

Under the High Patronage of His Majesty King Mohammed VI



XIX WORLD WATER CONGRESS
International Water Resources Association (IWRA)
Marrakech, Morocco | 1-5 December 2025

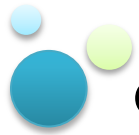
Kingdom of Morocco



Ministry of
Equipment and Water

Progress and Perspectives of Sorption-based Atmospheric Water Harvesting

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IBN ZOHR UNIVERSITY, AGADIR, MOROCCO
2 DECEMBER 2025



Overview of the presentation



Background of Atmospheric Water Harvesting

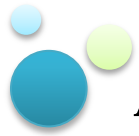


Sorbents for Sorption-Based AWH



Applications and Future Perspectives

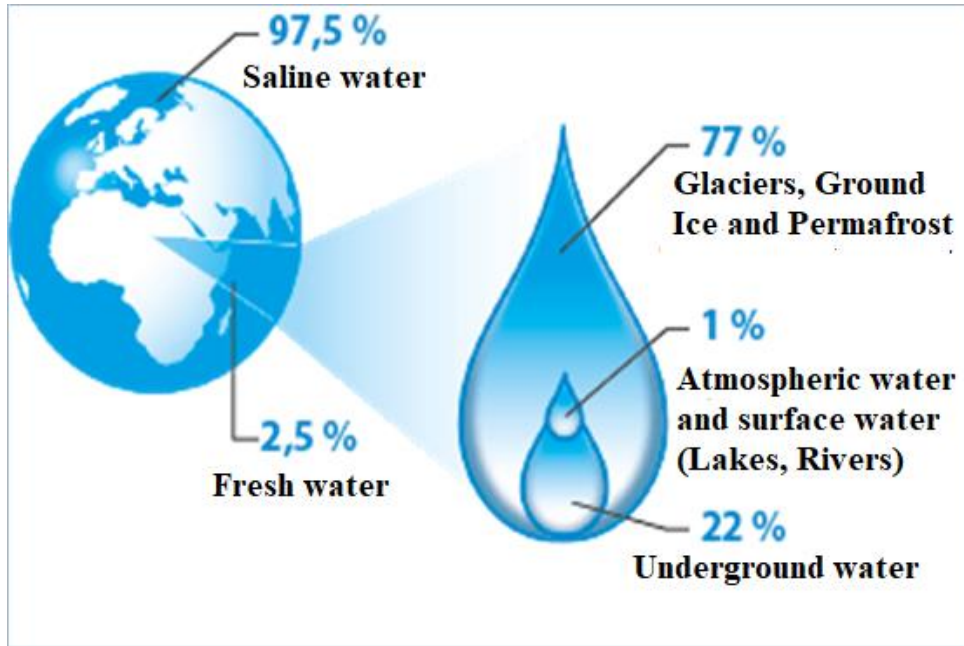




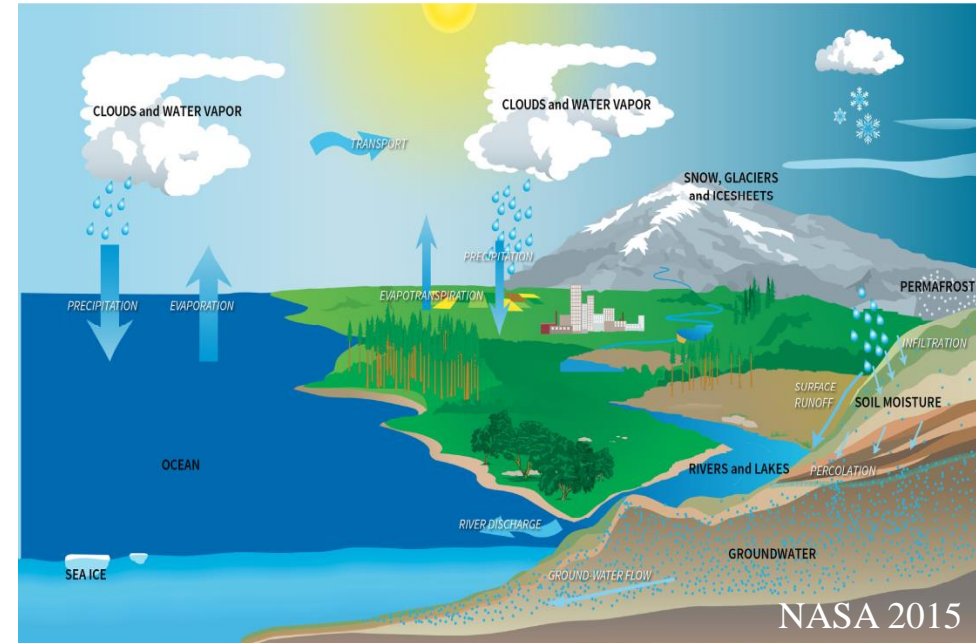
Available water on Earth

“water is the driving force of all nature”

