Water sector resilience - Reimagining a blue future

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Foreword by KPMG in India

The key elements that define development alongside growth for an economy include meaningful employment, inclusivity, poverty alleviation, standard of living, robustness of institutions and infrastructure. Tracing back to independent India which focussed on the trickle-down approach for development, the recent decades have aimed at direct interventionist policies at target-oriented groups. The convergence of the outcomes is inevitable, however, only with vigour of alignment around the mentioned binding factors and with unhindered commitment to measurable results. The vision of a 'New India' resounds the trajectory of a growing nation by focusing on inclusivity and self-sustainability.

Various progressive reforms and initiatives have already been implemented by the Government of India with a wide focus ranging from enhancing the business environment to ascertaining macroeconomic stability, the economic activity of the country has received a tremendous boost.

The next generation social programmes such as Skill India, AMRUT and Swachh Bharat are designed in a manner that aim at inclusiveness and integration, entrepreneurship, productivity enhancement and are self adequately aligning themselves with the sustainable development goals that endeavour to formulate one of the leading economies in the decade to come. Ensuring the equitable and sustainable distribution of potable and adequate drinking water to all is non-negotiable and is of the highest importance in achieving forward momentum in our ambitious development goals

Given the vast expanse of the country and the multitude of hindrances faced by it in its path towards progress, it is pertinent to address the fundamental issues for socio-economic development of India from the grass root level. In such a scenario, the state governments of India can play a critical role by letting the planned measures percolate down to the rural areas. The effective and timely execution of reforms, utilisation of the funding given by the central government for development of infrastructure and other areas, the implementation of schemes has to be flawlessly carried out by the state governments. The active promotion of states by their state governments showcasing them as investment destinations to global investors would also increase the flow of FDI into the country. The thought befits the idea that 'strong states make a strong nation'.

We recognise the need for coordinated action by both the public and private sectors for the strategic resolution of this pressing issue.

By involving the state governments extensively for implementing measures alongside the central government and empowering them by guiding them in the right direction, India can strengthen its federal structure of governance. With proper governance and empowered states, the nation could rise through the ranks and move closer to achieving its vision of a 'New India'.

Nilaya Varma
Partner and Head
Government and Healthcare Practice
KPMG in India

Foreword by KPMG in India

Asian economies are undergoing rapid urbanisation. By 2050, more than half of the Asian population close to 3 billion is expected to be living in towns and cities, particularly in tier II and III cities. This is roughly twice the current population of 1.6 billion[1]. Managing a finite resource such as water in the light of such demand poses tremendous challenges. The impact of climate change will further exacerbate these challenges.

India's accelerated growth has led to tremendous stress on the finite water resources that are depleting on account of overexploitation and mismanagement. Sectoral demands for water are growing rapidly in line with urbanisation and industrial growth. The World Economic Forum named water crises as one of the top three highest global risks to economies, environments and people, in terms of impact in 2016[2].

Delivery of water supply for domestic and Industrial purpose remains an issue. Poor management of water sources has put them under tremendous stress. Despite various attempts over the years, water continues to be mismanaged with the over-exploitation of ground water, contamination of surface water sources, depleted flow in river basins, salinisation, etc. The per capita water has been declining at an alarming rate and the gap between demand and supply is also widening.

There is a need of comprehensive analyses of water management systems in India. With huge pressure on the service providers, it is imperative to translate good principles into practice. There are many questions on the quality and quantity of water, current levels of non-revenue water, financing and poor performances of utilities which needs to be looked into for better management of water sector infrastructure.

There is a growing imperative to focus on managing water resources efficiently. In order to do that, India needs to focus on best practices in water management through robust policy directives.

In this report we have focused on innovative technologies and sustainable water management approaches which are of utmost importance to streamline the current water management practices in the country.

Nilachal Mishra
Partner
Social-IGH Practice
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1. Report on World Urbanization Prospects, UN
2. The Global Risk Report, Weforum, 2017

Foreword by ASSOCHAM

Sustainable water management is critical for socio-economic development, healthy ecosystems and for human survival itself. India has 4% of world's water but caters for 16% of the world's population. Our total demand for water resources is expected to exceed the utilizable potential by 2050. Since only 2.5% of available global water is fresh, clean potable water remains an ever growing challenge. A quarter of humanity on this earth forced to rely on contaminated water sources and about half of our Indian villages do not have any source of protected drinking water. Water is a finite and irreplaceable resource and only renewable if well-managed. Water resource management in India is challenging owing to conflicts between constitutional authorities, various sectors (industry versus agriculture, urban versus rural), and commercial entities. Declining natural water resources mandate a more cooperative approach and judicious use of existing sources, retrieval of contaminated sources and efficient water supply, usage and recycling using science and engineering. A synergism of government and nongovernmental initiatives coupled with translational research and development spanning the entire spectrum from policymaking to the community end user is inescapable.

Water is a public good and a fundamental right of the citizens as per the Indian Constitution. These make it a popular thought that only through private sector participation it is not likely to lead to efficient market outcomes. Thus, as a remedy to market failures and attain an optimal production and distribution of public goods, the role for governments is of utmost importance and water sector is no different. However at the same time, there is no denying the fact that there is huge amount of gap between total investment required to meet the burgeoning demand of the growing population, urbanization, climate change, water pollution viz a viz government planned investments. This makes private sector participation coupled with innovative business models and funding mechanism as an inevitable way forward.

We believe this conference with a focus on Science, Technology, Innovation and Sustainability for an integrated management of water resources and water governance provides us a holistic perspective and enlightens us about a strategic implementation of innovations in the water sector.

Sandeep Jajodia
President
ASSOCHAM

Foreword by ASSOCHAM

India with the second largest mass of humanity in this world cannot afford to insulate itself from the ongoing global water crisis. We face huge challenges in availability, accessibility, quality and sustainability of safe water in our country. The problem is going to be compounded in the coming decades with the demographic, socioeconomic and climatic transitions we continue to witness since the past century. Unsafe water continues to underlie a major bulk of health related issues in our country. Industrial effluents, sewage, irrigation needs and agricultural runoff continue to contaminate our water bodies. The ills of gradual shrinkage of our natural water resources ironically is also being aggravated with flood related disasters in recent years in our country. Sustainable management of existing water resources is the key to averting a looming water crisis. Widespread government initiatives (such as Swachh Bharat, and National Drinking Water Mission) that integrate water and sanitation across communities have been path breaking However, a successful and self sustained translation into communities requires action beyond the government. Unaware community and private sector participation with development of innovative business models and funding mechanisms are equally important cogwheels in this water management cycle.

We live in exciting times where science and technology bring in new innovative changes to our lives every day. Water technology innovations open new vistas for pragmatically addressing the water crisis. Adoption of new technologies and innovations in predictive ways requires integrated and adaptive management strategies. Newer approaches to water technology continue to enable us to develop new and sustainable means to supply, recycle, and reuse water resources.

It is our privilege to release the knowledge paper titled, **"Water Sector Resilience - Reimagining A Blue Future" jointly prepared by KPMG and ASSOCHAM at "National Conference-cum-Exhibition & Awards on Science, Technology & Innovation in WATER MANAGEMENT" on June 28, 2018 at Hotel Le-Meridien, New Delhi.**

We recognize the efforts and contribution of **Dr Om S Tyagi, Ms Purnima Dhingra and Mr Nitesh Sinha** in organizing this conference. We believe the outcomes of this conference as well as our knowledge paper will serve as an important reference document for different stakeholders in the field of water management.

D S Rawat
Secretary General
ASSOCHAM

1. Introduction

1. Introduction

As per UNICEF, more than 2,000 children under the age of five die every day because of water borne diseases – around 780 million people lack access to safe drinking water. More than 25 per cent of the earth's population is forced to rely on water from contaminated sources for fulfilling their basic needs. The fresh water source are unevenly distributed and not accessible for human consumption. The total volume of water on earth is 1.4 billion cubic kilometres out of which only 41,000 cubic kilometres of water is accessible for human consumption. Against this water availability, the total population that can be served is likely to touch 9.1 billion in 2025. In addition to the quantity available, it is critical to understand the rate at which the water resources are renewed. As compared to this global context, scenario in India is not too different.

1.1 Water Sector in India- Current scenario

WATER

1545 m3/annum: The per-capita availability of water in India has declined from 1,816 cubic metres in 2001 to 1,545 cubic metres in 2011. As per the United Nations, any region with annual water availability below 1,700 cubic metres per person is a water-stressed region.

