Fresh Water

Technology Reviews

- Solar Desalination
- Atmospheric Water Condensers

India, Raj Nagar, New Delhi
People using a water ATM in the suburb of Dwarka. The solar-powered machines installed by a for-profit social enterprise called Piramal dispense clean drinking water via a pre-paid smartcard to residents who have no access to water on tap in their homes.

Credit: Stuart Freedman – Panos


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Solar desalination

What is the challenge or opportunity?

Water stress occurs when there is insufficient quantity or quality of water supply to meet diverse needs and demands[241] in a specific area or region,[242] It is rising globally because of changes in living patterns and food production, high levels of pollution, and the rising cost of treating and distributing water. Globally, this means that billions of people need to mitigate, overcome or in some other way manage high levels of water stress.[243] In developing countries this translates into large numbers of poor and vulnerable people who do not have access to affordable, safe, sufficient, sustainable and environmentally safe water.[244]

Solar desalination as a frontier technology

Historically, people have tried to increase water availability to meet demands by exploiting unutilised fresh water sources, such as rainwater, groundwater and atmospheric water, or through improved water management practices, including demand management, water recycling, river flow regulation and so on.[245] While these practices are widespread today, their potential mitigating impact on escalating levels of water stress is somewhat limited because fresh water only accounts for around 3% of global water volumes. As a result, increasing attempts have been made to harness the remaining 97% of saline water, comprising seawater and brackish water.[246] Experts argue that methods to turn saline into fresh water are likely to play an important role, especially in developing countries. Some go as far as to suggest that 'desalination [could] make a revolution in water supply globally.'[247]

Technological advances have led to considerable improvements in these processes, ranging from the use of new energy-efficient means of heating water to evaporation point to the invention of more effective membranes and materials for filtration.

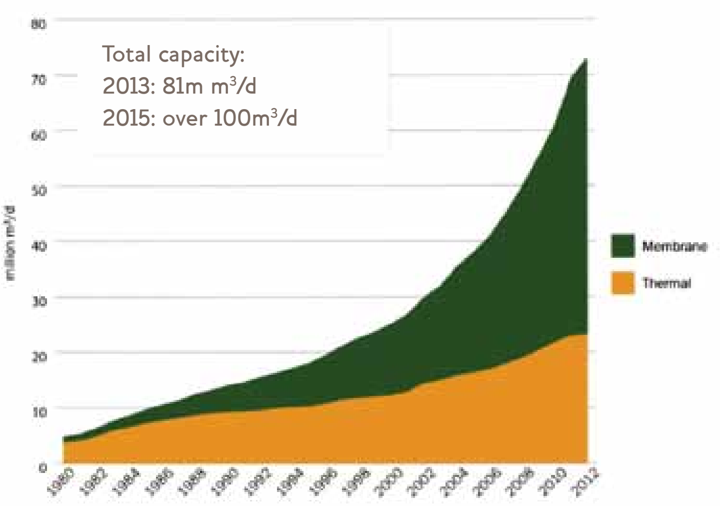
Definition

Desalination has been practised for centuries through one of two methods: *distillation*, through the evaporation of saline water into steam, and then condensing it into a pure non-saline form; and second, through the application of intensive *filtration* processes to extract salt from the water.[248]

The effectiveness of new desalination technologies has led to rapid diffusion of facilities. There are more than 16,000 desalination plants worldwide, with a total global output capacity of 100m cubic metres per day in 2015.[249] Private sector consortia typically set up and run the plants, with a mix of public and corporate clients.

A Sundrop farms seawater greenhouse, which uses solar desalination technology to grow vegetables in the South Australian desert.
Photo credit: Seawater Greenhouse, www.seawatergreenhouse.com/australia.html

Figure 11 Installed water desalination capacity



Source: Ghaffour *et al.* (2015)[251]

Global capacity has grown considerably over the past decade and is anticipated to continue growing exponentially as more countries and regions seek out new ways to combat water stress (see Figure 11).[250]

Plants tend to use one of three main processes:

- **Thermal distillation:** this involves the distillation of saline water into steam, which is then condensed into pure fresh water;
- Extraction processes:
  - **Electro-dialysis:** whereby salts are separated from water by means of applying an electric load; and
  - **Reverse osmosis:** whereby a pressurised flow of water passes through a semipermeable membrane that prevents the salts from passing, with higher saline water requiring higher pressures.