Leonardo da Vinci

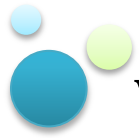


<https://www.annabac.com/revision-bac/la-diversite-des-ressources-en-eau>



Water cycle

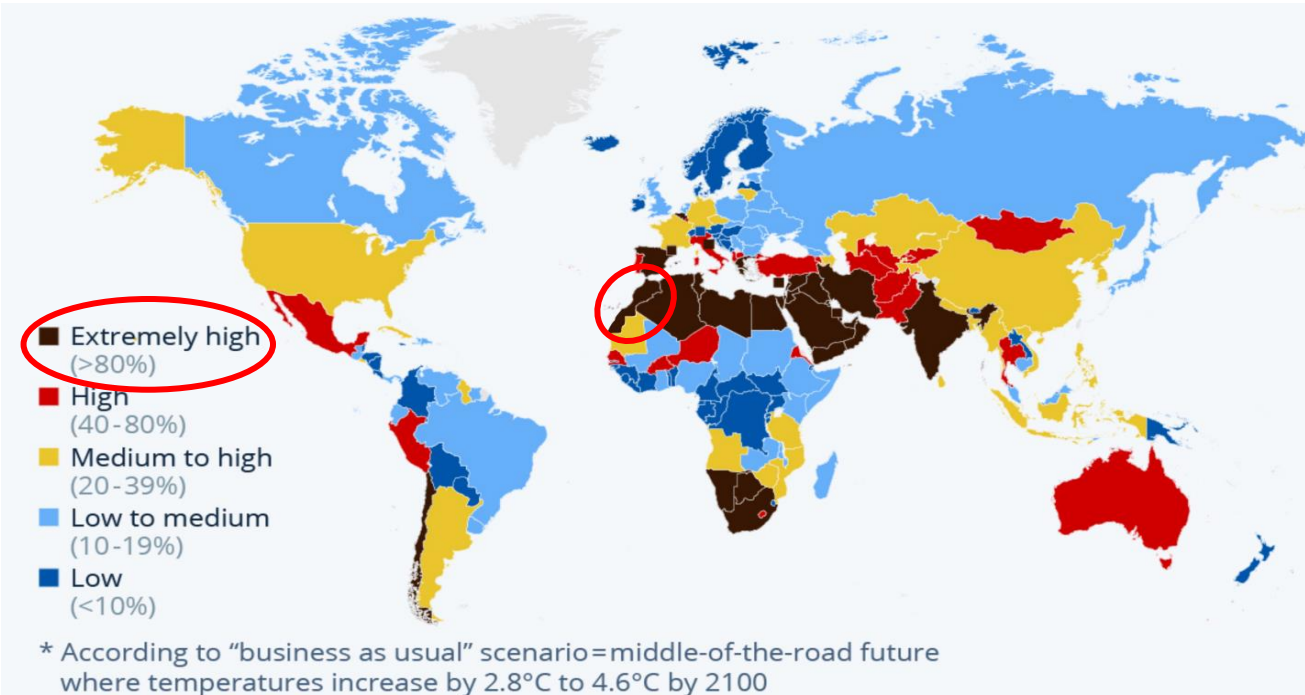
The Earth's water is not lost or added. It transforms.