20 per cent: Groundwater blocks critical or overexploited

302 river stretches on 275 rivers across the country have been polluted due to discharge of both municipal and industrial wastewater over the years.

8.5 per cent and 10.1 per cent: Freshwater abstraction by industries in 2025 and 2050, respectively.

23 per cent: Industries do not get water easily or get it at high cost.

River Basin Per capita: The per capita availability of rivers in India varies from 300 cubic meter to 2000 cubic meter per person per year.

Water leads to an overall cultural, social, economic and political development of India. The per-capita availability of water in India has declined from 1,816 cubic metres in 2001 to 1,545 cubic metres in 2011. More than 60 per cent of India's irrigated agriculture land and 85 per cent of drinking water supplies are dependent on groundwater supply. In this evolving hydrological context, climate change is expected to play a key role.

The United Nations defines any region with annual water availability less than 1,700 cubic metres per person as a water stressed region. The water resources in urban areas are under huge pressure owing to factors like intense demand and pollution. Almost 80 per cent of water supply to municipalities is disposed back into the ecosystem in the form of wastewater, which is a highly critical environmental and health hazard.

We are in the midst of a severe, and perhaps, an unprecedented water crisis. India has 4 per cent of the world's water resources and a disproportionate 16 per cent of world's population. A report[1] by NITI Aayog draws attention to the fact that 600 million or 48 per cent of India's population is under 'high to extreme' water stress. It further says, that about 75 per cent Indian housholds do not have drinking water connections at their homes. Moreover, nearly 70 per cent of the water that is supplied is contaminated by biological, toxic, organic, and inorganic pollutants, which makes it unsafe for human consumption, irrigation and industrial use.

Pressure on urban water resources will be double of as much as available water supply by 2030. Water scarcity would also account for a 6 per cent loss in India's gross domestic product (GDP).

1. Report on Composite Water Management Index, June 2018

Governments, water corporations, industry, lawmakers and the public have a formidable challenge at hand to create an effective approach for management of water resources.

The growing demand for water comes at a time when the potential for augmenting the supply is limited – water tables are falling (by 1 to 3 meters every year) and so is the quality of the water available.

India's urban population is expected to increase from 377 million in 2011 to 600 million by 2031[2], in turn leading to corresponding increase in demand for all resources including water. There is strong linkage between challenges such as population increase, increased migration to cities, poor management of water resources and climate change. Droughts and floods have become more frequent and intense. The current drought and flood management strategies are not geared up to tackle these challenges effectively.

Efficient and sustainable water management is one of the key areas of focus. Increasing efficiency of water use entails certain key activities such as recycling of treated water; adoption of water efficient technologies; mandatory water audits; development of eco-friendly sanitation systems and improvements in the efficiency of urban water systems.

This knowledge report, prepared by KPMG and ASSOCHAM, focuses on technology, innovation and sustainable water management approaches. It is a call to action for policy makers, investors and the business community to take positive steps to address the Indian water crisis and create a more resilient future for all.

1.2 Challenges and key interventions needed

The current infrastructure in the sector is insufficient to meet with growing socio-economic developments. Climate change and environmental pollution also lead to source contamination. Over the years, significant efforts have been made to provide safe drinking water in the urban and rural areas. However, most utilities are not operating efficiently due to poor infrastructure maintenance, lack of rehabilitation and retrofitting, and contamination or depletion of groundwater sources. With all the challenges revolving around the operation and maintenance of water systems, it creates many opportunities for innovative technological approaches through transfer of technology knowledge, experiences and best practices in water management.

According to India's Central Ground Water Board (CGWB), Groundwater accounts for over 60 per cent of the total area irrigated in the country. About 85 per cent of the rural drinking water supply is also met through groundwater resources.

Agriculture is the lifeline of the country. It requires ~800 billion cubic meters of water annually out of which 60 per cent is dependent on rain and nearly 40 per cent is through assured water supply (irrigation). The irrigation system in the country is underdeveloped. Out of 4000 billion cubic meter precipitation every year, only 18-20 per cent is actually used in recharge of India's surface and ground water bodies. Due to lack of infrastructure like storage facilities and water management framework.[3] **This creates a serious need for improving water efficiency for irrigation infrastructure in India**

India is one of the largest groundwater users in the world, accounting for more than a quarter of the global usage. According to CGWB, the share of bore well irrigation increased from just 1 per cent (1960-1961) to 60 per cent (2006-2007). **Therefore, there is a need to focus on efficient groundwater management technologies.**

With increase in population and water demand, depleting groundwater sources and outdated treatment technologies, there needs to be a long term planning for identifying alternative sources of water coupled with adoption of efficient water treatment technologies. **Desalination is one such technology, which could be useful in developing alternative source of water in India.**

With fossil fuels having the biggest water footprint, the energy sector is inextricably linked with water since almost all forms of energy production rely on the supply of water. In India, the power sector is expected to account for 98 per cent of additional water withdrawals and 95 per cent of additional consumption between 2010 to 2035. **Hence, reuse of treated water is essential for sustainable water management.**

The national water policy 2012 talks about setting up a water regulator to manage various issues around water. Considering the enormous challenges in water sector and with multiple disputes around allocation of water, lack of a regulatory authority is hampering the growth of this sector. **A regulator is essential to create proper legislation, regulations for private sector participation and innovative financing mechanism.**

2. Reference Urban Water Sustainability Report, MoHUA, 2017
3. World Bank Report on the water sector in India 2016

Pricing is a key factor affecting the water situation in India.Water services – irrigation, domestic and industrial water supply, and wastewater treatment– are heavily subsidised by most governments, leading to more consumption and wasteful utilisation

Another key area is the funding gap in the sector to meet these challenges of burgeoning demand of the growing population, urbanisation, climate change and water pollution. This warrants for innovation in business as well as financing models.

In addition, lack of capacity building of the utilities in managing water infrastructure is leading to poor service delivery. There is a requirement to involve the community (end beneficiary) in the process of infrastructure management for optimum use. Similarly, the capacity available in the private sector should also be tapped for bringing in efficiency in the management systems.

The above scenario presents abundant opportunities for new and emerging technologies, innovations and approaches to strengthen and cater to the fast growing water requirements.

2. Innovations in water management

Challenges in the sector are complex and there is a need for improved service delivery in the form of innovative and easily adaptable solutions for the community and service providers. technological innovations focused on an integrated management of the existing water resources may provide a sustainable solution to the impending water crisis. This section addresses some of the emerging trends and innovative approaches adopted in the area of water management.

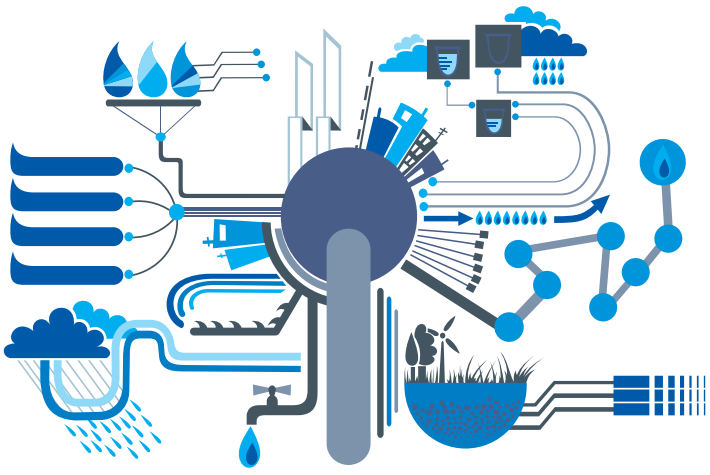
2.1 Emerging Technologies

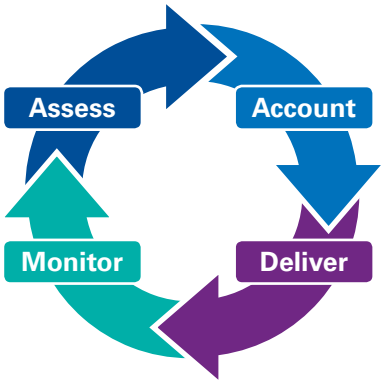
Cities today more than ever, need to realise the economic value of water. One of the biggest challenges in the water utility space in India is the lack of data pertaining to the source and user consumption, which affects governance and decision-making. In order to better understand the water problem and to provide customised solutions there is a need for smart and technology-aided water management systems, which not only help in collecting data, but also ensures that data and information consumed leads to informed decision making.

Apart from the technology aspect, efficient water resource management practices are also required which focus on reuse and recycling of wastewater and enhancing water use efficiency. This requires careful assessment and accounting of the water resource performance levels across sources.