Globally, 68 per cent of all desalinated water is produced using filtration or membrane processes, and 30 per cent using thermal distillation (with the remaining 2 per cent coming from other processes).[252] Membrane technology has become dominant since the 1990s, with reverse osmosis being the most widely used approach. Desalination water is split, with 59 per cent coming from seawater and 22 per cent from brackish groundwater sources; the remainder comes from surface water and saline wastewater. These figures tend to change frequently because of the rapid growth and evolution of the desalination market.

The high energy costs of filtration and distillation contribute to high financial and environmental costs. These are especially pronounced because the majority of desalination facilities are powered by fossil fuels. Desalinating water is estimated to use at least 75.2 TWh/year, which amounts to approximately 0.4% of global electricity consumption.[253] Significant capital investments and maintenance costs are also involved in setting up and running desalination plants.[254] According to researchers from the International Water Management Institute (IWMI), this poses a significant constraint on the wider adoption of desalination technologies in developing countries: ‘The major present hindrance in using desalination to help alleviate global water scarcity is the cost of this technology, which, in turn is due to energy cost involved.’[255]

In recent decades efforts to develop renewable energy-based desalination technologies have grown, with various ways of incorporating renewable energies into the desalination process being tested. The most frequent application is the combination of solar energy and reverse osmosis,[256] which is seen as having considerable potential because of the abundance of solar energy in those areas and countries that face the greatest levels of water stress, its permanence and minimal environmental impacts.

Growing numbers of initiatives and studies have shown that a number of solar-based desalination processes have considerable scope for widespread application in developing countries and with reduced costs compared to conventional desalination approaches and the cost of centralised infrastructure investments. Box 2 shows four of the more prominent examples.

A Seawater Greenhouse in Somaliland aims to transform the hostile local environment into ‘micro oases’ to efficiently and effectively grow crops using solar desalination technology. Photo credit: Seawater Greenhouse, www.seawatergreenhouse.com/downloads/Somaliland%20Seawater%20Greenhouse%20Flyer.pdf

Box 2 Types of solar desalination

Solar-powered reverse osmosis

Also known as photovoltaic powered reverse osmosis (PVRO). The process uses solar power to pressurise water and push it through a membrane where salts are intensively filtered out.[257] Such systems are generally used to meet clean water needs for small remote communities in low- and middle-income countries. Although such systems have technical, cost and operational challenges, technology reviews show that effective community engagement in the design, implementation, operation and maintenance of the systems can resolve them.[258]

Membrane distillation

A thermally driven distillation process that uses a porous membrane, either side of which is maintained at a different temperature.[259] The feed water is heated and brought into contact with the membrane, which allows only vapour to go through the dry pores, which condenses on the other side. A temperature difference of 7–10°C between the warm and cold sides is sufficient to produce fresh water. The process works at relatively low temperatures, and so can use low-grade water and renewable energy including solar and geothermal. High feed salinity does not greatly affect performance, as has been proved in benchmarking and pilot studies.[260]

Adsorption desalination

A form of distillation that uses a low-temperature heat source to power the desalination process, producing cooling and high-grade potable water. Brackish water or seawater is fed into an evaporator at an ambient temperature. An adsorbent material such as silica gel is used to draw out vapour at very low pressure and temperature. This process is energy efficient and low maintenance because of the lack of major moving components. It is also between five and 12 times less polluting in terms of CO_2 emissions when compared with conventional desalination processes.

