"Think Blue"

Effective water management: integrating innovation and technology

EY-ASSOCHAM report

June 2019

ASSOCHAM INDIA

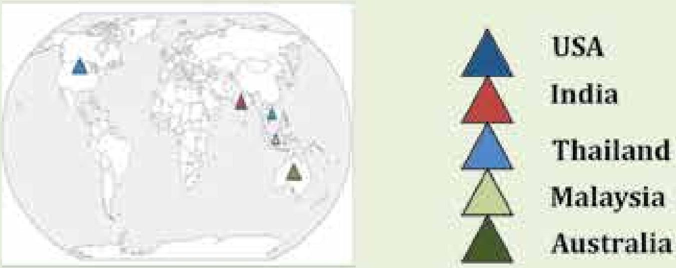
EY Building a better working world

JS Water Energy Life Co. Pvt. Ltd.

Global Leaders in Phyco-Remediation

Highlights of the technology:-

- Designed at the intersection of Nano and Bio-Technology.
- Improves water quality rapidly. River, Wetlands and Lakes can be brought under CPCB standards within 3-6 months.
- Revitalizes Aquatic Food chain and enhances Fish population and Fish growth.
- Neutralizes Water Hyacinth, Blue Green Algae and other Aquatic Weeds.
- Treated water can also be used for Irrigation as it contains all the essential nutrients.
- Global Exporters of Phyco-Nutrients to 15 countries.



Phyco-Remediation projects by JS-Water Energy Life

Contact Us- 0124-4780075, 9958066588

Email- info@js-wel.com

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An initiative by ASSOCHAM and EY

June 2019

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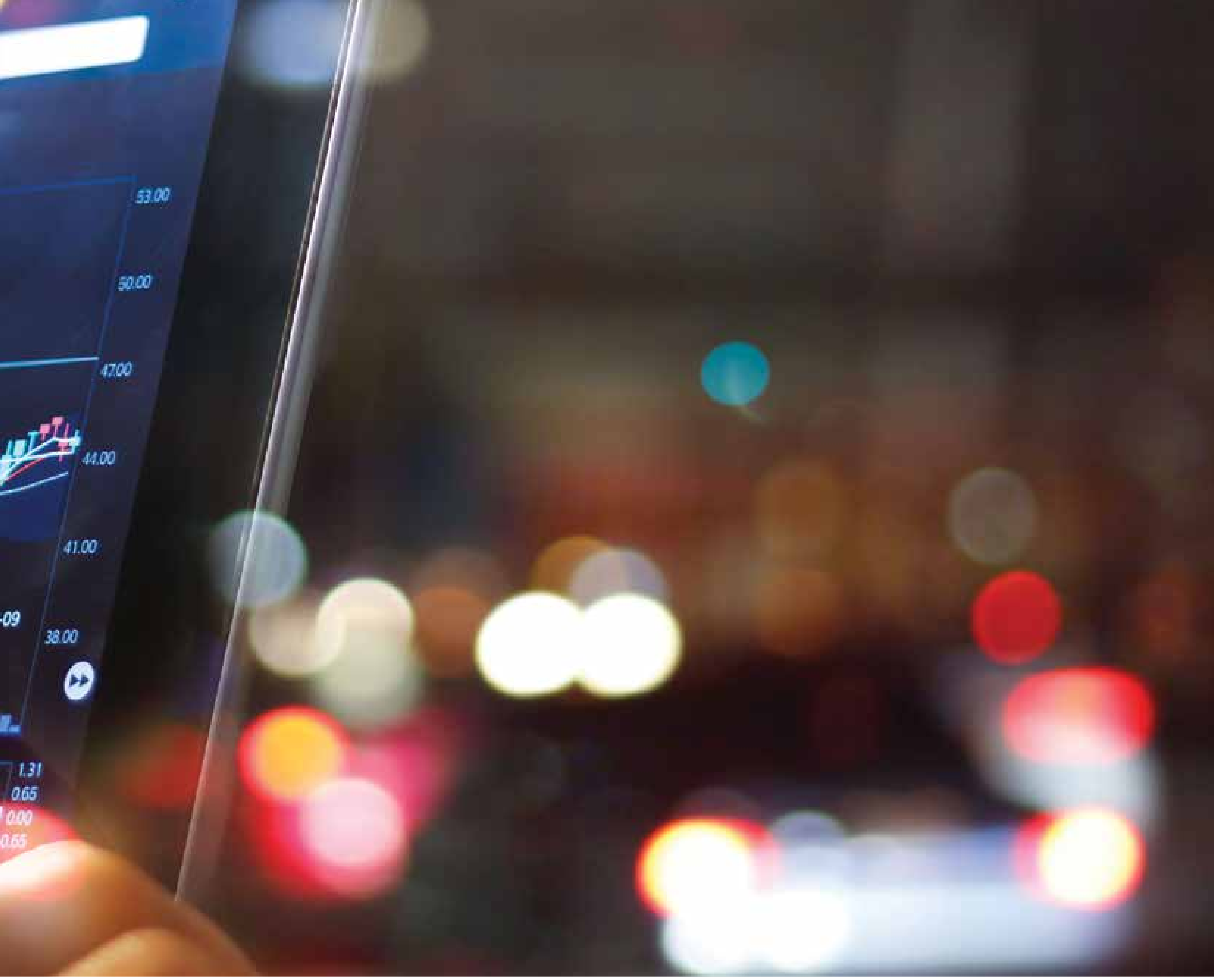
Executive summary

Water resources are under serious threat across the globe. Availability of safe drinking water, inefficient water and waste water treatment systems are some of the greatest challenges the world is facing. The groundwater withdrawal rate as compared to available supplies is extremely high due to rapid industrialization coupled with population growth. The combined effect of increasing population and expanding cities will see the demand for fresh water supply rising exponentially. In response to the rising concern, there is an urgent need to develop a quality and adequate water infrastructure; to meet both domestic and industrial water demands.

Currently, the water and wastewater sector in India has been a slow-moving market driven by compliance with regulation and needs reforms. This report aims at providing an in-depth analysis of the water balance situation in India highlighting various factors responsible for the current water scenario. The report provides insights on the current water supply and the need to manage water by setting policies and regulations. In an agrarian country like India, the demand for water is being managed against the backdrop of increasing population pressure, industrial growth and agricultural needs in a climate of water scarcity and climate change. Besides water scarcity, problems related to the poor quality of the available fresh water exacerbates the situation. Implementation of good water treatment techniques and approaches would help to manage and augment the water demand.

A section on regulatory framework details the various policies and frameworks formulated to govern planning and development of water resources and their optimum utilization. It strives to provide a holistic view of water policies developed and implemented at a national and state level. In India, there are several policies on water and related areas. For instance, there is policy support for recycling and reuse of waste water. It began with regulating industrial water consumption and enforcing mandatory water reuse targets for industries. The National Water Policy (1987, 2002 and 2012) and the National Water Mission 2009 has been the government's response to tackle the challenges associated with water management in the country. Further, the Sustainable Development Goals (SDGs) and India's response to the same has also been discussed. To efficiently tackle the water management scenario in India, a sustainable approach needs to be adopted keeping in mind both the present and



future generations. The government needs to focus on areas where water has been overexploited. Participatory water management should be the way forward to achievable sustainable water reuse and recycling.

Against this background, the report describes various technologies like scale-ban and membrane technology that are cost effective, energy efficient and environmentally safe in comparison to traditional methods of industrial water treatment. In the face of ever-growing water demand, wastewater is gaining momentum as an alternative source of water, shifting the paradigm of wastewater management from "treatment and disposal" to "reuse, recycle and resource recovery". Our report briefly dives into the treatment technologies that ensures reduced burden on fresh water supplies, thereby creating a sustainable closed loop cycle. The water treatment market is in its nascent stage in India and opens opportunities for private investment and the development of new and innovative technologies.

While the technologies are emerging, questions about the financial sustainability and business models behind these water technologies. The section on business models in water and waste water sector focuses on description of most commonly used models such as private sector participation, PPP models and so on for water supply projects for efficient water management practices. Participation of private players is the way forward for developing smart and sustainable water technologies.

There is an urgent need for us to realize the criticality of the situation and its impact on us at present and in the future. In addition to the above aspects, the ASSOCHAM EY report highlights the reforms required with regard to regulatory framework, decentralized model and technological aspects so as to address the unprecedented challenges with regards to water management.

This document on effective water management technologies, aims at bringing together the current water scenario, reasons for concern, policy and regulatory regime, available technologies and probable solutions, best practices and case studies; and more importantly key learnings from these success stories.

Water scarcity is a global concern and an issue that cannot be neglected. It is imperative for policy makers to exchange ideas and adopt best practices and technologies to address this issue.

Balkrishan Goenka
President, ASSOCHAM

There is no doubt that water is one of the important resources on earth and the most essential one for the survival of living organisms and their well-beings. It is also a key resource to many sectors of the economy. Globally, the demand for water is increasing significantly due to population growth, industrialization and changing consumption patterns. Globally, water crisis is fast assuming alarming proportions and there is an imminent need for effectively managing the fast depleting water resources. The World Water Forum aptly summarizes it as, "water is everyone's business"..

India is one of the countries facing severe water crisis, with ground water being the main source of consumption for drinking and irrigation purposes. The resulting stress calls for a radical shift from over-dependence on groundwater to boosting surface water resources by investing in irrigation networks, adoption of recycling technologies and closely monitoring water supply and demand to curb the wastage.

Hon'ble Prime Minister Narendra Modi, indicated that the next five years of his government would be dedicated to water. In line with his promise, Indian Government has proactively initiated the setting up of a Ministry of Jal Shakti, which under its "**Jal Jivan Mission**" and "**Nal Se Jal**" scheme, intend to provide clean drinking water to all households by 2024 and fight India's water woes. This is also aimed at improving its "ease of living" agenda.

In addition to this, schemes on River Linking, Ganga Rejuvenation, the centrally-sponsored Command Area Development Programme (CADP), Accelerated Irrigation Benefit Programme (AIBP) and Dam Rehabilitation are also working on conservation and revival of natural sources of water. One of the key mission that works towards such agendas is the National Water Mission, under the National Action Plan on Climate Change, that involves state-specific action plans and setting up of a National Bureau of Water Use Efficiency (NBWUE). It is well recognized that a proper resource allocation and better water management together would serve to reduce the stress on the already depleting water resources.

In the context of fresh water, the need for water availability becomes more imminent, to ensure social, economic and environmental sustainability. Increasing fresh water demand requires appropriate treatment methods to remove contaminants as required for domestic or industrial purposes. Developed countries have achieved high standards of safety and hygiene in public drinking water supplies, a system which needs to be emulated. The United States has one of the safest public drinking water supplies in the world. Over 286 million Americans get their tap water from a community water system.

Various technological options are being initiated across the globe to treat industrial waste water. These options ensure reduced dependence on fresh water resources and allow a shift towards water treatment efficiencies, especially in those countries where fresh water is scarce.

There is an urgent need to take collective efforts to ensure technological capabilities, policy effectiveness and regulatory framework function seamlessly so as to achieve practical and meaningful solutions. With this report, we intend to initiate a dialogue on harnessing water technology in a larger and more profound context. **ASSOCHAM** and **Ernst & Young Associates LLP** have contributed immensely to publish this report, and we believe that it will be beneficial to all stakeholders.

Message

Saurabh Sanyal
Deputy Secretary General,
ASSOCHAM

India's urban population is estimated to increase from 461 million in 2018 to 877 million in 2050[1] and India's share to the global urban population growth will be the largest between 2018 to 2050[2]. This poses a serious challenge for the government to provide infrastructural facilities and public services of high quality.

Water security is emerging as an increasingly vital challenge for India. According to a report, over 2.1 billion people lack access to clean drinking water. It is expected that two-thirds of the world's population will face water shortages owing to the current consumption patterns. The simultaneous effects of urbanization, agricultural growth and industrialization have resulted in increased stress on this already scarce resource. The problem lies not just with water scarcity but also with the lack of adequate infrastructure for waste water treatment.

Recognizing the need of the hour, India needs to focus on developing innovative solutions for the treatment of water and implement effective business models for the same. Delivery of public utilities is publicly controlled in the country and there needs to be a paradigm shift to decentralize the operations.

We take real pride in organizing a **National Conference and Awards on "Innovative Water Solutions" in New Delhi on 28 June 2019**. The aim of this conference is to create a forum to address the current state of global water challenge and explore opportunities for the exchange of technological ideas and solutions, decision making, policy and sustainability related dialogues for the holistic growth and development of the country.

ASSOCHAM is committed towards driving sustainability and has been engaged in creating such platforms for a larger group of stakeholders. I, certainly believe that this conference would provide a unique and enriching experience for all.

1 https://www.financialexpress.com/opinion/cooperative-federalism-2-0-states-must-decentralise-and-devolve-funds-and-powers-to-cities/1591845/

2 https://www.financialexpress.com/opinion/cooperative-federalism-2-0-states-must-decentralise-and-devolve-funds-and-powers-to-cities/1591845/

Chaitanya Kalia
National leader & Partner
Climate Change and Sustainability Services
Ernst & Young Associates LLP

ASSOCHAM, in association with EY is pleased to present a report titled, **"Think Blue" Effective water management: Integrating innovation and technology**. India is one of the fastest growing economies in the world. It is on its way to becoming the third largest consumer economy by 2025, after the US and China. From water scarcity to water management, there are several challenges associated with this consumption led growth in India.

With India's rising consumerism, natural resource consumption and waste water generation is increasing at an alarming rate. According to the United Nations, most of the world's population will be living in cities by the year 2030. In developing countries like India, urban population growth is high and is growing at twice the rate of overall population growth. Rural urban migration is high with approximately 160,000 people migrating from rural to urban areas every day. The water requirements of this current urban population in India is 740 billion cubic meters per year and by 2030 this figure is expected to increase exponentially.

India is grappling with the problem of water scarcity and the need of the hour is to develop adequate water and waste water treatment infrastructure in the country. If India deploys efficient technology for treatment of water and waste water, then it will be able to significantly increase its water supply availability for both domestic and industrial use. The nature of investment required by the waste water treatment market is high and thus investment by private players is often not forthcoming. Water reuse and recycle is crucial to meet the ever growing demands of the economy. Thus, a concerted effort of the government, private players and individuals is required for effective water management, treatment and conservation.

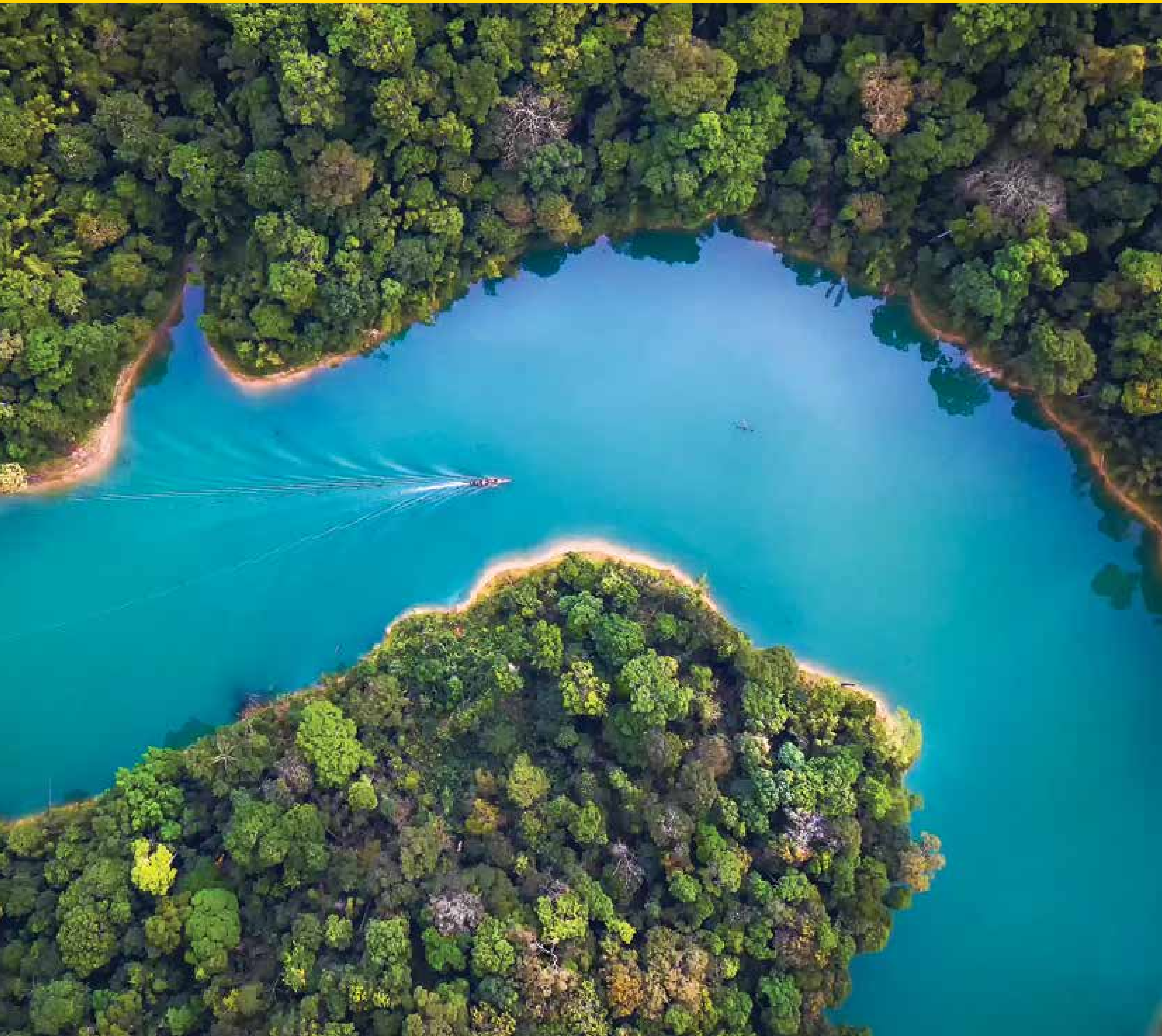
In our report, various technologies for the treatment of water and waste water have been discussed, along with the business models suitable for effective water management in the country. Existing policy frameworks and recommendations have been outlined in the study. The water systems in India are predominantly centralized and capital intensive with limited reach. Moving forward, India can benefit by adopting hybrid systems with both centralized and decentralized facilities. India should adopt an integrated sustainable approach based on increased water tariffs, polluter pays principle, and incentivization of early adopters for addressing the challenging water scenario in the country.

We hope that this ASSOCHAM-EY report will guide all stakeholders to bring about reforms for a sustainable future.

Foreword

3 https://economictimes.indiatimes.com/news/economy/indicators/india-to-become-third-largest-consumer-economy-by-2025-bcg/articleshow/57755835.cms

Section 1:
Background



1.1. Water depletion and burgeoning demand for water

The World Bank describes the present water crisis we are facing as a crisis of "too much", "too polluted", and "too little". "Too much" because the impacts of floods, exacerbated by climate changing is affecting poor people worst, "too polluted" because so much wastewater doesn't get collected or treated and "too little" because globally 2.1 billion[4] people lack reliable access to safely managed drinking water and 4.5 billion[5] people don't have access to safe sanitation. Going forward, the effects of climate change will only make themselves more strongly felt, which will increase the stress on already depleting water resources.

Of the 2.1 billion people lacking reliable access to safely managed drinking water, 844 million[6] do not even have a basic drinking water service. Of the 4.5 billion people who don't have safely managed sanitation, 2.3 billion[7] don't even have basic sanitation. As a result, over 300 million[8] children under the age of five die due to disorders and diseases like diarrhea, cholera, dysentery and typhoid.[9]

The water situation has globally been acknowledged as one of the greatest impediments to development and "Clean Water and Sanitation" has been enshrined in one of the SDG (SDG 06). Clean water is critical to survival and the lack of it has far reaching consequences in health, food security and families around the world. As part of the SDGs, the international community has committed to expand international cooperation and capacity building on water and sanitation related activities and programs. Universal access to safe water and adequate sanitation is the end goal, which is to be achieved by 2030. A sustainable water supply is inseparable from national priorities like reliable energy, resilient architecture and sustainable industrialization.

India is clearly one of the countries which is yet go a long way with regards to SDG06. Between 1992–93 and 2015–16, there has been an increase in access to improved drinking water resources from 68% to 89.9%[10]. There are innumerable reasons given for the water situation today. However, all things considered, this list can be reduced to six main drivers that are responsible for water scarcity:

1. **Climate change:**

   Climate change is a global phenomenon. It is known that climate change is the cause for variability of rainfall patterns and unpredictability of monsoons and disasters on a global scale. Phenomena like Hadley-Cell expansion makes clouds move towards the poles depriving tropical regions of water. Different phenomena with similar consequences are experienced around the world all contributing to the larger scarcity problem.

2. **Increase in population and incomes:**

   With an increase in population and incomes, water demand is expected to increase. By 2050, India's population is projected to grow to 1.5 billion in 2030 and 1.7 billion in 2050. We are currently at a stage where we are not meeting the water demand of existing population. An increase in population will only compound this already complex problem.

3. **Groundwater depletion:**

   30% of the Earth's water is found in underground aquifers[12]. Over the last century, this resource has been extracted excessively for industrial, agricultural and drinking purposes, with no thought for the future. India is the greatest extractor of groundwater, which is why 54% of India's wells are decreasing[13] (being used up faster than being recharged). Unless drastic measures are taken, 60% of wells in the country will be in a critical state in 20 years[14].

4. **Water infrastructure:**

   Availability of water is not the only concern. The processes that make it accessible like transportation, treatment and discharge are equally important. In all countries in the world, there are high levels of water loss due to infrastructure. Leakage in water distribution systems is an important issue which is affecting industries. In the United States itself, there is a daily loss of 6 billion gallons[15] due to leaky taps. Built infrastructure is especially difficult to maintain, so many places simply ignore the problem until disaster strikes.

4 https://www.worldbank.org/en/topic/water/overview
5 https://www.worldbank.org/en/topic/water/overview
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11 https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf
12 https://www.wri.org/blog/2017/08/7-reasons-were-facing-global-water-crisis
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15 https://www.wri.org/blog/2017/08/7-reasons-were-facing-global-water-crisis

5. **Destruction of natural infrastructure:**

   Healthy ecosystems serve as the best buffer against storms/floods and also help regulate water supply. Plants are responsible for water retention in soil and anthropogenic activities like deforestation and overgrazing limits the benefits we can reap from this natural infrastructure. In the past 14 years, watersheds have lost close to 22% of their forests.[16]

6. **Water Pricing:**

   The cost of water, as it is considered today, rarely includes total cost of service, transport, treatment and disposal. The result of this is misallocation of water and inadequate investment in infrastructure and new water technologies.

1.2. Sector-wise water consumption trends

Over the last 30 years, there has been unprecedented economic growth in India. This growth has been characterized by a booming economy, an ever-growing population and large-scale urbanization. These, along with changes in food consumption, lifestyle and land use patterns have played a considerable role determining the country's water requirements. Though India receives ample rain during its monsoons, this rain is not equally distributed. In fact, India can be categorized as "water stressed" with an annual per capita water availability of 1,545 meter cube (anything below 1,700 meter cube is considered water stressed).[17]

India is an agrarian country and therefore, agriculture, or more specifically irrigation is the single largest consumer of water in the country. This is followed by the municipal and industrial sectors. As the country continues to industrialize and grow, the needs of each sector are projected to increase. This increase will be at a rate which is unsustainable because water resources will be used at a rate higher than the recharge rate. This issue will be further exacerbated by climate change, which creates uncertainty and unpredictability about the monsoons and increases vulnerability to natural calamities.

