POLICY BRIEF

'AIR TO WATER' TECHNOLOGY - OFFERING POTENTIAL TO ACHIEVE WATER FOR ALL

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Creating Innovative Solutions for a Sustainable Future

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India's population makes up almost 18% of the global human population. However, the availability of freshwater resources is limited to almost 4% of the global freshwater resources. Sparse resources in tandem with a growing population disrupt the demand and supply balance making the availability of potable water for the population a formidable task. In India, the major source of water is precipitation, including both rainfall and snowfall. The precipitation is distributed irregularly across different seasons and throughout the country. This rainfall flows to rivers and other natural and man-made structures such as lakes, ponds, reservoirs, tanks, etc. So, availability of water resources is sufficient, but due to high spatial and temporal variability, there is an immediate need to effectively and efficiently manage these available resources and work towards innovative solutions to address the growing demand for drinking water.

1. Government's Initiatives to Improve Drinking Water Supply

Since early independence, several government policies have been formulated to address water security issues. In 1949, the Environment Hygiene Committee recommended the provision of a safe water supply to cover 90 per cent of India's population in a timeframe of 40 years. Subsequent efforts over decades through the introduction of multiple schemes and allocation of large funds have indeed resulted in improvement in access to water and sanitation for the population. Based on the response towards schemes, the policies have changed over time from a 'Government-oriented supply-driven approach' to a 'People-oriented demand-responsive approach' (Figure 1).

1947-1969 Early Independence	1969-1989 Transition Phase	1989-1999 Restructuring Phase	2000-2009 Consolidation Phase	2009-2022 Bottom-up Approach
1949: The Environment Hygiene Committee (1949) recommends the provision of a safe water supply to cover 90% of India's population in a timeframe of 40 years. **1950**: The Constitution of India confers ownership of all water resources to the Government **1969**: National Rural Drinking Water Supply Programme was launched with technical support from UNICEF and Rs.254.90 crore is spent during this phase	**1972-73**:Introduction of the Accelerated Rural Water Supply Programme (ARWSP) by the Government of India **1981**: India sets up a national level Apex Committee to define policies to achieve the goal of providing safe water to all villages **1986**: The National Drinking Water Mission (NDWM) is formed **1987**: Drafting of the first National Water Policy by the Ministry of Water Resources	**1991**: NDWM is renamed the Rajiv Gandhi National Drinking Water Mission **1994**: The 73rd Constitutional Amendment assigns Panchayati Raj Institutions (PRIs) the responsibility of providing drinking water **1999**: Sectoral reforms to initiate community participation in the implementation of rural drinking water supply schemes. Paradigm shift from the 'Government-oriented supply-driven approach' to the 'People-oriented demand-responsive approach'.	**2002**: Nationwide scaling up of sector reform in the form of Swajaldhara, and revision in National Water Policy **2004**: All drinking water programmes are brought under the umbrella of the RGNDWM. **2005**: The Government of India launches the Bharat Nirman Programme **2007**: Pattern of funding under the Swajaldhara Scheme changes share to 50:50 centre-state share.	**2009**: The National Rural Drinking Water Programme (NRDWP) launched **2013**: NRDWP was upgraded to increase availability of clean water to 55 lpcd from 40lpcd **2017**: NRDWP was reformulated to make a provision for tap water availability to all villagers **2019**: Jal Jeevan Mission was launched to provide 55 lpcd drinking water supply to every rural household

Figure 1: Chronology of rural drinking water supply schemes initiated by Indian Government

Source: Adapted from Khurana and Sen, 2008

- In 2002, the Swajaldhara initiative gave local communities the right to participate in planning, implementation exercise, and undertake the operation and maintenance of drinking water structures.
- In 2009- 2010, the National Rural Drinking Water Programme (NRDWP) was launched. The focus was to enable all households to have access to use safe and adequate drinking water within the premises.
- The program was upgraded in 2013 to increase the availability of clean water to 55 lpcd from 40 lpcd. Furthermore, in 2017 the program was reformulated to make a provision for tap water availability to all villagers.
- Finally, in 2019, the Jal Jeevan Mission (JJM) was launched under the Har Ghar Jal program. The Jal Jeevan Mission aims to provide 55 lpcd drinking water supply to every rural household (as per the BIS 10,500 standard) on a regular and long-term basis at affordable service delivery charges.