Greenhouse desalination

Greenhouse desalination processes use sunlight, seawater or brackish water, and the atmosphere to produce fresh water and cool air, creating suitable conditions for crop cultivation.[261] The process recreates the natural hydrological cycle in a controlled environment, using humidifiers to keep the greenhouse cool while allowing crops to grow in strong sunlight. Saturated air leaves an evaporator and passes over a condenser. The fresh water condensing from the humid air has zero salinity, and this is then piped to storage tanks for irrigation. The system has several benefits such as flexible capacity; moderate installation and operating costs; simplicity of design and operation; and the possibility of using low temperatures and numerous renewable energy sources, including solar, wind and geothermal. Pilots have been developed and tested in the Canary Islands, United Arab Emirates, Oman and Australia.[262]

A Seawater Greenhouse (left) uses solar energy to desalinate water for crop production (right). Photo credit: Seawater Greenhouse, http://www.seawatergreenhouse.com/projects.html

Potential for acceleration

Current installed desalination capacity powered by renewable energy is relatively small compared with the world's total desalination capacity. The Prodes Group of Experts suggested in 2009 that the target for the use of solar energy should be a 3–5% share of new installations in the global desalination market by 2016. According to the International Renewable Energy Agency, by 2012 this had reached 1%.[263]

Mass production and diffusion of solar energy systems has led to significant cost reductions in many related applications and this trend is expected to continue for solar desalination also. Growing demand is starting to facilitate commercialisation opportunities. Combined with the growing cost of fossil fuels, these factors are serving to increase the competitiveness of solar desalination. However, a number of issues need to be addressed relating to the production and operation of the solar desalination technology and improvements in efficiency and output levels.[264]

In terms of production most solar desalination systems are not developed as a single coherent system, but instead are the result of localised efforts to identify a workable solution, using a number of components that are usually made by various suppliers. This poses a particular challenge to production costs and reliability. An added complication is that solar desalination systems are not based on a single technology but on the effective coupling of water desalination and solar technologies. Work needs to be done if all combinations of these technologies are to integrate in a smooth and efficient fashion. However, some approaches that have been developed and tested are more advanced than others, such as the greenhouse desalination described in Box 2.

As well as these technological and commercial aspects, the scope for acceleration in solar desalination in different settings is influenced by a number of context-specific local factors. These include:

- **Plant location** - Solar energy is abundant in many coastal areas of arid and semi-arid regions where a large proportion of the developing world population lives.
- **Self-Sufficiency** - It is possible to increase energy diversification by including solar energy in the energy source mix; increased use of solar energy further reduces dependence on energy imports if no national fossil fuel resources are available, and this can lead to a virtuous circle for solar desalination systems.[265]

> Small-scale solar membrane systems can provide a viable treatment option for rural areas in many developing countries because they are able to reliably treat many feedwater types to meet drinking water standards, and work in settings where there is low infrastructure for water and electricity.

- **Economics -** Solar desalination is an ideal solution for remote areas and inland cities, which otherwise often depend on fresh water transport over long distances, which leads to high costs and potential microbial contamination due to poor hygiene.
- **Operation and maintenance -** Solar energy systems can generally be operated and maintained more easily than conventional energy systems and are therefore a more suitable option for remote areas because they are self-contained.[266]

Potential value generation and impacts

Evidence shows that the viability and value of solar desalination is greatest in areas undergoing the highest levels of water stress, where the cost of fossil fuels is high, where infrastructure for water supply to arid areas is limited, and where national or international financing mechanisms subsidise or offset investment costs in solar desalination.

Relatively small-scale solar membrane systems can provide a viable treatment option for rural areas in many developing countries because they are able to reliably treat many feedwater types to meet drinking water standards, and work in settings where there is low infrastructure for water and electricity. Compared to the costs of infrastructure and untreated water, the cost of the system may not be as big a barrier as is often assumed. Solar desalination systems have been described as having strong leapfrogging potential.

However, for it to achieve its potential in a variety of settings will require in-depth consideration of many parameters - a one-size-fits all solution not likely.