Table 1 shows the sector-wise consumption of water across three-time periods. A brief on the three largest water consuming sectors is given below:

1.2.1. Municipal sector

Very often, mostly in low-income areas, a large proportion of wastewater is discharged without treatment into surface drains. The wastewater that finds itself in these drains includes household effluent and human waste, urban-based hospital waste and small-scale mining, motor garage waste, chemicals, etc. Some of these wastes dumped in the wastewater system are highly toxic. Even in places where collection and treatment is done, the efficiency of treatment varies based on the system being used. This is a problem that needs to be addressed immediately, especially since urban populations continue to grow at a rapid rate. Unless there is a revamping of systems in place, cities will be overrun with untreated wastewater which can otherwise be treated and reused for other purposes. For example, Delhi had adopted aspirational reuse targets to treat and reuse 25% of total sewage produced by 2017[18] and increase the same to 50% by 2022 and to 80% by 2027.[19] Against this background, municipalities across India have started to pursue reuse projects.

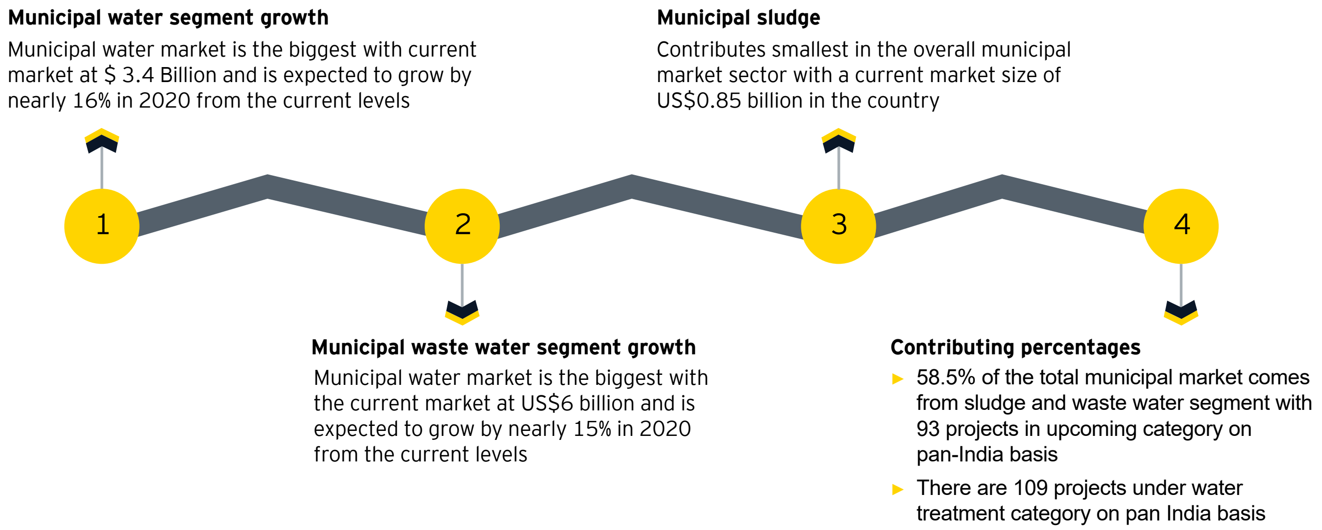
Table 1: Sector-wise projected water demand in India

Sector	Water demand (billion cubic meters)					
	2010		2025		2050	
	Low	High	Low	High	Low	High
Irrigation	543	557	561	611	628	807
Drinking water	42	43	55	62	90	111
Industry	37	37	67	67	81	81
Energy	18	18	31	33	63	70
Other	54	54	70	70	111	111
Total	694	710	784	843	973	1180

Source: UNICEF's report on water situation in India, 2013

16 https://www.wri.org/blog/2017/08/7-reasons-were-facing-global-water-crisis
17 http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/93/CountryReport_India.pdf
18 http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/93/CountryReport_India.pdf
19 EY Research

Figure 1: Trends of municipal markets across value chain



Source: EY Research

1.2.2. Agriculture sector

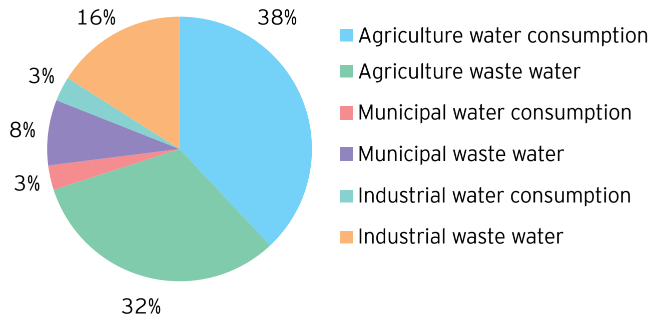
Agriculture is by far the largest consumer of water globally and accounts for 70% of water withdrawals worldwide. India ranks second worldwide in terms of farm output and employs 50% of the country's workforce[20]. More than 80% of India's total water usage goes to agriculture. Over 50% of this water is sourced from underground.[21] This high dependence on groundwater is a concern as extraction rates are exceeding the recharge rates, causing a drop in the water table. The major problem faced in the agricultural sector is the pollution of groundwater and surface water by the agricultural use of untreated wastewater. This is a problem seen predominantly in developing countries. If proper remediation measures are taken, the health of workers can be improved as a result of reduction of risk of exposure to pathogens. However, once adequately treated, this nutrient rich wastewater can be used in agriculture and can play a role in improving farmers' livelihoods and food security.

1.2.3. Industrial sector

Industrial water used to be indiscriminately discharged into water bodies without treatment for a long time before people realized its deleterious impact on both health and the environment. Today, even though such practices continue, the scale at which it is happening is much smaller. Societal and environmental pressures are responsible for this reduction. Various technologies have made it possible for industrial wastewater to be looked at as a resource and not waste, it is even possible to derive some monetary profit from this water.

In developed countries, it was found that water consumption by industries was around 50% of the total water use whereas the same figure for developing countries was 4–12%.[22] It is safe to assume that in the coming years, industrial water consumption in developing countries will shoot up and this reason is enough to ensure that robust wastewater treatment facilities are in place. Some of the uses of treated industrial wastewater include toilet flushing, irrigation, coolant and vehicle washing.

Figure 2: Global water consumption and wastewater generated



Source: The United Nations World Water Development Report, 2017

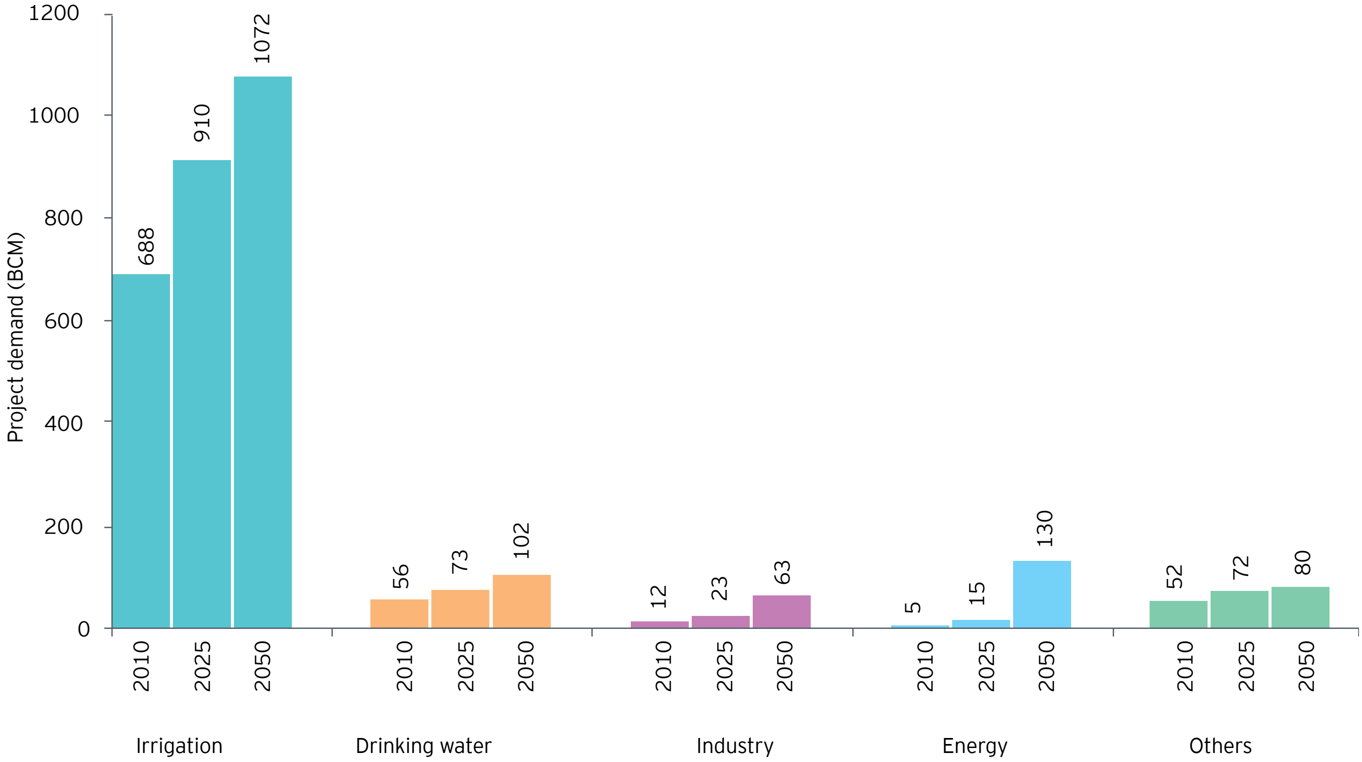
According to an estimate, global fresh water withdrawals amounts to 3,938 billion cubic meter per year of which 44% is consumed and remaining 56% is released as waste water in the form of municipal, agricultural and industrial drainage (Figure 2).

20 https://www.oav.de/fileadmin/user_upload/5_Publikationen/5_Studien/170118_Study_Water_Agriculture_India.pdf
21 https://www.oav.de/fileadmin/user_upload/5_Publikationen/5_Studien/170118_Study_Water_Agriculture_India.pdf
22 http://www.unwater.org/water-facts/quality-and-wastewater/

1.3. Water availability and wastewater generation trends in India

According to an estimate, the total utilizable water in the country accounts to 1,123 billion cubic meters. Approximately 688 billion cubic meters of this water is used for irrigation in 2010 which is estimated to increase to 1072 billion cubic meters by 2050 (Figure 3).

Figure 3: Projected water demand by different sectors



Source: Wastewater production, treatment and use in India, Research paper

India has 2.45% of the land area in the world, is home to 16% of the world's population and accounts for 4% of the water resources of the planet.[23] There is a clear disparity between the demands of the population and the water available, which makes the judicious use and reuse of water important. As mentioned, the total quantity of water available for use in the country is estimated at around 1,123 billion cubic meters out of which 690 billion cubic meters is surface water and 433 billion cubic meters is groundwater[24]. 85% of India's water is being used for agriculture, making it the largest water consuming sector in the country by far[25]. India is a developing country with a growing population. Because of these two factors, the availability of annual water per capita has been steadily decreasing. Given this scenario, where fresh water availability is a challenge both from a quantity as well as a quality perspective, the ideal solution is to reuse and recycle water.

According to an estimate, major Indian cities generate about 0.038 billion cubic meters of sewage a day.[26] However, the combined capacity of all the sewage treatment plant (STPs) is only around 0.012 billion cubic meters per day.[27] Similarly, out of all the industrial wastewater produced in the country, only 60% gets treated. Clearly there is a huge gap between the amount of wastewater generated and the amount treated[28]. It is projected that by 2050, due to increased population and

23 http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/93/CountryReport_India.pdf
24 http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/93/CountryReport_India.pdf
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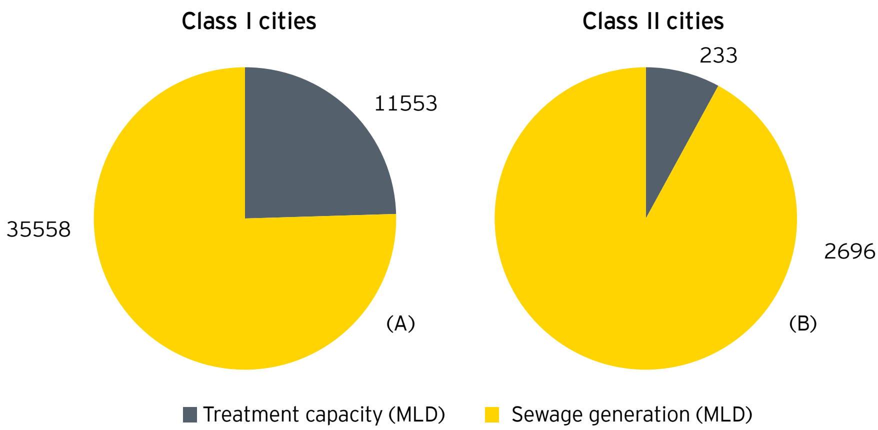
27 http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/93/CountryReport_India.pdf
28 http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/93/CountryReport_India.pdf

industrialization, the amount of wastewater generated will increase to around 0.132 billion cubic meters per day, further widening the gap[29], if the current treatment capacities are not increasing proportionately.

1.3.1. Water and wastewater management-state of play

According to the Central Public Health and Environmental Engineering Organisation (CPHEEO), 70-80% of the total water supplied for domestic use gets generated as waste water. Estimates from Class-I and Class-II cities which constitute 72% of India's urban population, places daily water consumption per capita at 98 liters. As per CPCB reports, total wastewater generation from Class I and Class II towns in the country accounts to 35,558 and 2,696 million liters per day respectively. When this figure is compared with the capacity of all the sewage treatment facilities in these cities, i.e., 11,553 and 233 million liters per day, it is found that full capacity is reached and 26,468 liters of water are left untreated. UNESCO and World Water Assessment Program (WWAP) have estimated that India has the lowest industrial water productivity in the world. In the coming years, the country will be faced with a twin-edged problem, an unavailability of fresh water and an excess of wastewater.[30]

Figure 4: Sewage generation and treatment capacity in 498 Class I cities and 410 Class II cities in India



Source: Central Pollution Control Board, 2009

SNAPSHOT

1,545 meter^3: Low per-capita water availability

20%: Groundwater blocks critical or overexploited

55%: Households have no or open drains

91%: of 302 river stretches polluted, high health impacts

37,000 MLD: Untreated sewage flows

8.5% and **10.1%**: Freshwater abstraction by industries in 2025 and 2050, respectively

23%: Industries do not get water easily or at high costs

In India, there are 234 STPs.[31] Most were developed under river action plans and are located in cities along major river banks. The technologies employed to treat most of the waste water is the "Activated Sludge Process" and "Anaerobic Sludge Blanket Technology". Waste Stabilization Pond Technology, a treatment system favored by the World Bank, are used in 28% of STPs in the country.[32]

When it comes to industries, about 0.013468 billion cubic meters of wastewater is generated daily, of which 60% is treated.[33] In the case of small scale industries, which cannot afford wastewater treatment plants, central effluent treatment plants (CETPs) are used. The most commonly used treatment techniques are dissolved air flotation, dual media filter, activated carbon filter and tank stabilization. Treated water from CETPs are discharged into rivers.

29 http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/93/CountryReport_India.pdf
30 http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/93/CountryReport_India.pdf
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33 http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/93/CountryReport_India.pdf

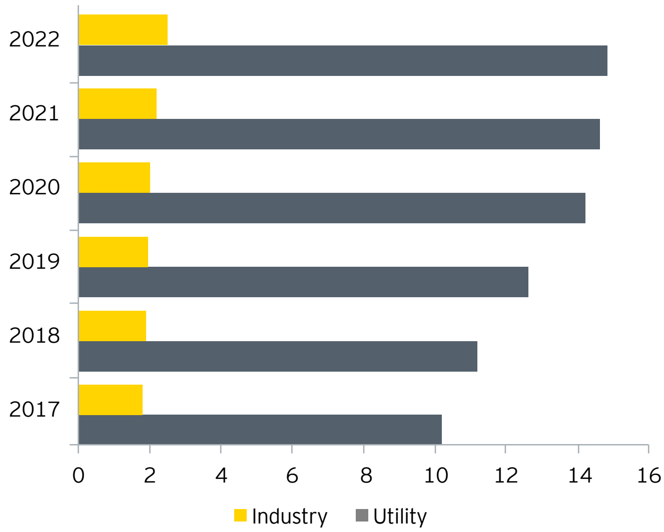
Conventional water treatment processes are expensive and require lot of maintenance. Sludge removal, treatment and handling have been observed to be the most neglected areas in the operation of the STPs in India. The treatment facilities created for wastewater from all sources suffer from issues like improper design, poor maintenance, frequent electricity breaks and a lack of manpower. Consequently, many of these facilities do not function properly or are shut. Secondly, none of the presently available technologies employed offer a direct return. This discourages private players from investing in this area.

1.3.1.1. Water and wastewater market in India – by size

The water market is majorly governed by the municipal segment which falls under the utility sector. The utility market is set to top US$14 billion within five years, while annual spending in the industrial sector is estimated to approach US$2 billion. The wastewater treatment sector is expected to grow faster than water treatment, due to the central and state government's renewed drive in mitigating and eliminating the pollution in India's rivers, exhibiting a CAGR of 15.3% to reach US$6.78 billion in 2020, up from US$3.3 billion in 2015. Spending on water supply will grow from US$5.56 billion to US$9.4 billion over the next five years.

The cumulative water and wastewater capex increased by **~71% from 2013 to 2017** and is expected to increase by **~59% in 2022 from 2013** levels. It is to be noted that the forecasted cumulative expenditure is expected to reach US$17.3 billion[34].

Figure 5: Water and wastewater capex



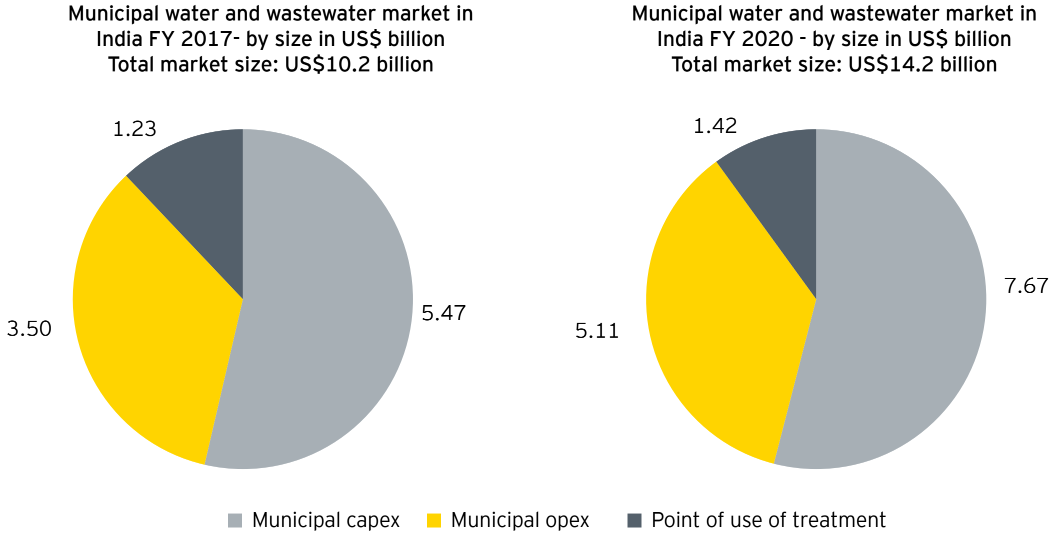
Source: EY research

34 EY research

1.3.1.2. Municipal water and wastewater treatment market in India – by size

Municipal capex contribution is ~ 34 % and municipal opex is ~ 54% in the overall expenditure outlay for water and wastewater market[35].

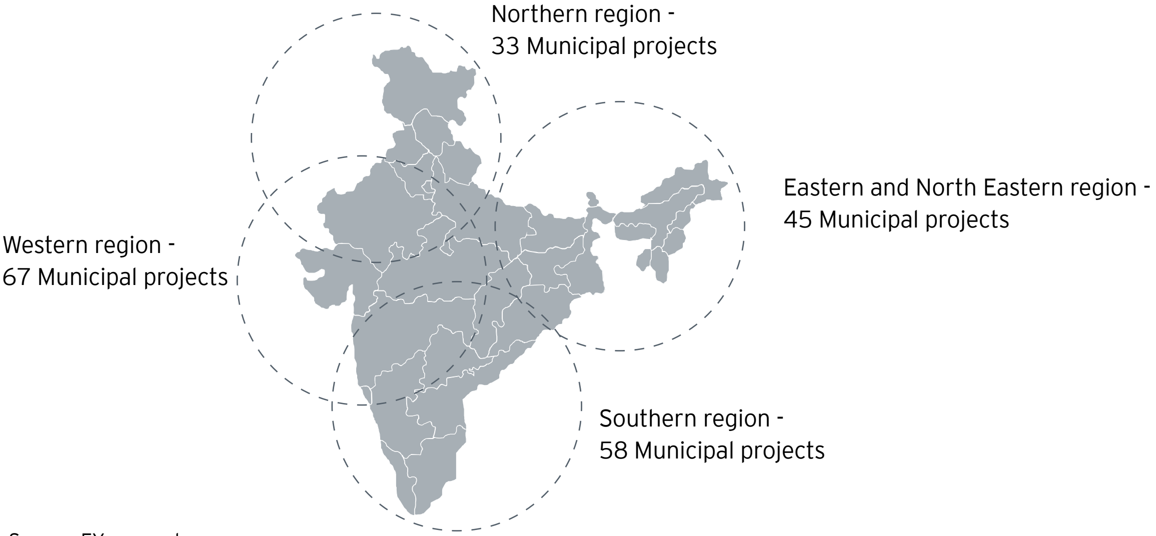
Figure 6: Municipal water and wastewater market



Source: EY Research

1.3.1.3. Municipal water and wastewater treatment market in India – by volume

There are 203 municipal projects in the upcoming category with the regional split as 33 in northern region, 45 combining eastern and north-eastern region, 67 projects in western and 58 in southern region of the country[36].



Source: EY research

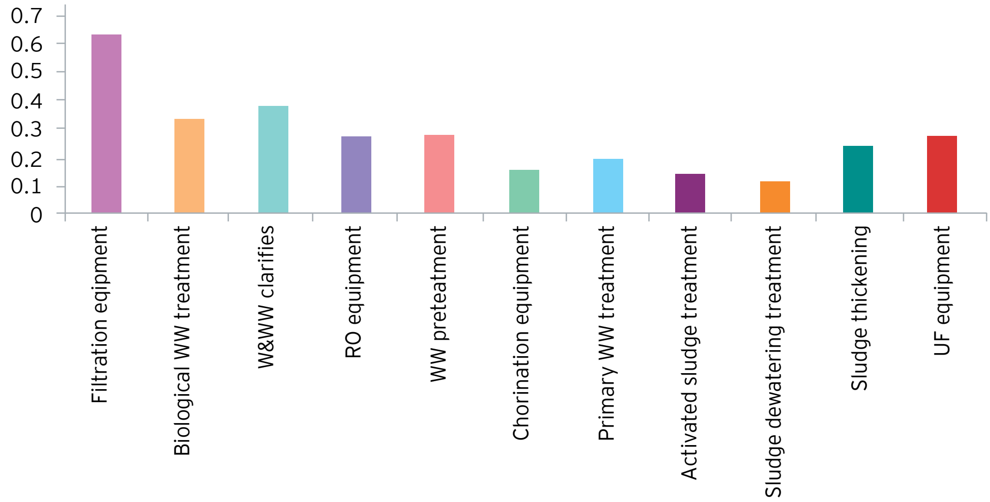
From the above exhibit, we can conclude that the **Western region**, in terms of opportunity, has the highest potential in the country for the municipal category which constitutes more than 88% of the entire opportunity space for water and wastewater market in India.