2. Advent of Jal Jeevan Mission

Since the launch of Jal Jeevan Mission in 2019, active efforts are being undertaken at different government levels, to achieve the target of water for all, which in turn may improve the quality of life, enhance ease of living and reduce the urban-rural divide. The target provision of every household tap connection in rural areas till 2024 would be beneficial for the population as well the economy. This would also aid in reducing the drudgery of women and young girls who are burdened with the task of collecting water from far-off locations for meeting daily household needs (such as drinking, cooking, cleaning,

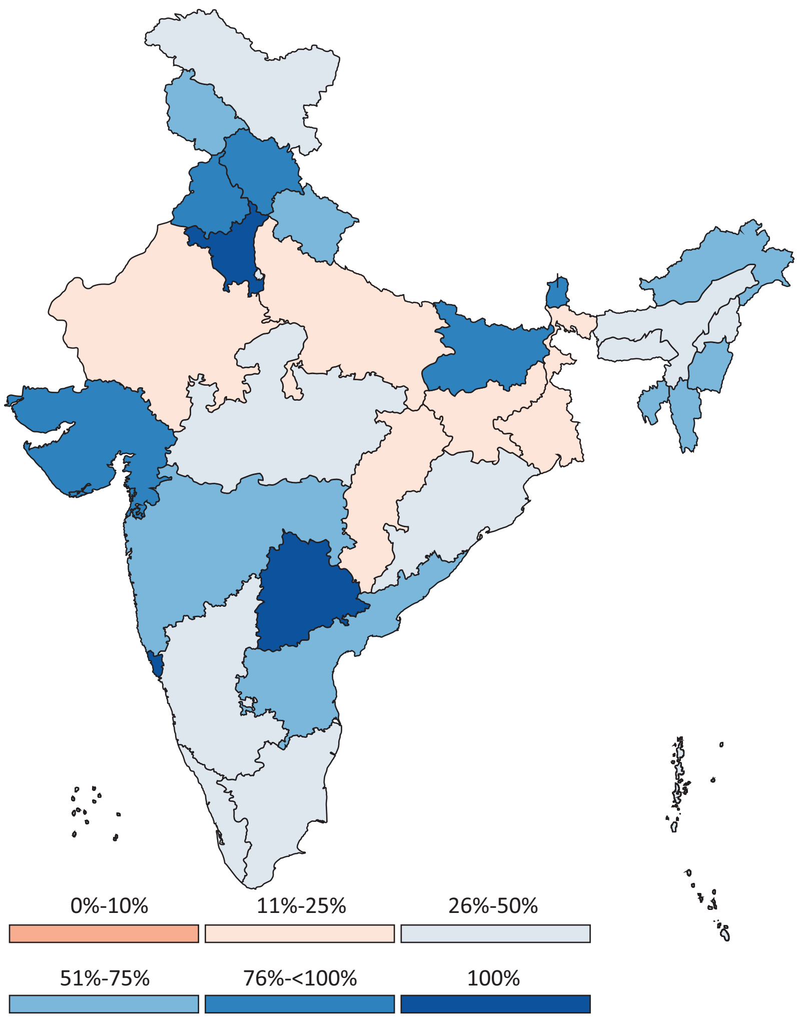

Figure 2: Tap water supply in households (HHs) across Indian states

Source: JJM Dashboard

animal consumption, etc.). Access to potable water at the household level will not only improve household health (resulting in a reduction of water-related diseases) but also contribute to the overall quality of life of women. Additionally, women will be in a position to contribute financially by undertaking income-generating opportunities due to the availability of time.

2.1 Current Status of Jal Jeevan Mission- Rural and Urban

Before 2019, only 16.83% (i.e., 3.23 crore out of the total 19.22 crore) of the country's rural households had access to a functional tap water supply. After the launch of the Mission, the percentage increased exponentially to 58.7% (i.e., 11.4 crore) of households having Piped Water connection, and this number is increasing on a daily basis (Figure 2). Some remarkable examples include states like Goa, Haryana, Gujarat, Telangana, Andaman and Nicobar Islands, and Puducherry which have achieved 100% tap water supply in rural areas.

Jal Jeevan Mission - Rural

- Jal Jeevan Mission is a bottom-up approach, and the community forms the core of the program. The Public Health Engineering Department officials guide the Gram Panchayats to formulate a 5-year 'Village Action Plan' based on baseline surveys, resource mapping, and felt needs of the community. The requirement of the community is prioritized and local knowledge is taken into account while planning the water supply scheme.
- Planning, implementation, management, operation, and maintenance of the infrastructure created in the Gram Panchayat are done by the village community. This program is designed so as to instill a sense of ownership in the community.
- Furthermore, water testing laboratories in the States/ UTs are assigned the responsibility of frequently testing the quality of water supplied and escalating the matter for remedial action in case any contamination is reported.