Information impacts change – SCADA

At present, most of the data around water management is obtained manually. There exists very few automated systems and communication media through which the site data could be transferred to the centralised location for online controlling and decision making. Manual recording of data is prone to errors and the frequency of measuring various parameters is very limited.





There is a need to efficiently bridge the gap between data and decision-making, which requires:

- Measurement and assessment of resource performance levels across the entire water supply value chain.
- Safety planning, water budgeting and accounting followed by sectoral allocation for domestic, industrial and agricultural usages.
- Rigorous and independent surveillance and monitoring systems to produce intelligent data to optimise the water distribution network.

The economically sustainable water management models must focus on improving overall productivity and delivery across the value chain of water systems. This requires automation of the plant operations by effectively controlling the systems and the processes. **SCADA or supervisory control and data acquisition is a technology solution** widely used in the water treatment and distribution to automate the control processes and assist the operators in critical decision making.

There are huge benefits in the application of SCADA systems in water facilities as well as in water distribution plants. SCADA systems allow the plants to function uninterruptedly and helps reduce labour cost, energy costs, and drastically improves system efficiency.

Applications of SCADA in Water Management		
Water treatment	**Water distribution**	**Water resource**
Integrated decision making and automated plant control – valve and pump operations	Reservoir automation, remote valve operations, pressure monitoring	Gate position indicators for dams and remote controlling of gates
Remote Monitoring of system – Water quality, quantity, flow	Energy management by monitoring electrical parameters - Water trunk main distribution Metering	Analysis such as spill discharge calculation from the central control room
Filter bed automation, bed wash alarm	Modelling and simulation system based on flow, pressure – analysis of real-time hydraulic data	Continuous dam level monitoring
Failure and leakage detection	Data logging and MIS reporting	Weather monitoring – rain monitoring
Alarm system and security alerts	Supervisory control and alarm systems	

There are numerous advantages to having a SCADA system installed such as:

- Improved system performance and reliability through integrated, easy and remotely accessible real-time monitoring and control.
- Reduction in operating costs, enhanced energy savings through reduced consumption, efficient usage through streamlining of processes.
- Better utilisation of staff though process automation, improved data and information flow and a seamless communication network.
- Reduction in manpower cost by centralised monitoring and control which allows flexibility by preventive operation and maintenance and reduces manual intervention on a daily basis.
- Reduction in system failure and breakdown by early detection and warning systems and increased accuracy due to automated controls and real time recorded data.
- Improvement in plant performance through effective control, which preserves equipment life and enhances the investment by enabling optimal plant operation.

Navi Mumbai Municipal Corporation implemented SCADA system through which NMMC can now perform all operations remotely from a central control room (CCR) located in Belapur (Navi Mumbai). NMMC has also developed a real time dashboard for monitoring water transmission and its distribution to all eight wards in NMMC. NMMC has also installed real time alarms in CCR to monitor any unexpected drop in water pressure and levels. NMMC successfully operates the radial gates(~ 2 tonne) at Morbe Dam Morbe dam remotely through CCR. As a result of the SCADA interventions, the NRW (Non-revenue Water) has been reduced from 23 per cent to 18.50 per cent.

Smart water meters: Key to intelligent decision making

Information, Communication and Technology (ICT) aided intelligent systems have proved to be highly effective in water conservation and asset management across the globe. The application of Internet of Things (IoT) based smart water networks has the potential to become the future of effective water utility management. Smart systems can significantly assist government and private utility service providers by:

a. Providing smart techniques to access and measure data across the distribution system.

b. Deconstructing complex data to identify problem areas and aid in informed decision making.

c. Improving overall revenue by strengthening system efficiency.

Smart systems may be applied across the service levels for both supply side and demand side water resource management.

Intelligent water management tools and applications				
Supply side	**Ground water**	**Surface water**	**Waste water**	**Others**
	• Real time monitoring of GW levels • Technology aided GW locator and aquifer identification • Rainwater harvesting and artificial recharge	• Smart weather stations for real time rainfall, soil moisture and forecasting hydrogeological risks • Flood Forecasting and Early Warning System • Green infrastructure and smart storm water management	• Intelligent web based decision support system using sensors, controls	• Desalination • Staged Urban Wetlands • Use of GIS based land use zoning management • Sub surface water harvesting structures and bio-drainage
Demand Side	**Drinking water**	**Industry**	**Irrigation and farming**	
	• Smart metering of piped water supply systems – remote monitoring and detection of non-revenue water loss, automate meter reading and billing • Pressure management, Leakage detection and management • Automation - SCADA systems • Smart Water Grid and Water distribution systems • Hydrological modelling	• Advanced effluent treatment systems – media filters, membrane bioreactors • SCADA based water and waste water treatment plants	• Precision irrigation • Integrated river basin information and decision support system • Intelligent crop cultivation system • Mobile based weather alerts to farmers	

Smart Water Systems may significantly ameliorate the deteriorating water infrastructure in India by offering an end to end integrated technology enabled approach using systems, software and ICT platform.

Smart meters for efficient water management

One of the crucial aspect to effective water demand management and an issue faced by majority of cities in India is that of Non-revenue water (NRW). NRW is the water lost in the system not leading to any revenue. Reduction in NRW to acceptable levels is vital for the technical and financial sustainability of the water utility and cities need to achieve acceptable benchmarks of 15% of NRW.

Smart meters are an integral part of the array of offerings that come with the intelligent water management systems, which are being rapidly adopted by water utilities to help in measuring the NRW levels in the system.

Installation of smart meters helps in optimising the water network to regulate and monitor different parameters such as hydraulic pressure and flow, water quality, head losses, water and energy consumptions. Smart meters provide instant, reliable, real time reading and analytics along with remote decision making capabilities at the monitoring location. This improves the system reliability by reducing error in manual reading and with 100 per cent metered connection, reduces revenue leakages for the local authority. Application of smart meters curbs extra water usage, tracking water consumption, flow patterns and allows equitable distribution to all consumers by better managing distribution. Smart

meters also come with features such as automatic billing, leakage and tampering detection as well as water quality monitoring along the distribution network. An integrated approach is required to holistically bridge the gaps in water management.

Nagpur municipal corporation under the AMRUT scheme implemented extensive household level metering to curb non revenue water loss from 50 per cent to below 25 per cent and provide 24-hour safe drinking water to 100 per cent population including slum dwellers The project included management of the entire water cycle from production, treatment, transport, storage and delivery to the customer's tap. It involved replacement of over three lakh house service connections, rehabilitation of treatment facilities, service reservoirs and pipelines. Nagpur also undertook a waste water reuse project for which National thermal power Corporation (NTPC) proposed to reuse 200 MLD of treated water from the STP for its Mauda plant.