Water scarcity across the globe

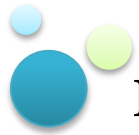
Global water stress by 2050

➤ 5.7 billion people are expected to face water shortages by 2050



United Nations World Water Development 2021





Moroccan context

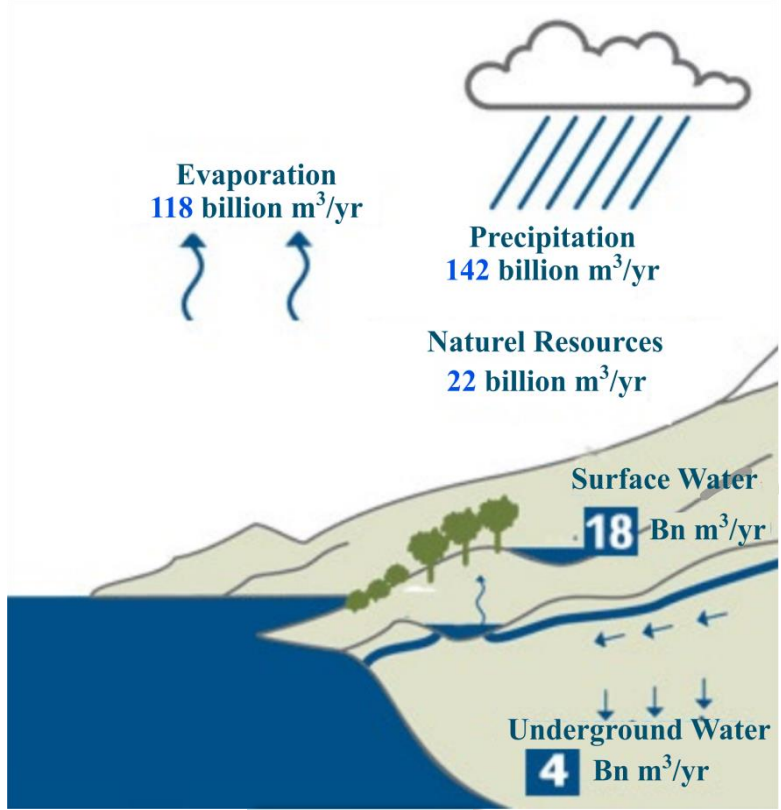
Benefits

- Unshared water resources
- Good knowledge of the national water potential

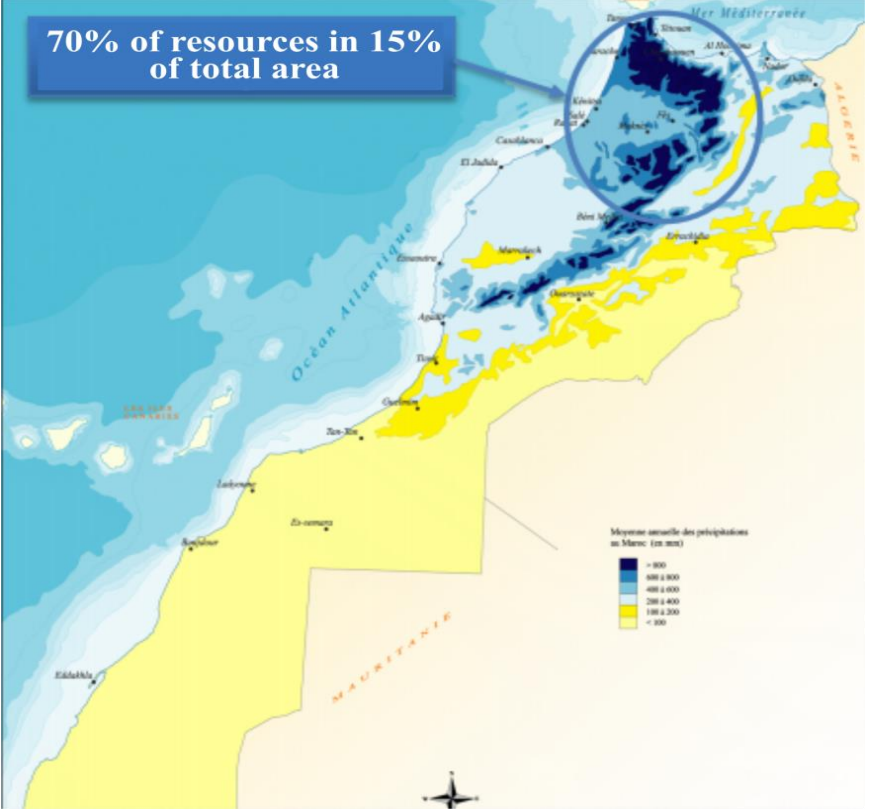
Constraints

- Fragile hydroclimatic context
- Uneven distribution in space and time

Facts



Water Cycle



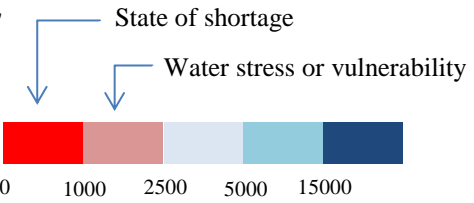
Uneven distribution of precipitation in space and time

Water demand by 2030:

16,2 billion m³/yr

Water availability per capita by 2030:

500 m³/cap/yr

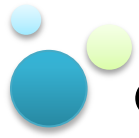


Water consumption:

Agriculture : **80%**

Industry and Domestic use : 20%

<https://www.equipement.gov.ma/eau/Ressources-en-eau>



Governance of water resources in Morocco

Mobilization of conventional water resources

Water surface

- Construction of **152 dams** with a total capacity of **19.9 billion m³**
- **20 large dams** under construction to reach a capacity of **27.3 billion m³** by 2027
- **16** water transfer structures with a total length of nearly 785 km and a flow rate of 346 m³/s