Jal Jeevan Mission - Urban

- At present, there is a ~2.68 crore estimated gap in urban household tap connections. Under the JJM urban plan, rejuvenation of water bodies is also included in order to augment the sustainable freshwater supply.
- Furthermore, linking JJM to the AMRUT scheme, creating green spaces and sponge cities to reduce floods and enhance amenity value through an Urban Aquifer Management plan are other key areas covered under the Mission.
- The urban mission also boosts the circular economy of water through the development of a city water balance plan for each city focusing on recycling/reuse of treated sewage, rejuvenation of water bodies, and water conservation. Under this, it is aimed that 20% of the water demand is to be met by reused water with the development of an institutional mechanism.
- JJM Urban also promotes a technology sub-mission for water, under which it is proposed to leverage the latest global technologies in the field of water. Additionally, Information, Education, and Communication (IEC) campaign are proposed to spread awareness among the masses about the conservation of water.

3. Issues and Challenges to Drinking Water Supply

As the drinking water sources are sharply declining, efforts are being made towards source conservation and protection. Still, climate change led impacts on water resources, changing pattern of rainfall in the country and increasing demand for water, Water for All is a huge challenge. Some of these issues and challenges are:

3.1 Changing Climate and Increasing Number of Water-Stressed Regions

Around 74% of the natural disasters between the years 2001 to 2018 were related to water. The occurrence of disaster events such as droughts and floods has been exacerbated by climate change leading to an increase in their frequency and intensity. When such disasters hit, it can lead to destruction or contamination of water resources, thereby increasing the risk of incidence of water-related diseases and overall water stress in the region.

- Climate parameters including temperature, radiation, humidity, and wind speed greatly influence water availability.
- The changing climate is affecting the precipitation, runoff, snow/ice melt, overall hydrological systems, water quality, and groundwater recharge.
- Furthermore, climate change has also led to several areas with alarmingly low levels of water resources leading to increased resource competition and even conflicts in extreme cases.
- Climate change has also led to rising sea levels which mix with freshwater water, thereby compromising the quality of water. It is estimated that by 2020, globally, almost 1 in 4 children will live in areas of extremely high water stress.

3.2 Decline in Groundwater Level

India is home to vast Indo-Gangetic and Brahmaputra plains which are rich in groundwater reserves. The total replenishable groundwater is estimated to be around 433 BCM. Presently, both rural domestic (~85%) and urban (~50%) water requirements are met from groundwater reserves. This demand has sharply increased since the policy changes in the water sector in the 1980s (Khurana and Sen, 2008).

- In the past few decades, uncurbed extraction of groundwater has had detrimental impacts on the quality and quantity of the resource. The groundwater resource depletion has also resulted in a cascade of pernicious impacts on the ecology, water table, farmland, etc.
- The extent and nature of dependency on groundwater resources are still not well understood. In the urban context, the household level access to groundwater is primarily through public supply connections provided by urban municipal bodies, private supply from bore wells, and informal/ semiformal trading of groundwater (Narain, 2012). The complexity of extraction and supply makes it tedious to generate an inventory of supply and estimate population dependency, thereby optimizing regulatory decisions.
- According to the NITI Ayog report (2018), almost 54% of the groundwater wells are declining due to over overutilization. As per the zones of groundwater, since 1992, the percentage of semi-critical, critical, and overexploited areas has increased to ~30% while the safe areas have drastically reduced to 70% (Figure 3). In several states, the annual groundwater draft is more than the net annual availability, exceeding the national target of 70% for the stage of groundwater development.