In commercial terms, a recent review by Mahmoudi and Ghaffour[267] noted that while solar-assisted desalination has proved to be technically feasible, the processes have not yet been successfully commercialised.[268] A more critical assessment suggests that a range of technological and economic factors come into consideration that limit the commercialisation of solar desalination including the cost of photovoltaic (PV) cells, water collectors and related plant equipment such as membranes and pumps. Until these individual technologies can be mass-produced, and issues of interoperability considered at the design stages, overall costs are unlikely to drop significantly, and the opportunity may seem unattractive to potential innovators and investors.

Potential benefits for development

The successful application of renewable energy for solar desalination can help achieve three sets of goals: social, economic and environmental. These goals are not always compatible and trade-offs are typically required. The potential benefit of solar desalination systems is that they present an investment 'sweet spot', whereby it is possible to meet goals in all three areas simultaneously.

The majority of applications in developing countries have been in remote and arid areas, and where national and local investment or external financing through development assistance meet the costs of plant set-up, operation and maintenance.[269]

For example, research has been undertaken on German-built solar-powered desalination systems in northern Namibia, near the Etosha salt pan, which receives an annual average rainfall of 470mm and an annual average daily solar irradiance of 46 kWh/square metre. The CuveWaters project involved four different solar desalination pilot plants in the villages of Amarika and Akutsima in the Omusati region in July 2010. The plants are important because roads are poor and there are no electricity, mobile phone network or piped water connections. In Amarika, the chosen technologies were PV-powered reverse osmosis (with battery back-up) and solar thermal membrane distillation; in Akutsima, two non-membrane evaporation-based solar thermal systems were installed.

Over the pilot period and subsequently, the CuveWaters project showed that it is possible to install and operate small solar-powered desalination plants in a remote area of sub-Saharan Africa. According to the project evaluation, 'the first step on the path to the realization of a financially, environmentally, and socially sustainable provision of clean drinking water in developing countries using solar-power has been demonstrated.' The Namibian Ministry of Agriculture, Water and Forestry has since taken over operation of the plants and is looking to use the technology in other similar settings.

DFID is currently in the process of setting up a new programme of solar desalination systems in Bangladesh, and a critical consideration has been how to find the right business model for sustainable operation. Achieving long-term benefits requires ways of designing and implementing collaborative arrangements between communities, industry, government and innovators.

Enablers and barriers

Enablers

To reach greater scale, solar desalination needs to be perceived as a viable or at the very least a promising way of meeting the growing demand for fresh water. Context-specific conditions such as extreme water stress, high water costs, and natural characteristics that are favourable for desalination can contribute to its viability.

The wider growth in the use of solar-generated electricity, especially from PV sources, is likely to lead to growing scope for experiments in solar desalination. The potential for the electricity generated to also be used for other purposes is likely to strengthen arguments for investments.[270] Many installed plants could connect to an alternative grid to serve households, for example.

A key driver of solar power has been positive public support and opinion. There is also a strong environmental impact argument that could lead to greater levels of solar take-up across desalination investments more generally.

Although solar is still less efficient than fossil fuels in solar desalination by direct cost comparison,[271] numerous studies of these new approaches suggest that the feasibility of desalination systems based on renewable energy becomes more justified if environmental degradation costs associated with fossil fuel-based desalination are taken into account.[272]

Where solar desalination plants have been installed in developing countries, it is because their costs are not assessed relative to fossil fuel-powered desalination, but rather as an alternative to centralised infrastructure investments and related operation and maintenance costs. A key enabler is therefore the extent to which solar desalination is framed as a leapfrogging technology.

Barriers

Although capital investments are important, as with many different forms of water and sanitation investments in remote and rural settings, the challenge relates to the need for sustainable use. This demands skilled operators, infrastructure for operation and maintenance, robust technology service networks, availability of spare parts and, perhaps most importantly, the adaptive capacity of communities to adopt and develop solutions specifically suited to local conditions.[273]

Other barriers that need to be overcome for the typical sites where solar desalination could be applied include a general lack of infrastructure; limited accessibility, especially during rainy seasons; and lack of suitably skilled staff who are permanently on site to deal with set-up challenges.

