CTO

This month in Chief Technology Officer:

MARKET MAP

Where do atmospheric water generators really fit?

As hype continues to build around the potential for atmospheric water generators, GWI investigates whether the sky really is the limit.

Atmospheric water generation (AWG) – the process of producing drinking water from moisture in the air – has seen recent advances in efficiency that have created new potential for the technology. Players in this sector regard themselves as the vanguard of an inevitable technological revolution that will see the decentralisation of water production from municipal treatment plants to neighbourhoods and individual homes. Some even allege it is already a clean, cost-effective alternative to large-scale desalination. This may seem farfetched, but AWGs could find a niche in emergency response and even industrial water, as well as posing a formidable challenge to the bottled water industry.

AWG is not a new concept (despite it often being spun as such) and it is also plagued by wild performance claims or dishonest discrediting of desalination by its proponents, while in many cases the process is still highly expensive and energy intensive. However, several vendors are now claiming to produce water for less than $20 per cubic metre and the cost is continuing to fall, making it a more competitive technology.

The technology landscape

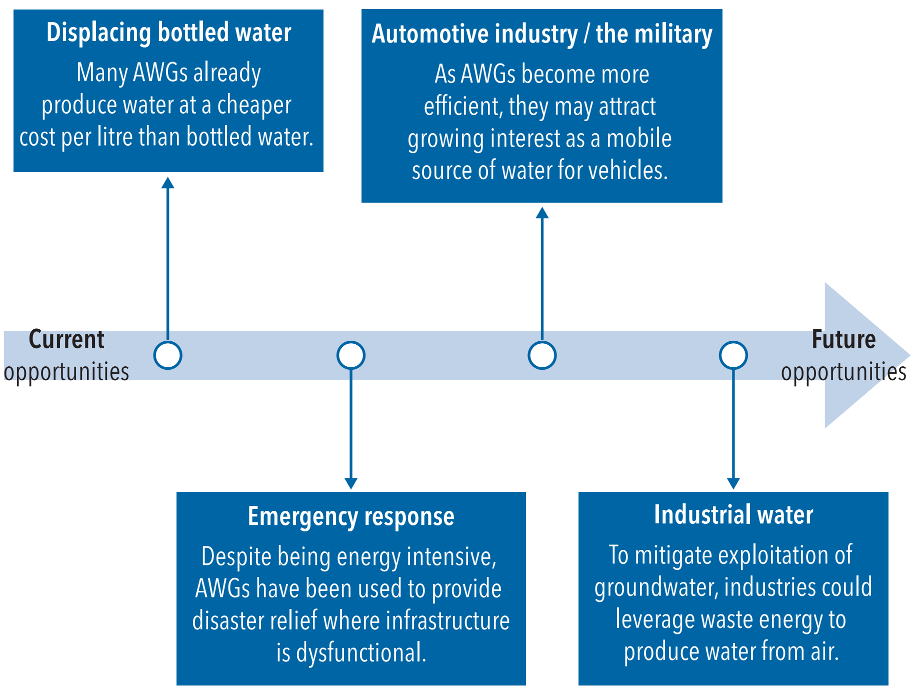
Harvesting water from air can be done, broadly, by one of two ways: condensation and absorption. The condensation process is in essence that of a dehumidifier – water is drawn into the machine where it is filtered and cooled to the point of condensing. This can consume a lot of energy and often they need high temperature and humidity to function, but in the right conditions with sufficient power they can produce thousands of litres a day. Condensation is by far the most common process on the market, with many small players struggling to distinguish their products from one another.

The absorption process involves passing air over a desiccant that catches water, which is then heated to extract the moisture. Usually, these systems absorb water at night when relative humidity is highest and extract the water during the day. The absorption process is more energy efficient than condensation and can work in a broader range of atmospheric conditions, but most models currently on the market are limited to producing about 50 litres per day.

