Atmospheric water harvesting using solar energy technology

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Key Messages

- Drinking water scarcity is a global problem due to not only a lack of water sources but also increasing numbers of contaminated water sources. Creating drinking water from air and sun or atmospheric water harvesting technology can be easily installed and work well in low- to high-humidity areas where solar energy is available but clean drinking water is absent.
- Investment cost of the system is the main barrier to individual ownership. Therefore, the technology should be initiated by the private sector, such as restaurants, hotels, and service businesses, to attract attention and ensure affordability. Schools, which also have great inspiring impacts, need financial support from governments and international organizations.
- Air-to-water systems may face cultural barriers; hence public education is essential to build trust in the hygiene and quality of the water source.

Introduction

According to a report from World Health Organization (WHO) and United Nations International Children's Fund (UNICEF), about 785 million people cannot access essential drinking water services[1]. Water covers nearly 70% of the earth's surface, but only 2.5% of that is suitable for human consumption[2]. More terribly, the forecast predicts that two-thirds of the world will confront water scarcity by 2025[1]. Thus, water is a crucial resource that people should prioritize[3]. At the same time, new sources of water should be explored to meet the clean drinking water demand in places where normal water sources are absent or contaminated.

A few advanced techniques are applied to meliorate the source of freshwater via the use of fossil fuels, such as reverse osmosis, membrane distillation, multistage, and multiple effect distillation. Nonetheless, to operate these techniques effectively, users must pay a high initial expense for investment and consume a considerable amount of energy[4]. The application of filtration systems for drinking water production is affordable in various areas with a feasible price, saving energy, and easy installation. Yet, this technique needs to be examined more thoroughly because of risks arising from chemical contamination in water[5]. Furthermore, filtration systems cannot be applied in areas where severe water shortage occurs.

Atmospheric Water Generator (AWG) is a motivative and potential solution which takes water from the air, generates clean water, and installs easily in a location where it is too difficult to have clean water in daily life. Yet, a considerable disadvantage traditional AWGs fail to overcome is the need for a power grid which has high operational expenses and consumption of energy[6]. The new initiative for this problem is that solar energy is used as a power supply. Atmospheric water harvesting using solar energy is the key to not only the drinking water issue but also the power source problem that other AWGs face. Drinking water that is distilled and condensed from the air via use of the sun may be determined as a promising solution in the future. The atmospheric water harvesting system using solar energy technology is a self-contained system that resembles a solar panel and does not need an external electricity source[7]. This pioneering invention could contribute to the UN sustainable development goals (SDGs) 6 and 7.

How does it work?

The AWG system works through a 3-step process (Fig 1). 1) The fans powered by solar photovoltaics (PV) draw air from the surroundings through an air filter, then absorbent materials collect the water vapor. 2) The vapor is then converted into clean water using the sun's heat. 3) Calcium and magnesium are added by the mineral cartridge to improve mineral composition and replicate the ideal taste. Furthermore, the system is also equipped with a large water tank for later use[8]. Besides, the sorbent material is the material that can take and keep the water vapor from the air till its full capacity, then can be heated to produce water. There are many kinds of sorbent materials, such as silica gel, zeolite, other hygroscopic materials, metal-organic framework (MOF), and composite sorbents. Recently, a sorbent material made with agricultural waste can capture around 0.5 to 1.8 kg water/ kg material for 8 hours test at a relative humidity of 20-80% showing the chance to work in every weather condition of this technology[9].

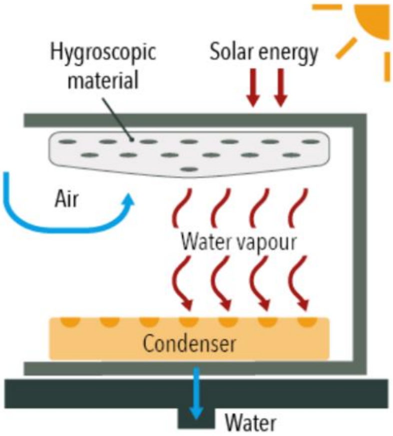

Figure 1: Illustration of proposed AWG system[10]

Strengths and weaknesses of the technology

Strength

The most prominent advantage of the technology is its mobility. Being supplied by solar energy, this technology does not need an electricity source and is a self-sufficient, self-contained system[7]. Besides, this technology can work in a wide range of relative humidity due to its absorbent material. Some devices which some companies have invented can produce water quite literally anywhere with ambient humidity as low as seven percent, which is about as dry as it can get[11]. Moreover, this technology can be considered an environmentally friendly system because it does not generate any waste or carbon by-products[7].

Weakness

First of all, the biggest disadvantage is the cost of this technology. The estimated cost is about $ 5500-$6500 for a standard system[11]. Moreover, the number of liters produced by this system depends a lot on the sun and is available in the daytime only. Hence, the production efficiency of water is not stable and can be changed by the hour, by season, and even by geographical location. There could also be a lack of maintenance in remote regions because it requires trained technicians from the company which sells this device to perform maintenance or repair. Additionally, replacing defective components is another issue. For these reasons, it is suggested that investment in electricity infrastructure could be a better choice in places with raw water resources since electricity could support other kinds of living activities as well as clean water production[12].