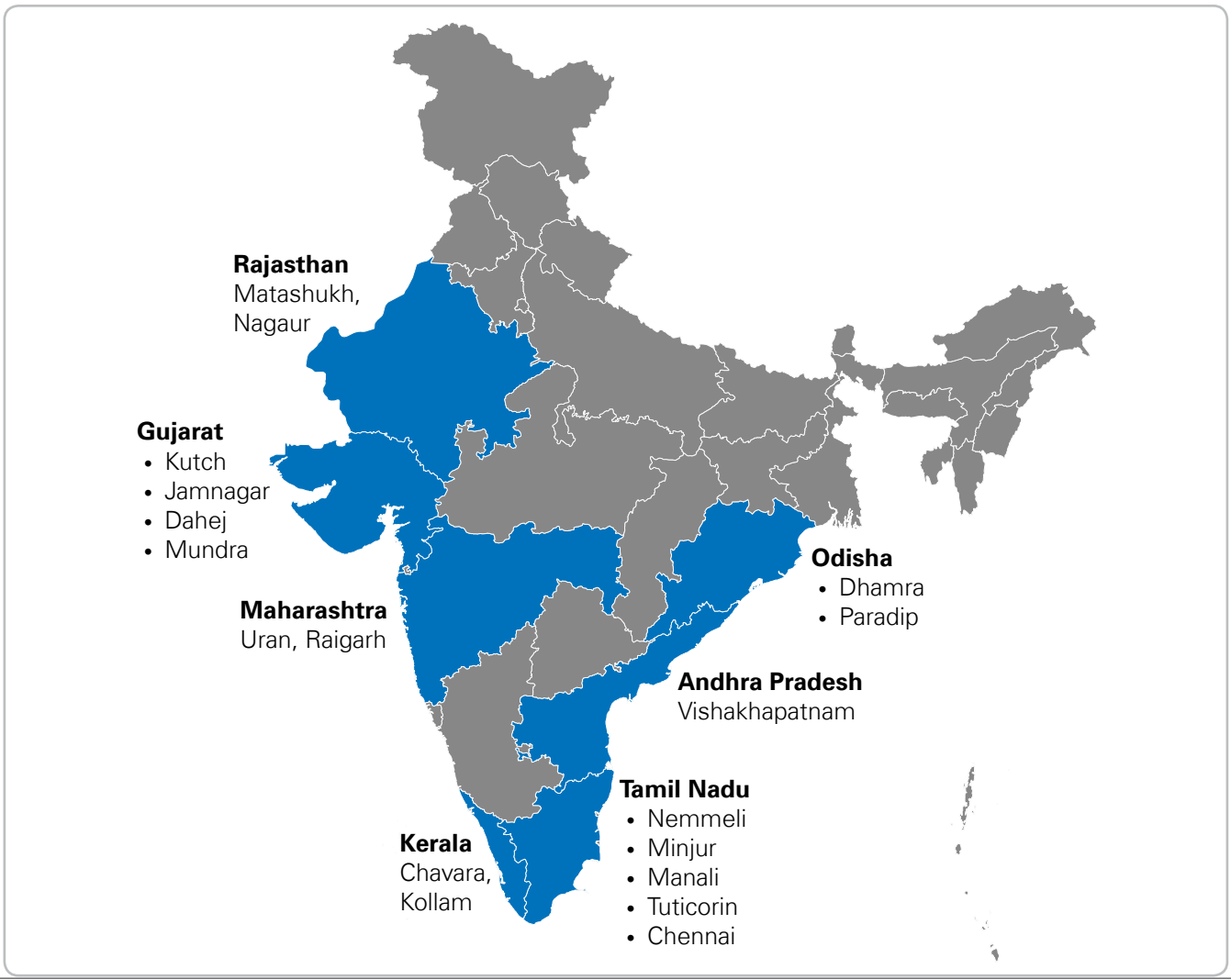
4. Article titled "Desalination industry enjoys growth spurt as scarcity starts to bit" published by Global Water Intel https://www.globalwaterintel.com/desalination-industry-enjoys-growth-spurt-scarcity-starts-bite/

Desalination

Desalination is a promising technology with a potential to bridge the ever-rising demand-supply gap of fresh water. Around 97 per cent of the total water available on Earth are in the oceans and is saline; and provides for a virtually unlimited stock of raw material for desalination. In addition to saline water from sea, brackish water found in river estuaries, is also used for desalination. Desalinated water is consumed for industrial, domestic and agricultural purposes. Presently, the installed capacity of desalination plants across the world is around 86,572 MLD of which 44 per cent is located in the Middle East and North Africa. Desalinated water is used by 1 per cent of the global population on a daily basis. By 2025, around 14 per cent of the world population is expected to start using desalinated water.[4] In India, desalination can be a suitable technology for coastal regions and port cities to meet their industrial and domestic water demand.

Desalination Techniques

The salt concentration in seawater is ~40,000 ppm and in brackish water is ~20,000 ppm. Through desalination, salt concentration is reduced to around 300 ppm, which makes the treated water suitable for drinking.



A stellar example of using desalination technology is in Israel, which has transformed itself from being semi-arid to a freshwater surplus nation. The Sorek desalination plant in Israel is one of the largest reverse osmosis (RO) desalination facility in the world supplying treated water to 1.5 million people.[5]

Interestingly, India too ranks reasonably high in the use of desalination, particularly for industrial use. At present, India has around 182 desalination plants located in different states. Gujarat has the maximum capacity for production of desalinated water in the country with plants located at Kutch, Jamnagar and Metapur. Tamil Nadu is the country's second highest desalinated water producer with plants at Minjur and Nemmeli, each with a capacity of 100 MLD.[6] In fact, an additional 400 MLD capacity is planned to be installed at the Nemmeli plant. In addition, a Greenfield desalination plant with a capacity of 400 MLD is also being planned at Porur (Chennai).[7]

Key Challenges

Despite advances in technology and its adoption, several significant constraints and risks are currently holding back a wider adoption of desalination as an alternative cost effective technology for water supply. Some of the key constraints and risks are discussed below.

Environmental impact

The waste from the desalination process is discharged back into the sea and is a source of pollution for the oceanic ecosystem.

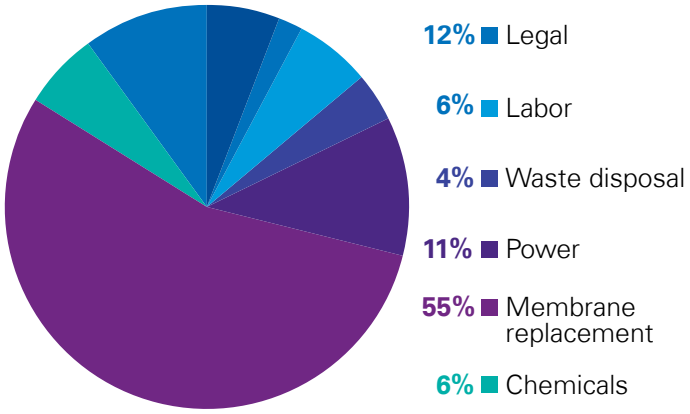
Technology

- The desalination plants need to be adaptive to varying salinity level of the sea, which is technologically challenging.
- Pumping infrastructure required to draw seawater from deep within the sea (up to 1-2 km).

Cost

Capital and operating costs associated with desalination are quite high. As a thumb rule, the capital cost to set up desalination capacity of each incremental MLD is around USD 1 million or INR 70 million or more. Operating expense is around USD 1 or INR 70 per kl of water produced where power costs and membrane replacement costs comprise 2/3rd of the total operating cost. The operating expense break-up is provided below.[8]

Desalination - Operating expense breakup



Source: White Paper titled "Seawater Desalination Costs" published by WateReuse Association

From the graph alongside, it is evident that power, membrane replacement and chemical costs contribute to more than 70 per cent of the total operating cost. The unit cost of producing water through desalination is several times that of conventional water treatment technologies. High investment requirement and operating cost is an impediment to wider adoption of desalination technology.

Emerging Trends

Significant research and development is currently devoted to the development of better materials and efficient design for thin membranes that will reduce energy intensity of the desalination process. Some of these trends include use of graphene (consisting of a single layer of atoms) an ideal 'RO membrane', Low Temperature Thermal Distillation (LTTD) and use of a "water chip" which creates a small electric field to separate salts from the seawater. The dramatic fall in the price of solar power also augurs well for desalination plants, which can now easily switch to solar power to reduce operating cost. The world's first solar powered desalination plant was set up in Surat, India in 2012.[9]

The challenge in the water desalination industry is the large gap between affordability and willingness to pay for water vis-à-vis the cost of desalination. Traditionally, in India, citizens pay very less or often nothing for water supply. Only recently, some municipalities have adopted a usage based water tariff. Currently, the acceptable water tariff in India is estimated to be around INR 20-25 per kl. In contrast, desalinated water costs four times this tariff at around INR 70-80 per kl. The technological challenge at hand is to bring down the cost of desalinated water down to the acceptable levels. With the emergence of these newer energy efficient technologies and innovative approaches, desalination technology may be looked at as an alternative to meet our fresh water requirements.

5. Article titled "Israel proves the desalination era is here" published by Scientific American
6. Report titled "Desalination- Easing India's Water woes" published by EPCWorld.
7. New Indian Express Paper, 27th March 2018.
8. White Paper titled "Seawater Desalination Costs" published by WateReuse Association
9. The Times of India, 2nd February 2010

2.2 Sustainable water management

Modelling of water resources – River basin management approach

Sustainable water management is critical for the development of humanity. It is a finite resource and needs to be managed judiciously.

The total expected population living along the river basins is around 1.7 billion wherein the rate of depletion is higher than rate of discharge and may lead to **two-thirds of the world's population living in water-stressed countries by 2025**.[10]

Poor management of water is leading to a serious threat to the sustainable development. However, if managed efficiently, it can lead to playing a key role in the growth and development of social, economic and environmental systems.

River Basin Management in India

Rivers and their basins including the related groundwater bodies are important sources for water use including drinking water supply and agricultural activities in India. Water in India contributes for socio-economic development, livelihoods and serve as ecosystem. Healthy river landscapes provide habitats for many plants and animals and often have high cultural and religious significance. Many of the Indian rivers and the related groundwater resources are heavily polluted, overexploited and disturbed regarding their natural features including environmental flows, and can as such no longer provide important ecosystem services.