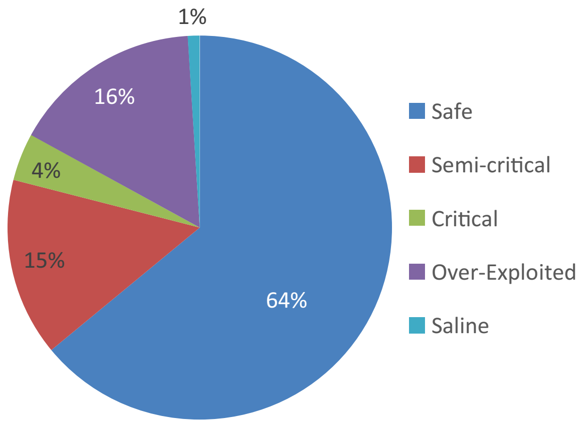

Figure 3: Percentage unit of groundwater available under safe, semi critical, critical overexploited categories

Source: CGWB Report, 2020

3.3 Spatio-temporal Variability

Water is disproportionately available due to geographical and local climatic conditions. The spatial distribution and variations in annual precipitation and the precipitation concentration are affected due to geographical factors. With a combination of topography, the Indian subtropical high, and monsoon weakening, precipitation may be more concentrated in one period or region, leading to the risk of floods and droughts. The impact of natural factors such as hydrological regime, water temperature, etc., and anthropogenic activities such as land use and contaminant capacity are considered as driving factors to understand the water quality and hence the drinking water availability.

3.4 Lack of Accessibility at Distant Locations

The availability of drinking water is still 'away' or distant from many households in the country. Despite several initiatives, long-distance (beyond 500 meters) must be traveled to achieve this basic need to get water for drinking, cooking, and other household chores. Several government initiatives encourage rain-water harvesting and check-dam for ground-water recharge through a community participation approach. This is enabled through support for Panchayat Raj Institutions and local communities to manage their drinking water sources and systems within their villages. Despite the efforts, success is not seen due to the lack of infrastructure, huge energy costs, the possibility of water losses due to pipe breakage, and an increased source-to-supply ratio due to the increasing population.

3.5 Competition for Shared Water Resources

Water being a shared resource is subjected to competition and disputes arising at inter-district, inter-state, and international levels. This has resulted in competition and the need for negotiations between subject regions for their water supply. A notable case of urban surface water demand resulting in direct competition with rural users is that of Chennai city and the Telugu-Ganga project (Celio & Giordano, 2007). Such issues require devising and implementing a regulatory framework to transfer water from agricultural lands to cities, eliminating sectoral competition for water to efficient management of the resource.

3.6 Quality of Available Water

Over the years, both Government and non-government initiatives have been taken up to address the issues related to drinking water supply and quality. Yet, the decline in the groundwater has led to contamination of source and lower-income groups resorting to consumption of inferior quality water.

- Consequently, we have over 21% of the diseases that are water-related, majorly affecting young children and women. In India, 1 in 5 children dies before 5 years of age due to consumption of contaminated water, lack of access to water, inadequate sanitation, and hygiene. Contaminated drinking water carries the risk of many diseases (such as diarrhea, typhoid, amoebiasis, hepatitis, gastroenteritis, giardiasis, campylobacteriosis, scabies, cholera, and worm infection), some of which can turn deadly. Therefore, checking the quality of water and using it post-treatment is an effective way to avoid ailments related to water-borne diseases.
- Furthermore, geochemical characteristics of the aquifer material impact the groundwater. This leads to various forms geogenic contaminants such as arsenic, fluoride, nitrate, iron mixing with the groundwater and hence the drinking water, leading to severe health problems in consumers (Table 1).

Table 1: Number of states and districts in India affected by geogenic contamination in groundwater

Geogenic containments	Number of affected states	Number of affected districts
Arsenic	10	68
Fluoride	20	276
Nitrate	21	387
Iron	24	297

Source: Central Ground Water Board; PRS.

3.7 Infrastructure Issues

The drinking water supply is also affected by the lack of focus on infrastructure/ asset creation up until a few years ago. There is a lack of knowledge among various stakeholders. Also, the role of the private sector and civil societies was limited until a few years ago. In order to promote public private partnerships (PPP) under JJM Urban, it has been mandated for cities having a million plus population to take up PPP projects worth a minimum of 10% of their total project fund allocation. There is a greater need for rethinking public financing and investment in the direction of sustainable, equitable, affordable water supply options. New technologies have come up that ensure a sustainable supply of potable water availability.

4. Air to Water – An Alternate source for water supply

Given the perspective of water scarcity in several districts of India, it is necessary to explore alternate water supply/ resource options for the people to ensure the achievement of the sustainable development goal of equitable access to safe drinking water for all citizens. The AWG is one such decentralized solution that is environmental-friendly, has zero water waste, and generates re-mineralized instant potable water. Such a renewable water installation might be scaled to supply water in an arid locality or hilly region, with water harvesting even in the harshest climate conditions and most difficult landscapes to walk in order to fetch water.