35 EY research
36 EY research

1.3.1.4. Municipal water and wastewater treatment market in India – by equipment

The exhibit below shows the trends in market sizing and forecasts for municipal water &and wastewater equipment market in India (US$ billion) by equipment.

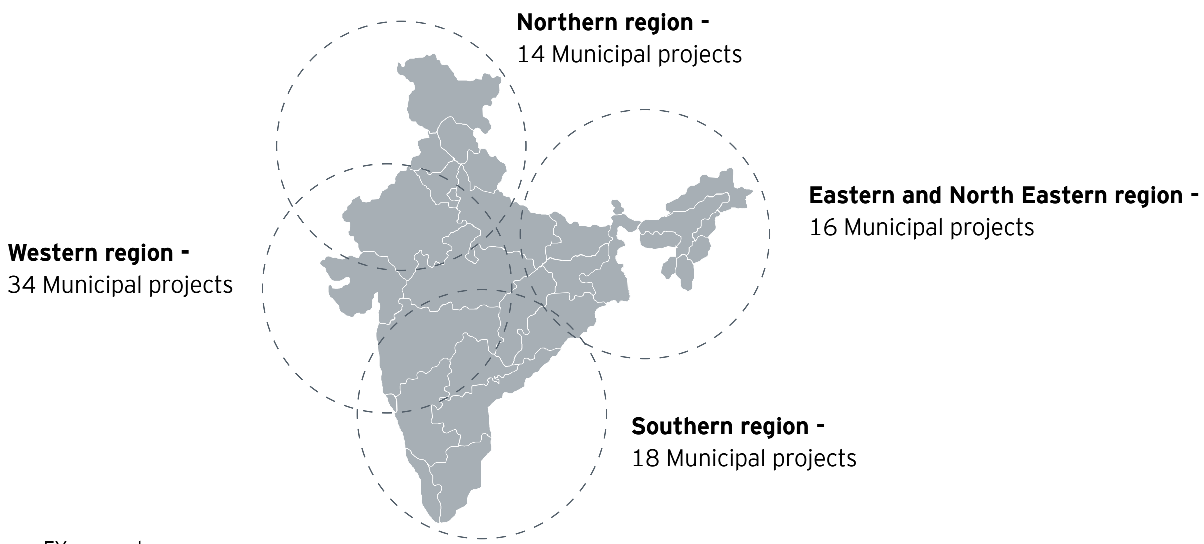
Figure 7: Municipal water and wastewater equipment market for 2020



Source: EY Research

1.3.1.5. Industrial water and wastewater treatment market in India – by size

In India, the refinery and power generation sectors are deemed to be highest opportunity segment for water and wastewater treatment. Further, the food and beverage segment has evolved to be one of the highest grossing opportunity part of the industrial sector over the last decade. For the study of the market size, the projects were mainly considered across refinery and petrochemicals, power generation, steel, food and beverage and pharma sectors.



Source: EY research

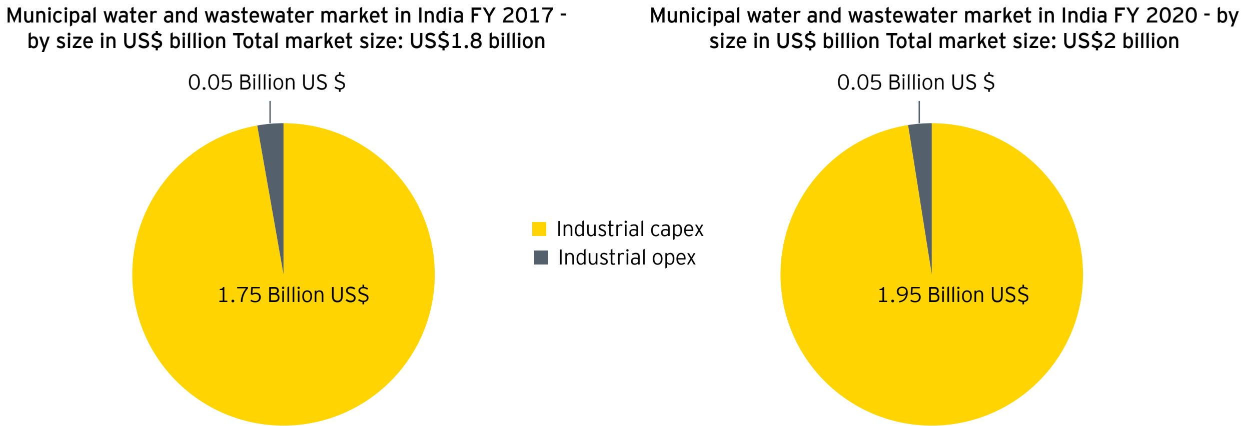
1.3.1.6. Industrial water and wastewater treatment market in India – by volume

India has several upcoming industrial projects across the following sectors:

- Thermal plants
- Refinery and Petrochemical plants
- Steel production plants
- Food and beverage plants
- Pharma units

There a total of 82 projects with the regional split as 14 in northern region, 16 combining eastern and north-eastern region, 34 projects in western and 16 in southern region of the country[37].

Figure 8: Industrial water and wastewater treatment market in India – by volume



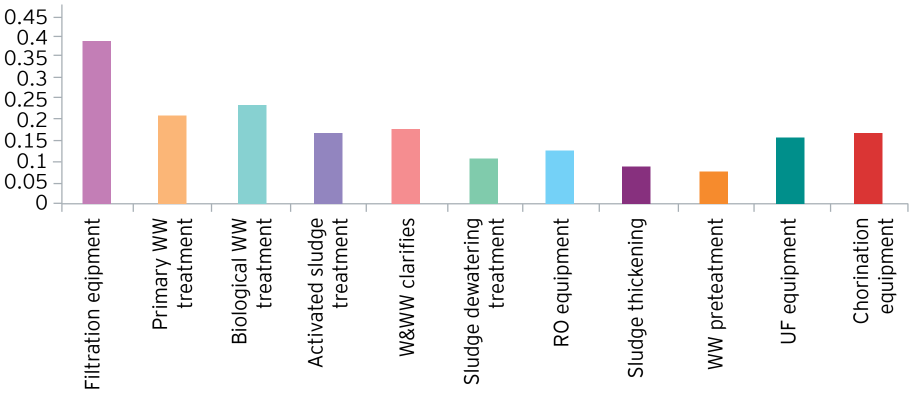
Source: EY research

Western region in terms of opportunity offers highest potential in the country for industrial category which constitutes more than 42% of the entire opportunity space for W&WW market in India .

1.3.1.7. Industrial water and waste water treatment market in India – by equipment

The exhibit below shows the trends in market sizing and forecasts for industrial water and waste water equipment market in India (US$ billion) by equipment.

Figure 9: Industrial water and wastewater equipment market for 2020 – by equipment



Source: EY research

37 EY research
38 EY research

Realizing the importance and scarcity attached to fresh water, it is essential in sustaining all life forms. The forthcoming section highlights the current regulatory framework pertaining to the water sector at a central and state level. It gives a brief on how the current water policies deal with the complex situation characterized by water scarcity and increasing demand.

1.4. Other related areas

1.4.1. Water-energy nexus

Particular to the Indian context is the water-energy-food nexus, as subsistence and food security demands exert further pressure on water resources. A sound understanding of the nexus may shed light on the susceptibility to climate change. Climate change is going to affect the availability of water both spatially and temporally. This will directly affect the nexus since local variations in climatic conditions will have an impact of the production of biofuels, hydro-energy and so on. Given that it is the use of fossil fuels that is driving climate change, we can again see how producing energy in a certain manner has consequences on the availability and accessibility of water. Many parts of India, as mentioned earlier, are water scarce. With the advent of climate change, this scarcity has become more pronounced, with unpredictable rainfall and monsoons. In a water scarcity situation, some argue that power generation will come at the cost of other uses. To further compound this program, India's largest water consuming sector, agriculture, has a highly inefficient system (yield/unit input). Such inefficiencies coupled with the over-extraction of groundwater (a common property resource), causes stress to this finely balanced water-energy nexus, which could have disruptive long-term consequences.

Some possible solutions to this problem in an Indian context are as follows:

- Changing India's energy mix to include a higher proportion of renewables and nuclear energy
- Streamlining of subsidies to make sure that those who need them receive them
- Adoption of climate smart agriculture policies like the growth of less water intensive crops and import of water intensive crops
- Incentivize farmers to adopt more efficient agricultural practices

1.4.2. Water and sanitation

Water and sanitation related diseases are common globally due to poor hygiene. As discussed, more than 4.5[39] billion lack access to safely managed sanitation. The impact of this is devastating as millions of people die due to poor infrastructure, inadequate water supply and hygiene which in turn will lead to further losses in biodiversity and ecosystem resilience, undermining prosperity and the efforts towards a more sustainable future. Open defecation is a cause of concern as it leaches into the water sources and causes negative health impacts on communities. To ensure clean water and sanitation for all, we need to invest in adequate infrastructure for sanitation and encourage hygiene at every level.

To address the issue, access to water and sanitation will help drive progress toward the sustainability development goals. Businesses should also commit to the WASH (water, sanitation and hygiene) pledge by the World Business Council on Sustainable Development (WBCSD). When corporates commit to the WASH pledge, they commit to implementing access to safe water, hygiene and sanitation at the workplace[40]. The Sustainable Development Goals, includes Goal 6 for clean water and sanitation for ensuring their availability and sustainable management. A country like India will be highly productive if all its population have access to clean drinking water and improved sanitation and if scientific hygienic habits are adopted.

1.4.3. Smart cities

Making cities smarter is emerging as a key area of focus for governments. A smart city can be described as a city equipped with the core infrastructure with digital transformation to create a clean and sustainable environment. The idea is to tap a range of approaches such as digital and information technologies to create a difference . As a part of the smart city development, improvement in the water supply infrastructure and quality are top priorities. Smart city mission is an initiative undertaken by the Government of India with a mission to develop 100 smart cities across the country by harnessing technology to create smart solutions. The Smart City Mission will be operated centrally and the central government proposes to give financial support to the mission. Following are the objectives to facilitate better water availability in the proposed smart cities:

- To achieve 24×7 water supply
- To achieve adequate pressures in the systems

39 https://www.worldbank.org/en/topic/water/overview

40 https://www.wbcsd.org/Programs/Food-Land-Water/Water/WASH-access-to-water-sanitation-and-hygiene/WASH-at-the-workplace-Pledge

- Quality of water to be as per IS 10500
- To implement smart billing, collection and supervisory control and data acquisition (SCADA) system
- Operation and maintenance of the improved water supply set up

Water management is one of the core areas in the smart city mission. Smart meters and management, leakage identification, preventive maintenance and water quality monitoring are some of the areas of intervention[42].

1.4.4. Rural water management

The inadequate availability of safe drinking water in rural India has become an urgent threat to the physical and economic health of the country. Access to safe drinking water is inadequate and inconsistent in rural India. Despite allocating significant water resources by the government, the delivery of water sources remains a challenge due to high costs and failure rates.

The Swajal Scheme[43], launched by the Government of India, in the year 2018, aims at providing clean drinking water to the rural areas, covering over 115 districts across India. Similarly, the Swatch Bharat Mission (SBM) focuses on sanitation. The SBM Gramin has (as on October 2014), built 961.58 lakh toilets, with a 60% increase in households with toilets[44].

In addition, some organizations are taking initiatives to deploy community-level solutions for creating affordable access to clean water for underprivileged communities. Water ATMs is one such innovative and reliable water solution to improve the life of people residing in remote areas of the country. These ATMs ensure safe drinking water is made available for 20 paisa per liter. As a part of rural water management programs, water purification units and solar powered water ATMs are being installed schools.

Most of these initiatives are being undertaken as part of the Corporate Social Responsibility (CSR) initiatives of corporates. However, the intent and penetration of some of these programs are commendable and are meeting the goal of providing access to safe water to rural communities.

Another such initiative is the watershed management programs, wherein efforts are made to increase the water table and develop man-made structures (bunds, tanks, etc.) for water storage. These are mainly for agricultural purposes.

The demand for process water treatment and waste water treatment is increasing in India as industries feel the need for uninterrupted and continuous water supply. The water business in India has risen exponentially with the rising water shortages and companies are entering into the market with innovative technologies and solutions. This opens the possibility for new project structures and inflows of private investment and provides powerful incentives to devote more resources to develop promising technologies. Indian entrepreneurs are taking note of these opportunities and are seeking ways to work with the government and other private partners to support the growth of this nascent market together and, in so doing, contribute to the sustainable development of this sector in India

Technological innovations offer hope for this sector as services around smart water management is recognized as best bet in reducing massive water losses in pipes and shrinking overall water consumption.

41 http://smartcities.gov.in/upload/uploadfiles/files/What%20is%20Smart%20City.pdf

42 http://smartcities.gov.in/upload/uploadfiles/files/What%20is%20Smart%20City.pdf

43 https://www.indiatoday.in/education-today/gk-current-affairs/story/government-launches-schemes-to-provide-clean-water-to-rural-districts-1263307-2018-06-18

44 https://sbm.gov.in/sbmReport/Home.aspx

Section 2:

Legal and policy framework for water

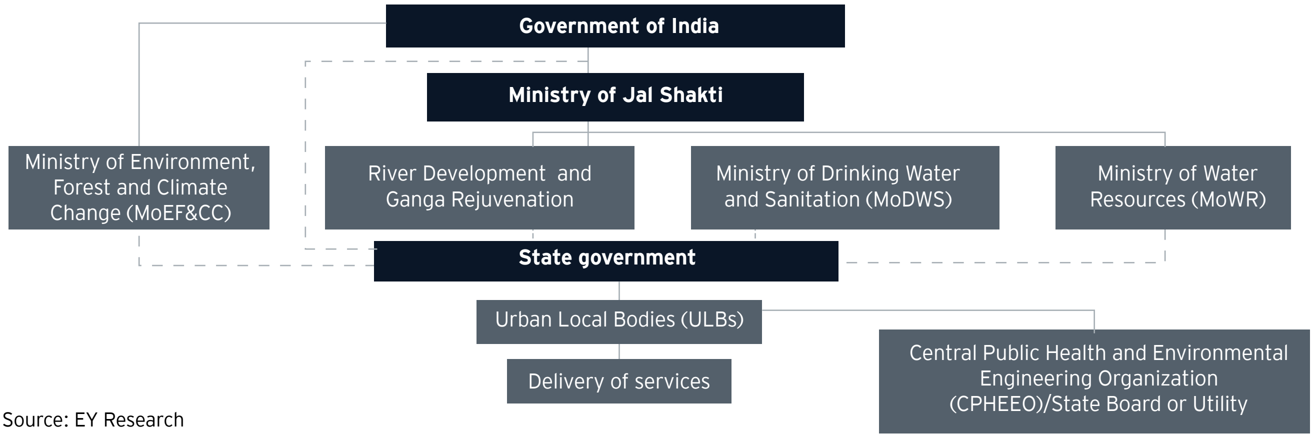
National water management policies are extremely important from legal and institutional perspectives as these reflect the direction of the government in context of water resources planning and management. To minimize and limit the negative impacts of the overuse and misuse of water and to ensure to guarantee that our valuable water assets are utilized ideally; it is necessary that we have a water policy which recognizes and adequately addresses the challenges we face and are going to face with regard to water consumption and reuse.

In India, there is policy support for recycling and reuse of water. It began with regulating industrial water consumption and enforcing mandatory water reuse targets for industries. Cities have set their own, stringent targets. The Ministry of Jal Shakti, Government of India (Ministry), is responsible for the formulation and administration of rules and regulations relating to the development and regulation of the water resources in India. The Ministry of Jal Shakti was formed by merging the Ministry of Water Resources, River Development and Ganga Rejuvenation and Ministry of Drinking Water and Sanitation; with an aim of bringing together all program working in the areas of water and related issues, under one Ministry[45].

The newly formed ministry, aims at reaching 100% tap water availability in India by 2024; from its current state of 18%. In addition, 14 crore households are to be receiving clean drinking water as per the plan[46].

Further, there are several other central government bodies with roles in the water sector relating to planning, policy formulation, monitoring of water quality, standard setting, research and development, project development, etc.

Figure 10: Institutional structure for water and wastewater in India

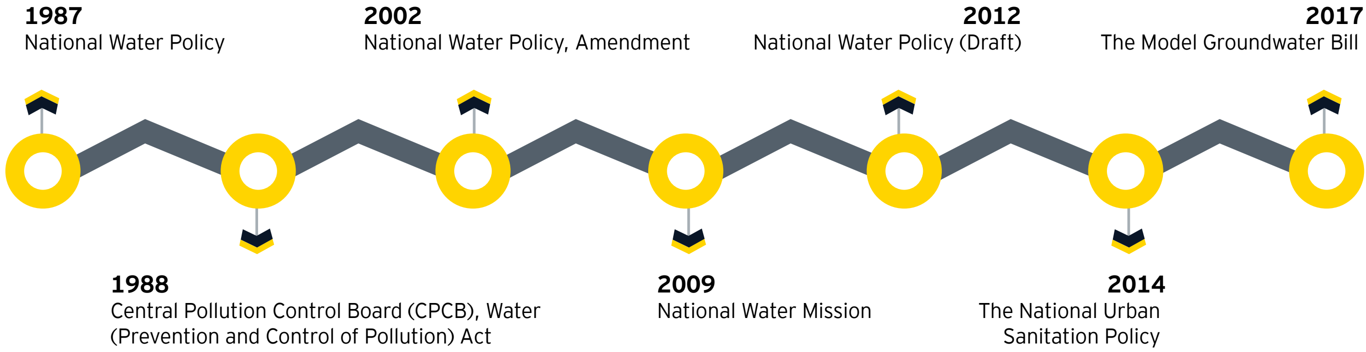


Source: EY Research

There have been two major policy responses from the government to address the said issues faced in the current water consumption scenario and for effective management of the country's water resource:

- National Water Policy (1987, 2002, 2012)
- National Water Mission (2009)

Figure 11: Evolution of water policies in India



Source: EY Research

45 https://www.downtoearth.org.in/news/water/government-launches-new-jal-shakti-ministry-64869
46 https://www.news18.com/news/india/drought-alert-in-6-states-but-indias-first-jal-shakti-minister-says-water-scarcity-a-media-creation-2182305.html

2.1. National Water Policy (NWP)

The Government of India drafted national water policies in the years 1987, 2002 and 2012. Every draft was considered as a push to improve the past strategies to address the contemporary difficulties and to apply cutting-edge innovation and technologies to manage nation's water assets.

NWP 2002 has graduated from the NWP 1987. The policy talks about the incorporation of the integrated IWRM. The policy recognizes that water is a scarce and precious natural resource and needs to be planned, thereby, it emphasizes developing management strategies for the conservation of water keeping in view the socio-economic aspects and the needs of the states. Considering the largescale use of water in agriculture and the fact that water rights in India are loosely linked with land rights, policy also talks about the integration of the water use and land use policies. The policy holds central and state government equally responsible for preventing the detrimental overexploitation of water. The policy is also vocal on the issue of seeking scientific and technical assistance for the water sector development and planning through public private partnership on need basis.

Be that as it may, there are yet numerous issues on which there is no unanimity among the experts and few open-ended queries still exist. The principle components of every one of the national water drafts, beginning from 1987, have been given in table 2.

Table 2: Comparison of provisions of National Water Policies 1987, 2002 and Draft National Water Policy (2012)

Principle components of India's National Water Policy		
1987	**2002**	**2012**
Priority given to supply of drinking water development of information systems	Priority given to supply of drinking water	Priority given to supply of drinking water
Conservation of resources	Limiting ground-water exploitation	Water as an economic need
Emphasis on multi-purpose Projects	Monitoring and enforcement of water quality	Management initiatives
Periodic assessment of ground-water	Increased private participation	Efficiency of water usage
Water supply rates	Access to commercial borrowing	Volumetric pricing of water & establishment of water regulation authorities

Source: Riding the wave, EY

2.2. National Water Mission (NWM)

Environmental change is probably going to antagonistically influence the water balance across India due to changes in precipitation, rising ocean levels and rising sea levels. The NWM, a defined mission of the National Action Plan on Climate Change (NAPCC), identifies the risk to water assets in India due to climate change.