Underground water

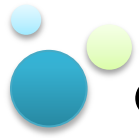
- Creation of thousands of wells and boreholes

Construction of dams



Water transportation





Governance of water resources in Morocco

Unconventional water resources

32 million cubic meters of water yearly

- 9 seawater desalination plants with a total capacity of **10 million m³**
- 7 seawater desalination under construction with a combined capacity of **396 200 m³/day**
- 41 wastewater treatment stations

Wastewater treatment



Seawater desalination



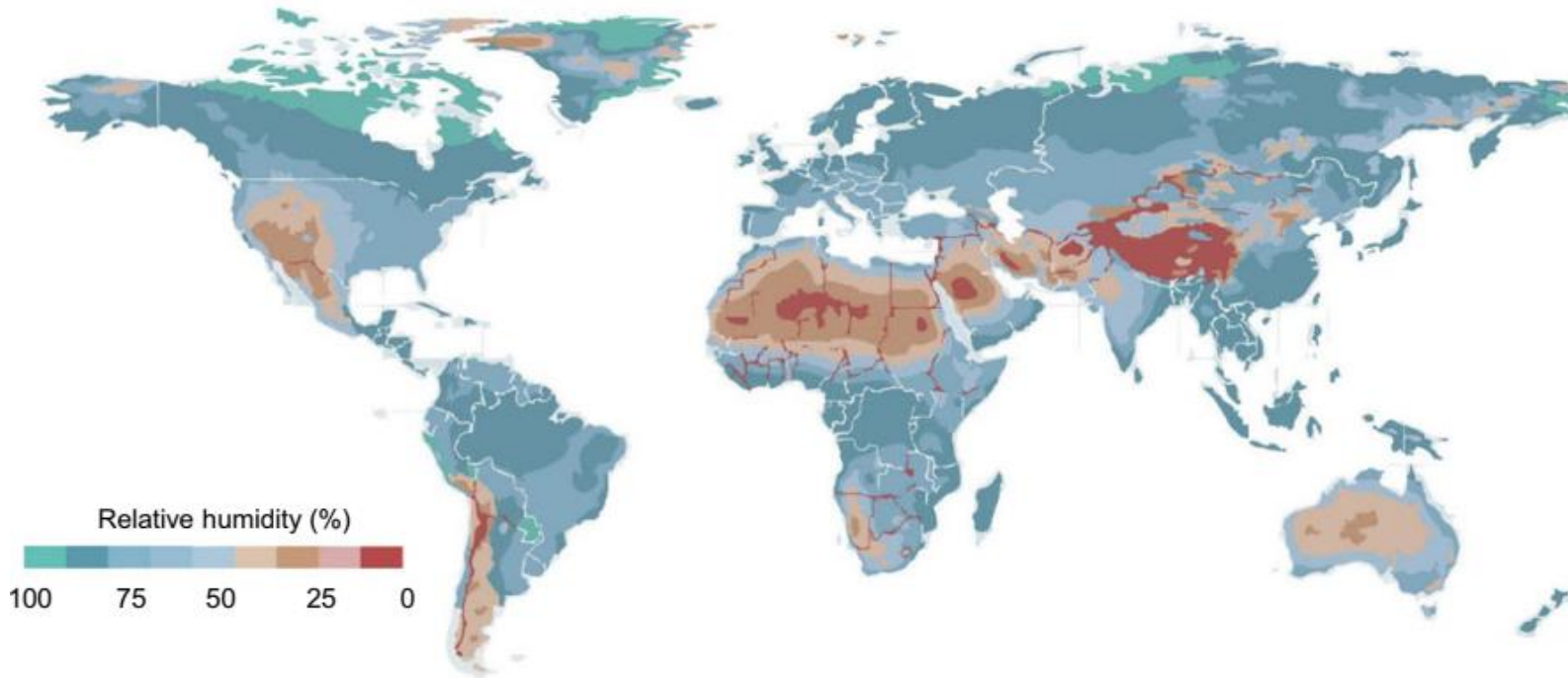
Desalination drawbacks

- High infrastructure and maintenance costs
- Energy consumption
- Negative environmental impacts (contaminate groundwater aquifers)
- Increase sea salt concentrations



Atmospheric water

Global annual relative humidity distribution



Total capacity:

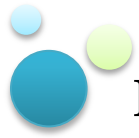
12,900 km^3

Equals to:

6 times of water terrestrial rivers

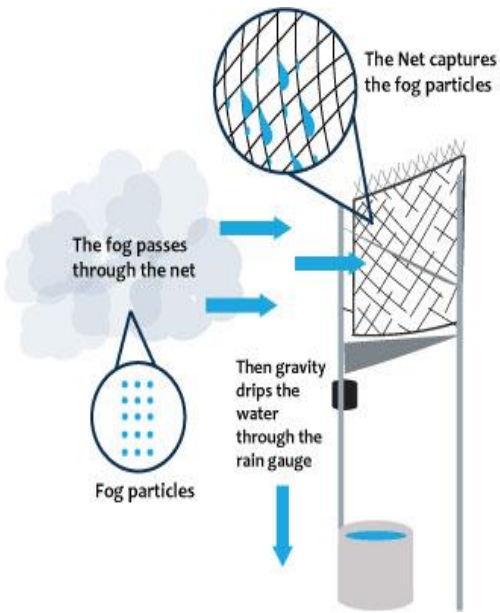
Atmospheric water:

Fog & rain (liquid phase)
Water vapor (vapor phase)



Fog harvesting: harvest liquid-phased atmospheric water

6300 liters of water can be harvested daily



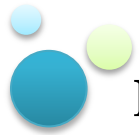
Locations suitable for fog harvesting



(Energy 2023, 280, 128186)

Drawbacks

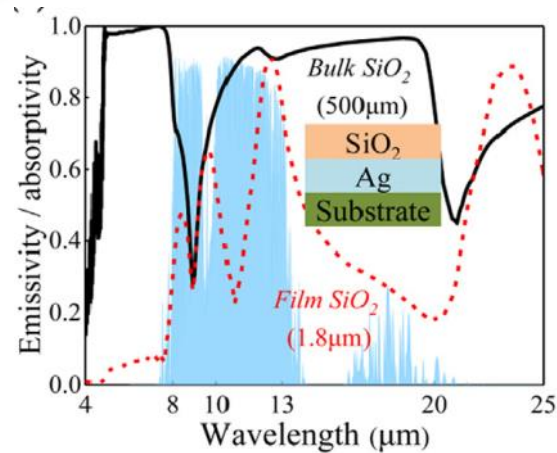
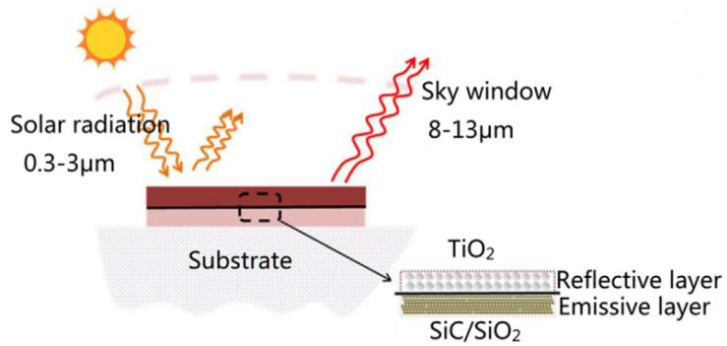
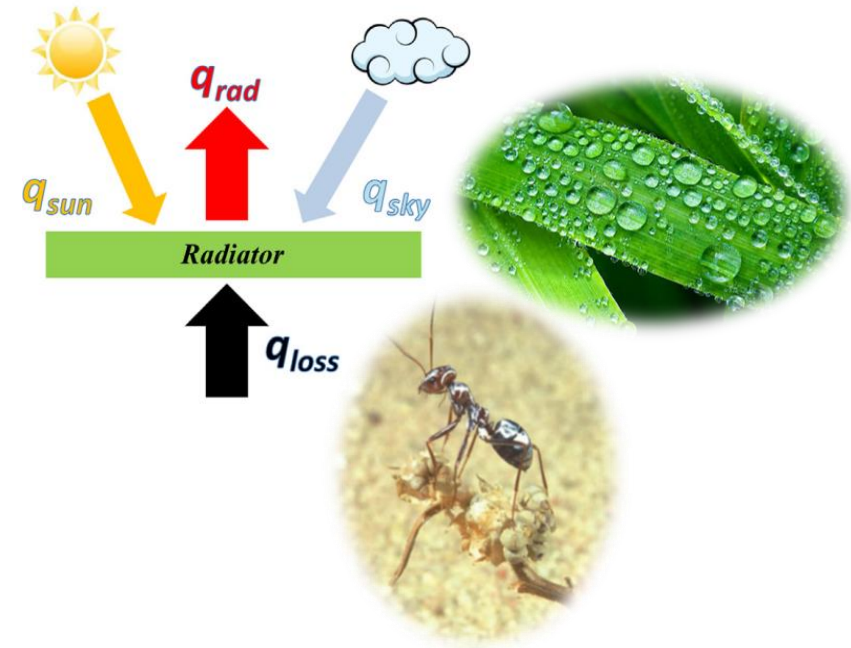
- Energy passive but requires **consistently high** levels of relative humidity (100%)
- Very quick evaporation rate of harvested droplets