Recent innovation in this sector is pushing the efficiency of both processes. One of the most prominent standard bearers for atmospheric water generation is Israeli start-up Watergen, which condenses water with a patented heat exchanger based on food grade polymer. The advantage of this system is there is no metal contamination, and it can reportedly generate water ▶

THE HEADLINE OPPORTUNITIES

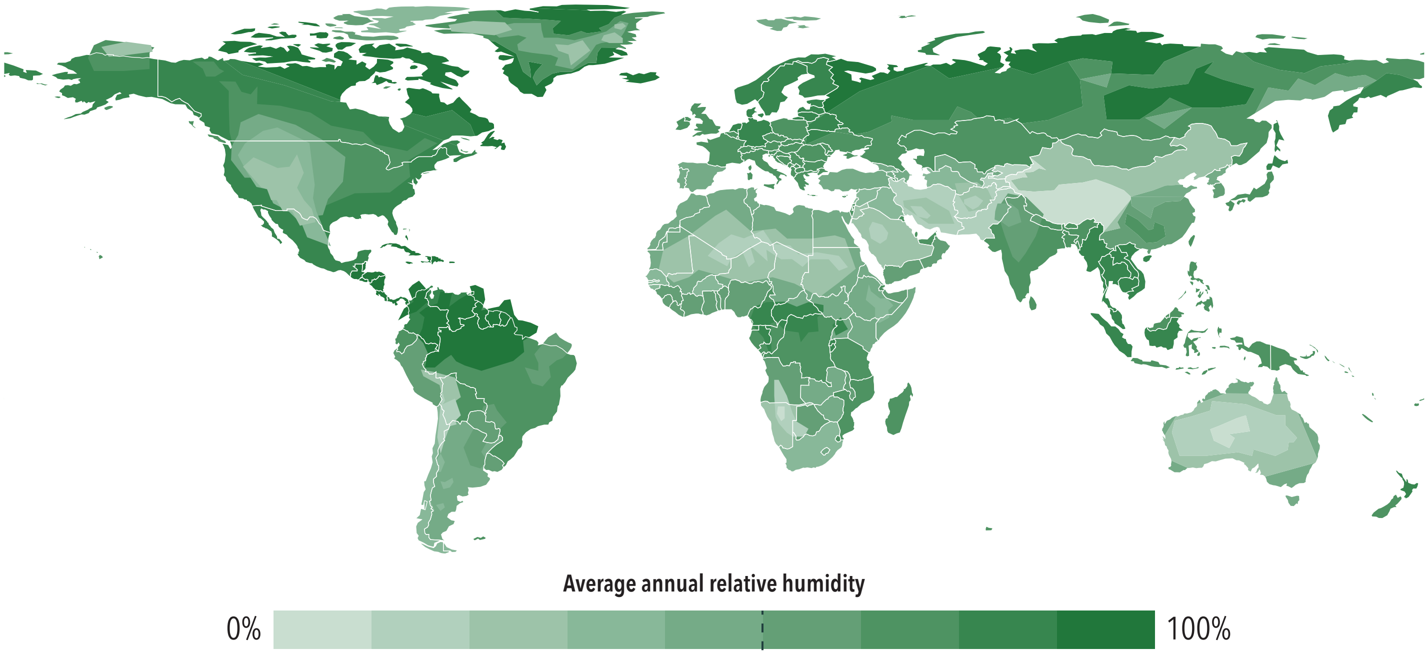
AWGs can already produce water more cheaply than the bottled water industry and without the vast plastic waste. Exploiting mobile water and industrial opportunities can depend upon improved energy efficiency.



Source: GWI

FEELING THE HEAT

AWGs, especially those which use the condensation process, often need a relative humidity of at least 60% to function properly. As the map below shows, ideal conditions for AWGs do not always correlate with the areas which are most water stressed, such as central Africa, central Asia and the southwest United States.