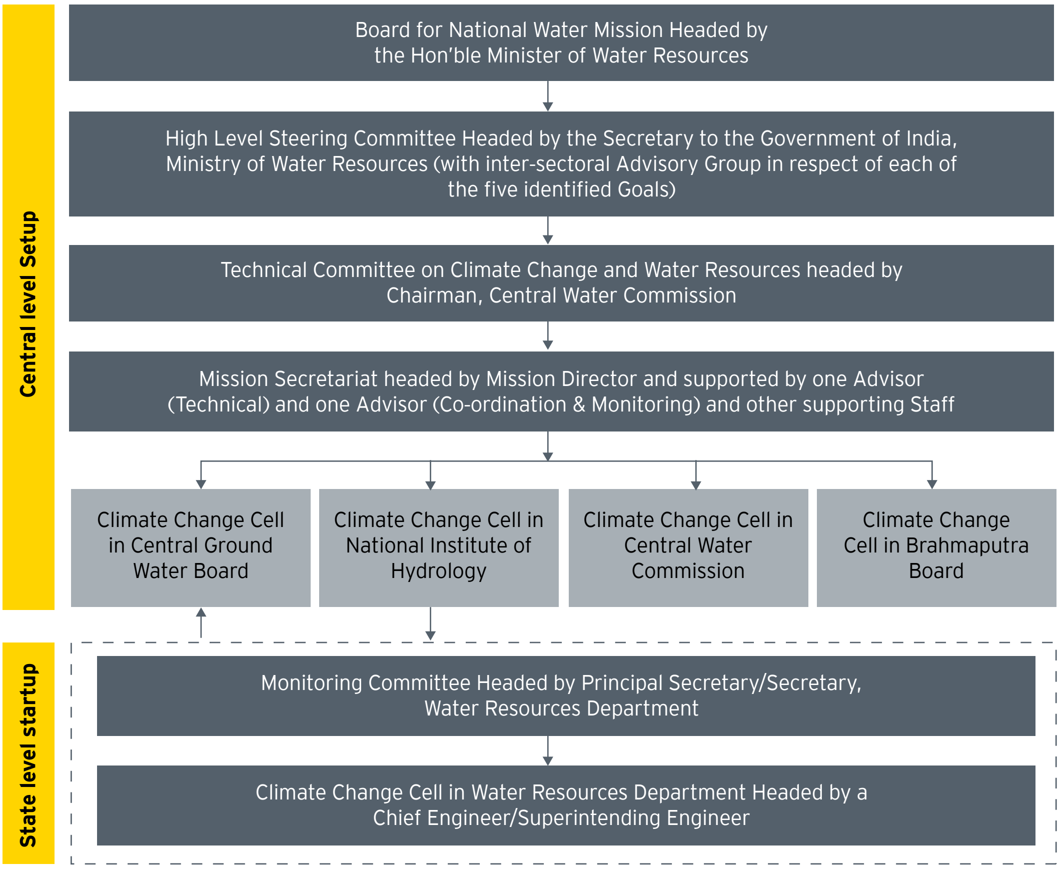
The NWM has been envisaged within the NAPCC, with the core objective of "conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within states through integrated water resources development and management". The NWM mission outlines five goals across which major initiatives have been envisioned and aligned pertaining to the development and management of water resources in the country:

1. Create comprehensive water database in the public domain and assess the impact of climate change on water resource
2. Promoting citizen and state action for water conservation, augmentation and preservation
3. Focusing attention on overexploited areas
4. Increasing water-use efficiency by 20%
5. Promoting basin-level integrated water resources management

Some of the Initiatives taken under NWM are as follows[47] :

1. Implementation of project India-WRIS WebGIS would enable generation of database and implementation of web enabled water resources information system in the country) This aims at receiving a consistent and comprehensive data on India's water resources. It is a joint venture by Indian Space Resource Organization (ISRO), Central Water Commission, Ministry of Water Resources (MoWR) and central government
2. Allocation of fund up to INR50 lakhs by NWM to the states to help them formulate and implement their state specific action plans (SSAP)
3. Analysis of irrigation projects baseline studies are being carried out

Figure 12: Institutional setup for National Water Mission



Source: National Water Mission, NAPCC draft, 2008

47 http://www.indiaenvironmentportal.org.in/files/file/coping-climate-change-NAPCC.pdf

2.2.1. Key activities and achievements

Some of the key achievements under NWM policy until 2017 is detailed out in Table 3

Table 3: Major achievements under NWM policy

Activities	Targets	Achieved
Establishment of hydrological observation station	800 in 2012-2017	702 till 2016-17
Establishment of new groundwater monitoring wells	9,360	6,376
Restoration of water bodies (INR264.67 crore was released for this)	10,000	1,237 were restored till March 2017
Establishment of forecast station	100	24
Work on SSAP	Complete in all 29 states & 7 UTs	Just begun not completed fully in any states
Establishment of water quality monitoring stations	113	36
Training sessions conducted	-	668 till March 2017
Number of stakeholders trained	-	56,768 till March 2017
Number of baseline studies in irrigation sector in progress (till March 2017)		21

Source: Indian Environmental portal

Some of the other developments were undertaken to conserve and efficiently manage the water resources.

1. To protect, conserve, manage water resources, a national law on water National Water Framework Bill was proposed in 2016
2. To provide the local institutions their right and duties on groundwater the modal Groundwater (Sustainable Management) Bill was passed in 2017.

Groundwater, being an increasingly important source of freshwater in India, is exploited extensively mainly for irrigation and drinking water needs. This exponential increase in groundwater extraction over the past few decades has led to deterioration in water quality and quantity. As per the Central Ground Water Board (CGWB) data, there is a rapid fall in water tables over the past decade with a fall of two to four meter in 61 percent wells between 2007 and 2017 .

To ensure that groundwater is protected, conserved and regulated, the Union Ministry of Water Resources has set up a modal bill for conservation, protection and regulation of groundwater. According to this modal bill, groundwater is no more a private property resource and will be considered as a common pool resource. "State" has been given the status of a trustee of groundwater in their jurisdiction. It is a decentralized administrative structure where gram panchayat is authorized to manage groundwater resources. Objective of this bill are as follows:

a) Guarantee the acknowledgment of the fundamental right to life through the provision of water

b) To meet food security, livelihoods, basic human needs, livestock and aquatic life

c) cProtection of biodiversity and ecosystem

d) Prevention of groundwater depletion and contamination

48 http://www.indiaenvironmentportal.org.in/files/file/coping-climate-change-NAPCC.pdf

49 http://cgwb.gov.in/Ground-Water/GW%20Monitoring%20Report_January%202016.pdf

2.2.2. State acts and regulations

Out of 30 states and five union territories the country, most of the states have passed acts and regulations with respect to ground water[50]

- Andhra Pradesh Ground Water (Regulation for Drinking Water Purposes) Act, 1996, and the Andhra Pradesh Water, Land and Trees Act and Rules, 2002
- Bihar Groundwater (Regulation and Control of Development and Management) Act, 2006;
- Delhi NCT Groundwater Regulation Directions, 2010
- Goa Ground Water Regulation Act, 2002;
- Himachal Pradesh Ground Water (Regulation and Control of Development and Management) Act, 2005
- Jammu and Kashmir Water Resources (Regulation & Management) Act, 2010, and J & K State Water Resources Regulatory Authority Regulations, 2013
- Karnataka Ground Water (Regulation for Protection of Sources of Drinking Water) Act, 1999, and the Karnataka Ground Water (Regulation and Control of Development and Management) Act, 2011
- Kerala Ground Water (Control and Regulation) Act, 2002
- Lakshadweep Ground Water (Development and Control) Regulation, 2001
- Maharashtra Groundwater (Regulation for Drinking Water Purposes) Act, 1993, and the Water Resources Regulatory Authority Act 2005
- Puducherry Ground Water (Control and Regulation) Act, 2002
- Tamil Nadu Groundwater (Development and Management) Act, 2003 and Chennai Metropolitan Area Ground-water (Regulation) Act, 1987
- Maharashtra Management of Irrigation Systems by Farmers Act, 2005
- West Bengal Ground Water Resources (Management, Control and Regulation) Act, 2005

In the following states a bill from the legislature has been adopted but at the time of writing not yet passed or received the final assent:

- Assam Ground Water Control and Regulation Act, 2012 (yet to be notified)
- Chhattisgarh Ground Water (Regulation and Control of Development and Management) Bill, 2012 (pending)
- Haryana Groundwater Management & Regulation Bill, 2011 (pending)
- Maharashtra Groundwater (Development and Management) Bill, 2009 (awaiting the Governor's assent)
- Odisha Groundwater (Regulation, Development and Management) Bill, 2011 (pending)
- Uttar Pradesh Groundwater Conservation, Protection and Development (Management, Control and Regulation) Bill, 2010 (pending)

Many states have adopted highly specialized formal groundwater law that regulates the irrigation sector only:

- Gujarat Irrigation and Drainage Bill, 2013 (seeks to replace and repeal the existing Gujarat Irrigation Act of 1879, but will only regulate groundwater pumped for farming purposes)
- Haryana and Punjab (both) Preservation of Subsoil Water Act, 2009 (prohibiting sowing of nursery paddy (rice) and transplanting paddy into the fields before notified dates in order to reduce groundwater use)
- Madhya Pradesh Irrigation Act, 1931

50 http://www.watergovernance.org/wp-content/uploads/2015/06/2013_No3_Groundwater_Governance_India.pdf

Implementation of rules and arrangement of water administrations is intrinsically a state subject in India, with states overseeing the water supply management. However, there is a wide variation in the types of institutions engaged in supplying water between and within different states.

Table 4: Institutional bodies engaged in supplying water and provisioning at the state level

Agency type	Jurisdiction	Responsibility		
		O&M	Capital works	Examples
State-level Specialist Agency (SSA)	▶ Entire state ▶ Large cities	▶ City-level specialist agency	▶ SSA ▶ SSA	▶ Kerala ▶ Uttar Pradesh
SSA	▶ Small cities	▶ Local government	▶ SSA	▶ Karnataka, ▶ Maharashtra ▶ Tamil Nadu ▶ UP ▶ Delhi
Public Health Engineering Departments (PHED)	▶ Entire state ▶ Small cities	▶ Local government	▶ PHED ▶ PHED	▶ Rajasthan ▶ Andhra Pradesh
Municipal departments	▶ Large municipal corporations	▶ Municipal department	▶ Municipal department	▶ Gujarat ▶ Tamil Nadu ▶ Andhra Pradesh
Metropolitan Level Specialist Agency (MSA)	▶ Metropolitan centers	▶ MSA	▶ MSA	▶ Bangalore, ▶ Chennai ▶ Hyderabad
Specialist Municipal Undertaking (SMU)	▶ Metropolitan centers	▶ SMU	▶ SMU	▶ Mumbai Metropolitan Area

Source: Riding the wave, EY

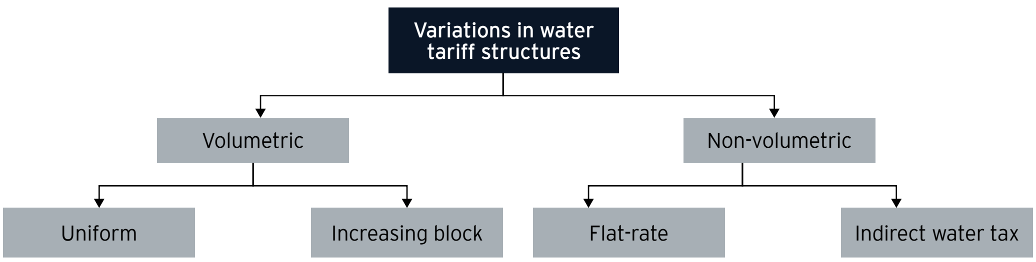
2.2.3. Water pricing and tariff structure in India

Water tariff structures varies state to state and across institutions in their provision. The current tariff structure in India is not suitably designed to accomplish their principal objectives. They are unable to generate sufficient revenues to recover even the financial cost of utility.

- Setting water tariff requires that one strikes a balance between four main objectives.
- **Cost recovery**: It should produce revenue equal to the financial cost of supply
- **Economic efficiency**: Prices signal to the consumers the costs of water usage
- **Equity**: It treats similar customers equally and customers in different situations differently
- **Affordability**: It shall be provided to the poor at price which they can afford using subsidies
- **Simple**: It should be simple and easy to understand and implement

The various mechanisms for levying water tariffs in India are summarized in the diagram below.

Figure 13: Water tariff structure in India



Source: EY Research

2.2.3.1. Key challenges in water pricing and tariff structure in India:

- Non- volumetric water tariff structure is dominant across most of the sates. They do not reflect the true cost of water supply because under this structure water tariff is charged as per the plot size over which water is supplied or as a certain percentage of the regional property tax rate
- The areas that follow water volumetric tariff structure face difficulties due to absence of effective metering structure
- The water tariff structure is not even same for different user groups. For example- Industries are charged six to seven time's higher tariff than the domestic user group whereas agricultural tariffs are highly subsidized
- Water tariffs are not revised on a continuous basis due to which the states are unable to come up with an accurate water pricing structure
- The currently prevalent water tariff structure has no provision of awarding or incentivizing the users who effectively manage their water resources neither the defaulters are penalized

State initiatives

- Maharashtra is leading in the process of water trading in India. MWRRA is authorized to establish, regulate and enforce water entitlements across domestic, industrial and agricultural users in the state
- Odisha adopted Orissa Water Consolidation Project (OWRC) under the banner of Farmers Organization and Turnover (FOT) with an objective to promote and secure equitable distribution of water among its users, adequate maintenance of irrigation system, efficient and economical utilization of water to optimize agricultural production and to protect the environment and to ensure ecological balance[51]
- The Gujarat government unveiled its "Reuse of Treated Waste Water Policy" which aims to reduce the state's dependence on freshwater sources like the Narmada River. The policy will promote the use of treated wastewater and will see the setting up of STP in all major towns and cities of Gujarat
- Rajasthan has climbed the ladder in the federal think tank NITI Aayog's composite water management index (CWMI). Rajasthan was able to improve its ranking because of transformational state water policies such as Mukhyamantri Jal Swavlamban Abhiyan (MJSA) and effective irrigation management –integrated irrigation solutions. MJSA is a multi-stakeholder project, which aims to make the remotest of the villages in the state water-sufficient, by focusing on reviving water bodies, increasing groundwater levels, and providing clean drinking water[52]

2.3. Sustainable Development Goals (SDGs)

As mentioned in the Introduction, SDG 6 - Clean Water and Sanitation emphasizes the equitable access, efficiency, and integrated management of water resources to all sections of society. SDG 6 also has a target on improved water quality through elimination of hazardous chemicals. While SDG 6 is the core SDG for action on water, there is also SDG 15 - Life on Land, SDG 14 - Life Below Water. Both SDG's focus on the maintenance of ecosystems and species. In particular, SDG 15 stresses on the importance of conserving inland freshwater ecosystems. In addition to the above, there are closely related SDG's, particularly SDG 12 - Responsible Consumption and Production, which has a target on the sound management of chemicals and waste and reduce their impacts on water resources. SDG 11 - Sustainable Cities and Communities is also connected with building systems for resilience against water-related disasters.

6	11	12	14	15
Clean water and sanitation	Sustainable cities and communities	Responsibile consumpton	Life below water	Life on land

Source- United Nations Development Program (UNDP), sustainable development goals (https://sustainabledevelopment.un.org/)

51 https://niti.gov.in/writereaddata/files/document_publication/BestPractices-in-Water-Management.pdf

52 https://www.business-standard.com/article/pti-stories/rajasthan-improves-ranking-in-composite-water-management-index-118061901037_1.html

2.4. EU water framework directive

Moving on to global water policies, the European Union (EU), realizing the need for a water policy, proposed the need for a water framework directive based on the idea that modern water management must to consider ecological, economic (including pricing) and social functions throughout the entire river basin.

In EU, an efficient and effective water pricing system has been adopted to reduce water consumption. The water framework directive made it mandatory that by 2010, all user groups across EU member states have to pay for the water services such as pumping, weirs, dams, channels, supply systems. Member states were required to split the costs according to the "polluter-pays" principle so as to minimize the effect on environment and elevate financial instruments to handle the deterioration of natural assets.

It was noticed that, in many European eastern countries, the removal of subsidies from water prices and increase in water prices resulted in significant reduction in water consumption.

In Estonia, after the subsidies were removed, water price increased tremendously which forced them to adopt advance sanitation devices and water measuring system which led to reduction in water use by 50% in the last 15 years

Table 5: EU – India policies and regulatory framework

EU	India
Adopted an integrated framework of ecological, economic (including pricing) and social functions throughout the entire water basin to manage its water resources. The Water Framework Directive (WFD) also established a combined approach for regulation of point and non-point sources of contaminants and set specific compliance deadlines for a number of regulations.	NWP – formulated by the MoWR of the Government of India to govern the planning and development of water resources and their optimum utilization. The first NWP was adopted in September 1987. It was reviewed and updated in 2002 and a final draft came out in 2012.
Related directives ▶ Bathing Water (76/160) (now replaced by 2006/7) ▶ Drinking Water (80/778, as amended by 98/83) ▶ Urban Wastewater Treatment (91/271), Nitrates (91/676) ▶ Integrated Pollution Prevention & Control (96/61, codified as Directive 2008/1/EC), Sewage Sludge (86/278)	**Major programs** ▶ Accelerated Urban Supply Program - increased coverage of water services in urban areas ▶ Accelerated Irrigations Benefit Program – dams and canals ▶ Jawaharlal Nehru National Urban Renewal Mission (JNNURM) – financial support for development of urban infrastructure in 63 cities ▶ Urban Infrastructure Development Scheme for small and medium towns - for towns not covered under JNNURM ▶ Project implementation agencies – access to finance from private players and capital markets ▶ Pooled finance development schemes: Financial and technical support to urban local bodies for preparation of projects

2.5. Water regulatory framework of India and China

Due to overconsumption of water and inefficient use, China and India are both facing a water crisis. About 70% of water is unfit for human consumption. In India, almost 70% of the surface water resources are contaminated through biological and toxic pollutants. Inefficient water use is a common problem in both the countries. In India, non-revenue water is 41% on an average compared to 21% in China .

The table given below gives a comparison on water governance between China and India in terms of water laws and policies.

Table 6: China–India policies and regulatory framework

China	India
China's main approach to solve its water (and energy) crisis is to build more, large dams and diversion canals. The number of dams in China accounts for half the world's current total dams. The world's largest dam – the Three Gorges Dam of China- serves the purpose of meeting 15% of China's energy need as well as addresses China's water issue by supplying water for agriculture and to rapidly expanding cities	In India, water rights and authority is conferred to the states and all state governments do not have the same capacity- engineering, financial, administrative and political will – to undertake massive dam building projects. A lot of veto power holders, i.e., central vs. state and local government, parliament, courts, inter-governmental agencies, opposition parties, media, NGOs and local communities play a major role during the approval process
China has a centralized political structure which allows the central government to impose its authority if any conflicts arises on water rights among different user groups and states	India has decentralized political structure wherein the authority is conferred to the states and not the central government
In China, local water utilities and irrigation agencies have been practicing cost recovery for the last 20 years	Urban and irrigation water supply remain subsidized, implicitly and explicitly by the government

Source: EY research

India finds itself in a peculiar situation where the country is facing a water crisis but at the same time, there is great scope for development in the industry.

India needs to focus on initiatives that ensure water efficiency and minimum wastage of water. For instance, Delhi has access to more than 200 liters of water per capita per day[54]. However, people do not receive water 24/7. This is due to system losses in its supply system caused by water leakage. 40% of the city's water is lost[55], mostly due to old and leaking pipes. The government should consider using smart systems to detect and repair leaks using modern technology and install water meters to ensure that there are no distribution losses.

In order to succeed, regulations must be well-designed and resources need to be made available for enforcement. The authorities must be given the required financial capabilities and powers to enforce rules and regulations for an efficient water management system. Managing wastewater effectively requires support from institutions/local government. Efforts are required across the nation/states to support local governments in managing water and waste water.

Presently there are no separate regulations/guidelines for safe handling, transport and disposal of wastewater in the country. Guidelines can be issued to help manage the impact downstream.

53 https://drive.google.com/file/d/0B6vN2Zv5F7-ESzFELTlCUjFSc1k/view
54 http://web.worldbank.org/archive/website01291/WEB/0__C-217.HTM
55 http://web.worldbank.org/archive/website01291/WEB/0__C-217.HTM

Section 3:

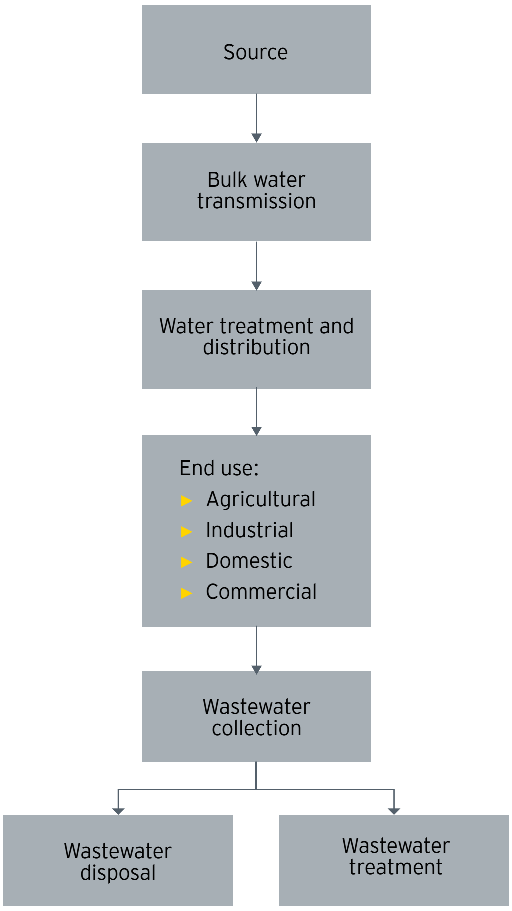
Water treatment technologies

Of the total water reserves on earth, only 3% constitute freshwater whereas the remaining 97% is saline water[56]. This implies that the quantum of water available for the consumption is very low in comparison to its demand. With rapid industrialization and urbanization, the quantity of waste water being generated is also increasing.

Industrialization has resulted in the generation of huge quantities of solid and liquid wastes by industries such as pulp and paper, sugar, fruit and food processing, sago/starch, distilleries, dairies, tanneries, slaughterhouses, poultries, etc. Despite taking pollution control measures, these wastes generally get discharged into water bodies or get dumped on land without being given an adequate treatment.

Over the years, various projects, methods and technologies have been developed to make industrial water and waste water suitable for reuse.

Figure 14: Water and wastewater value chain



Source: EY Research

The project cycle of any water and wastewater project is divided into the following five segments:

a) Project development: planning of project, from location analysis and approval processes to technical planning of implementation.

b) Project finance and investment: matchmaking of suitable technologies with optimal financing and incentives through identification of financiers.

c) Project design and engineering: optimized design and engineering of water treatment plants, wastewater treatment plants, sewerage network, bulk distribution network, etc.

d) Project construction: selection and execution of construction processes to increase installation speed, reduce labor costs and environmental impact, and maximize solar energy's output through the entire lifecycle of the solar projects.

e) Operations and maintenance: optimize and drive water and wastewater projects through professional maintenance to realize projected revenues.

56 https://oceanservice.noaa.gov/facts/wherewater.html

The diagram below outlines the key players involved in each segment of the water and wastewater project cycle[57].

Segments of the water and wastewater project cycle

Project cycle	Project development	Project finance and investment	Project design and engineering	Project construction	Operations and maintenance
Key players	IL & FS Water Ltd. SPML Infra L&T IDPL HCC Projects and Development India Ltd	World Bank Asian Development Bank UNDP Central Government State Government	SPML Infra IL & FS Water Ltd. Dorr Oliver Enviro control Associates Ion Exchange SFC Environmental Technologies Pvt. Ltd. UPL Environmental Engineers VA Tech Wabag Veolia IVRCL Suez Environment	SPML Infra IL &FS Water Ltd. Enviro Control Associates L&T NCC Limited Ramky Infrastructure Simplex Infrastructure Ltd. Triveni Engineering and Industries Ltd. UPL Environmental Engineers HCC Projects and Development India Ltd. IVRCL	SPML Infra IL &FS Water Ltd. Enviro Control Associates L&T NCC Limited Ramky Infrastructure Simplex Infrastructure Ltd Thermax UPL Environmental Engineers Ltd. HCC Projects and Development India Ltd. Veolia

Source: EY Research

Globally, the demand of water is anticipated to increase significantly in future. In addition to the agricultural sector, which is responsible for major water abstractions worldwide, huge increment in water demand is predicted for the energy generation.