The need for greater efficiency in the technology is also a sticking point that will need to be addressed. At present, solar desalination is not a viable option for large-scale applications, either technically – due to fluctuation in energy supply leading to operation at different loads – or economically. In addition, solar energy is only available during daytime and its intensity changes from morning to evening, with peak intensity in the afternoon, whereas the energy requirement of conventional desalination processes is constant and continuous. In general, system efficiencies tend to be low if operated at variable loads and operating conditions. These limitations may pose a challenge to attracting investments in the technology, which in turn limits the rate of improvements in small-scale applications.

The potential for the electricity generated to also be used for other purposes is likely to strengthen arguments for investments. Many installed plants could connect to an alternative grid to serve households.

Currently, the cost of solar desalination exceeds those of conventional desalination by at least a factor of four. While solar energy is available free of charge, capturing it is far from free. More efforts is needed globally, which will serve to drive down the cost of solar for desalination applications. These activities should be undertaken by solar and water experts working in collaboration.

Risks

In general, the risks are the same as those that desalination efforts face generally. Intensive efforts can create new kinds of water and environmental stresses, especially due to by-product saline brines being discharged back into water sources, with brine disposal proving more challenging inland than in coastal areas. Other risks include the growing use and impact of chemical additives in various desalination processes. No specific standards for impact assessments exist, only guidelines drawn up by the United Nations Environment Programme (UNEP), and environmental impact assessments have not played a central role in solar desalination set-up and management policies.[274]

> The optimal size and location of facilities should be assessed, as well as the potential uses of water, including by households, communities, agriculture and small and medium enterprises.

What next for development sector actors?

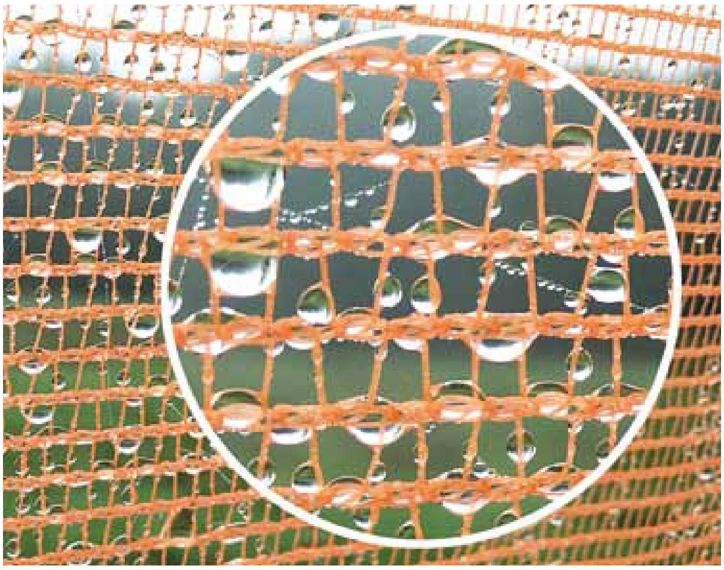
- **Local engagement** – Development actors should seek to build on research already undertaken to assess and evaluate in a comprehensive fashion where solar desalination might fit local and regional needs and opportunities. Such assessments should involve the engagement of communities to determine the interest in and capacity for solar desalination initiatives.[275] The optimal size and location of facilities should be assessed, as well as the potential uses of water, including by households, communities, agriculture and small and medium enterprises.[276]

- **Pilot programmes and cross-organisational engagement** – Efforts should also be made to develop and pilot test programmes, as has already happened with the USAID Desal Prize for acceleration of solar desalination.[277] Such efforts should look at partnerships between international organisations providing initial outlays; NGOs and civil society organisations with good knowledge and understanding of community capacities and needs; private sector organisations bringing technological knowhow and skills; and government bodies providing policy frameworks and, where possible, investment and maintenance guarantees. As well as testing the technology for further applications, efforts need to be made in testing out different kinds of contractual and institutional arrangements, both for the operation of plants and facilities, and for the distribution of water.

