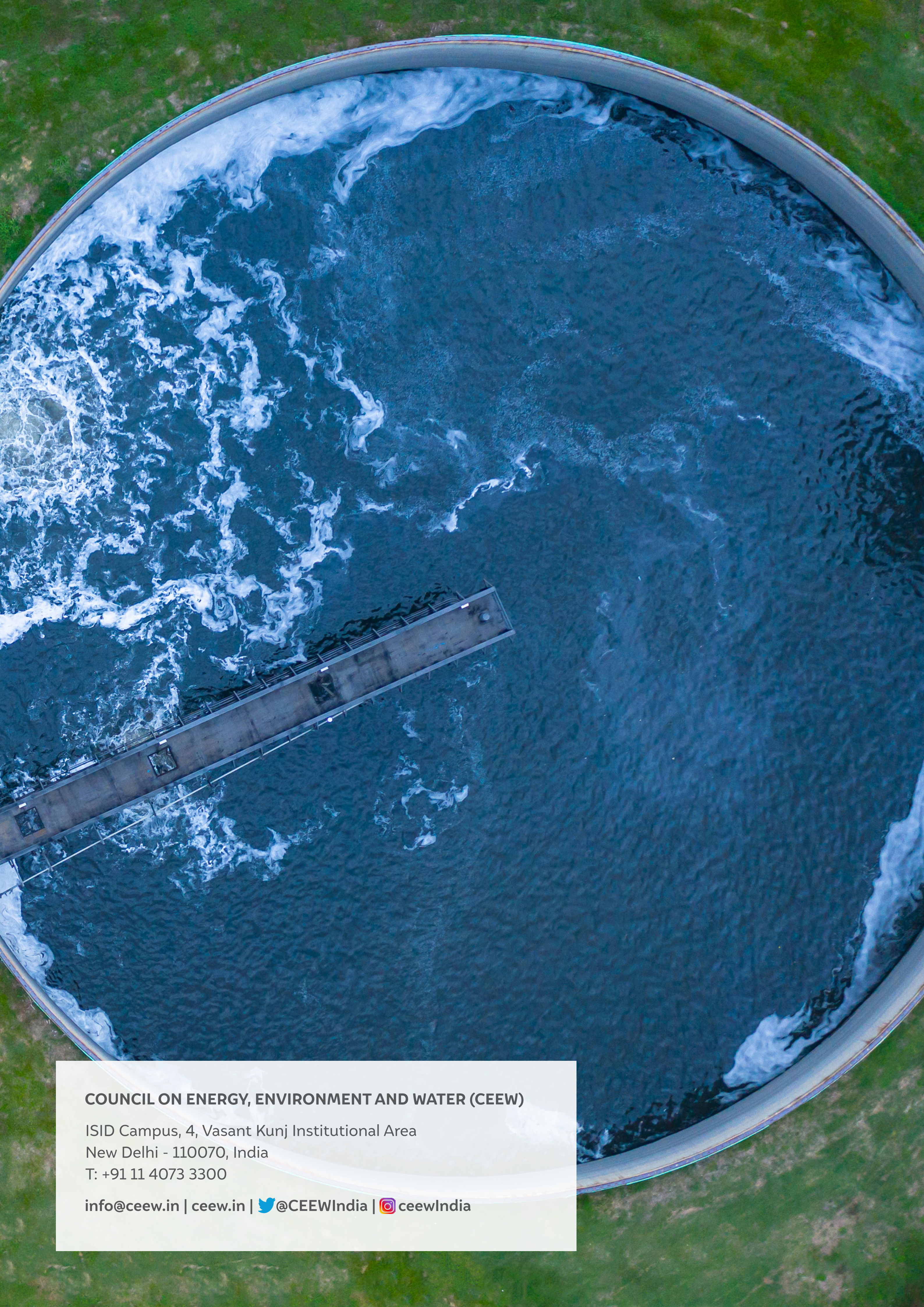


with **Shimon Tal**
Former Water Commissioner, Israel

with **Dr Guido Schmidt**
Senior Water Policy Expert, Spain

Images: CEEW

CEEW's Sustainable Water team with multi-sector stakeholders consulted for the study, 13 January 2023



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