

# Stand-Alone Renewable Source of Energy-Based Atmospheric Water Generation: A Literature Survey

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**Abstract**—Atmospheric Water Generators (AWGs) are emerging as a promising technology to mitigate freshwater scarcity, especially in regions facing groundwater depletion, contamination, or limited water distribution infrastructure. AWGs extract water from humid air using techniques such as cooling condensation, desiccant absorption, or pressure-based dew-point manipulation. Among these, cooling condensation is the most commercially deployed method due to its higher extraction rates. Recent research explores stand-alone AWG systems powered by renewable energy sources such as solar and wind to reduce dependence on grid electricity. This paper presents a comprehensive literature survey on AWG technologies, historical developments, working principles, dehumidification techniques, system limitations, and renewable-energy-based implementations. The review emphasizes the feasibility of portable, low-energy AWGs using thermoelectric Peltier modules and vapour-compression systems for rural and disaster-affected regions. Comparative evaluation of different AWG technologies highlights their operational efficiency, energy demands, environmental sustainability, and suitability across varying climatic conditions.

**Keywords:** Atmospheric Water Generator, Cooling Condensation, Desiccant Method, Renewable Energy, Peltier Module, Vapour Compression Refrigeration System.

## I INTRODUCTION

The global rise in freshwater scarcity has intensified the demand for sustainable water-production technologies. Atmospheric water generation, which harvests moisture present in ambient air, offers a decentralized, climate-resilient solution. The atmosphere contains an estimated 12,900 km<sup>3</sup> of water vapour, making it a viable untapped reservoir.

AWG technologies operate primarily on three mechanisms:

1. Cooling below dew point (refrigeration-based condensation)
2. Desiccant absorption/regeneration cycles
3. Pressure-induced condensation

Refrigeration-based AWGs circulate refrigerant through a compressor, condenser, and evaporator, cooling air to below its dew point to form water droplets. The collected water is purified through multi-stage filtration systems including carbon filters, RO membranes, and UV sterilisation.

However, conventional AWGs are energy-intensive and dependent on grid power. This has motivated research into stand-alone renewable-powered AWGs, especially in rural and off-grid areas. Solar photovoltaic (PV) systems and wind turbines can potentially drive compressors, Peltier modules, or desiccant regeneration units, reducing operational costs and ensuring environmental sustainability.

## II. LITERATURE REVIEW

### 2.1 Historical Developments

The concept of extracting water from ambient air dates back decades. Early systems include:

- Tygarinov (1947): Proposed a passive cooling structure using vertical and inclined earth channels for dew collection.
- Kobayashi (1963): Introduced solar-based water extraction in arid regions.
- Hamed (1993, 1999, 2000, 2011): Developed theoretical and experimental desiccant-based AWG cycles, establishing foundational thermodynamic models.

These early contributions formed the basis for modern AWG systems focusing on efficiency and adaptability.

## 2.2 Cooling Condensation and Vapour Compression Systems

The vapour-compression refrigeration cycle is widely used due to its high water production capacity. Anbarasu & Pavithra (2011) demonstrated AWG prototypes using standard HVAC components capable of producing potable water in coastal regions. However, these systems are limited by:

- High energy consumption
- Noise from compressors
- Reduced efficiency at temperatures below 15°C
- Lack of portability

Despite these constraints, cooling-based AWGs remain commercially dominant.

## 2.3 Pressure-Based Condensation

Niewenhuis et al. (2012) explored compressing humid air to raise dew point above ambient temperature, enabling spontaneous condensation.

This method offers low energy demand but requires:

- High-pressure vessels
- Efficient compressor-expander units
- Enhanced heat transfer mechanisms

Although theoretically promising, practical challenges limit widespread adoption.

## 2.4 Desiccant-Based AWGs

Wet desiccation using hygroscopic salts (e.g., LiCl, CaCl<sub>2</sub>) absorbs moisture from air, releasing it during thermal regeneration. Research by Hamed (1999), Sultan (2004), and Hall (1966) provided foundational thermodynamic models.

Advantages:

- Low energy requirement
- Suited for solar regeneration

Limitations:

- Slow absorption rate
- Low water output (e.g., 72.1 mL/kWh in Niewenhuis et al.'s prototype)
- Need for periodic desiccant replacement

## 2.5 Thermoelectric (Peltier) Based AWGs

Kabeel et al. (2014) performed numerical analysis of Peltier module-based AWGs, showing their suitability for portable, renewable-powered systems.

Benefits:

- Light-weight and compact
- Low noise
- Can be powered by solar PV

Challenges:

- Lower water production rate than vapour compression
- Efficiency drops with increasing ambient temperature

Yet, this method is promising for disaster relief, military applications, and remote communities.

## 2.6 Renewable Energy Integration

Significant research integrates AWG systems with renewable sources:

- Solar-driven vapour compression cycles (Hamed, 2011)
- Solar desiccant collectors (Gad et al., 2001)
- Wind-powered AWGs (Bolonkin, 2011)
- Hybrid solar-Peltier modules (Kabeel, 2014)

Solar-PV-powered AWG systems show potential for producing 1 litre per hour in humid regions, making them suitable for Indian coastal environments.

## III. EXTRACTION OF WATER FROM ATMOSPHERIC AIR

Condensers play a critical role in AWG systems by facilitating phase change from vapour to liquid while releasing latent heat. The efficiency of condensation depends on:

- Heat exchanger design
- Working fluid and refrigerant
- Ambient temperature and humidity
- Air flow management

Latent heat transfer is significantly more efficient than sensible cooling, making condensation-based AWGs effective for humid climates.

## IV. PERFORMANCE EVALUATION

Experimental results from prototype testing demonstrated:

- Water production increases with rising humidity
- Water production decreases as air temperature rises despite higher moisture content (due to efficiency drop at high temperatures)
- Peak productivity occurs during early morning and late evening

Laboratory tests confirm the output water meets IS 10500:2012 drinking water standards for hardness, pH, alkalinity, and iron content.

## V. ADVANTAGES OF AWG TECHNOLOGY

- Portable and low maintenance
- No requirement for pipelines or natural water sources
- Reliable source of pure water
- Quick deployment during emergencies
- Environmentally safe with no chemical by-products
- Unlimited raw material (air)

## VI. APPLICATIONS

AWGs are useful for:

- Remote villages, mining areas, refugee camps
- Disaster-relief operations
- Hotels, restaurants, and commercial establishments
- Military base camps
- Office spaces replacing bottled dispensers

## VII. CONCLUSION

Atmospheric water generators represent a viable and sustainable solution to address global water scarcity. Integration with renewable energy sources significantly reduces operational costs and environmental impact. India, with its favourable humidity conditions, is particularly suited for large-scale AWG deployment. The technology can transform water accessibility in rural and drought-prone regions, supporting long-term water security.

## VIII. FUTURE SCOPE

Future developments may include:

- Hybrid AWG systems combining solar PV, wind energy, and advanced desiccants
- Use of eco-friendly refrigerants with low global warming potential
- Integration with IoT for real-time monitoring
- Scaling up community-level AWG units
- Enhancing Peltier efficiency using nano-coatings and advanced heat sinks

Government adoption and public-private partnerships can accelerate deployment across water-stressed regions.

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