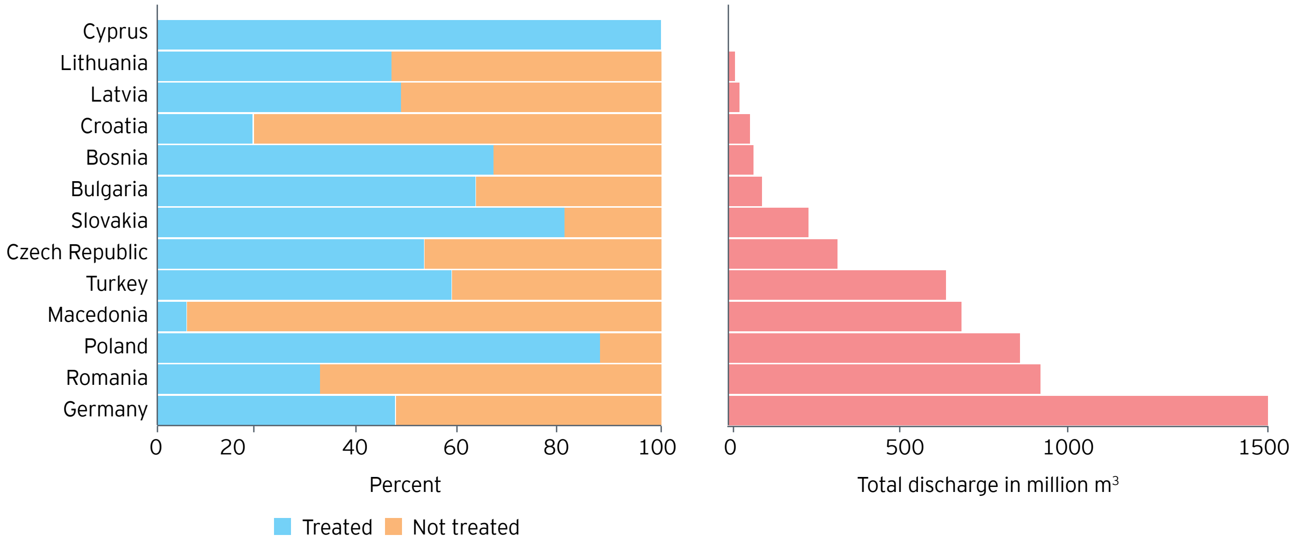
The availability of water supply is inextricably linked with how the waste water is managed. On an average, high-income nations treat about 70%[58] of the municipal and industrial wastewater. The proportion of treatment drops to 38% [59] in upper middle-income nations and 28%[60] in lower middle-income nations. In low-income nations, just 8% [61] of wastewater generated undergoes treatment of any kind.

In high-income nations, the inspiration for cutting-edge wastewater treatment is either to maintain ecological quality, or to give an alternative water source while coping with water shortage. In any case, the discharge of untreated wastewater stays a common practice, particularly in developing nations, because of the lack of infrastructure, technical and institutional capacity as well as financing.

The variability in the industrial waste water treatment trending across 13 countries is depicted in the below figure. From the figure, the percentage of wastewater that is released untreated can also be inferred.

57 EY Research
58 https://reliefweb.int/report/world/2017-un-world-water-development-report-wastewater-untapped-resource
59 https://reliefweb.int/report/world/2017-un-world-water-development-report-wastewater-untapped-resource
60 https://reliefweb.int/report/world/2017-un-world-water-development-report-wastewater-untapped-resource
61 https://reliefweb.int/report/world/2017-un-world-water-development-report-wastewater-untapped-resource

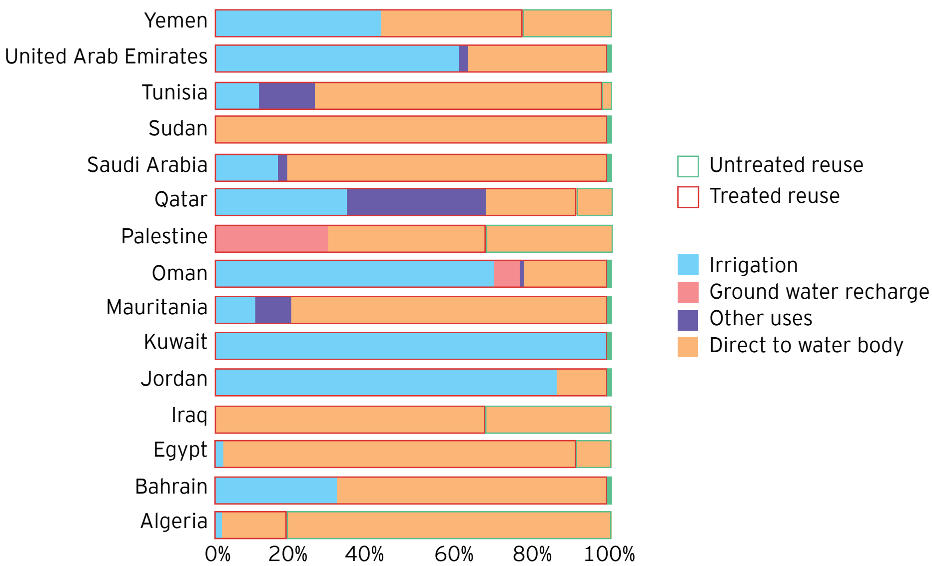
Figure 15: Industrial wastewater treatment data



Source: UN Habitat, 2018

One of the most arid parts of the world is Arab nations who face a major challenge in water scarcity. In order to overcome this issue, they have proactive policies in practice that address water scarcity and monitor progress. Jordan, Kuwait and Oman use secondary treatment prior to using the water in agriculture as depicted in the figure below. Other countries have critical proportions of untreated wastewater, which represent viable opportunities to increase the treatment of waste water and making its productive use for irrigation and groundwater recharge.

Figure 16: Wastewater reuse in Arab States



Source: UN Habitat, 2018

3.1. Water treatment technologies

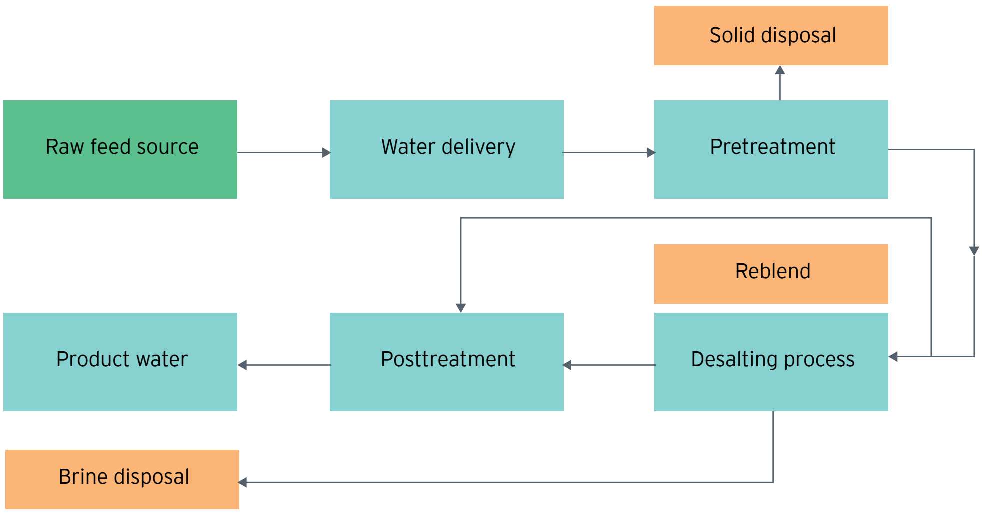
Desalination | Hybrid treatment methods | Scaleban technology | Soil biotechnology

3.1.1. Desalination technology

Desalination technologies have been used globally and rapidly over the past few decades to produce clean drinking water from groundwater, seawater and brackish water. This technology is being used to improve the quality of existing supplies of fresh water for human consumption, commercial applications or to treat industrial and municipal water. Through this process, salts from the water get extracted. With rapid technological advancements, desalinization has emerged as a cost competitive method to produce water fit for human consumption.

The process of desalination is illustrated in the diagram below:

Figure 17: Illustration of the desalination process



Source: Desalination for water supply, 2015

3.1.1.1. Desalination processes

The commercially utilized desalination technologies are based on thermal and membrane processes.

Thermal technology

- MSF
- MED
- VCD

Low temperature evaporation desalination

Membrane technology

- MF
- RO
- NF

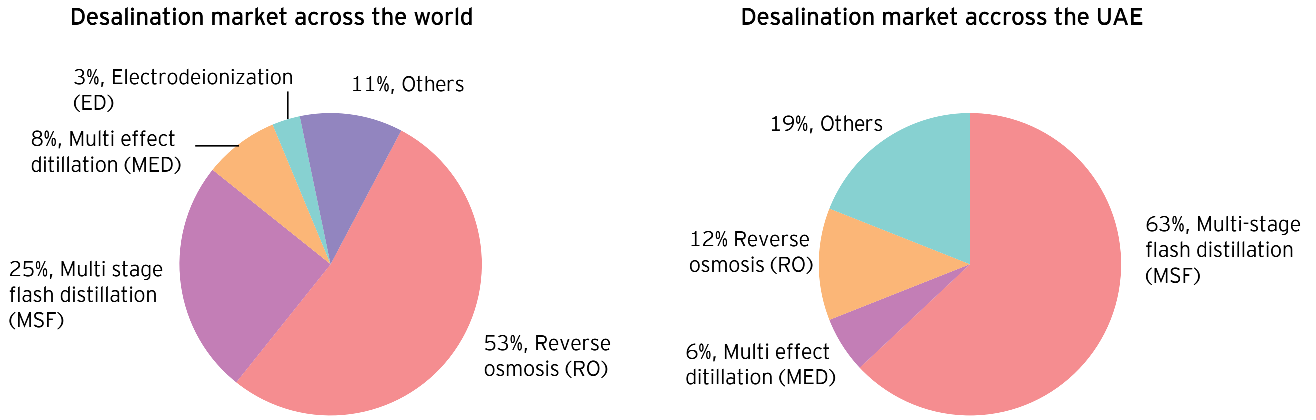
Other processes

- Solar desalination
- CDI
- (ED/EDI)

3.1.1.1.1. Worldwide capacity for desalination processes

Membrane technology is more widely used for desalination since it is cheaper in comparison to thermal technology. The figure below, however, varies significantly across different regions of the globe, as for e.g., in the UAE, MSF is dominating the desalination market.

Figure 18: Worldwide installed capacity for desalination processes



Source: Development of an advanced, innovative, energy autonomous system for the treatment of brine from seawater desalination plants, 2012

3.1.1.1.2. Thermal technology

Thermal desalination is the process wherein saline water is heated to produce water vapors and the distillate collected (condensed water) is used to produce pure water. The different thermal desalination processes include MSF, MED and VCD. These processes produce high purity water suitable for industrial consumption and their unit capacities are also higher compared to the membrane process[62].

3.1.1.1.3. Multiple flash distillation (MSF)

The MSF, together with RO, consist of the most commercialized desalination technologies, with RO having by far the largest share of installed plants, globally. This process involves the heating of seawater in a container known as a brine heater (Figure 18). The heated water is passed to another container known as a ''stage'', wherein the surrounding pressure is lower than that in the brine heater. The unexpected passage of heated water into the stage with low pressure results the water to boil quickly so as to streak it into steam. The remaining water is passed through a series of stages, each having a lower surrounding pressure compared to the previous stage. As the vapor is created, it is condensed on the tubes of heat exchangers. A single MSF desalination unit can include stages from 4 to 40[63]. Multi-stage flash produces about 60% of the world's desalinated water.

The world's largest desalination plant is the Jebel Ali Desalination Plant in the United Arab Emirates. It is a dual-purpose facility that uses multi-stage flash distillation and is capable of producing 0.3 billion cubic meters of water per year[64] .

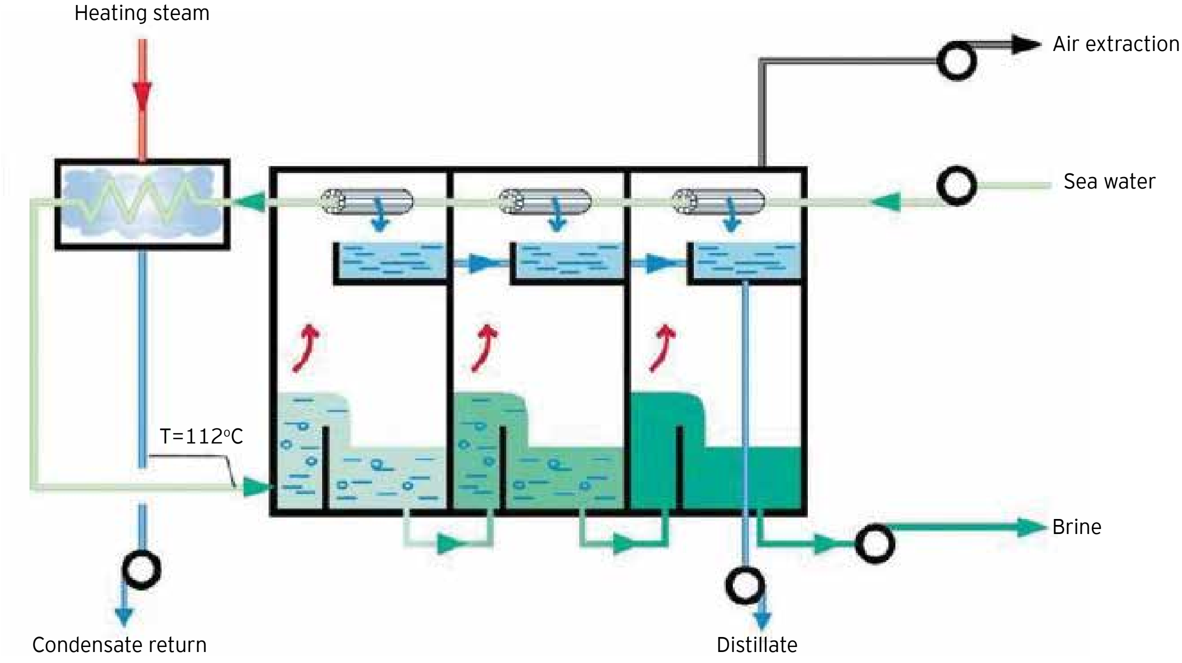
The key characteristics of MSF plants include high volume, corrosion, scaling and high use of treatment chemicals. It is capable of accepting higher contaminant levels (heavy metals, oil, suspended solids, COD, BOD, etc.) in feed water and can produce distilled quality water good for power plants, industrial processes and other processes that require high-purity water.

62 https://www.theseus.fi/bitstream/handle/10024/124763/desalination.pdf?sequence=1&isAllowed=y

63 http://solbrine.uest.gr/uploads/files/Deliverable1.2.pdf

64 https://www.bartleby.com/essay/Desalination-of-Water-F35FFCJ4K6YZS

Figure 19: Multiple flash distillation



Source: ASEE's 123rd Annual Conference and Exposition, 2016

Table 7: Advantages and disadvantages of MSF

Advantages	Disadvantages
Generation of high quality	High energy consumption
Easy to operate	Slow response to water demand fluctuations
Does not generate wastewater during back wash	Higher rate of scaling in tubes
Limited downtime as it can be semi operational during maintenance (cleaning/filter replacement)	

Though MSF is simple to operate and generates high quality water than RO, the potential of improvement in RO is more than that of MSF because RO's desalination method has grown in popularity during the last decade as it has experienced noticeable developments while MSF has reached a stagnation point in advancements. The initial investment in MSF is also more than RO.

Table 8: Comparison of MSF and RO

Component	MSF	RO
Investment (US$/(metre3/day))	1,000-1,500	7,000-1,500 (including 10% for membranes)
Robustness	High	Medium (problems: fouling sensitivity and feed water monitoring)
Improvement potential	Low	High

3.1.1.1.4. Multi-effect Distillation (MED)

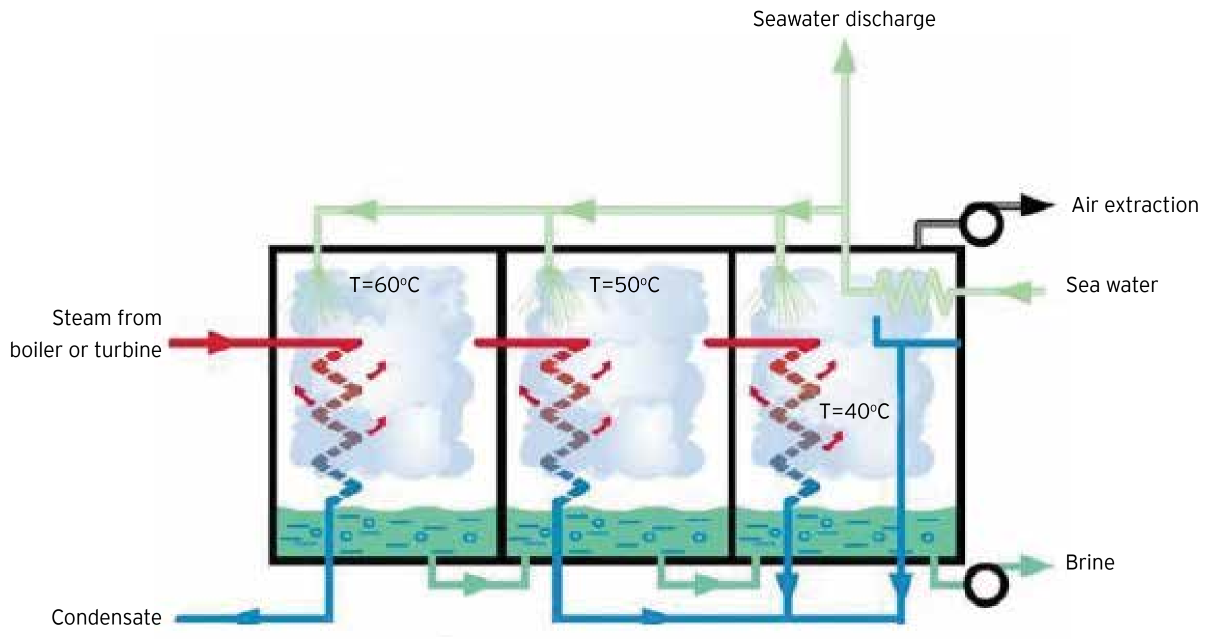
Multi-effect Distillation (MED) was the first technology used in the desalination industry for the production of fresh water from seawater, but it was overtaken by the MSF technology due to the problems of fouling and scaling of evaporated tubes which are avoided in MSF units.

MED is the most efficient thermal desalination process currently in use. It consists of a low temperature thermal process, where fresh water is obtained by recovering the vapor of boiling saline water in a sequence of vessels (called effects), each maintained at a lower temperature than the previous effect. Each effect has a horizontal tube bundle. The feed water is either splashed or conveyed onto the surface of evaporator tubes in a thin film to promote boiling and evaporation. As the boiling point of water starts decreasing with the pressure reduction, the vapor boiled off in one vessel can be utilized to heat the following one and only the first one requires an external source of heat[65]. MED has also proven itself in large-scale drinking water production.

Some of the advantages of MED includes:

- Wide selection of feedwater
- High quality of product water with high reliability
- Less energy consumption than MSF
- Requires lower temperature operation (reduces scaling and energy costs).

Figure: 20 Multi effect distillation



Source: ASEE's 123rd Annual Conference and Exposition, 2016

Along with lower energy consumption, MED requires lower capital cost as compared to MSF. The capital cost of MED is US$3.5 to US$4.5 per installed gallon/day whereas the capital cost of MSF is US$5 to US$6 per installed gallon/day[66].

65 http://solbrine.uest.gr/uploads/files/Deliverable1.2.pdf
66 https://desline.com/Geneva/Banat.pdf

Table 9: Typical unit size and electrical energy consumption

Component	MSF	MED	RO
Typical unit size (metre^3/day)	50,000-70,000	5,000-15,000	24,000
Electrical energy consumption (kWh/metre^3)	4-6	1.5-2.5	3-5.5

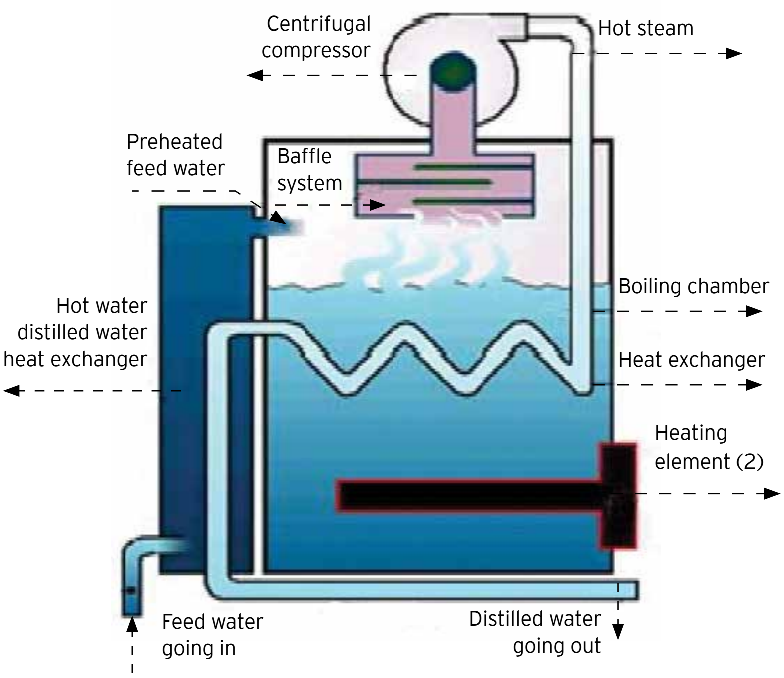
Source: ASEE's 123rd Annual Conference and Exposition, 2016

3.1.1.1.5. Vapor compression distillation (VCD)

In this process, the source of heat used to generate the steam from seawater and the vapor is compressed using a compressor. The temperature and pressure of the steam increases as a result of the compression. The work done in the compressor is then changed into heat. The incoming seawater is used to cool the compressed steam which then condenses to distilled fresh water and at the same time, the seawater is heated further to produce more steam. This process can be used independently and also along with multi effect distillation. Vapor compression units are built in different varieties of configurations. As a result, the mechanical compressor is used to produce heat for evaporation[67].

The capacity of these compressors is usually small and they are mainly used in industrial applications and the hotel industry.

Figure 21: Vapor compression distillation



Source: Desalination in water treatment and sustainability, 2016

The main advantages of VCD include the following:

- This method is simple and reliable and hence it can be considered as a better option for small-scale desalination units. They usually have a capacity of 3000 metre3/ day and are generally used for resorts, industries and drilling sites, where fresh water is in shortage[68].
- The operating temperature of VC distillation or evaporation is low as compared to MSF and MED which makes it a simple and an efficient process in terms of power consumption.
- Since the operating temperatures are low (below 70°C), the potential for scale formation and tube corrosion is reduced.

67 http://www.barc.gov.in/publications/tb/desalination.pdf

68 https://climatesmartwater.org/wp-content/uploads/sites/2/2018/11/Water-desalination-technologies-utilizing-conventional-and-renewable-energy-sources.pdf

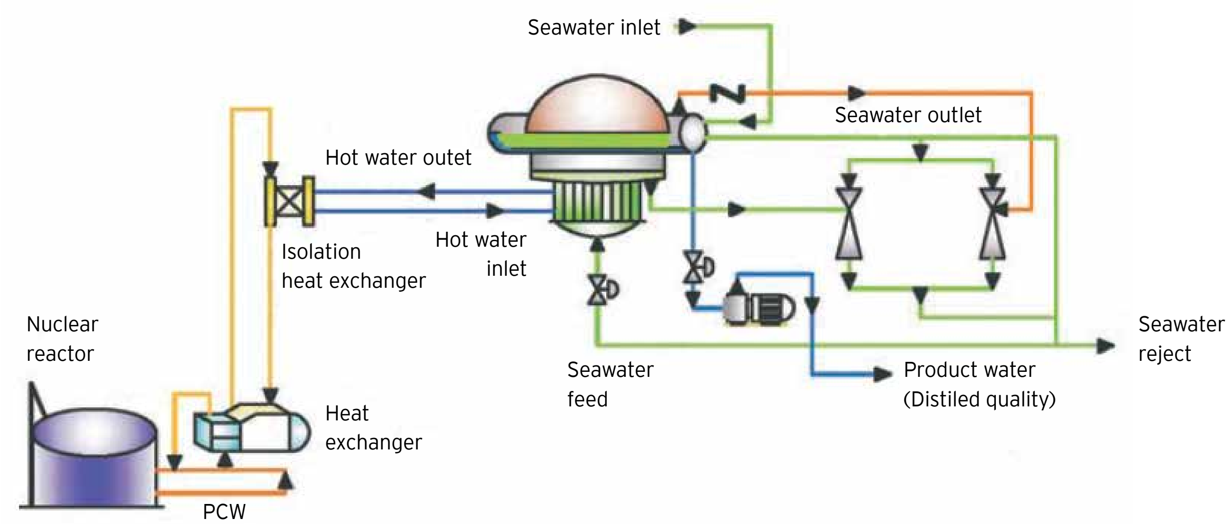
3.1.1.1.6. Low temperature evaporation desalination

As the energy cost component is a major fraction of the desalinated water cost, utilization of waste heat as an energy input for seawater desalination is an attractive option. It is one of the eco-friendly ways to produce desalinated water as it does not require chemical pre-treatment of feed seawater.