In addition, when PV panels are outside, they be blocked by dust, natural wastes, and debris on their surfaces, reducing their efficiency. Hence, continuous cleaning requirements would also cost much time and money[4]. Maintenance may not be a big problem and training local people to perform maintenance is feasible because more complicated technology like cars, motorbikes, and airplanes can be used in remote regions, so there is no reason why these local people cannot be technicians for this technology[13]. Additionally, the technology with a two-squared meter PV panel that produces 500W per hour seems to be simple and does not require skillful technicians[14]. Besides, some absorbent material issues also need to be addressed, such as the high cost of these materials, the speed of the sorption cycle, and contamination of the sorbent bed by airborne pollutants[9]. However, there is a lack of research on the contamination of absorbent material[12].

Opportunities and challenges for application

Opportunities

This technology can be used where the water source is contaminated or scarce, such as in Malehuala, San Luis Potosi (SLP), Mexico region where mining activities are performed a lot[15]. Especially, due to its mobility characteristic, this technology is suitable for both emergency needs and decentralized water supply, such as in Middle East countries like UAE[16] where distance portable water transport needs[17]. Moreover, the tax policy for solar panels has recently favored the end-users in developing countries[18], such as Vietnam with 0% imported tax for solar panels[19].

Challenges

First is the high cost of this technology: identifying who will pay for it or how to convince the government or investors to give a hand is an issue. Secondly, if getting sponsors for this technology, persuading local people to treat it like their own property will be very hard because local people in these remote regions will not take care of this technology or even ruin them if they think AWG technology is from outside [12]. Moreover, according to one interviewee, in some places people may not feel normal or safe driving water from this technology because they believe that water should be free[13]. Thirdly, there are two major kinds of PV panels: multi-crystalline or crystalline silicon (which accounts for 90% of PV panel production) and thin-film (accounts for 7-8% of PV panel production). Thin-film PV panels can be recycled; however, there are very few factories for multi-crystalline PV panels, making them harder to recycle. Since multi-crystalline PV panels are cheaper than thin-film PV panels, they are likely to be applied for most technology, even our air-to-water technology. So, the PV panel recycling treatment must be considered[14].

Successful case studies

H2E of X

There has been much research conducted about this technology. One of the projects is H2E from the Alphabet-owned company, X. Their meter-squared device can produce water for 0.1$ per liter and about 150 $mL/h/m^2$. Additionally, the price of water per liter is acceptable, and the feasibility of scaling up the technology is possible. Furthermore, they proved that the devices could be used to supply drinking water to roughly a billion people. However, although there is potential to make the device lower cost, the project has been stopped since the next step of this project requires hardware integration and mass production expertise which they do not have[20]. A lot of support from many kinds of expertise is needed to improve the technology.

Hydropanel of Source

Typically, the Source Hydropanel system created by Cody Friese is an excellent example of this technology. In such a way, the power from solar energy will be used efficiently to fulfill the need for about 5 to 8 liters of water a day via a free of waste and carbon production[7]. Another characteristic of the system is that it can produce water even in a 7% humidity environment[11]. Some specifications of one Hydropanel are 4' x 8' x 3'8" / 1.2 m x 2.4 m x 1.1 m for dimensions, 340 lbs/154 kg for weight, and 15 years for life span[8]. Moreover, the estimated cost is about $5500 - $6500 for a standard SOURCE array (2 hydro panels)[21].

120 Hydropanels were installed on the College of Engineering-National University of Science and Technology, Muscat- Oman to meet the 1200 liters water demand of campus. The cost of 120 Hydropanels is around 120,000 USD (46,207.20 OMR), while there are about 2400 bottles of water (500 ml) with a total price of 240 OMR sold daily. With this amount, investment costs were recuperated within a year. Besides, by not using

water bottles, a significant amount of energy was saved[7].

Although there is a very high initial cost for the system, it is much cheaper than using water bottles which are used a lot in hotels, restaurants, schools, and universities.

Recommendations

Based on the above SWOT analysis and the case studies, key recommendations for promoting this technology in the places absent of both electricity and clean water are as follows:

1. If the technology is installed by the government, it is necessary to build **public awareness for local people who will receive the technology** about how good and safe the AWG technology can bring for them. The connection between local people and technology needs to be formed so that local people can treat the technology as their asset and take good care of the air the water system.
2. Besides, **the private sector can be a great way to raise attention from communities** for this technology if it is possible to find the right customer for a good start. Applying this technology in hotels, restaurants, and service businesses, which can afford the initial cost of investment, may be a potential opportunity as many case studies show that using this technology for drinking water is cheaper than using water in bottles. In addition, these hotels and restaurants can advertise using this technology as a flagship of their operation to draw great attention from not only customers who tend to the environment but also the government.
3. **Schools and universities, which also have significant inspiring impacts, may need financial support** from governments and international organizations to not only save water bottle waste and energy consumption but also spread the spirit of environmental protection for students. Hence, the government should promulgate a policy that encourages these applications.
4. **Train local people properly for maintenance and management**. With the detailed instruction of skillful technicians, simple repair and maintenance tasks such as component (filter, cartridge) replacement and cleaning PV panel procedures will be carried out easily by local people.
5. Developed and developing countries should collaborate to build recycling plants for PV panels with good policies which bring many incentives for using this technology. So, the end-of-use PV panel can be reused and recycled effectively.

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ANNEX 1, Consulted Experts

Name	Instituition	Position	Interview date	Country
1. Olalekan Adekola	York St John University	Senior Lecturer	17/11/2022	United Kingdom
2. Fayaz Hussain Katper	University of Malaya	Associate Professor	19/11/2022	Malaysia
3. Hoang Le	Viet Sky Power Company	Founder	21/11/2022	Viet Nam
4. Daniel Beysens	OPUR	President	22/11/2022	France
5. Bui Van Cong Chinh	First Solar Vietnam	Director	30/11/2022	Viet Nam