Source: University of Wisconsin-Madison

in 15° Celsius and with a relative humidity of 20%, though the yield is reduced. Founded in 2009 to help meet the water needs of the military, Watergen now produces a range of machines that can produce up to 6000l/d.

Another AWG that has made recent headlines is Skysource's WEDEW. The novelty of Skysource's machine is that it is powered by biomass and simultaneously extracts water from the air and the biomass itself. Considering that as much as 50% of biomass is water, this is a rich source of moisture. The system met and exceeded the XPRIZE challenge of developing a machine that can generate at least 2,000l/d for less than $20 per cubic metre.

Swedish startup Drupps is pushing the limits of absorption by substituting solid desiccants for liquid ones. Though the extraction process can be energy intensive, the liquid concentration can be adjusted to match the humidity and maximise the water yield. Drupps' main market is industry, and it tries to mitigate the energy consumption issue by capturing waste heat from the industrial process to power the extraction. Using this process, Drupps claim it can produce more than 200,000l/d.

AWGs usually contain in-built filtration and mineralising systems, which must be replaced every few months. A study by the University of Tel Aviv found that water produced from the air in Tel Aviv without any additional filtration or treatment "overall met drinking water standards," though this may depend on local meteorological conditions. The US EPA concluded that water produced by AWG is generally high quality but there is potential for microbial growth inside the device and recommended the use of chlorination and ozonation as a precaution. Most machines do not contain such thorough treatment systems, casting some uncertainty over their long-term safety.

What is the market for AWG?

Much of the excitement around AWGs is drawn from the prospect of producing clean, limitless water anywhere in the world. The Source Hydropanel, which raised $50 million in capital investment in 2020, makes the bold claim in its marketing that it can "help meet the drinking water needs of the more than seven billion people on earth".

The principal drawback of AWG is the energy efficiency of the process. Using solar power, Source usually produces less than 5 litres per day at a cost of $3000 per panel, amounting to approximately $150 per cubic metre over its lifetime (*See GWI May 2020, p.48*). Though alternatives can produce significantly more water for less money, the energy consumption challenge is one that must be overcome for AWGs to realistically grasp the markets they are reaching for.

Watergen identifies three main commercial areas for which it produces a series of bespoke products. The first is its 'industrial' range, comprising machines that can produce between 250 and 6,000l/d, designed for schools, hospitals, community centres and emergency response. Second, its 'commercial' generators produce around 50 litres a day for homes, offices, and other buildings, aimed principally at replacing water coolers. The third area is the automotive sector, building small generators to function as a mobile water source for drinking and cleaning sensors, the latter of which is thought to be a burgeoning opportunity as the autonomous vehicle industry takes off.

Small scale generators are expected to drive much of the growth in the AWG sector. "One of the biggest problems of the 21st century is the amount of plastic waste that we have. All our products for the mobility sector and the home and office sector will reduce dramatically the amount of plastic wastage that we have in the world," Michael Rutman, co-CEO of Watergen, told GWI. ▶

A study by the US EPA in 2018 compared several AWGs against bottled water and found that Watergen's home office GENNY system could produce water at about a quarter of the cost per litre of a single-use water bottle.

However, the GENNY remains highly energy intensive, producing water at a rate of 350 kWh/m^3, which is at the more efficient end of the market with units from other vendors exceeding 600 kWh/m^3. The same study from the EPA concluded that although the water may be cheaper and save plastic, "AWGs typically have higher impacts across all environmental impact categories as compared to the bottled water systems." These categories included cumulative energy demand, fossil fuel depletion and global warming potential, though the study did acknowledge that these problems could be mitigated by powering AWGs with renewable energy.

Amortising the cost of water over the lifetime of Watergen's largest 6000 litre a day GEN-L unit, including the cost of electricity and annual maintenance, the EPA found each litre is worth approximately $0.09, or $90 per cubic metre. This places the cost far above municipal water, which charges approximately $1.2 per cubic metre out of the tap as a global average. However, there may be an application for AWGs in emergency response where there is no functioning infrastructure and needs are so critical that they justify the expense.