Efforts to restore and rejuvenate rivers should follow integrated river basin management approaches, good governance, collaborations, projects and investments. Water resources management in India does not follow the catchment approach and human pressures and impacts on water resources are not assessed holistically but in a rather selected way. Planning and management approaches are largely water-use oriented and, hence, emphasis is often given to the assessment of water quantity as basis for water use and to urban wastewater pollution. Water quality is being assessed for monitoring sites/points but not on water body level.

Institutions in India regarding water resources management

One important institutional step towards improved water resources management was taken with the creation of the Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR, RD&GR) in 2014. Several River Basin authorities such as the Ganga Council and the National Mission for Clean Ganga (NMCG) were revived and supported in strengthening their functions and human resource's capacities.
However, the institutional set-up and operational structure or governance of these politically defined bodies is not yet sufficiently developed and needs improvement. A coordinated implementation together with the concerned Indian States requires well-defined approaches. In addition, implementation know-how regarding other water-related Directives and as applied in the cooperation frameworks of International River Basin Commissions can support future river basin management in India.

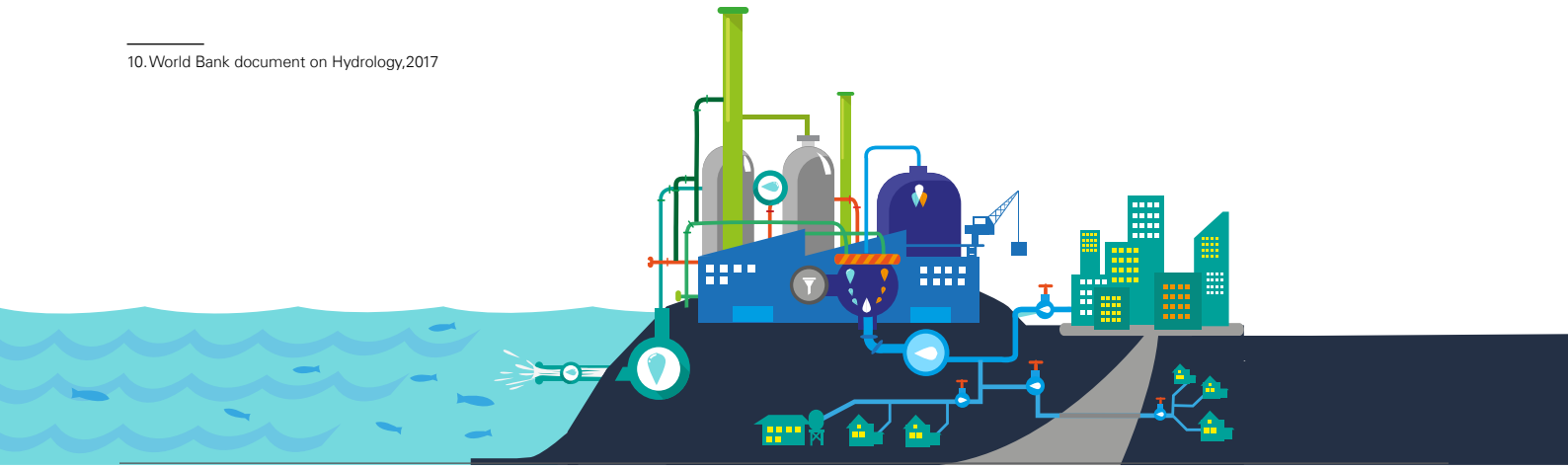
River Basin Approach

As per World Bank, a four-pronged approach is the need of the hour i.e.;

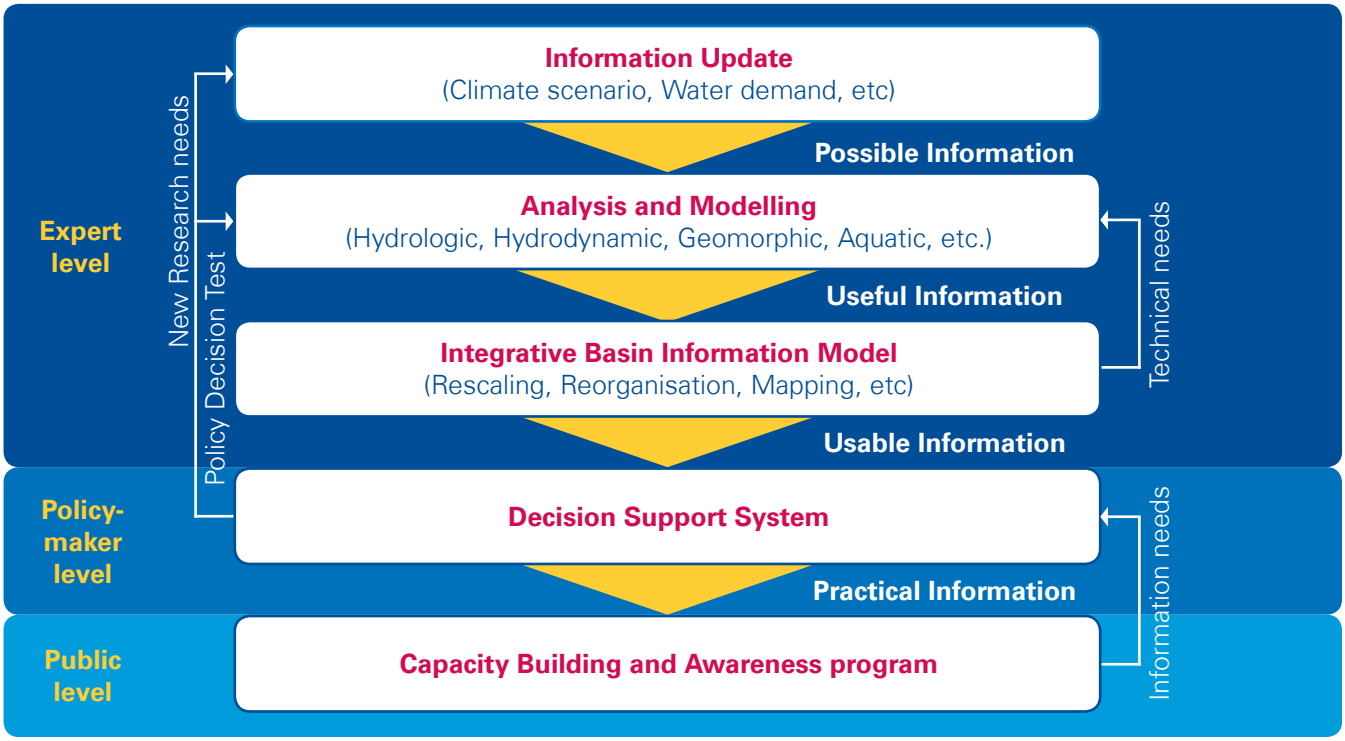
1. **Data monitoring systems**, including establishing comprehensive, automated, real-time monitoring and data management systems for different sources of water, both quality and quantity;
2. **Developing analytical tools** for assessment of water resources, flood forecasting and river basin management;
3. **Knowledge centre**, using internet, different devices, cloud computing, and other tools to access and visualisation of customised water information; and
4. **Institutional development** in people and institutional capacity.

A robust information model for decision support system is required to implement and monitor the river basin management approach.

10. World Bank document on Hydrology,2017



Integrative Basin Information Model and a Decision Support System



Source: World Bank report on hydrology, 2017

To meet the four-pronged approach, there is specific need to focus on developing the following:

- Developing hydro-met observation network
- Supervisory control and data acquisition systems for water infrastructure
- Establishment of hydro informatics centre on regional basis
- Development of analytical tools and decision support system
- Water Resource Knowledge centre

The hydro-met data acquisition system needs to be modernised with automated and real-time communication systems with placement of sensors, installation and operation of hydro-met systems for meteorology, stream flow, groundwater and water storage measurements, and portable and laboratory equipment for water quality testing. With real time data acquisition systems for reservoirs, canal and groundwater operation systems will be equipped with the remote control systems (SCADA) that will allow the control of gates and operation from a control room or other remote areas and allow system response on a real time basis during floods or other emergencies.

The facilities for automated data collection, collation and processing at state and regional levels need to be looked into with development/ improvement of Hydro-informatics (data) centres to serve as hubs for both real-time and long-term data management and operational control systems with data storage servers including cloud servers.

At the national level, strengthening of water information centres with web-enabled water resources information systems through categorising the databases and products, developing integrated water resources information available to decision makers for effective planning, decision making and operations is of prime importance. The source of information has to be from the real time data acquisition networks and centres established at state and regional level.