Passive dewing (radiative) : harvest vapor-phased atmospheric water



Passive: does not require any additional input energy to collect dew water



Surfaces with high emission coefficient in the infrared region and low thermal mass

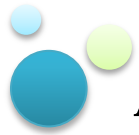
Drawbacks

- High relative humidity
- Low cloud cover
- Moderate or low wind speeds

Low water collection:

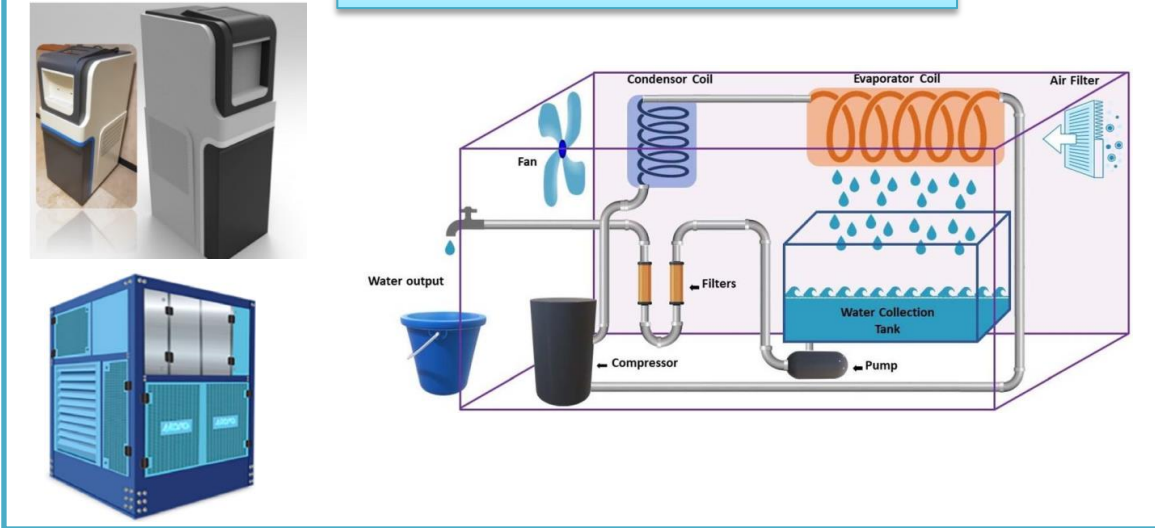


300 to 600 mL/m²

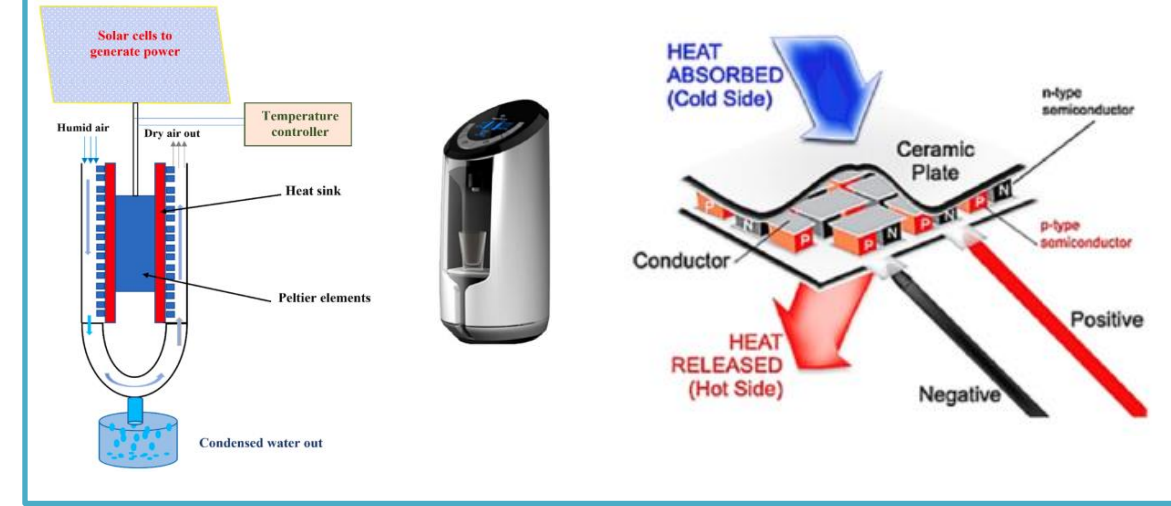


Active dewing : harvest vapor-phased atmospheric water

Vapor Compression Cycle (VCC)