4.1 About 'Air to Water' Technology

Extracting water from the air is one of the most phenomenal innovations in the last few decades that could ensure future water scarcity. Several challenges such as poor water management strategies, growing populations, geopolitics, and both natural and anthropogenic environmental changes are all aiding in pushing some areas to run critically low on potable groundwater. Human ingenuity may have delivered a partial solution to this imminent disaster. The atmospheric water generators (AWG) are able to effectively condense water vapor from the humidity in the ambient air.

- Among the existing technologies, most AWGs tend to work in a similar way- by using heating/cooling coils. The AWG machine reduces the temperature of the collected air below the dew point of water vapor in order to turn it into liquid water (Figure 4). Such machines become pivotal in areas of potable water scarcity.
- While most AWG machines can extract only small amounts of potable water, the output water is clean, readily available, and avoids outside trips to fetch water. The technology is a scalable, portable, and cost-efficient solution to modern-day water problems!
- The atmospheric water vapors condense when the temperature goes below the dew point temperature (Figure 4). Using this principle in AWG eliminates the need to build any water-transport infrastructure. The AWGs are active condensers and use water harvesting apparatuses that can be placed almost anywhere.
- The technology requires favorable weather conditions in order to maximize the condensation of dew. An ideal condition for any AWG is relative humidity ~80%. The AWG is less impacted by variable abiotic conditions such as sky emissivity, wind speed, and topographic location. The water yield per day is impacted by these variables and hence could result in higher or lower output.
- The AWG can yield higher outputs of as much as 5000L/day of potable water during favorable conditions and through additional energy inputs.

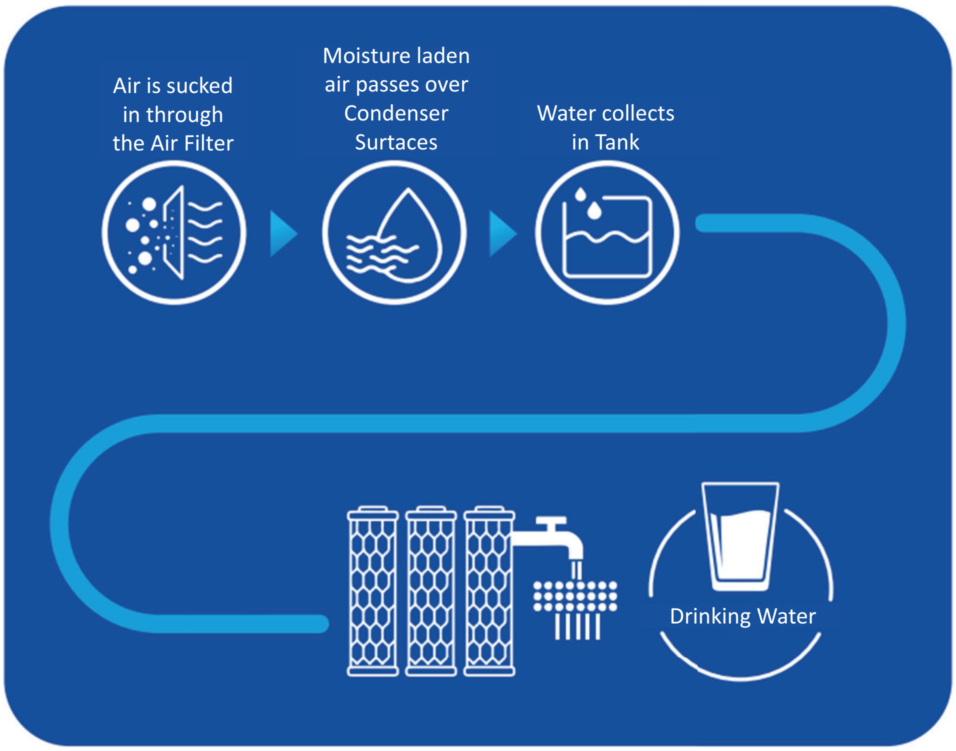

Figure 4: The basic concept behind AWG technology

Source: Maithri Aquatech Pvt Ltd.

This makes AWG a fitting alternative option or supplemental source of potable water in water-scarce regions.