Low temperature evaporation desalination units basically consist of three parts: heater, separator and condenser. Heater cells consist of vertical tubes. The sea water feed which enters at the bottom of the tubes partly evaporates till it comes out of the top. The condenser is separated from the heater through a vertical shell. When the mixture of water and vapor comes out of the heater, the vapor passes through the vertical shell and enters the condenser and condenses around the tubes (which are cooled by sea water flowing inside) producing desalinated water. The desalinated water is then pumped out.

This process utilizes waste heat as an energy input and as a result, is considered cost effective. Since it is does not require chemical pre-treatment for water, it is also considered environment friendly.

Figure 22: Low temperature evaporation desalination[69]



Source: Technical document by Department of Atomic Energy, 2010

Case study

Anglo-American eMalahleni Water Reclamation Project, Mpumalanga, South Africa

Emalahleni, a city in north-eastern South Africa, launched a water reclamation initiative to ensure environmentally responsible management of excess water in the mines, and a continuous supply of treated water for mining activities, while eliminating the need to import water and the keeping consequent competition with other stakeholders for a scarce resource. The eMalahleni Water Reclamation Plant treats water from the three Anglo-American thermal coal operations and uses desalination technology. The water from the mine is converted to drinking water, processed/industrial water and water that can be safely released into the environment. In the treatment process, gypsum is separated from the water and used as a construction material. Some of this treated water is used directly in the mining operations, but the majority is for social use and meets 12% of Emalahleni's daily water needs, offering a reliable and potable water supply[70].

69 http://www.barc.gov.in/publications/tb/desalination.pdf

70 https://www.unido.org/sites/default/files/2017-03/UN_World_Water_Development_Report_-_Full_0.pdf

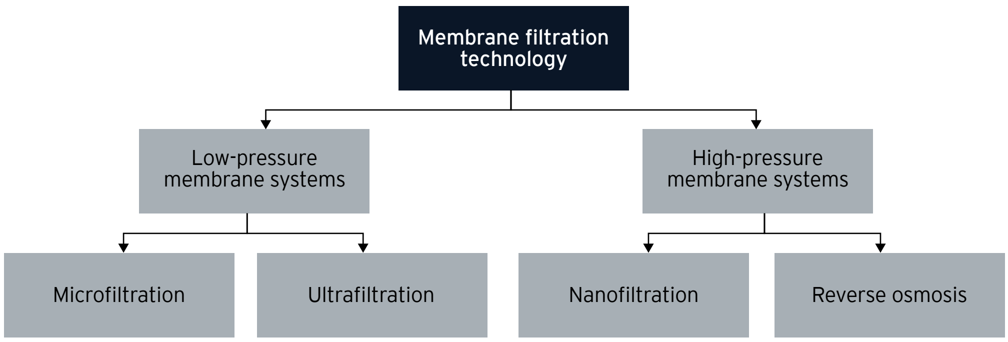
Case study

Kuwait is an arid country located in the Middle East, rich in oil but poor in water resources. Here, fresh water streams do not exist. Fresh water resources are limited to groundwater, desalinated seawater and brackish groundwater, and treated wastewater effluents. The conventional fresh water resources available in Kuwait are 0.006 billion cubic meter/year while the total water demand has exceeded 0.350 billion cubic meter/year in 2000. With the continued deterioration of existing groundwater resources, almost 90% of the water demand is currently satisfied through seawater desalination plants. Currently, the desalination capacity in Kuwait is 0.0016 billion meter cube/day, of which 0.0014 billion meter cube/day is provided by MSF and 0.17 million metre3/day is supplied by RO[71].

3.2. Membrane processes

Membrane separation is replacing traditional water and wastewater treatment technologies such as physical filtration or biological and chemical treatment. It is one of the most effective and economical water treatment methods available and is currently being used across the world. Membrane separation is based on selective filtration through pores of different sizes and consists of two classes of membrane treatment systems that are mentioned below.

Figure 23: Membrane treatment systems



Source: EY Research

3.2.1. MF treatment system

Many industries such as refinery, manufacturing, etc. require high-purity water for process operation, which involve several processing steps. There has been a shift towards membrane technologies replacing conventional technology. Microfiltration (MF) is the most fundamental of the four membrane separation types and has a wide range of industrial applications.

The process is based on a basic permeable membrane layer which takes into consideration the partition of huge atomic weight suspended or a colloidal compound from dissolved solids. Due to these properties, it is widely used for sterile filtration and in desalination process as it is capable to lower the turbidity of feed water and eliminate suspended solids and microscopic organisms.

Applications

Water treatment plants, pre-treatment in desalination plants, preparation of sterile water for industrial consumption, food and beverage industry and microelectronic sectors.

Some of the advantages of MF include:

- MF requires low operating pressure compared to other membrane treatment systems
- MF requires low energy consumption compared to NF or RO treatment systems
- Few manual actions are required
- Relatively cheaper than RO and NF

71 https://www.theseus.fi/bitstream/handle/10024/124763/desalination.pdf?sequence=1&isAllowed=y

Typical installation costs for micro-filtration (tubular membranes and polyvinyl difluoride PVDF membranes) with a volume of 25 metre³/day, ranges from €25.00 and €50.00, depending on the quality of the water supply. For MF, one should assume average operating costs of 0.1€/m³ to 0.15€/m³ produced permeate[72].

3.2.2. UF treatment system

UF is also one of the most widely used water and waste water technologies as they are more effective and efficient in filtering colloidal particles. Their pore size ranges from 20 nanomicrons to 0.1 microns, due to which only particles smaller than 20 nanomicrons can pass through them[73]. UF's low pressure driven membrane leads to low energy consumption.

Applications

Drinking water treatment, pre-treatment process in desalination and membrane bioreactors, food and beverage industry, microelectronics industry and for the treatment of general industrial waste water.

3.2.3. NF treatment system

This process provides finer filtration than UF, but it is commonly referred to as a "loose" RO because of the pore structure of the membrane used. The structure of the membrane is relatively large compared to RO membranes, and unlike them, it allows the passage of salts. Their pore size ranges from approximately 1–5 nanomicrons . Membranes used in this process are better than the ones used in reverse osmosis because they have a large membrane structure and higher water permeability as compared to RO and can operate at much lower pressures.

Applications:

Food and dairy sectors, in chemical processing and textile industry, desalinization pre-treatment and dye manufacturing industries.

Some of the advantages of NF include:

- Lower discharge volumes and lower retentate concentrations than RO
- Reduction in salt content and dissolved matter content (TDS) in brackish water
- Reduction in heavy metals
- Reduction in nitrates and sulphates
- Reduction in color, tannins and turbidity

A nanofiltration installation for the production of 100 metre³/h permeate, approximately costs between €300.00 and €350[75].

3.2.4. Reverse osmosis (RO) treatment system

RO systems offer a cost-effective and sustainable solution for water and reuse applications. RO is a form of a membrane separation which uses pressure to force feed water of high solids content through a membrane that retains the solute and allows the water with low solids content to pass through. Typically, this membrane is designed to allow only water to pass through while the solutes (for e.g., salt ions) are being separated. The process is used for separating dissolved solids and other selected dissolved substances.

RO together with electro dialysis emerged as a new technology in the second half of 20th century and since then became an alternative to commonly used techniques of evaporation and distillation.

Applications

Treatment of fresh, process and waste waters and production of ultra-pure water.

3.3. Other processes

3.3.1. Solar desalination

Solar desalination is a technology suitable for small community level plants due to their economic viability. The heat generated from the sun warms up the water in a glass-covered tank causing evaporation. The vapor is condensed on a glass cover and the resulting fresh water is collected. This system is most commonly used where grid electric supply is scarce. This methodology of desalination is cost effective but is not suitable for large-scale water production. This method also requires proper maintenance to ensure its effectiveness.

3.3.2. Capacitive deionization

CDI, often called capacitive desalination, electrochemical desalination or flow-through capacitor, is a new desalination method. Over the past couple of decades, CDI has been promoted as a cheap, low-energy and high-yield competitor to RO and electrodialysis, with applications ranging from water softening to seawater desalination.

72 https://emis.vito.be/en/techniekfiche/microfiltration
73 https://www.gita.org.in/Attachments/Reports/TechView_Water_Filtration.pdf
74 https://www.gita.org.in/Attachments/Reports/TechView_Water_Filtration.pdf
75 https://emis.vito.be/en/techniekfiche/nanofiltration

The major market advantage that CDI currently has is its over competing technologies which have the ability to remove nearly all ionic contaminants – sulphates, nitrates, iron, arsenic and fluorides, along with sodium, calcium and magnesium salts with high recovery rates (up to 90% or more). RO, which forces on salty water through a nano porous membrane, removes water from salt. CDI, on the other hand, removes salt from water.

CDI technology uses the electric field created between the electrodes to retain the ions on the electrodes' surface by means of electrostatic attraction. The ions accumulated on the electrodes are a thermodynamically reversible process and when the electrodes are depolarized, these accumulated ions are removed.

The operation is carried out in two phases:

1st phase: the first step of the process is deionization or desalination phase, and more technically, the ionic adsorption phase. This phase continues as long as it takes the equivalent capacitor to charge to the ideal potential, dependably lower than 1.2 V, to evade water dissociation and the water between the electrodes will be deionized during this stage[76].

2nd phase: In the second phase, the depolarization of electrodes leads to circulation of water which enables removal of accumulated ions which get evacuated in the form of a concentrate or brine. This phase is called the regeneration or cleaning phase since it makes the electrodes ready for a new cycle again.

The major challenge for CDI is its cost – both capital and operational costs are concerns. An RO system, capable of treating 1,000 liters/hour, costs between US$3,000 and US$4,000, whereas a similar capacity of CDI system costs about US$10,000.

3.3.3. Electro deionization

EDI, also referred to as continuous electro deionization (CEDI), is a chemical free technology that significantly reduces the ions present in water. This method utilizes cation/anion exchange resins that are continuously regenerated using an electric current.

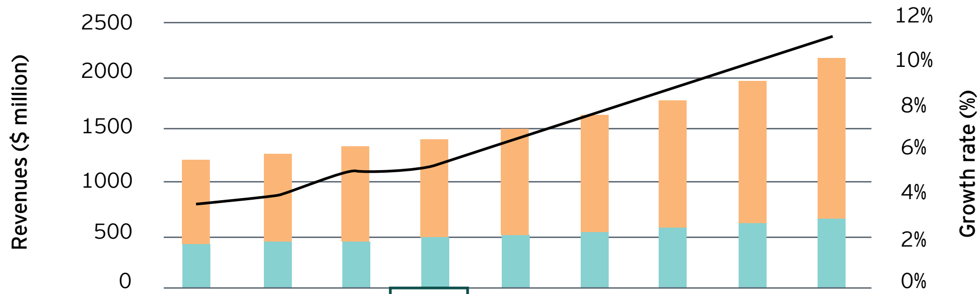
EDI modules/stacks, consist of a pair of cells, each containing an anode and cathode on different sides. Each cell consists of a frame and a cation-permeable membrane that is bonded on one side, and an anion-permeable membrane on the other. Ion exchange resins are filled in the center of the cell between the ions-selective membranes and the cells, which are separated by a screen separator. The feed water enters the modules in three parts: electrodes, resin beds and the screen separators.

3.3.4. Global scenario of the membrane technology market

Membrane technology, due to its scientific and technical excellence, has occupied a solid position in the European market, which is expected to continue in the coming years. Membrane systems have acquired global acknowledgment as a reliable and proven technology. It is recognized as one of the most sustainable approaches as it has low operating cost and reduces water and energy footprints.

The European membrane market for water and waste water filtration is expected to grow until 2020 as demonstrated in the chart below[77], with the shift of the core membrane investments from the western to the eastern part of European due to replacement of some traditional waste water treatment technology.

Figure 24: European membrane based water and wastewater treatment market



	2012	2013	2014	2015	2016	2017	2018	2019	2020
MF and UF	792.6	825.9	872.2	923.6	990.1	1076.3	1186.1	1321.3	1486.4
NF and RO	426.8	444.7	465.2	488	513.8	544.2	579.5	624.1	679.7
Growth Rate (%)	3.8%	4.2%	5.3%	5.6%	6.5%	7.7%	9.0%	10.2%	11.3%

Source: Source: Fraunhofer Centre for International Management and Knowledge Economy, tech view report

71 https://www.intechopen.com/books/desalination-and-water-treatment/energy-recovery-in-capacitive-deionization-technology
77 https://www.gita.org.in/Attachments/Reports/TechView_Water_Filtration.pdf

3.4. Wastewater treatment technologies

3.4.1. Hybrid waste water treatment methods

A hybrid energy system consists of two or more energy methods used together to increase system efficiency and provide savings of fuel. Hybrid waste water systems are based on the combination of biological unit processes, physical processes and chemical processes for the treatment of water.

Physical-biological hybrid system

Physical-biological hybrid processes are used for the removal of pollutants consisting of high suspended solids, oil and grease, organic and inorganic components. Membrane bioreactor (MBR) is one of the most common physical-biological hybrid systems that is used in waste water treatment plants.

Physical-chemical hybrid system

Physical-chemical processes are used for the treatment of waste water that contain suspended solids, oil and grease, turbidity, metals or ions content.

Chemical-biological hybrid system

The adoption of chemical-biological hybrid systems are typically for wastewaters that are rich in nitrogen, phosphorus and refractory toxic organic, which are normally reflected as COD level, BOD level and TOC level from the wastewater.

Physical-chemical-biological hybrid system

A physical-chemical-biological hybrid system is required for the treatment of wastewater that comprises of a wide range of pollutants such as suspended solids, oil and grease, volatile organics, degradable organics, ions, nutrients such as nitrogen or phosphorus, and metals.

The diagram below elucidates a combination of systems and processes that can be used to improve the quality of wastewater. The selection of the type of hybrid wastewater systems depends on the type of pollutants present in the wastewater[78].

The selection of the types of hybrid wastewater systems depend on the types of pollutants. Pollutants such as volatile organics, degradable organics, nitrogen and refractory toxic organics are removed using biological treatment processes. Whereas, suspended solids are removed by physical processes and those like metals are removed by chemical processes. Since waste water contains a combination of one or more pollutants, a hybrid system is used for its complete treatment.

3.4.2. Zero-liquid discharge and SCALE-BAN technology

Zero-liquid discharge is a water treatment process in which waste water is purified and recycled, leaving zero discharge at the end of the treatment. It is an advanced method of treatment that includes processes like UF, RO, evaporation and EDI.

RO and MEE are two conventional technologies of achieving ZLD that is used worldwide. On the other hand, **SCALE-BAN** is a non-conventional technology that is used for achieving ZLD. Developed as an indigenous technology, **SCALE-BAN** utilizes effluent water like process effluents in place of fresh water for cooling towers, thus achieving ZLD on a sustainable basis.

SCALE-BAN is an online pipe-shaped mechanical device with a specially designed core that is sintered with electronegative elements in their increasing order of electronegativity in the direction of the water flow. When feed water passes through the device, it acts like an electrolyte when it comes in contact with the core that is placed inside the device. Its working principle is based on fluid dynamics, galvanic principle and the chemical characteristics of water.

SCALE-BAN locally increases pH value of the water before it reaches the high temperature zone and then precipitates salts like Calcium and Magnesium that cause waste hardness as it flows through **SCALE-BAN**. **SCALE-BAN** has a significantly lower capital and operational expenditure in comparison to conventional sources of technology. Its key characteristic is that it can be quickly installed and can handle variable water quality. This method is an online equipment and thus does not require any extra space either.

It is preferred over conventional technology that entails high capital and operational expenditure.

78 http://www.elsevier.com/locate/rser

Case study

SBT based sewage treatment plant at Gujarat[79]

Jambudiyapura is a tribal village in Gujarat, which is devoid of proper water and sanitation facilities.

Gujarat Road and Infrastructure Company Limited, a subsidiary of IL&FS, collaborated with Nalanda Foundation and deployed its CSR budget to provide sanitation, i.e., wastewater treatment facilities to this village. Under this initiative, a sewage treatment plant based on SBT technology was provided to the village.

The efficiency of the plant installed in the village is illustrated in the diagram below:

Parameters	Inlet to Continuous Aerobic Multistage System (CAMUS SBT)	Outlet to Continuous Aerobic Multistage System (CAMUS- SBT)
Total dissolved solids	1262	<10
COD	422	35.17
BOD	131	<5.0
Ammonia	51.41	<1
Dissolved oxygen	<1	8.2
PH	7.5	7.99

The treated water released by the plant is of high quality and is reused for various activities like irrigation, washing, flushing, etc.

3.4.3. Soil Biotechnology (SBT)

SBT is an innovative and indigenous technology used for waste water treatment. It is based on a bio-conversion process wherein fundamental natural processes, like respiration, photosynthesis and mineral weathering take place in a media housing micro and macro organisms which bring the desired level of purification. SBT works on the principle of trickling filter, which is capable of removing the suspended solids, organic and inorganic contents of the wastewater by combining various physical processes like sedimentation, infiltration and bio-chemical processes. It is an oxygen supplying biological engine and can be used to treat waste water with different types of effluents. This process is 100% ecologically safe. This technology is energy efficient, reliable and cost effective[80].

CAMUS-SBT is an improved version of SBT that uses bio-chemical method of oxygenation, where along with atmospheric oxygen, atmospheric nitrogen is also used in a specially engineered ecology to obtain a higher level of purity.

Case study

SBT plant in BMC Worli, Mumbai treats 3,000 kiloliters of water a day

This plant is located in Worli, Mumbai, where about 700 million liters of sewage from various localities is collected in a day through different trunk mains and gravitated in to the sea by providing larger diameter pipelines along the sea bed. This wastewater contains domestic sewage, industrial effluents, grey water from commercial establishments, etc. Out of the 700 million liters/day, only 3 million liters/day is being collected separately and pumped in to the SBT plant for treatment. The treated water is being used for irrigation purpose.

At present, the maintenance of the plant is being taken care of by Mumbai Municipal Corporation, and the staff in charge of the plant reported that in a recent study on the plant, the tests showed that the BOD and COD are less than 30 with the removal efficiency of BOD and COD greater than 90%, and treated water is used for the requirements of the golf course.

79 http://www.visionearthcare.com/social-media/blogs/csrprojectintribalvillage
80 https://www.cleanindiajournal.com/soil_biotechnology_for_sewage_treatment/

Case study

SBT plant in HDIL, Virar treats 650 kiloliters/day

The SBT plant, with a capacity of 650 kiloliters/day, is located in a housing colony at Virar about 50 kilometers from Mumbai in Kalyan municipal corporation area.

The maintenance of the SBT plant is being taken care of by M/s Vision Earth Care Company and the staff in charge of the plant reported that in a recent study of the discharged effluent of the SBT plant, the test results show that the BOD and COD are less than five with the removal efficiency of BOD and COD greater than 99%, and the treated sewage (effluent) quality is nearly equal to that of the drinking water. The effluent is used for construction, flushing, plantation, car washing and floor cleaning[81].

Case study

IOCL Paradip ETP - CSR initiative

Paradip, a port town of Odisha, had shortage of drinking water. Being a water-intensive industry, IOCL was dependent on the water resources of Paradip. Realizing the agony of the surrounding operating community, IOCL planned to set up effluent treatment and water reclamation plant inside its premises to ensure optimal utilization of the external water sources and to solve the problem of availability of clean drinking water for the residents of the town. India's largest effluent treatment and recycling plant was set up with the help of WABAG who was responsible for its designing, engineering, procurement, construction, installation, and start-up and test.

The environment-friendly and cost-efficient water management system can recycle around 54,000 meter3 of treated water every day for the IOCL refinery and the generated effluent is reused as process water in the refinery. The recycle and reuse of water has reduced the dependency of the refinery on the freshwater by over 17,000 milliliters every year. The freshwater is now used for irrigation and domestic purposes.

The effluent is a cocktail of oily water, stripped sour water, spent caustic, cooling tower blow down, sanitary wastewater and demineralization (DM) plant regeneration waste which could severely impact the environment, if discharged untreated.

This complex effluent is treated at various stages. At the first stage, American Petroleum Institute (API) and tilted plate interceptor (TPI) separators are used for the removal of oil and then DAF is used to remove the emulsified oil. The effluent is then subjected to a biological treatment, using bio-tower, and an activated sludge process followed by a treatment of caustic and landfill leachate. The treated effluent is further treated using the process of UF and high efficiency RO, so that the water can be reused in the refinery. At the final stage, sludge treatment is done using the process of thickening and dewatering. In order to ensure that the environment around the refinery does not get polluted, the VOC is first treated and the RO rejected water is passed on a hard COD management unit before being discharge into the sea.

https://www.wabag.com/project/outstanding-contribution-in-water-efficiency-conservation/

81 http://smartcities.gov.in/upload/smart_solution/593f9500c0719SharingofPractices.pdf

Case study

Hindustan Coca-Cola Beverages Pvt. Ltd., in order to make the surrounding community water-positive, has undertaken water replenishment projects and water conservation projects and has also set up a sewage water treatment plant.

Water replenishment project

Soda, one of the villages in Malpura Mandal in the Tonk district in Rajasthan, is suffering from the shortage of water as its ground water resources are contaminated with high levels of fluoride, chloride and other minerals.

The village has a huge water reservoir "Swarn Taal" which is the only source to meet all the water requirements of over 900 households, be it for drinking, agriculture, domestic or live stocks. The storage capacity of the reservoir, which is spread over 100 acres, has reduced due to accumulation of silts resulting in severe water crisis in Soda.

Hindustan Coca-Cola Beverages along with Soda Panchayat and the World Vision of India (an NGO) has undertaken a water replenishment project of deepening and renovation of Swarn Taal. The project also includes strengthening of embankment, installing a regular iron flood gate to release excess water, and stone pitching of four islands, which receive migratory birds also.

Water conservation project

Hindustan Coca-Cola Beverages has joined hands with the Regional Agricultural Research Station (RARS), Acharya N G Ranga Agricultural University, Guntur, Andhra Pradesh to set up a water conservation project. This will solve the problem of water scarcity in that area.

The project covers a catchment area of a 100-acres of farm land and a four-acre pond, separated into three acres and one acre for recharge shafts and water storage for irrigating the 100 acres of the research farm land.