- **Regulatory and legal frameworks** – Ultimately, solar desalination programmes need to be considered as part of overall water resource management strategies and a potential alterative to other forms of water generation and access technologies. Better regulation and legislation is needed for solar desalination to fulfil its potential as a viable alternative approach to dealing with water stress.[278]

- **Donor support** – Donor bodies in particular have a role to play in expanding the understanding of solar desalination and finding ways to subsidise and kickstart new pilot programmes, and assess viability and cost benefits in a rigorous fashion.[279]

Atmospheric water condensers



The mesh materials of fog collectors often mimic properties found in nature (from insects and plants) to maximise the amount of water collected.
Photo credit: Warka Water http://www.warkawater.org/

What is the challenge or opportunity?

Access to safe drinking water remains out of reach for 663 million people. Diarrhoea, often caused by unsafe drinking water, is the leading cause of malnutrition and second leading cause death of children under five years of age globally.[280] Furthermore, climate change threatens to increase water insecurity and many have predicted inter- and intra-state conflict as nations find it increasingly difficult to acquire the scarce resources needed to grow food for human consumption.

Atmospheric water condensers as a frontier technology

Atmospheric water collectors are most effective as a source of drinking water in places where drinking water sources are sparse, ground water is unsustainable or expensive, and there is an abundance of fog, dew or rain. Because of the aforementioned criteria, these systems have been mainly deployed in arid/semi-arid and tropical/subtropical climates, often in mountainous regions near coasts.[281]

A review of fog collection initiatives around the world showed that in almost all cases the water produced from the technology meets World Health Organization (WHO) standards for safe drinking water.[282] It has been put to a variety of uses including reforestation efforts, fighting and preventing forest fires, combating desertification, supporting agricultural activities, gardening, and providing safe drinking water to church visitors, schools, and entire communities,[283] as well as for business and recreational purposes such as making beer.

Definition

Fog collectors use atmospheric water condensing processes to extract water from the atmosphere – whether in the form of dew, fog or rain – and collect it for human use.[284]

Many of these technologies draw on the emerging field of ‘biomimicry’ or ‘bio-inspiration’, which seeks to develop innovations based on observations of naturally occurring processes such as how desert beetles’ carapaces or rain forest systems collect and use water.[285]

Naturally occurring wind currents push fog through a meshed material, on which it condenses and drips down into storage tanks.[286] Because the process of evaporation by the sun naturally desalinates fog water, fog collectors typically provide a fresh source of water for irrigation and consumption. The most famous example of fog collection systems is in northern Chile, where the Chungungo community was able to produce considerable volumes of water for use by villagers. The initiative led to the creation of international NGO FogQuest, which works to disseminate the technology worldwide.[287]

Fog collectors are not the only technologies capable of capturing safe drinking water from the air. Other examples include passive and active dew collectors, which work by providing some form of engineered funnel or surface to collect moisture from the atmosphere. The difference between active and passive dew collectors is that active dew collectors require additional energy inputs – such as fossil fuels or solar energy – whereas passive dew collectors do not. Dew collectors have not been included in this report but could be a potentially exciting area for further research.

Fog collectors have provided Chilean villages in the Atacama Desert with safe drinking water since 1992. Photo credit: Nicole Saffie, cc BY-SA Creative Commons licence: BY-SA, https://commons.wikimedia.org/wiki/File:Atrapanieblas_en_Alto_Patache.jpg

Potential value generation and development benefits

Because water collection may be possible all year round in some regions, it can potentially free up time for household members – often women – who are in charge of getting water for other productive activities, especially if the fog collector is nearer and easier to access than previously used sources.[288] Studies suggest that poor communities are the usual beneficiaries of fog collection because it allows homes in areas that are not currently linked to water sources to gain access to clean water.

Atmospheric water condensers have been around since the 1960s.[289] In 1987, a fog water collection project was implemented in a north Chilean fishing village consisting of 100 fog collectors serving 300 people in one village. The fog collectors yielded a daily average of 331 litres of clean water per person.[290] Apart from providing drinking water, the water generated from this project also allowed the village to undertake small agricultural projects, thus diversifying people's diets, attracted tourism, and led to reverse migration. Its success led to many more projects being implemented across the world.