"In Cambodia, during recent floods, those machines were installed by the Cambodian government and provided water to thousands of people," said Rutman. "In Kerala, India, after the floods those machines also performed beautifully, and in South America. After a disaster we have a lot of requests asking for help to install those machines."

Scaling up AWGs for community use beyond emergencies is made more difficult by the large upfront capital cost of these machines. Units that produce thousands of litres a day are usually priced well in excess of $100,000, though many suppliers offer flexible rates for communities in need. "We have a separate price line for humanitarian plants. First, we want to save lives, then we want to make business. That is our priority," said Rutman.

Bolstering resilience is key to the value proposition that the AWG sector is making. "The whole idea is that a distributed water system offers inherently more resilience than centralised water that you have to transport long distances," explained David Hertz, leader of the Skysource project. "Our market is looking at self-reliance, climate adaptive strategies and disaster relief."

Skysource is still seeking investment and is not yet selling WEDEW units on the market, but the intention is to adopt the model of the power purchase agreement whereby an impact investment fund covers the first cost of the equipment, which is then leased to the community and paid back over time. "Most of the communities that we would serve in the developing world would not have the cash to buy the system, but they could afford it by paying over its lifetime," said Hertz.

Though Watergen has been involved in several high-profile projects in deprived, water scarce parts of the world such as Gaza and Uzbekistan, it is currently hoping to demonstrate its value in places like Flint, Michigan, which suffer from chronic water quality issues. Rutman argues Watergen may offer a solution.

"The issue with Flint is the atmospheric conditions in winter are not suitable for water generation. However, Watergen is launching a new device that can work indoors and provide water throughout the year," said Rutman. "Very soon you will see more and more installations of our small device in Flint."

Competing on cost efficiency

In many areas with dubious water quality, a household reverse osmosis filter or UV disinfection unit may prove to be a more cost-effective solution, but experts have warned that such filters do not prevent contamination that leaches from pipes inside the home and whole house filters can cost hundreds of thousands of dollars. AWGs may therefore find a market in areas of mass contamination where household treatment systems are insufficient.

While most AWGs operate in a similar space to Watergen and Skysource, Drupps is one of the few that boasts the ability to produce large enough volumes of water to serve the industrial sector. Using a modular system with a liquid desiccant, Drupps designs AWGs tailored to the client's circumstances and can produce more than 200,000l/d.

"The absorbing part of the system needs electricity but the major energy consumer in the system is the extracting module, and if we can run that on waste heat or any low-cost thermal heat, you only need to pay opex for the electricity of the fans and general operating system, which creates really efficient water," explained Jonas Wamstad, Drupps' chief business development officer.

Assuming waste heat is available, the system can generate one cubic metre for every 70 kilowatt-hours of energy. This climbs to 150 kWh/m^3 if additional electricity is required to power the extraction. Although surface water treatment consumes approximately 0.3 kWh/m^3, this is still one of the most efficient processes for AWG.

The reported opex cost of their process is roughly $7 per cubic metre. Drupps is not specific about how the capex affects this figure, but Wamstad told GWI "for a mid-sized or big system, the capex is lower than the opex."

Drupps sees a lucrative market in industries such as food and beverage, and pharmaceuticals where a premium is paid for high quality water. "These industries can't make quality products unless they have quality water, and if they run out of water, they might have to shut down production, so water availability is a key strategic issue for them," said Wamstad.

"We say, 'Don't change source, add another source,' so you don't need to overexploit local sources. That would relieve local ground water levels and make it easier to rebound, which will make operations more sustainable," continued Wamstad.

Drupps launched its system at the end of 2019 and has been working on devel- ▶

Terminology

Absorption: the process whereby air is passed through a highly absorbent material that traps moisture, which is then heated to extract the water.