For effective implementation, dedicated expertise and a pool of experts are required and to ensure that the knowledge, tools and innovations developed under the project are applied to improved water resources management through knowledge centres. The knowledge centres should be co-located with the data centres for optimum usage of knowledge and effective analysis of data collated. Different type of centre should be established such as:

- Flood forecasting centre
- Ground water modelling centre
- Surface water modelling centre

Ground water management

Over the years, ground water has been the preferred source of water for different category of consumers due to lack of or no monitoring system, source of water available at very nominal or no cost. The dependency has increased considerably on ground water systems due to lack of proper surface water systems which has resulted in depletion and contamination of ground water across the country.

- As per NITI Aayog, at least 21 major cities, Including Delhi and Bangalore
- Are expected to runout of groundwater by 2020,
- Affectingabout 100 million people

With extraction of groundwater over the years, a substantial decline can be seen in the level of water leading to affecting of aquifer zones without much focus on recharge of the aquifers. Extraction of water from deeper levels have led to affecting the quality of water leading to intrusion of saline water.

The model bill for ground water management proposes compulsory registration of bore well owners; compulsory permission for sinking a new bore well and; creation of a groundwater regulatory body; Restrictions on the depth of bore wells and Establishment of protection zones around sources of drinking water. However not much has happened after conception of the bill.

Management of ground water resources:

Random extraction of ground water especially in the areas near the river or coastal basin is a common practice in the country. Due to this, no single strategy has led to proper ground water management. In addition, the management systems needs to take into account the climatic conditions, hydrology of the zone, groundwater availability and utilisation pattern.

There needs to be clear focus on the supply side as well as the demand measures. The same has been depicted below:

Supply side measures	Demand side measures
1. Scientific Development of Ground Water Resources	1. Ownership of ground water
2. Rain Water Harvesting and Aquifer Recharge	3. Pricing ground water sources
	3. Proper monitoring of ground water extraction
	4. Focus on Regulations

Water efficiency: irrigation sector

The country requires immediate action on two accounts to achieve its ambition to become a Water Secure nation

- Increase in assured water supply by construction of new irrigation infrastructures and elimination of farmer distress (more than 12000 farmers lost their lives from 2013-17).
- Focus on improving water use efficiency by improving and maintaining the existing irrigation infrastructure in the country.

Water secure nation: challenges

Water security, access at all times to sufficient water, is a critical aspect. The challenges in achieving water security are:-

- **Institutional challenges:** Post independence, we have incurred an expenditure of 4 lakh crores to create an Irrigation potential of 113 Mha. However, total irrigation potential utilised is 89 Mha. This gap can be attributed to the absence of adequate last mile connectivity. Therefore, there is a strong need to have an integrated approach and change in institutional setup for addressing the irrigation requirement.[11]
- **Overexploitation of groundwater:** India is largest user of groundwater in the world with an average abstraction of 251km3/year. Groundwater satisfies two-thirds of the irrigation needs. Ground water resources are depleting rapidly and 60 per cent of India's districts are facing groundwater over exploitation.[12]
- **Low Productivity/Efficiency:** The current agricultural practices in the country are highly inefficient. It is estimated that our farmers use 2-4 times the water to produce a unit of food crop than in China/Brazil. Water use efficiency in India is 25-35 per cent which is much lower compared to 40-45 per cent in Malaysia and Morocco.
- **Lack of penetration of Micro Irrigation systems:** Micro-irrigation systems are practiced only in 5 per cent of India's cultivated area. On the other hand, penetration of micro-irrigation systems is as high as 50-60 per cent in countries like Israel, Japan, and Taiwan etc.

11. India Water Reforms Report by Mihir Shah,July 2016
12. India Water Reforms Report by Mihir Shah,July 2016

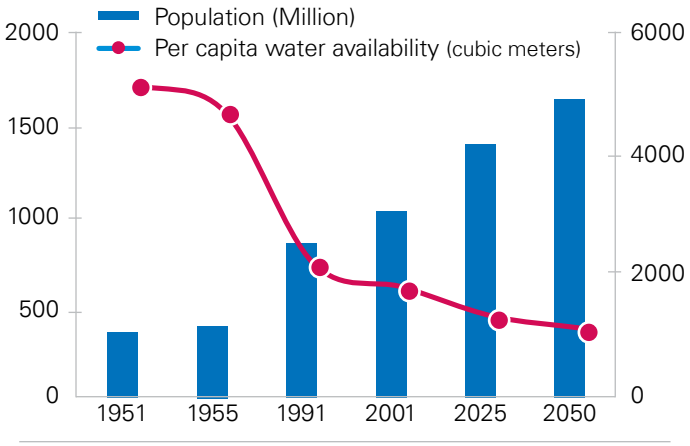
Water and Wastewater: PPPs, Innovative business and financing models

As per the Indian Constitution, access to clean and potable water is a fundamental right of the Indian citizen. Natural water reservoirs remain a public good and are easily accessible to the citizens.

Undoubtedly, the involvement of private sector leads to increase in innovation and efficiency. However, factors like high revenue risks on account of lower tariffs, high capital costs, lack of central level regulations for the sector and lack of local stakeholder capacity and support requires the government to efficiently allocate and share substantial responsibilities to avoid market failures and attain optimal production levels. Looking at the successes and failures of historical PPPs in water sector, the government needs to create mechanisms to address few critical risks and share responsibilities in order to attract private participation of highest service quality and efficiency.

In this section we look at few select PPPs, focusing on the key success factors of private participation in the water and wastewater sector. These cases lead to the specifics of risk and responsibility allocation between government and private sector and lead us to the current innovative business models being explored by Government of India in the sector.

India – Population growth & per capita availability



Source: Ministry of Water Resources, GoI

PPPs in Indian water sector and key learnings

Traditionally, until economic liberalisation, government took the onus to address the cost of building and maintaining water treatment plants, wastewater plants, water distribution and sewerage networks. The government entities assumed most of the financial risks for the project such as construction delays and repair costs, revenue risks.

With the onset of economic liberalisation, all major types of PPP models have been tried in the water and wastewater sector ranging from BOT, Performance linked contracts, DBO, lease contracts to currently adopted Hybrid annuity models. A brief overview of the various PPP models has been shown here:

Engineering Procurement Construction	Performance and lease contracts	Design Build Operate	Hybrid Annuity	Build-Own-Operate-Transfer	Build-Operate-Transfer (Toll/User Fee collection)	Design Build Finance Operate Transfer
Entire project financed by project owner (i.e. govt.). Private player is responsible for engineering, procurement and construction for which it is paid as per defined milestones	Performance linked payments given by government. Private player is only responsible for operational performance outputs	Concessionaire (i.e. pvt partner) bears no revenue risk. Capital investment is funded by government. Concessionaire is responsible for design, construction and operation. Payments during operational phase are linked to performance outputs	Typically, 25%-40% of the project cost is paid by the government to the private partner during the construction period The remaining amount is paid as annuity along with O&M during the operations period and are linked to performance outputs	Concessionaire becomes the 'Owner' of the facility during the Concession period and bears capital and in few instances revenue risk	Concessionaire (i.e. pvt partner) collects user fee, bears traffic / revenue risk. Capital investment is funded through user revenue.	Private partner assumes responsibility for design, construction, finance, and operations for concession period and thus bears design, capital, revenue risks

Low **Risk transfer to private partner** **High**

However water largely being a state and ULB level matter in India, unlike in other infrastructure sectors (such as power, highways), PPP has been adopted as a sector strategy and sector-level enablers have been created (such as model concession agreements, Electricity Act, and so on). Compared to this, PPP momentum in the water sector has been a project-level initiative. Stakeholder support for water PPPs often fails to capture the strategic long term objective which leads to excessive risks being unfurled to the private sector.

We have categorised few such select water supply and wastewater projects, which have witnessed private sector participation over the past couple of decades and alalysed the factors contributing to the success/failure of these projects.