The aim of the project is to recharge the groundwater table and to solve the problem of water scarcity. It will also help RARS to meet the water requirement for their on-going research activity.

Sewage water treatment plant project

HCCB in partnership with the Municipal Corporation of Greater Mumbai will set up a sewage treatment plant project of capacity to treat 1 million liters of water per day. The project will be set up at Mahim Causeway Pumping Station, Mumbai and the technology which will be used in the sewage water treatment plant is a rotating media biological reactor(RMBR). This initiative is aimed at conserving the fresh water as the treated water can be used for non-drinking and non-domestic purposes like horticulture, cleaning of public places, etc. for which, currently, fresh water is being used.

http://ficci.in/spdocument/20748/Publication-Sanitation.pdf

A typical industry has several water systems such as cooling water, process water, etc. The water required for each of these systems varies with different types of industries and also depends on their source; for instance, the boiler feed water requires maximum treatment in a refinery. Membrane technologies are the most widely used systems for generation of process water in industries as they provide an attractive solution for cost effective removal of contaminants with a small footprint.

The waste water generated from industries contain an array of contaminants, including chemicals such as ammonia, VOCs, oil, etc., which are sometimes difficult to treat. Such waste can be either be treated separately in the treatment plants or in combination with different technologies to remove residual particles and microorganisms making it fit for industrial use. The treatment structures are not rigid as they depend on the concentration of contaminants in the effluent. The treatment technology used would also depend on the demand and treatment cost of the industrial water.

Further, smaller technologies such as injection wells, as part of rain-water harvesting systems, is worth a mention. While, the above-mentioned technologies are suited for large-scale installations, aquifer recharge, resulting in increase of groundwater tables, provide local solutions to address the issues pertaining to the availability of fresh water in the long run. These injection wells collect rain water and recharge the aquifer, rather than the top soil.

With a wide array of available technologies that can be customized to the sector and requirement, it is the business models of these technologies that need to be addressed, in order to have their large-scale implementation and success.

Section 4:
Business model

There are several business models that operate in the areas of water and wastewater management and this section will deal with each of these models in detail through representative case studies which highlight the main features.

4.1. Private sector's participation

There are a number of reasons why countries introduce private entities into their water management sectors. Firstly, the introduction of a profit motive may increase efficiency as compared to a state-run system. Secondly, already existing private players have increased the productivity through fine-tuned planning, control systems, sound accounting systems and procurement systems.

The private sector's participation can be in a number of forms. These include privatization, greenfield projects, concessions, leases, outsourcing, etc. None of them are better than another, rather the type of participation chosen is based on a specific need that needs to be fulfilled. The type of participation also depends on the social, economic and regulatory objectives of the local market in question. Most of the times, a mix of methods are used.

Privatization also affects the cost of water in a country. When water is supplied by the public sector, it is commonly seen that the prices are kept artificially low, for political or social reasons. This is done through subsidies, which is possible due to tax revenues. These subsidies no longer stand once the private sector is involved. Since these companies are profit driven, it is not in their best interests to maintain low prices and hence, privatization may result in the increase of water prices.

Goal	Method of achieving goal
Increase efficiency of water/wastewater service operations	Introduction of a profit motive often leads to lower costs, lower prices and water conservation.
Increase stock of water infrastructure	Invite private investment to increase the available capital without raising taxes to unsustainable levels.
Raise revenue for government	Privatize water sector by selling off existing, government-owned water assets.
Reduce government responsibilities	Transfer ownership or management of the water services industry to the private sector.

Source: Compiled by the U.S. International Trade Commission

A note on each of the major types of private sector participation in water and wastewater management is detailed below:

1. **Privatization**: privatization entails a formal transfer of ownership of water and wastewater treatment utilities from the public to private sector. It involves the sale of assets like water supply, distribution systems and wastewater treatment plants to a private sector company. This sale allows the government to raise money and also introduce a profit incentive which would translate to lower prices and better services for customers. This form of private participation has been adopted in many industrial companies. Since 1989, there have been 29 instances where ownership has been transferred completely from public to private sector. The UK was the first country to do this, selling off 100% of its equity. Other countries since have sold between 20%–70% of their equity[82].

2. **Greenfield projects**: Greenfield projects refer to projects which are being undertaken for the first time in a particular place and as a result, the whole procedure begins from scratch, owing to a lack of previously existing infrastructure. Contracts are given out to private firms usually of BOT type or the BOO type. Upon receiving a contract, these firms arrange finances for the construction of the facility and then charge a certain amount for the water services through the entire life of the contract. Typically, these contracts are valid for 20 to 25 years[83], giving the firm adequate time to earn back make back their investment. The companies that participate in these projects are usually large multinationals based in construction, engineering or water services industries. Often, more than one of these companies collaborate with each other to fulfil a particular project. One very important type of Greenfield project that has been important in areas of water scarcity is the desalination plant. Rapidly growing populations in the arid Gulf countries and small island states is a problem as these countries have limited access to freshwater resources. Energy is also produced as a bonus by these plants through the desalination process.

3. **Concessions**: concessions are a measure taken by governments to augment the efficiency of their wastewater management facilities through involvement of the private sector. There is no transfer in terms of assets between the public and private sectors. Instead, the firm becomes responsible for the operation and maintenance of an already existing facility and bears all costs incurred due to expansion. These firms make their money directly from consumers throughout the period of the concession contract, typically 20 years[84]. In this way, it is ensured that the private firm's profits are determined by the quality/efficiency of their operations.

82 http://cdn2.hubspot.net/hub/183438/file-569396420-pdf/docs/wdbc_handbook_web.pdf
83 http://cdn2.hubspot.net/hub/183438/file-569396420-pdf/docs/wdbc_handbook_web.pdf
84 http://cdn2.hubspot.net/hub/183438/file-569396420-pdf/docs/wdbc_handbook_web.pdf

4. **Leases**: leases are same as concessions with the only difference being that in a lease, the costs that entail expansion are not borne by the private entity but by the owner of the infrastructure. Lease contracts also have a shorter time period of around 8–15 years and they rarely involve large scale private sector investment[85].

5. **Outsourcing**: In these contracts, the private entity is not responsible for the entire water utility but are paid a certain amount to provide a particular service. Contracting out such tasks allows the utility to focus on its core functions and improve its performance. Outsourcing is done for tasks like equipment maintenance, meter readings, etc.

Case study:

Name of Company (private): Bharadwaj Ecotech

Location: Nashik, Maharashtra

Clients: Industrial, municipal, residential

Profile: The company is an exclusive distributor/implementer of the patented BERI bio sanitizer STP technology. These bio sanitizers are a component of a range of products, relating to wastewater treatment.

Business model: The company possesses an exclusive licensing agreement to design and retrofit systems with their patented technology. The company takes responsibility for designing, engineering, manufacturing, installation, commissioning and maintenance services in all its plants. The main components and key parts are taken from BERI Water Technology. Bharadwaj Ecotech can be described as an end-to-end vendor[86].

4.2. Public sector's participation

There is an ongoing debate in the global community on whether private management of water is more effective than its public counterpart. Increasingly, countries have started introducing private players into the field of wastewater management, and some may even argue that with the increasing degree of development, countries are moving towards privatization of wastewater management.

Public sector management of wastewater has both merits and demerits. Those in favor of public water management argue that public management ensures that the municipalities are by and large in control of the operations. A second merit of public management is that it allows for certain tax exemptions. This is very important as water is an essential resource and should be priced such that it is affordable and accessible to all. Private sector is praised for its superior technical expertise and efficiency with which they carry out their functions. This can be attributed to the fact that efficiency and expertise are both invaluable in the pursuit of profit, which is the primary goal of any private player. Private involvement is also favored by municipalities that have problems pertaining to funding construction and maintenance of facilities and municipalities and have to comply with stringent quality standards. As a general trend, it has been observed that large municipalities choose to opt for private systems whereas smaller municipalities prefer to manage their systems themselves[87].

Private and public systems are not necessarily at odds with each other. Neither is better or worse than the other and their selection is a decision based on the resources at the disposal of the country/state/city in question. Besides this, there is the middle ground, which has gained momentum globally, PPP.

In a developing country like India, public water management is still predominant though there has been an increasing involvement of the private sector through PPP projects in the recent years. Most of the times, the water treatment plants are designed and constructed by state public health engineering departments or the concerned water supply or sewerage boards. Their maintenance and operation, is however, carried out by the municipal corporations.

85 http://cdn2.hubspot.net/hub/183438/file-569396420-pdf/docs/wdbc_handbook_web.pdf
86 https://www.indiamart.com/bharadwajecotech/profile.html
87 http://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvTmV3SXRlbV8xMDNfc3RhdHVzb2Z3YXRlcnF1YWxpdHlwYWNrYWdlLnBkZg==

Case study:

Name of project: V Valley Waste Water Recycle and Reuse Project

Location: Bangalore, Karnataka

Client: Bangalore Water Supply and Sewerage Board (BWSSB)

Duration: April 2007 to August 2013[88]

Project description: The project serves two important requirements of Bangalore - first, a safe outlet for wastewater which does not cause pollution or environmental degradation, and second, a source of freshwater to augment the city's dwindling water supply. The plant has a capacity of 135 million liter of wastewater per day[89] and the technology used to treat all this wastewater is membrane and activated carbon technology. The plant was established by the BWSSB along with three other tertiary plants in the city. The plant is the largest of its kind in the country. Once the water is treated, it is discharged into the Akravathy river in a potable form.

Decentralized waste water treatment system in Bangalore in 2004

Only 58% of the wastewater generated was being treated while the rest was being dumped into the city's lakes, polluting them. The amount of water being imported by the city was also increasing every year. In order to address these problems, the Karnataka State Pollution Control Board mandated building either more than 50 residential units or a built-up area of over 5,000 square meters in un-sewered areas to install on-site STPs and reuse all the treated water generated. By 2014, there were at least 2,000 buildings which had installed such systems and the collective treatment capacity was around 110 million liters per day (MLD) (10% of the wastewater generated by the city). This water was used for a variety of purposes including toilet flushing (by incorporating dual pipeline), landscaping, gardening, car-washing, etc.

Introduction of a Decentralized Wastewater Treatment (DEWAT) system in Agra

The DEWAT system was designed and constructed on the Kacchapura drain, close to the Taj Mahal. This system was installed by numerous partners including Agra Nagar Nigam, Centre for Urban Regional Excellence (CURE), United States Agency for International Development and others. Prior to the installation of this system, the conditions were unsanitary with a high health risk for citizens. With the introduction of the new system, the biological oxygen demand levels have dropped from 170ppm to 30ppm. What was earlier an open drain which bred diseases is now a safe space for community activities and recreation.

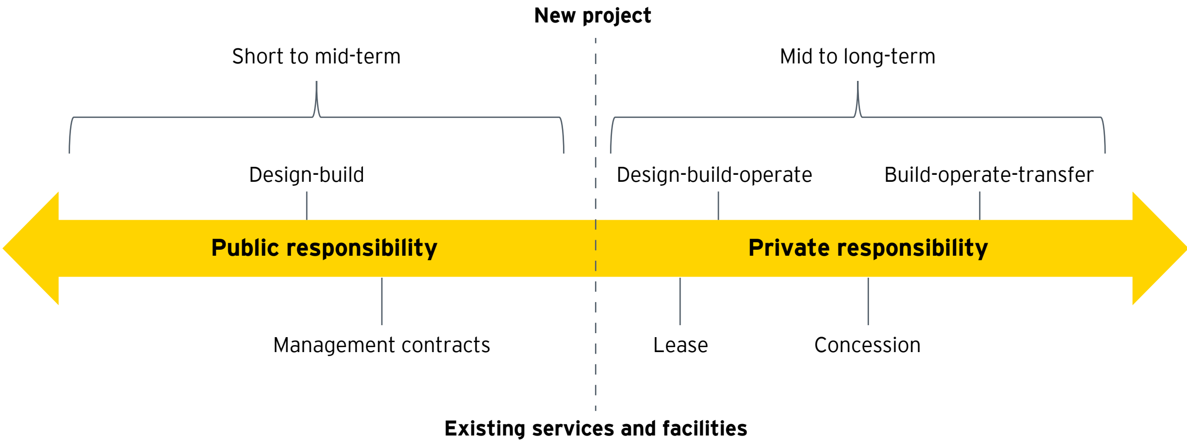
88 https://www.njsei.com/project/v-valley-waste-water-recycle-reuse-project/

89 https://www.njsei.com/project/v-valley-waste-water-recycle-reuse-project/

4.3. Private Public Participation (PPP)

PPP models focus on the distribution of risk between the public sector and the private sector based on the design and other responsibilities assumed by them. The share of responsibility between the public and private sectors in water supply through PPP contracts falls along a spectrum as shown below:

Figure 25: Share of public and private sectors' responsibility in PPP contracts



Source: EY Research

The following describes general PPP models used to undertake water projects. Four types of contracts that are most commonly implemented are described below:

1. **Performance based management contract**: the private developer has to undertake operation and maintenance of the entire system from source to consumer. The capital investment here is borne by the public sector. This contract aims to make the contractor responsible for successful operation and maintenance of the facility. In terms of risk, it is distributed between both public and private players.
2. **Lease**: the lease entails that the operator keeps whatever revenue is generated. Capital risk here is borne by the private sector. The goal of the lease is to obtain the private investment for operating and maintaining the system. The risk in this case lies entirely with the private player.
3. **Build and operate contract**: construction, operation and maintenance of the system are all undertaken by the concessionaire. The public sector is responsible for the capital investment. This contract aims to assign the responsibility of successful operation and maintenance to the contractor. The responsibility and risk is shared between private and public sectors.
4. **Invest, build and operate contract**: like in the case of "build and operate contract", the concessionaire must undertake construction, operation and maintenance of the system. However, the investment must be made by the private and not public sector. The objective of this contract is to make the contractor responsible for the successful operation and maintenance of the facility. The responsibility and risk lies with the private sector.

There are three PPP models on wastewater projects. The probable procurement models for the wastewater treatment infrastructure are:

BOT end user model: BOT stands for build, operate and transfer. This model is a form of a project financing, typically used to develop a discrete asset rather than a network. These assets are generally greenfield in nature. The revenue of the company is generated through a small fee to the government rather charging the tariffs from consumers. BOT is extensively used in infrastructure projects and PPPs. The private entity is responsible for building the facility and operating as well as maintaining it. However, once it is constructed, there is a transfer of assets from the private to public sector. The end users are typically water-intensive industrial clusters located in water deficient regions near urban areas. The end user industry usually sources the water from the nearby urban spaces and develops and operates the water treatment plant itself. The water generated is then reused for industrial purposes.

Case study:

Project name: As-Samra Wastewater Treatment Plant

Location: Jordan

Client: Ministry of Water and Irrigation

Scope: BOT, a modern plant treating wastewater of a population of 2.3 million[90]

Duration of project: 39 months[91]

Project description: The project commenced in 2003 and was completed in 2008 with the capability of treating the wastewater of the population of Amman and its surrounding areas. In 2009, owing to growing population, a 25-year expansion BOT plan contract was set up to expand the capacity from 2.3 million to 3.5 million[92]. The BOT scheme that is in place ensures that the private party's expertise is retained as it transfers the knowledge regarding how the plant is run and maintained.

Design, build, operate model: this is a kind of model where a single contractor is appointed to design a project, build it and then run it for a certain period of time. In this type of project, the funding is done by the government or a public agency. Given that this type of project does not simply involve financial delivery, the contractor theoretically must approach the project keeping its long-term success in mind, given that the contractor is also be responsible for the operation and maintenance of the facility for a stipulated period of time.

With regard to the wastewater, the private player designs and operates the plant basis specified output parameters. The capital expenditure for the plant is entirely borne by the public sector. The capital expenditure is usually reimbursed to the private player through an invoice (quarterly), while the operational expenditure payments are based on the performance of the private player. These are also usually disbursed quarterly[93].

Case study:

Project name: Clovis Sewage Treatment/Water Reuse Facility (CA)

Location: Clovis, California

Client: Clovis (the city)

Private player: CH2M Hill

Scope: The design, construction and long-term operations of a US$37 million – 2.8 million gallons of water per day[94] water recycling facility (WRF) to CH2M Hill through an integrated design-build-operate (DBO) contract. The new ST/WTF was designed to fulfil the growth needs of the City of Clovis' and provide highly treated recycled water.

Duration of project: 10 years[95] of operations and maintenance

Project description: Through the DBO delivery method, CH2MHill provided facilities for planning and engineering, design, construction, obtaining government approvals, permitting, acceptance testing, startup, O&M and warranty for the ST/WTF. The treatment methods being used include membrane bioreactor process and Siemen's Cannibal process. In 2008, the Clovis ST/WRF DBO project was honored with a Water/Wastewater Project Merit Award by the Environmental Business Journal in its yearly business achievement awards.

90 https://www.susana.org/en/knowledge-hub/projects/database/details/459
91 https://www.susana.org/en/knowledge-hub/projects/database/details/459
92 https://www.susana.org/en/knowledge-hub/projects/database/details/459
93 https://www.designingbuildings.co.uk/wiki/Design_build_operate_(DBO)
94 http://cdn2.hubspot.net/hub/183438/file-569396420-pdf/docs/wdbc_handbook_web.pdf
95 http://cdn2.hubspot.net/hub/183438/file-569396420-pd f/docs/wdbc_handbook_web.pdf

Hybrid Annuity Model (HAM): In financial terms, hybrid annuity means making its payment over two-time periods. First, it pays a fixed amount for a considerable amount of time, and then a variable amount over the remaining period of time. HAM was introduced by the central government to revive PPP in the area of highway construction but this model has been found to be applicable in other areas as well. In terms of features, HAM is a mix between two existing models – BOT and EPC (Engineering, Procurement and Construction). An advantage of using HAM is that it provides liquidity to the developer and also shares the risk with the government. While the private players continue to bear the construction and maintenance risks, they do not have to bear the entire financial risk.

Case study:

Project name: Namami Gange

Location: Varanasi, Mathura, Haridwar

Client: National Mission for Clean Ganga (Ministry of Water Resources, River Development and Ganga Rejuvenation)

Private player: Consortium led by Essel Infra Projects Ltd (Varanasi), Triveni Engineering and Industries Ltd. (Mathura) and HNB Engineers Private Ltd (Haridwar)

Scope: Namame Gange is the first ever-successful hybrid annuity PPP in sewage treatment in India. The project aims to ensure that no untreated wastewater enters the Ganges which is a lofty goal, given that presently close to 75%[96] of wastewater goes untreated into the river. Forty-percent[97] of the country's population, however, depend on the river as a water source and the success of this project would be a huge win for close to half of the population. If successful, the framework for this PPP model would be tried and tested and can be implemented for future projects.

Duration of project: 15 years[98]

Project description: Private sector developers would be responsible for designing, constructing, commissioning, operating and maintaining the STPs for 15 years. Forty-percent of the capital cost would be paid to the private entities upon completion of construction and the remaining 60%[99] would be paid over the life of the project as annuities and costs incurred for the operation and maintenance. This 60% will be paid based on performance of the STP, which ensure long-term performance of the assets created.

Water and wastewater projects are technically complex and require a huge investment. In order to improve the delivery of water utilities, private sector participation has been encouraged in planning, developing and managing of water systems. Drawing upon private sector support for water services systems is clearly one potential option to promote technical efficiency and fill huge funding gaps. Further, involving private sector innovation and experience, PPPs can deliver services more cost-effectively than the public approaches, including other benefits such as effective risk assessment and management; improved services provided and increased revenues. The National Water Policy, 2012, also explicitly encourages participation of private sector in the setup of the water infrastructure.

Engaging a private sector firm to design, build and operate a water plant is a good option as the roles and risks are shared between public and private firms. There have been various attempts to mobilize the private sector participation in water sector through PPP model in India, however, it invites several challenges. These are:

96 https://www.ifc.org/wps/wcm/connect/e614558e-c807-42e2-ab36-01c0a346795b/India_Clean_Ganga_PPP_Stories.pdf?MOD=AJPERES
97 https://www.ifc.org/wps/wcm/connect/e614558e-c807-42e2-ab36-01c0a346795b/India_Clean_Ganga_PPP_Stories.pdf?MOD=AJPERES
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99 https://www.ifc.org/wps/wcm/connect/e614558e-c807-42e2-ab36-01c0a346795b/India_Clean_Ganga_PPP_Stories.pdf?MOD=AJPERES
100 Riding the wave, EY

- The PPP model was developed based on the build-operate-transfer (BOT) or build-own-operate-transfer (BOOT) models, with the capital investment being made by private players either partially or wholly. Due to high risk factors and huge investment, private operators were unable to secure guarantees from public utilities for the payment of bulk service charges. Due to this, many projects turned non-operational[100].
- The public sector does not have the required capacity and resources to manage/monitor the services of the PPP.

There needs to be collective efforts made by the regulatory bodies to mobilize the private sector's involvement for the transformation of water usage in the country.