Atmospheric water generator: a machine that harvests moisture in the air and converts it into drinking water using either condensation or absorption.

Condensation: the most common type of atmospheric water generation. It involves drawing water into the machine where it is filtered and cooled to produce drinking water.

Desiccant: a substance capable of absorbing moisture, used as a drying agent. The opposite of a "humectant".

Metal-organic frameworks: highly porous compounds made by linking inorganic and organic units by strong bonds.

opment ever since, but it currently has a fully functional 5,000l/d demonstration plant in Uppsala, Sweden, and has recently signed two test contracts with firms in the United States and Thailand.

The future of AWG

Though harvesting water from air remains expensive, the cost is on a clear downward trajectory and advances are constantly being made. Encouraging results have been seen in experiments with highly absorbent metal-organic frameworks (MOF). A team of scientists led by Zhiyong Xia at John Hopkins University found that just a kilogram of one MOF could produce almost 9 litres of water per day. The process functions by using the MOF to trap the water, raising the relative humidity in its local environment so the water can be extracted with minimal energy, even in arid climates.

Other tests with MOFs have been conducted by MIT and the University of Berkeley-California with similar results. More work must be done to improve the efficiency of the extraction process and optimise the material to minimise degradation, but it could provide a leap forward in the cost-effectiveness of atmospheric water generation. Berkeley's Professor Omar Yaghi, who discovered MOFs in the 1990s, predicts commercial applications may only be a few years away.

It remains to be seen how far the efficiency of this technology can be stretched, but ambition in the sector is not in short supply. In 2016, a spokesperson from Drinkable Air argued that Dubai should consider scrapping its plan to build a 182,000m³/d desalination plant and instead install around 12,000 atmospheric water generators to cover the equivalent water production. While they may not produce a brine stream, AWGs are nowhere near the stage of beating desalination in cost effectiveness. Nonetheless, the pioneers of AWGs are optimistic that one day they will close the efficiency gap.

"Eventually, we believe that the world is going to decentralise and atmospheric water generators will replace the existing municipal water supply, but this is a tough goal and a very long way away. We are starting with a very clear market, and we believe that in the near future these machines will replace packaged water and the five-gallon dispensers." said Watergen's Rutman. "We believe that in the future new systems will use much less energy and eventually, with a lot of research from universities and our engineers, we will reach the point when our power consumption will be lower even than treatment plants."

It is currently difficult to see how this feat could be achieved, especially as fail-safe disinfection and post-treatment would likely be necessary to guarantee the safety of AWGs at a mass level. However, it would only take some modest advances for AWGs to establish a strong presence in more limited markets such as commercial water and emergency response. ■

SELECTED PLAYERS

Most companies in this fragmented market use the condensation process, as large amounts of water can be extracted as long as sufficient energy is provided. Growth in the absorption market is picking up pace, while liquid desiccants are new to arrive on the scene but may have potential to offer greater water yield.

Generation type	Company	Generation capacity (L/day)	Location
Liquid absorption	Drupps	200,000	Sweden
	H2oll	48	Israel
Solid absorption	Uravu	50	India
	Kara Water	10	
	SunToWater	36	USA
	Source	5	
	Sky River	20	UAE
	Majik Water	10	Kenya
Condensation	Gr8 water	13,000	USA
	Ecoloblue	10,000	
	EWDC *	10,000	
	Sky Source	2,000	
	Dew	5,000	
	Island Sky	1,100	
	Rainmaker	20,000	Canada
	DewPoint	10,000	
	Genaq	10,000	Spain
	Ray Agua	8,400	
	Hogen Systems	5,000	UK
	Planets Water	5,000	
	Requench	4,000	
	Watergen	6,000	Israel
	Akvosphere	1,000	India
	Bharat Electronics	1,000	
	Eshara Water	1,000	UAE
	Hendrx	1,000	China

** Energy and Water Development Corps.*

Source: GWI