One particular mesh material – the Raschel mesh, made in Chile – has been used in fog collectors in 35 countries on five continents. Other meshes are also available that are specifically geared towards contexts with extreme or no winds.[291] Newer bio-inspired materials have also begun to show promising results. The ability of certain insects, animals and plants to survive in very dry conditions thanks to microstructures and textures on their skins and surfaces that allow them to collect water from the air has long been noted.[292, 293] In an effort to replicate this capability, scientists have turned to biomimicry, using designs based on techniques found in nature. Park et al. (2016) found that a combination of elements inspired by the surfaces of Namib desert beetles, cacti, and Nepenthes pitcher plants produced mesh materials that are up to six times more efficient than current materials. With this novel bio-inspired surface, 'droplets rapidly grow and start to shed much earlier than on other state of the art surfaces'.[294]

The amount of water that a fog collector can collect depends on many factors including its size, how high it is off the ground, the mesh material used, the thickness of the fog, the speed of the wind, and seasonality, among other things. Tojuia village in Guatemala is located 3,300m above sea level and harvests approximately 6,300 litres of water per day using 35 fog collectors during the dry season, which lasts up to six months.[295] Outside the dry season, fog collectors' yields can be even higher due to their ability to capture rain. Typical water production rates from fog collectors range from 150 to 750 litres per day, but some schemes produce between 2,000 and 5,000 litres per day.[296]

According to the International Development Research Centre, in addition to Chile, Peru, and Ecuador, the areas with the most potential to benefit from fog collectors include Angola, Cape Verde, China, Kenya, Oman, Mexico, Namibia, Sri Lanka and eastern Yemen.

Apart from fog collectors in the form of meshes and nets, and dew collectors in the form of cones or other concave surfaces, a number of other structures have also been tested to collect fog and dew.[297] One of the most widely publicised has been the prototype Warka Water Tower, which is being piloted in northern Ethiopia (see figure 12). Rather than just relying on one source, the tower collects water from dew, fog and rain. It also collects water from all angles rather than having to face an optimal direction, as with conventional fog collectors. Many of the tower's components are sourced from the surrounding areas, including bamboo and Warka tree leaves. It is estimated to have taken ten community members ten days to build the component parts of the tower using simple tools and two hours to assemble them. The cost of a single tower is estimated to be about $1,000; and one tower is projected to collect 50–100 litres of water on an average day.[298]

Enablers and barriers

Enablers

Fog and dew collectors have mainly been tested in arid/semi-arid tropical/subtropical mountainous regions – usually 500+ metres above sea level – near coastlines, with positive results.[299] They are a feasible technology for many developing countries. In fact, fog collectors have been almost exclusively deployed and tested in developing countries that lack 'the means to extend a conventional water supply system to all parts of the country… located in arid and semi-arid regions of the world where there is a shortage of potable water'.[300]

Previous studies have shown that community involvement and ownership often make or break atmospheric water collection projects. It is important that the community is made aware of the project and involved in the installation process, and that the project is socially accepted to ensure its sustainability. It is especially important to involve women, because they are typically the 'primary users and direct beneficiaries of collected water'.[301]

Furthermore, although most upfront funding come from outside actors, the operation of collectors is ideally funded from within the community. Community members should be selected at the outset of the project to serve as technicians, who should be compensated by the community in exchange for water consumption. How and by whom this is done is likely to vary from context to context, but generally speaking the community must charge its members for water to fund the collectors' operation, minor repairs and maintenance.[302]

The International Development Research Centre (IDRC) review suggests that smaller communities are more likely to take ownership of projects. However, it also argues that because of the heavy workload in putting the project together and maintaining it, at least 80 people should be involved in an implementing village including at least 20–30 adults. Moreover, when villages grow in population size, the amount of water that a limited number of fog collectors can produce may be insufficient. This has led villages in the past to opt for other sources of water.