Name of Project	Name of authority	Type of PPP	Status	Key reason for Success/ Failure[13]
Krishna Bulk Water Supply Project, Andhra Pradesh	Hyderabad Metro Water Supply and Sewerage Board	Build Operate Transfer	Abandoned prior to award (prior to 2000)	• Low confidence of bidders on revenue risk mitigation mechanism • Unaffordable bulk water charge proposed by bidders
Selaulim Bulk Water Supply, Goa	Public Works Department, Government of Goa	Build Own Operate Transfer	Abandoned prior to award (prior to 2000)	• Changes in government • Unaffordable bulk water charge proposed by bidders
Haldia Water Supply Project, West Bengal	Haldia Development Authority	Build Operate Transfer	Awarded in 2012, operational	Less revenue risk due to presence of industrial customer
Salt Lake City Water Supply and sewerage system, West Bengal	Kolkata Metropolitan Development Authority (KMDA)	Design Build Operate Transfer	Awarded in 2007, operational	Institutional consumers in a growing area with high willingness to pay
Water Treatment Plant, Sonia Vihar, Delhi	Delhi Jal Board	Design Build Operate	Awarded in 2001, operational	Strong Project Ownership from government
Latur Water Supply project, Maharashtra	Maharashtra Jeevan Pradhikaran	Lease Contracts	Awarded in 2008, operational	Less complexity and performance based contracts
Mysore Water Supply Project	Mysore Municipal Corporation	Performance based O&M	Awarded in 2008, operational	• Adequate public funding • Safeguards for risks included additional payment for cost overruns
Smart Mini Sewage Treatment plants	New Delhi Municipal Council	Build Operate Transfer	Awarded in 2017, operational	Less revenue risk due to presence of institutional customers having high willingness to pay

13. PPP India, Case Studies – PPP Toolkit

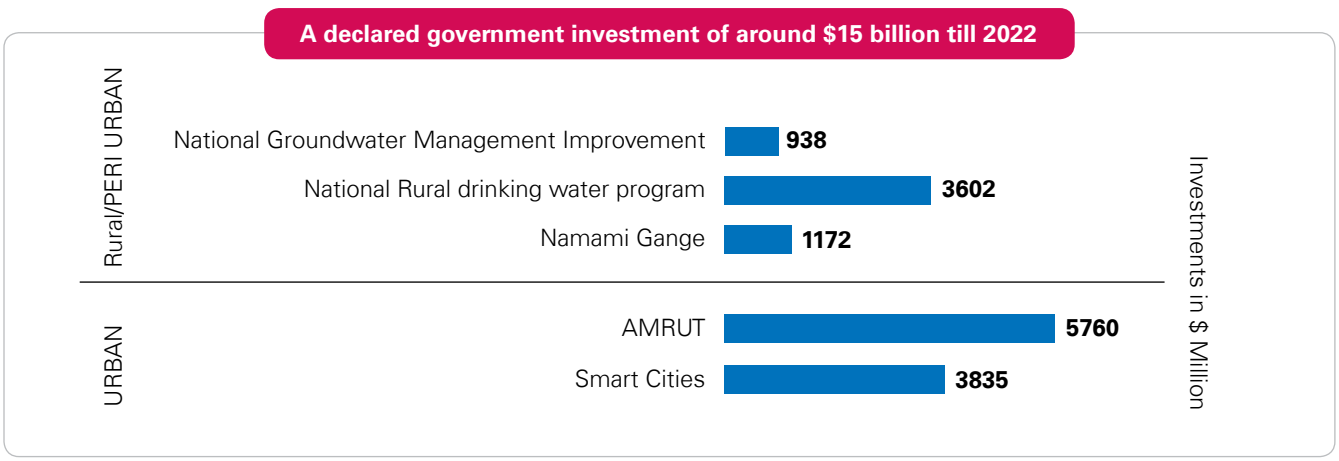
Since the list consists of few select projects, we cannot draw any direct correlation between the various success factors and associated PPP models. However there has been a trend which is evident from these cases that the Indian water sector market is still not ready for pure-play concessions like BOOT, BOT, barring cases of industrial/institutional water supply where there is less revenue risk. Though EPC and O&M are good for traditional water supply contracts, they cannot attract innovation, quality and efficiency for the sector, which is the need of the hour in all segments of the value chain right from treatment, supply to recycle and reuse. Few lessons from these case studies have been depicted herewith. These factors could be critical for successful private sector involvement in the sector:

- Adequate guarantee of public funding both during construction and project operation
- Government taking responsibility for viability funding gap through innovative financing mechanisms for addressing cost overruns and revenue uncertainties due to factors outside the control of the concessionaire
- Assessing demand and willingness to pay during the project design stage leading to accurate projections of tariff and revenue
- Presence of performance linked incentives for bidders
- Setting realistic and achievable performance indicators during the operational phase
- Adequate bid process management, project structure and contract terms
- Developing capacities of ULBs, state governments to design, monitor and implement PPPs

Addressing many of these issues, government in recent times has started adopting Hybrid Annuity models in water and wastewater sector which could be a trendsetter under the current scenario. Under the Namami Gange Programme, concession agreements have already been signed for Haridwar, Varanasi and Mathura wastewater treatment plants and many subsequent projects are at bidding stage. In water supply projects for both rural and urban, this model is being adopted in states like Andhra Pradesh and Rajasthan. This model is a classic combination of EPC and pure play PPPs like BOT, since up to 40 per cent of Capital Cost is paid by the Government and remaining funding is arranged by the private player during the construction stage. The private player in turn is repaid the remaining 60 per cent of the capex in annuity mode along with annual O&M costs. All payments are linked to performance standards. Here there is limited revenue risk on the part of the private player and it is given complete freedom in choosing the optimum design and technology to deliver the output performance parameters. At the government end, it is not only getting greater accountability from the private sector through capex risk sharing, but also innovative design, technology and efficient operations.

Widening the funding gap in the Indian water sector

In addition to innovative business models and private sector participation, the huge gap between total investments required and currently declared government funding, to meet the burgeoning demand of the growing population, urbanisation, climate change, and water pollution warrants innovation in financing models as well. An ASSOCHAM study in 2017[14] has envisaged need for investment worth USD291 billion in the Indian water sector by 2030. If we have a look at the current central government funding declared through the various schemes, the declared investment is of around USD 15 billion until 2022 in both water supply and wastewater infrastructure. The major government programmes in the sector and the associated investments are depicted in the figure herewith[15]:



14. Assocham – News Detail accessed on 12th June, 2018
15. PIB News Site accessed on 12th June, 2018

In addition to this, state level investments along with funds from various international financial institutions are also present. However, with the kind of investment gap as envisaged until 2030, even with central, state and large-scale private sector participation, there needs to be efficient financing mechanisms along with viable business models leading to creditworthiness in order to address the current challenges in the sector.

Examples of few Innovative financing instruments

Innovative financial instruments like impact investing, especially directed towards setting up sustainable water infrastructure, are getting increased traction in light of water being at the core of sustainable development goals. Many of these instruments have already been tried across other developed as well as developing nations. It is worthwhile to look at few of these instruments as in future they could be potential financing solutions for the Indian water sector.

Impact investing can be broadly categorised into two types – social and environmental – with instruments such as 'Social Impact Bonds' and 'Green Bonds'. Other subsets of bonds are also beginning to emerge in the market as presented below.

Municipal Bonds in India

Social impact bonds

Green bonds (labeelled)

Muni bonds (municipal/infrastructure)

Development impact bonds

Blue bonds (water)

Climate-aligned bonds

Out of these, Muni bonds and Blue bonds are being currently applied for water and wastewater related infrastructure. In fact, India is already witnessing the issuances of Municipal bonds especially for water supply infrastructure projects. Pune Municipal Corporation has been 1st Indian ULB to issue Municipal bond for water supply project at a coupon rate of 7.5 per cent in 2017.[16]

Another form of instrument for financing water sector projects is Blue bond. Proceeds are used for projects and assets that are related to water infrastructure or water management and have taken into account climate mitigation, adaptation and resilience opportunities. Governments, municipalities, banks or corporations can issue them. Globally issuances of blue bonds have already crossed USD10 billion until date.

In May last year, 94 cities in 14 states of India received credit ratings from rating agencies. As part of the cities' preparations for issuing municipal bonds. The ratings range from AAA to D. These are for cities that are part of the Smart City Mission and Atal Mission for Rejuvenation and Urban Transformation (AMRUT) where water and sanitation are key projects. Pune Municipal Corporation raised INR 200 crore by issuing 10-year municipal bonds; the money will be used to provide uninterrupted water supply in the city.

The various advantages of different types of impact funding include access to diversified investors including:

The San Francisco public utilities commission was the first to issue a climate bond standard certified water bond. Proceeds from the USD 240 million wastewater revenue bonds will fund eligible sustainable storm water management and wastewater projects from the utility's sewer system improvement programme.