4.2 Benefits of Air to Water Generators

- **Assured Quality of Water** – The water generated by AWG is pure, clean and safe potable grade water.
- **No Ground Related Impurities** – As the water does not get in contact with the ground, it is free from all ground related impurities such as Arsenic, Fluoride and other Heavy Metals.
- **No Source Water Required** – The AWG generate water from perennial source – AIR and does not need any ground/surface water sources.
- **Immediate Solution** – The AWG can start generating water within minutes of being turned on.
- **Rapidly Deployable and Re-deployable** – The AWG is a Plug & Play decentralised solution, that can be deployed to generate water in cases of Natural Disasters and calamities.
- **Predictable** – The quantity and quality of water generated by AWG is a predictable.
- **Zero Wastage** – Every drop of water generated by the AWG can be used for consumption
- **No Effluents & Carbon Emission** – There are no harmful effluents, by-product or rejects from the AWG. The AWG also has no direct carbon emission.
- **Last Mile Connectivity** – The AWG can be used to provide water in all the remote locations where access to water via conventional methods is a challenge.
- **Water for All** – AWG can be installed to provide high quality mineral enriched water at all Government Educational Institutions, Primary Health Care Centres, Hospitals Government Offices, Remote Villages, Across the Borders and any other location as deemed fit.
- **Renewable Energy Compatible** – Most of the AWG machines can operate on Renewable Energy like Solar, Wind or Hybrid model.

4.3 Other Applications of AWG Machines

In addition to providing pure, clean and safe mineral enriched water AWG can also be used in other applications, such as AWG powered cold rooms for Food and Water Security

AWG powered Cold Storage Room for Food and Water Security - The water-food nexus plays a major role in sustainable development, especially considering the growing demand of humanity . The Food and Agriculture Organization (FAO) of the United Nations estimates that as much as 30% to 40% of all food produced (and 40% to 50% root crops, fruits, and vegetables) is lost due, in part, to a "lack of proper post-harvest storage, processing, or transportation facilities. "In monetary terms, the amount of food lost every year is valued at more than $1 trillion. That is $1,000,000,000,000. According to the World Bank, every 1% reduction in postharvest loss results in $40 million of gains, and the main beneficiaries of these gains are farmers.

AWG is a possible answer to this solution, with the potential to provide drinkable water from the atmosphere, while also facilitating food preservation. This would significantly improve the living standards of many people across the country. Food items such as vegetables, dairy and meat produce require a low temperature and high humidity environment to be reserved for months. The by-

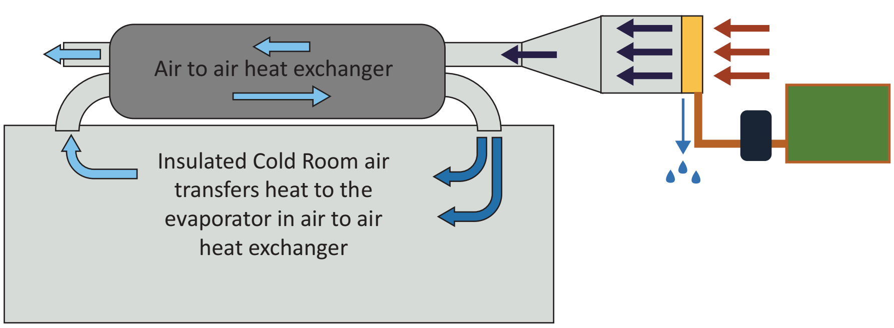

Figure 5: Schematic for Cold Room cooling with refrigeration cooling

Source: Maithri Aquatech Pvt Ltd.

product of AWGs i.e., cold air is made to absorb the heat from an insulated cold storage.

Apart from providing cooling for cold storage rooms, the cold air from the AWG can also be used for providing cooling solutions where required. This would eliminate the need for additional cooling units, air conditions.

The AWG powered cold room can be a disruptive technology providing solution for water & food security.

5. Challenges, Solutions, and Recommendations related to 'Air to Water' Technology

Access to safe and affordable drinking water for all is a big challenge that puts India's growing population in a predicament and may hinder the country's future economic development. The current coverage of tap water supply in rural India only adds to the immediate need for