Figure 12 Warka Water tower

WarkaWater towers collect fog, rain, and dew and convert it into safe drinking water for isolated rural villages in the North East region of Ethopia.
Photo credit: Warka Water, http://www.warkawater.org

Other factors recommend the use of fog collectors:

- They been widely tried and tested in suitable contexts;
- Their simplicity and high potential to deliver water to targeted communities;
- When there is fog, it tends to be abundant and fog collection projects are only limited by the number of fog collectors installed;
- It is a passive technology that does not require energy inputs to run;
- Fog collectors are durable, typically lasting for ten years if maintained and operated effectively;
- They are easy to maintain and maintenance costs are low;
- The technology is cost effective and usually cheaper than transporting clean water from far away.

Barriers

- High upfront costs – 100 fog collectors cost an estimated $40,000, but this can vary according to context;
- Systems are difficult to install and require expertise to find potential areas for installation, meaning communities must hire expensive external experts at the beginning of the project;
- Finding the best place to mount a fog catcher can be time consuming and expensive. However, innovations in easy-to-use probes capable of identifying these locations is promising. When linked to laptops the probes allow installers to 'measure the moisture content and velocity of the fog in hopes of inferring its prevailing direction';[303]
- Fog collectors are heavy and need to be transported to hard-to-reach high mountainous regions, which is expensive;
- The collectors are also difficult to assemble, creating even more reliance on external experts to install them. This has led to calls for collectors that could be flat-packed and assembled like IKEA furniture, but these do not yet exist;
- Although the water from fog collectors is clean in most cases, it can be prone to emissions and pollution if the collectors are located near power and industrial plants, leading to the need to for expensive evaluations to assess water quality before implementing a project;
- Collectors are susceptible to heavy winds and most models are inefficient at collecting fogs in conditions with little or no wind; and
- Collectors require regular maintenance and supervision, which can lead to their deterioration if communities do not take ownership of the project.[304]

> Previous studies have shown that community involvement and ownership often make or break atmospheric water collection projects.

What next for development sector actors?

- **Participate in networks** – An international conference bringing together scientists and practitioners working on fog and dew collection takes place every three years, with the most recent one occurring during the writing of this report in July 2016. [305] Development actors could also benefit from attending to learn from experts with knowledge in implementing fog-collectors around the world and users about what has worked where and why. This could also provide a good networking and partnership-building opportunity.
- **Ensure funding is paired with evidence** – Given the large upfront costs, international aid organisations have mainly financed fog collectors and their installation. Unless the high costs incurred at the beginning of fog collection projects are significantly reduced, they will probably have to continue to be funded this way. However, more research and evidence is needed to highlight the costs and benefits of such investments.
- **Engage communities** – The literature suggests that identifying villages that are suitable and can potentially benefit from fog collectors and towers is only half the battle. Development actors also have to find ways to involve communities in the identification and implementation process to ensure community ownership and sustainability of projects. The real potential of atmospheric water collectors will be achieved when they are used in conjunction with other strategies and approaches to addressing water needs in poor and rural areas.

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[241] Uses of water range from direct human consumption in drinking, washing and cleaning, to food production and farming, industrial production and development, a variety of environmental efforts, and a wide range of other applications such as in leisure and relaxation.

[242] www.eea.europa.eu/themes/water/wise-help-centre/glossary-definitions/water-stress

[243] www.wri.org/blog/2015/08/ranking-world%E2%80%99s-most-water-stressed-countries-2040

[244] www.oxfordmartin.ox.ac.uk/event/2036

[245] Schäfer, A, Hughes, G and Richards, B (2014) 'Renewable energy powered membrane technology: A leapfrog approach to rural water treatment in developing countries?', *Renewable and Sustainable Energy Reviews*, 40, pp.542–56

[246] Brackish water is salt water and fresh water mixed together. It results from natural mixing of seawater with fresh water, such as in estuaries, or it may occur in brackish aquifers.

[247] de Rooij, D (2015) *Solar water desalination: decentralized desalination systems*, SINOVOLTAICS – Solar Technology and Asia, http://sinovoltaics.com/technology/solar-waterdesalination- decentralized-desalination-systems-powered-solar-energy/

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