- Institutional investors such as insurance companies and pension funds
- Public agencies such as central banks and national governments
- Corporates
- Commercial banks
- Retail investors
- Investors with dedicated social impact bond fund

In India often the argument has been that the financial condition of the state governments and ULBs does not warrant issuance of the bond. However, out of the 94 Indian municipalities, 55 received investment grade ratings in 2017.[17] Hence, to bridge the ever-increasing funding gap in the sector alternative financing mechanisms such as impact investing (water being an environmental as well as social subject) needs to be explored.

16. Finacial Express Paper, 19th June 2017

Roles: Government and Private Sector

With the rapid growth of the Indian economy, it is slotted to play a vital role among other nations in the coming years. To maintain this growth, it is important that we create an enabling environment. Hence, sustainable management of water, land and natural resources is extremely important to achieve these objectives.

A revised water policy was prepared in 2002, which contained many positive elements. However, it was not quite adequate in dealing with the challenges of the 21st century. Further, the fact that water is a state subject creates coordination challenges between the states and the central governments. The states formulate their own water policies and operational action plans. Hence, there is a need to develop a new integrated water policy, which focuses on the following aspects:

- **Management of existing Infrastructure:** One of the most important objective for the water utilities in India is to bring in efficiency in the existing water systems. There needs to be a specific focus on rehabilitation and retrofitting of the existing infrastructure. The intent should be to cater to more of the population using the existing sources and assets rather than looking to exploit new sources and investing in the construction of new infrastructure.

KARNATAKA EXPERIENCE
In 2006, Karnataka entered into performance contracts with the cities of Hubli-Dharwad, Gulbarga and Belgaum and in partnership with the World Bank, made it possible to provide a continuous water supply to 180,000 people who had previously received water for only a few hours a week.

- **Right pricing of Water:** In the context of public-private partnerships, the public sector plays a dual role – it is the owner of water supply assets as well as the regulator that sets tariffs. It is imperative to ensure that the cost of an individual connection remains affordable even for the poorest man. It is important to set tariffs that are affordable to various customer segments, while capital and operating expenses are recouped for financial sustainability.

KARNATAKA EXPERIENCE
In the towns of Hubli-Dharwad, Belgaum and Gulbarga, solution was devised that ensured charges for individual connection to the water network were affordable for all.

- **Wastewater re-use Policy:** India needs a wastewater re-use policy to reduce pressure on fresh water soruces and progress towards sustainable water management. Government of India has started taking steps towards the same by signing an MoU between, ministry of water resources (MoWR) and ministry of power (MoP), wherein any thermal power plant in vicinity of 0-50 Km from a STP[18], will use treated water before extracting fresh water from source. Similar initiatives are required for commercial and industrial bulk users.

The government needs to encourage sustainable solutions of water management such as rehabilitation of existing infrastructure, wastewater reuse and river basin management, which closes the loop in the **circular economy for water.**

CHENNAI EXPERIENCE
Chennai Metro Water Supply and Sanitation Board awarded a PPP-based reuse project contract in 2016 to develop 45 MLD reuse capacity on the design, build, and operate model to supply non-potable water to industries.

Similarly, there is scope for the private sector to play a major role in the water sector. With the global population expected to increase by 29 per cent by 2050[19] and India being a significant contributor to it, the stress on fresh water source shall only exacerbate further. Hence, the private sector involvement can play a pivotal role in development of solutions for water management.

The focus now needs to be on development and application of innovative technologies and sustainable solutions for water management. The in-depth understanding of technological solutions and the efficiency of private sector needs to become an integral part of developing sustainable water management solutions.

With the current state of Water infrastructure across the value chain, major investments are required in the sector wherein much of these investments have to be made upfront to develop and sustain the infrastructure. Therefore, there is a need to develop innovative financing models wherein the public and private sector both complement each other.

A strong institutional structure and an enabling environment will be necessary to forge a strong partnership between the government and the private sector in developing sustainable solutions.

17. PIB News Site, 26th March 2017
18. Times of India News Paper, Jaunary 2017
19. UN website accessed on 16th June 2018

3. Way forward

There is a very urgent need to streamline the current management practices of water in the country. The goals of national water policy are not being realised due to the limited of knowledge on innovative solutions, a focussed approach and an inclusive framework for managing water. The broad categories for sustainable water management are water resources, water supply, data management, institutional strengthening and innovative financing. The government needs to adopt a holistic perspective towards the regulation of water resources. Following intervtions can be looked into:

- **Water policy:** Considering water is a state subject, it is imperative that the government of India makes it mandatory for each state to have a state water policy. This should focus on innovative technological approaches across various consumers of water (Domestic, Industrial, Commercial and Irrigation) for implementation, operation and maintenance and mandate the establishment of a water regulatory authority.
- **Setting up of water regulatory authority:** Establishment of water regulatory authority is the need of the sector. The country has already witnessed the kind of transformation telecom and power sector have achieved with a regulator in place. It is of paramount importance since the authority can then monitor the progress of goals set in the state water policy, regulate the quantity of water for different categories of users and ensure equitable distribution across users.
- **Setting up data informatics centre:** Most of the developed countries have understood the need of data information centre for developing efficient decision support system. Government of India has already taken the first step towards the same by setting up National Water Informatics Centre (NWIC) is to maintain comprehensive data of all water resources and to support in decision-making process.
- **Focus on 3Rs of Water (reducing, reusing and recycling):** One of the key components of the sustainable water management approach is to efficiently manage wastewater. With the depletion of fresh water resources, it is high time that we focus on recycle and reuse of treated water for non-potable purposes. With a reduction in consumption pattern and optimum utilisation of treated water, the 3Rs of water can play a prominent role in sustainable water management. The Government needs to focus on drafting a policy for wastewater recycle and reuse at the national level, which then may become a guiding document for water boards and utilities.
- **Ensuring more drop per crop:** There is an urgent need to create awareness regarding water budgeting. Popular irrigation techniques such as micro-irrigation, drip irrigation and sprinkler irrigation may be adopted. Some other techniques like tank rejuvenation and water shed development through involvement of local communities may be attempted.
- **Participatory groundwater management:** It is not possible to monitor 30 million groundwater structures through constant legal scrutiny. Hence, a participatory approach is required for sustainable and equitable groundwater management. This requires a sustainable 4P approach i.e. Public-Private-Panchayat-Partnership.[20]
- **Innovative Business models:** To address the increasing operational inefficiency in the sector, effective business models may be proposed with adequate guarantee of public funding during construction and project operation stage. These business models should define realistic and achievable performance indicators with performance linked annuitised payments, additional scope of performance linked incentives to attract innovation.
- **Innovative Financing models:** To bridge the ever increasing funding gap in the sector, alternative financing mechanisms such as impact investment, bonds etc .may be explored.

20.Report on Water Resources Development in India: Critical Issues and Strategic Actions

About KPMG

KPMG in India, a professional services firm, is the Indian member firm affiliated with KPMG International and was established in September 1993. Our professionals leverage the global network of firms, providing detailed knowledge of local laws, regulations, markets and competition. KPMG has offices across India in Ahmedabad, Bengaluru, Chandigarh, Chennai, Gurugram, Hyderabad, Jaipur, Kochi, Kolkata, Mumbai, Noida, Pune and Vadodara.

KPMG in India offers services to national and international clients in India across sectors. We strive to provide rapid, performance-based, industry-focussed and technology-enabled services, which reflect a shared knowledge of global and local industries and our experience of the Indian business environment.

About ASSOCHAM

The Associated Chambers of Commerce and Industry of India (ASSOCHAM), India's premier apex chamber, initiated its endeavour of value creation for Indian industries in 1920. Having in its fold more than 400 chambers and trade associations, and serving more than 4.5 lakh members from all over India, it has contributed significantly to the economy by playing a catalytic role in shaping up the trade, commerce and industrial environment of the country. It has significantly contributed in the emergence of new-age Indian corporates, characterised by a new mindset and global ambition for dominating the international business.

Known as the fountain-head of knowledge for the Indian industries, ASSOCHAM has emerged as forceful, proactive, forward looking institution that is equipped to meet the aspirations of corporate India in the new world of business. Ready to redefine the dynamics of growth and development in the technology driven cyber age, it aims empower Indian enterprises by inculcating knowledge that will prove to be the catalyst of growth in the technology driven global market. ASSOCHAM aims to help and guide businesses to upscale, align and emerge as formidable players in their respective business segments.
Its mission is to impact the policy and legislative environment so as to foster balanced economic, industrial and social development.

ASSOCHAM is working towards creating a model business environment in India that is at par with the rest of the world and that of a developed economy. It derives its strength from its promoter chambers and other industry/regional chambers/associations spread all over the country.

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