AWG technology - perception and social awareness

- Given the challenges in expanding the piped water supply coverage, as well as the claims related to air to water technology in dealing with these challenges, it is necessary to do a comprehensive assessment of the technology and its potential of success under India's different hydro-climatic scenarios.
- Based on the recommendations under JJM Urban to promote technological reforms in the water sector and spread awareness among the masses about water conservation, The Energy and Resources Institute (TERI) conducted a study to understand the acceptability of the technology using Maithri Aquatech Pvt Ltd's Atmospheric Water Generator (AWG) & Remineralizer product called 'Meghdoot' and create social awareness about the benefits of upcoming AWG technology.
- The AWG was placed in two different micro-climatic locations- Goa and Varanasi.
- During the study, TERI's Western Regional Office, Goa had set up the AWG machine at Cotigao village and Gaodongrem village, located in South Goa from 15th-18th March 2021. The TERI, New Delhi team visited the second location, i.e., Varanasi, and had set up the instrument at Lathia village from 26th-28th October 2021 and Khaira village from 28th-30th October 2021. A survey questionnaire was developed and administered to assess the current household-level drinking water demand, supply, and quality perception.
- After the team provided details about the technology, the technical specifications of the machine, and the benefits accrued, the local people appreciated the machine and showed a willingness to adopt/utilize it. People tasted the water and found it to be clear, odorless, and pleasant to drink.

Meghdoot's Perception by Community	
Knowledge about 'Air to water' technology	★
Curiosity toward novel technology	★★★★★
Delighted to learn about the new technology	★★★★★
Understanding of technical specification	★★★★
Apprised benefits on environment and society	★★★★★
Utilization and operation	★★★★
Output water quality, taste, and odor	★★★★
Feasibility of using at household/institutional level	★★
Willingness to invest in the product	★

Figure: Collective community response to AWG technology effective solutions that can address the impending water crisis. While 'air to water' technology presents an effective alternative, various challenges emerge in the on-ground implementation of the technology. Some key challenges and their possible solutions have been presented below:

5.1 Low-Cost Energy

One of the key challenges associated with AWG is the availability of low-cost power. In order to circumvent this challenge, access to subsidized or low-cost energy could be made available to make AWG an attractive alternative to present potable water availability options. As AWG generates potable water through green technology, the AWGs could be allowed to have access to renewable power and to tax subsidizes similar to solar products.

5.2 Improved Yield

Among the various challenges associated with 'air to water' technology, the major challenge includes a reduced overall yield due to low humidity and low-temperature conditions and overall low water generation capacity per machine. Generally, a single high-capacity machine can generate limited water, up to 5000 L. In order to avoid this issue, the AWG utilizes both conventional desiccants and Metal-Organic Frameworks (MOF) for improved yield across geographies and climatic conditions. As an advanced moisture sorbent, the combination will give an energy-efficient, high temperature, and low humidity water generation process.

5.3 Improvement in R&D Strategy

The technology needs to be optimized for improved efficiency and to ensure adequate delivery of substantial quantity and quality of water at affordable rates. The heavy taxes levied on the raw materials leads to high raw material cost, and hence overall high manufacturing cost. Improvement through R&D strategy with higher capacity compressors and advanced nano-coated evaporator and condenser coils will improve the overall efficiency. Beyond the technical issues and solutions, both social and institutional challenges are presented at various stages of acceptance of the technology.

5.4 Changes in the Policy Framework and Institutional Support

Some key aspects must be considered to promote 'air to water' technology with Government's support.

- AWGs could be allowed to have access to renewable power or grid power at subsidized rates. Free power being given across many villages, cities can be extended to AWGs.
- Government agencies can incentivize companies working on sustainable solutions through tax reductions and even share investments in implementation projects.
- The taxes levied on raw materials and finished goods should be at par with solar energy products, another renewable energy solution.
- Furthermore, the promotion of public-private partnerships in the sector can reduce the initial cost to end-customer. This would result in cost-cutting, with the end-user only having to bear operational and maintenance costs.
- Additionally, Production Linked Incentive Scheme (PLI) could be extended to the manufacturing of AWG as the machine works on the same principle of condensation technology as the air conditioner.
- Lastly, given the purity and zero microbial contamination in the water generated through AWG, the Government should extensively encourage its use in schools, primary health centers, hospitals and communities.

5.5 Lack of Awareness

Undoubtedly, considerable challenges linger but knowledge and awareness are the keys to encouraging technology adoption. There is a need for a community-based, demand-driven approach to propose AWS facilities to local communities in any targeted sector/area. Prior knowledge of the community's response towards their current water supply regime and AWG as an alternative option is key to understanding the acceptability of the technology. Social awareness programs and local capacity-building events could also help encourage and motivate communities to accept the technology and make it widespread.

For more information, please visit: **www.teriin.org/water**