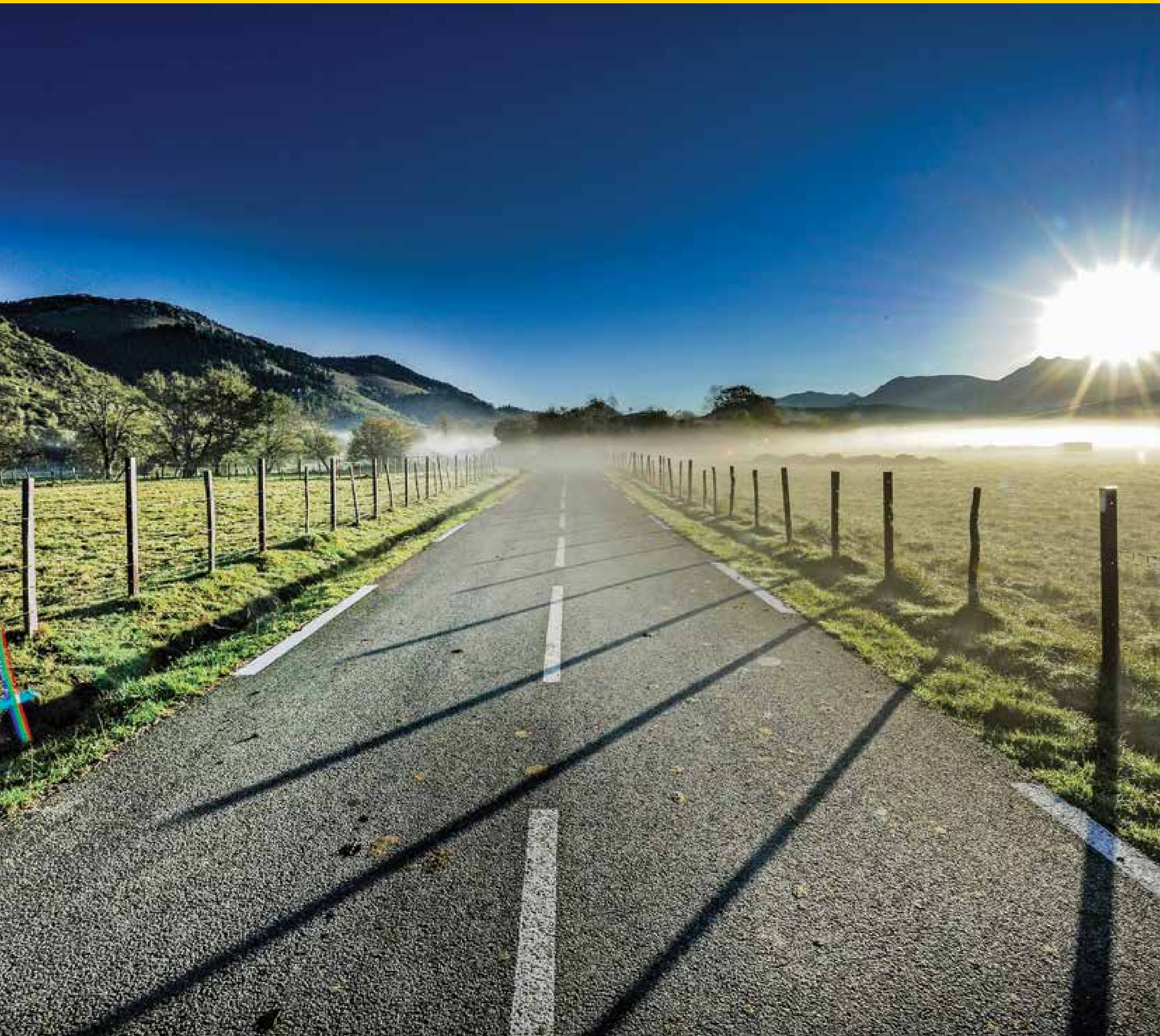
Table 10: Water and wastewater projects in India

Case study	Driver for the project	Description	Funding/Project structure	Revenue/Tariff structure	Risk allocation
Reuse of waste water at Chennai Petroleum Corporation Ltd (CPCL)	▶ Chennai does not have sufficient water sources to meet the drinking water demand. ▶ Industry has to use alternative options such as the reclamation of secondary treated sewage and seawater desalination. ▶ The extraction of groundwater for industrial purposes is not permitted.	▶ Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) operates 110 million liters per day (MLD). STP at Kodungaiyur. ▶ It supplies 23 million litres per day of secondary treated municipal wastewater from this STP to Chennai Petroleum Corporation Ltd (CPCL) refinery at Manali, Chennai. ▶ The water is further treated by CPCL and reused for cooling, boiler make-up water and in production.	▶ CPCL constructed and operates the treatment plant at its refinery for treating the secondary effluent for its industrial purposes. ▶ CMWSSB constructed and operates the Kodungayiar STP at its own cost.	▶ CPCL pays INR11.85/ cubic meters for secondary effluent to CMWSSB. ▶ CPCL procures freshwater at INR62/cubic meters to CMWSSB.	▶ CPCL bears the demand and funding risk.
Reuse of waste water at Mahagenco	▶ Mahagenco decided to expand the existing capacity of Koradi Thermal Power Plant by 1980 MW. Additional water requirement is 130 million liter of water per day. ▶ Vidharbha region is already water stressed. ▶ Alternative water sources comprise of construction of new dams/barrages and challenge in getting the water allocation.	▶ Nagpur Municipal Corporation (NMC) had already planned to set up 110 million liters of water per day STP under Jawaharlal Nehru National Urban Renewal Mission JNNURM. ▶ United States Agency for International Development (USAID) conducted a feasibility study for re-using the treated sewage from Nagpur for its use in a thermal power station. ▶ Mahagenco found the proposal feasible and economical and an MOU was signed for the same. ▶ STP along with secondary and tertiary treatment to be constructed, operated and maintained by Mahagenco as per their requirements.	▶ Total cost of the project - INR180 crores. ▶ Grant of INR90 crores received from JnNURM by NMC passed on to Mahagenco. ▶ Balance INR90 crores provided by Mahagenco. ▶ Land required for the project shall be provided by NMC. ▶ Operation and maintenance cost: INR1.50 crore/year.	▶ Mahagenco pays Nagpur Municipal Corporation (NMC) for raw sewage purchase: INR15 crore/ year. ▶ Cost of water to MAHAGENCO: INR3.40/cubic meter.	▶ MAHAGENCO takes the partial funding risk and the complete operational and demand risk.

Source: EY research

Section 5:

Way forward



The present water management system that is in place may not be able to keep up with the growing population demands and the rapid rate of urbanization. In order to offset the effects of urbanization and population growth, there needs to be changes made to the existing water treatment sector. These changes should be in terms of policies, technologies, systems, etc. with the final goal of achieving 100% wastewater recyclability. As discussed in section 1, despite progress being made in the water and wastewater treatment, there is still a large proportion of wastewater generated that is left untreated (26,468 million liters per day).

To manage the current challenges of water security, quality and availability, it is essential to view potential interventions through the simple lens of reduce, reuse and recycle. Rising water scarcity and stress are driving a number of industries to explore water technologies and strategies to help streamline the water usage. One of the ways to water savings can be achieved by reducing the overall water consumption and increasing the internal water use. Reduction can also be achieved by optimization of water use by industries as it can lower the freshwater abstraction rates, thus increasing the water availability and lowering the waste water discharges and pollution load. Investigating the actual water quality required, would help in water optimization within an industry. Wastewater generated by industrial processes needs to be viewed and treated as a resource. Water recycling systems can be built through the various business models suggested to treat the waste water which can be used further for internal processes. Recycling industrial water can increase profitability, reduce water input risk and lead to better conservation.

There are key levers that need to function in synergy to achieve progress on water reuse, its usage reduction and recycling. While technological interventions remain a crucial lever, policy interventions at various levels are also necessary, particularly to streamline the efforts of different stakeholders, provide guidance with regards to best practices and devise incentives for action.

Legal framework

Legislation is an important tool while dealing with water and wastewater management and it is important to deal with the problem at an international and a domestic level. It has been the case however, in some countries, that legislation has proved to be inadequate to solve the water treatment problem:

- **Legislative responsiveness**: every country has a different national reality when it comes to water management. These differences arise on the basis of the size of a country, administrative structure and pre-existing water contamination. All these factors must be taken into account while creating legislation. It is important to understand that one solution that works for a country may not be universally applicable. Standards must be studied closely especially at a national level since they eventually form the benchmark while distributing licenses and permits. It is also important to make provision for the national context while setting up standards The specific rights which should be considered are the right to water and sanitation, the right to housing and the right to food. Incorporating these ideas while framing a legislation ensures a more holistic understanding of the problem and allows public participation with regard to environmental decision-making.
- **Legislative comprehensiveness and enforcement**: in order to encompass the vast extent of the problem, an integrated sustainable approach should be adopted. Legal framework should encourage integrated permit systems for wastewater discharges, preferably administered by a local authority. The use of incentives and sanctions should also be considered to ensure compliance.

Treatment system - centralized and decentralized system

Most Indian cities have centralized wastewater treatment systems. These are not only capital intensive but also do not reach to large sections of society, particularly the low-income sector. An alternative to this would be to modify the centralized system, that is in place, into a hybrid system with both centralized and decentralized facilities.

It has been established[101] that a decentralized system is the best way for India to go about its wastewater treatment compared to centralized treatment system. Bangalore can be used as a model given its stringent laws and partial on-ground implementation. Combining a decentralized system with increased water tariffs, strict enforcement and incentives for early adopters, the decentralized wastewater system can pick up momentum.

Policy effectiveness

- There is a need for policies to be comprehensive. All issues at levels spanning from international to domestic need to be addressed. Transboundary cooperation may also be considered, given that the wastewater problem is not confined by the boundaries.
- Policy making should also be inclusive. It should not just include institutional stakeholders but also, persons from civil society.

101 https://www.researchgate.net/publication/313265646_Decentralized_Wastewater_Systems_in_Bengaluru_India_Success_or_Failure

Tariff structure

The current approach to tariff setting has resulted in tariff levels often being far below the operation and maintenance levels. The institutions responsible for the provisions of such services do not receive enough revenues to improve and maintain adequately resulting in poor services. Price reforms under these circumstances is desirable for the economic growth.

Innovative technology

While the quality and availability of raw water are declining, water treatment technologies are still expected to provide safe, healthy and clean water. Adopting innovative technologies in water treatment sector strengthens the efficiency and sustainability of drinking water or wastewater treatment in India. Innovative processes, technologies and systems can also focus on improving the local water resources and ecosystems, which in turn may help in reducing fresh water abstraction. Governments should take efforts to bring in innovative water technologies in order to improve the sustainability of water treatment systems.

Digitization

Large opportunities lie in enhancing operational efficiency through digitization – particularly in utilities and urban environments. Technologies for leakage detection, escalation and intervention allow for a quick repair of leakages. The predictive methods on critical connections help in preventive maintenance before the probability of springing leaks rises. According to the World Economic Forum, water efficiency, management and conservation can be enhanced by leveraging the technologies of the Fourth Industrial Revolution[102].

Sensor-based devices connected through platforms allow for better prediction of water demand, quality and supply. GIS mapping is being leveraged for location optimization and planning based on remote sensing data. The Government of India's Smart City Mission, which is receiving financial, technological and policy support, is an opportunity to build resilient cities through such technologies and platforms[103].

Water trading

Exchange of water rights, also referred as transfer of entitlements is carried out between irrigators, environmental water managers and water authorities. Water trading ensures availability of water when and where it is required the most. Certain states in India such as Maharashtra are leading the way in establishing water entitlement frameworks but there is a need to institutionalize such frameworks over every single Indian state in phases which is likely to help to transfer scarce water for the most productive use.

Recycled water certificate

A recycle water accreditation is likely to make water recycling and reuse mandatory across various user groups like domestic, commercial and agricultural users, by setting up a water conservation or recycling target (as a percentage of actual water consumption). If the recycling targets are achieved by the user group, they are awarded a tradable recycled water certificate. This certificate is a proof that the user has fulfilled its obligation of recycling the given amount of water. This mechanism is likely to help reduce water footprint, create and support recycled water market, promote company's commitment to recycle and reuse water, and promote a penalty mechanism for non-compliance.

102 http://www3.weforum.org/docs/WEF_WR129_Harnessing_4IR_Water_Online.pdf
103 http://smartcities.gov.in/content/

Conclusion

This paper details the governing institutions, policies, technologies and frameworks that can enable progress in managing India's water demands, supply and quality sustainably. Through extensive research, it emerges that collaboration among stakeholders is essential to achieve this progress. Policy levers enable a smooth functioning of the various projects, which in turn leverage technology that mandates the creation of new processes to align incentives.

It is encouraging to see the initiatives undertaken by the Government of India in terms of the National Water Mission, the National Water Policy, the formation of the unified Jal Shakti Ministry and various schemes such as the Nal se Jal and Swajal schemes for water supply in urban and rural areas, the Ganga Rejuvenation Scheme and the R&D Program in water sector. Leveraging these policies, all the concerned stakeholders – both public and private need to come together to set up and execute a unified action plan to reach the goal of an efficient water management.

India needs to take the right steps towards bringing concrete solutions in enhancing water resource management. It must promise itself a vision for a superior future which requires the incorporation of sustainability frameworks inside the nation's current water sector. All such frameworks need to come under a systematic water resource management structure, which is driven through instituted guidelines that relate to the development and operation of business models and consumption trends in the Indian water sector.

With the unified ministry being formed recently and with the support from the private sector and communities, we might soon reach our goal of efficient water management.

Glossary

MoWR	Ministry of Water Resources
MoUD	The Ministry of Urban Development
SLB	Service level benchmarking
IWRM	Integrated water resource management
NWM	National Water Mission
NAPCC	National Action Plan on Climate Change
SSAP	State Specific Action Plan
NERIWALM	North Eastern Regional Institute of Water and Land Management
CWC	Central Water Commission
CGWB	Central Ground Water Board
ADB	Asian Development Bank
MWRRA	Maharashtra Water Resources Regulatory Authority
OWRCP	Orissa Water Consolidation Project
FOT	Farmers Organisation and Turnover
CWMI	Composite Water Management Index
MJSA	Rajasthan's Mukhya Mantri Jal Swavlambhan Abhiyan
WFD	Water Framework Directive
NGOs	Non-governmental organizations
MSF	Multi stage flash distillation
MED	Multi effect distillation
ED/EDI	Electro-deionization
COD	Chemical oxygen demand
BOD	Biochemical oxygen demand
TOC	Total organic carbon
VCD	Vapor Compression Distillation

RO	Reverse osmosis
MF	Microfiltration
UF	Ultrafiltration
NF	Nanofiltration
CDI-	Capacitive deionization
MEE	Multi effect evaporator
ZLD	Zero-liquid discharge
SBT	Soil biotechnology
CAMUS-SBT	Continuous Aerobic Multistage-Soil Bio Technology
DAF	Dissolved air flotation
VOC	Volatile organic compound
RMBR	Rotating media biological reactor
RARS	Regional Agricultural Research Station
BOT	Build-operate-transfer
BOO	Build-own-operate
PPP	Public Private Partnerships
HAM	Hybrid Annuity Model
DEWAT	Decentralized wastewater treatment
CURE	Centre for Urban Regional Excellence
PPM	Parts per million
SDG	Sustainable development goals
UNESCO	United Nations Educational, Scientific and Cultural Organization
WWAP	World Water Assessment Program
STP	Sewage treatment plant

ASSOCHAM
THE KNOWLEDGE ARCHITECT OF CORPORATE INDIA

Evolution of value creator

ASSOCHAM initiated its endeavor of value creation for Indian industry in 1920. Having in its fold more than 400 Chambers and Trade Associations, and serving more than 4,50,000 members from all over India. It has witnessed upswings as well as upheavals of Indian Economy, and contributed significantly by playing a catalytic role in shaping up the Trade, Commerce and Industrial environment of the country.

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ASSOCHAM is seen as a forceful, proactive, forward looking institution equipping itself to meet the aspirations of corporate India in the new world of business. ASSOCHAM is working towards creating a conducive environment of India business to compete globally.

ASSOCHAM derives its strength from its Promoter Chambers and other Industry/Regional Chambers/Associations spread all over the country.

Vision

Empower Indian enterprise by inculcating knowledge that will be the catalyst of growth in the barrier less technology driven global market and help them upscale, align and emerge as formidable player in respective business segments.

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As a representative organ of Corporate India, ASSOCHAM articulates the genuine, legitimate needs and interests of its members. Its mission is to impact the policy and legislative environment so as to foster balanced economic, industrial and social development. We believe education, IT, BT, Health, Corporate Social responsibility and environment to be the critical success factors.

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Currently, ASSOCHAM has more than 100 National Councils covering the entire gamut of economic activities in India. It has been especially acknowledged as a significant voice of Indian industry in the field of Corporate Social Responsibility, Environment & Safety, HR & Labour Affairs, Corporate Governance, Information Technology, Biotechnology, Telecom, Banking & Finance, Company Law, Corporate Finance, Economic and International Affairs, Mergers & Acquisitions, Tourism, Civil Aviation, Infrastructure, Energy & Power, Education, Legal Reforms, Real Estate and Rural Development, Competency Building & Skill Development to mention a few

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Together, we can make a significant difference to the burden that our nation carries and bring in a bright, new tomorrow for our nation.

ASSOCHAM Contacts

Saurabh Sanyal
Deputy Secretary General
saurabh.sanyal@assocham.com

Purnima Dhingra
Head – Environment & Climate Change
011 4655 0514, 98734 83757
purnima.dhingra@assocham.com

ASSOCHAM
INDIA

The Associated Chambers of Commerce and Industry of India (ASSOCHAM)

Corporate Office:

5, Sardar Patel Marg, Chanakyapuri, New Delhi - 110 021
‣ Tel: 011-4655 0555 (Hunting Line) ‣ Fax: 011-2301 7008, 2301 7009
Website: www.assocham.org

ASSOCHAM's REGIONAL & OVERSEAS OFFICES

ASSOCHAM REGIONAL OFFICES

ASSOCHAM Western Regional Office
608, 6th Floor, SAKAR-III
Opposite Old High Court, Income Tax
Ahmedabad-380 014 (Gujarat)
Phone: +91-79-2754 1728/ 29, 2754 1867
Fax: +91-79-30006352
E-mail: assocham.ahd1@assocham.com
assocham.ahd2@assocham.com

ASSOCHAM Eastern Regional Office
18, Ballygunge Circular Road
Kolkata-700019
Contact Person: Ms. Perminder Kaur
Phone: 91-33-4005 3845/41
Mobile : 0967431223
Fax: 91-33-4000 1149
E-mail: perminder.kaur@assocham.com

ASSOCHAM North Eastern Regional Office
Global Express Group
House No. 7, Bye No. 2
Chandan Nagar, Survey, Beltola
Guwahati-781028
Contact Person: Mr. Munindra Kumar
Phone: 09957999367
E-mail: ner@assocham.com

ASSOCHAM Southern Regional Office
Ashirwad Towers, 1st Floor, 75/11,
2nd Main Road, Vyalikaval,
Bengaluru-560003
Contact Person: Mr. Chetan Shiva Kumar
Tel: 080-40943252
Fax: 080-41256629
Mobile: 9108563359
E-mail: chetan.s@assocham.com

ASSOCHAM Regional Tamil Nadu Office
International Law Centre, 61-63
Dr. Radhakrishnan Salai
Mylapore, Chennai-600004
Contact Person: Mr. Vinod Solomon
Phone: 044-28120000 • Fax: 044-28120001
Mobile: +91 9486204970
E-mail: chennairo@assocham.com
vinod.solomon@assocham.com

ASSOCHAM Regional Ranchi Office
503/D, Mandir Marg-C, Ashok Nagar
Ranchi-834 002
Contact Person: Mr. S. K. Singh
Phone: 06516555601, 06516555001
Mobile: 09534769548
E-mail: ranchioffice@assocham.com

ASSOCHAM Regional Hyderabad Office
Plot No. 1335, Road No. 45
Jubiliee Hills, Hyderabad-500 033
Contact Person: Mr. Srikant Badiga
Phone: 040-23557777

ASSOCHAM Regional UP Office
B-1, Kasmanda Regent Apartments
Park Road, Hazratganj, Lucknow-226001
Contact Person: Mr. C. P. Singh
Mobile: 9415026052
E-mail: rd.up@assocham.com

ASSOCHAM Regional Chandigarh Office
SCO: 55, 56, 57, II Floor, Sector-8
Madhya Marg, Chandigarh-160008
Contact Person: Mr. Dalip Sharma
Phone: 0172 4800855
E-mail: director.chd@assocham.com

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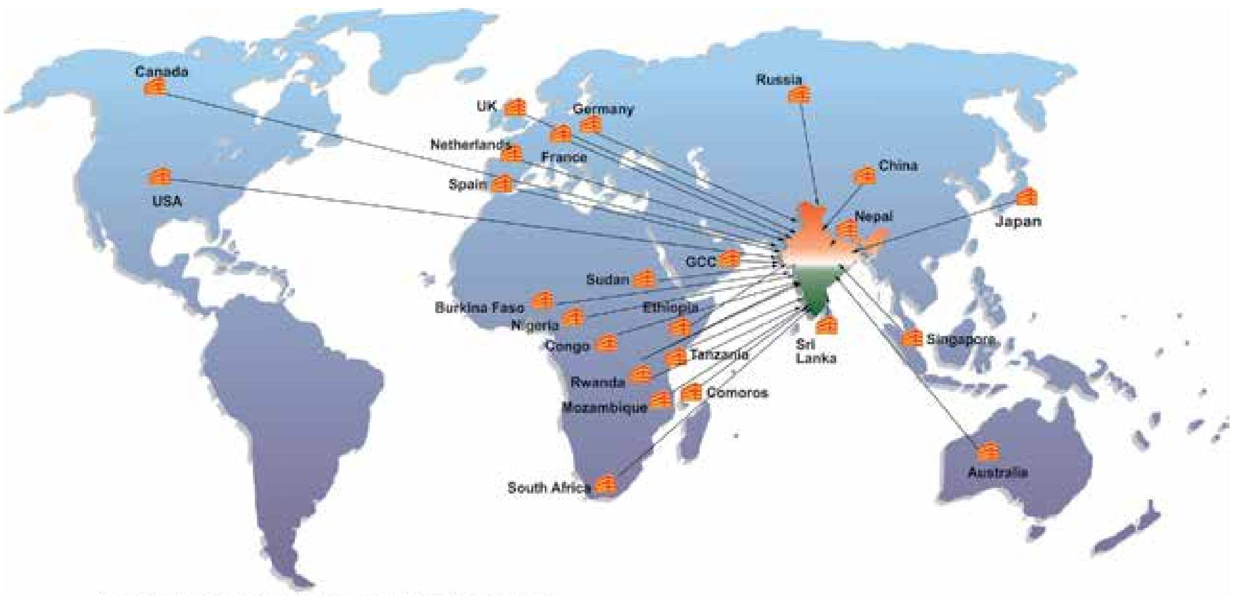

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ASSOCHAM International Department

Notes:

Notes:

EY offices

Ahmedabad
2nd floor, Shivalik Ishaan
Near C.N. Vidhyalaya
Ambawadi
Ahmedabad - 380 015
Tel: + 91 79 6608 3800

Bengaluru
6th, 12th & 13th floor
"UB City", Canberra Block
No.24 Vittal Mallya Road
Bengaluru - 560 001
Tel: + 91 80 4027 5000
+ 91 80 6727 5000
+ 91 80 2224 0696

Ground Floor, 'A' wing
Divyasree Chambers
11, O'Shaughnessy Road
Langford Gardens
Bengaluru - 560 025
Tel: + 91 80 6727 5000

Chandigarh
1st Floor, SCO: 166-167
Sector 9-C, Madhya Marg
Chandigarh - 160 009
Tel: + 91 172 331 7800

Chennai
Tidel Park, 6th & 7th Floor
A Block, No.4, Rajiv Gandhi Salai
Taramani, Chennai - 600 113
Tel: + 91 44 6654 8100

Delhi NCR
Golf View Corporate Tower B
Sector 42, Sector Road
Gurgaon - 122 002
Tel: + 91 124 443 4000

3rd & 6th Floor, Worldmark-1
IGI Airport Hospitality District
Aerocity, New Delhi - 110 037
Tel: + 91 11 4731 8000

4th & 5th Floor, Plot No 2B
Tower 2, Sector 126
NOIDA - 201 304
Gautam Budh Nagar, U.P.
Tel: + 91 120 671 7000

Hyderabad
Oval Office, 18, iLabs Centre
Hitech City, Madhapur
Hyderabad - 500 081
Tel: + 91 40 6736 2000

Jamshedpur
1st Floor, Shantiniketan Building
Holding No. 1, SB Shop Area
Bistupur, Jamshedpur – 831 001
Tel: + 91 657 663 1000

Kochi
9th Floor, ABAD Nucleus
NH-49, Maradu PO
Kochi - 682 304
Tel: + 91 484 433 4000

Kolkata
22 Camac Street
3rd Floor, Block 'C'
Kolkata - 700 016
Tel: + 91 33 6615 3400

Mumbai
14th Floor, The Ruby
29 Senapati Bapat Marg
Dadar (W), Mumbai - 400 028
Tel: + 91 22 6192 0000

5th Floor, Block B-2
Nirlon Knowledge Park
Off. Western Express Highway
Goregaon (E)
Mumbai - 400 063
Tel: + 91 22 6192 0000

Pune
C-401, 4th floor
Panchshil Tech Park
Yerwada
(Near Don Bosco School)
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ASSOCHAM Corporate office

The Associated Chambers of Commerce and Industry of India
5, Sardar Patel Marg, Chanakyapuri, New Delhi 110 021. India
Tel: 011 4655 0555 (Hunting line), 011 4655 0514 (Direct)
Fax: 011 2301 7008, 2301 7009
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