Thermoelectric cooling method

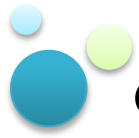


1. A compressor circulates a cooling fluid through a condenser to lower the temperature of the air
2. When the temperature of the air gets lower than the **dew point**, water condenses
3. The dew point of water in the air streams depends on its **relative humidity** and **temperature**

By passing an electric current through them, they produce a temperature difference resulting in a cooling effect

Drawbacks

- **Complicated designs**
- **Limited to RH > 60%**
- **Energy intensive (cooling air + condensing water)**



Overview of the presentation



Background of Atmospheric Water Harvesting



Sorbents for Sorption-Based AWH



Applications and Future Perspectives

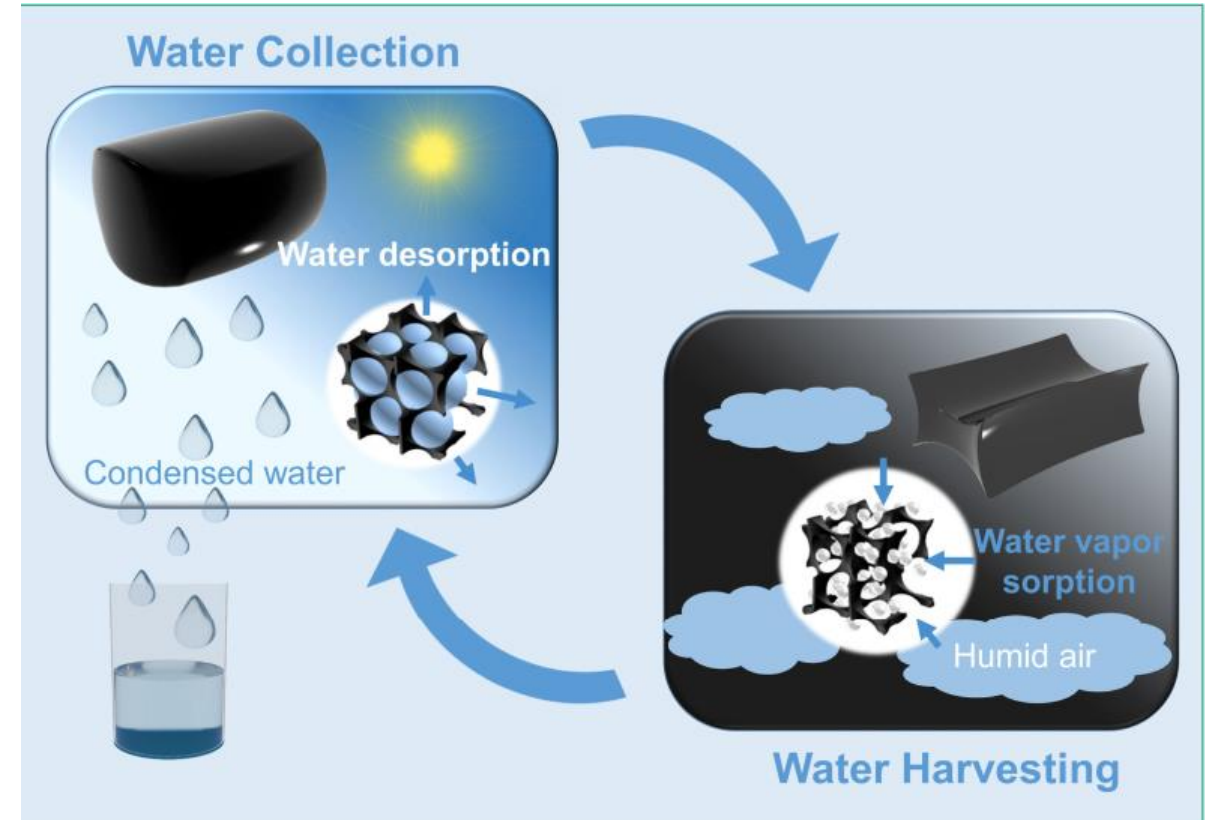


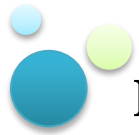


Sorption-based atmospheric water harvesting

Advantages:

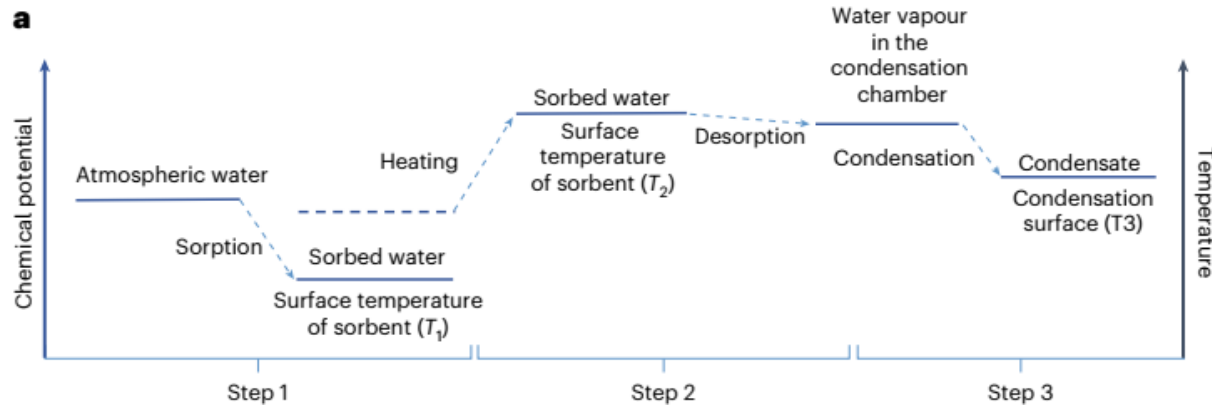
1. Solar energy is sole energy source; no electricity consumption.
2. Suitable for wide range of humidity.
3. Very simple setup.
4. Decentralized



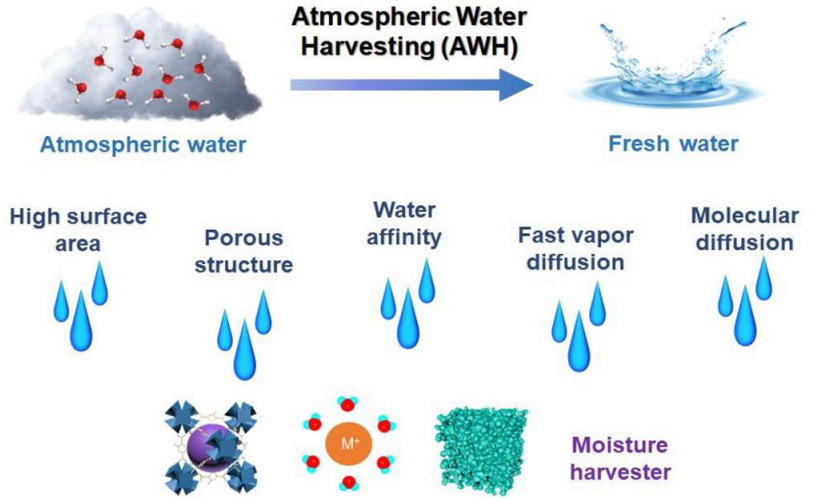


Driving forces of sorption-based AWH

Schematic of chemical potential variation during the sorption-based AWH process



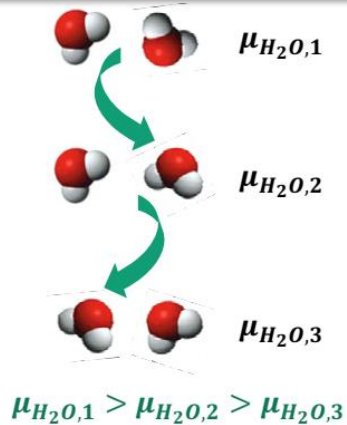
Sorbent characteristics



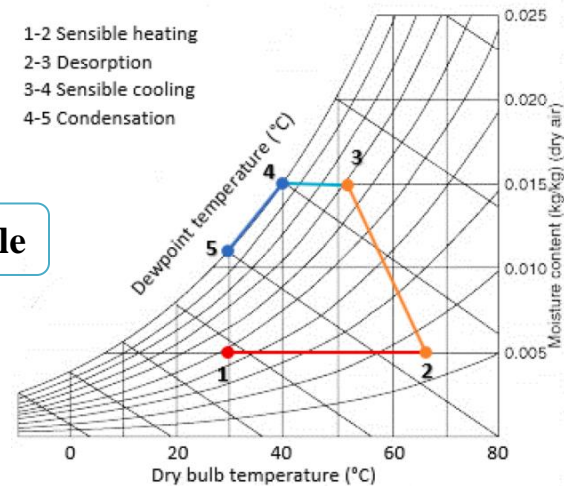
$$\mu_{H_2O} = \mu_{H_2O}^\theta + RT \ln P_{H_2O}/P^\theta$$

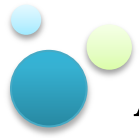
- $\mu_{H_2O}^\theta$: Chemical potential of water at standard state
- R : Gas constant (8.314 J⁻¹mol⁻¹K⁻¹)
- T : Temperature (K)
- P_{H_2O}/P^θ : Fraction of water vapor in the air

Spontaneous movement



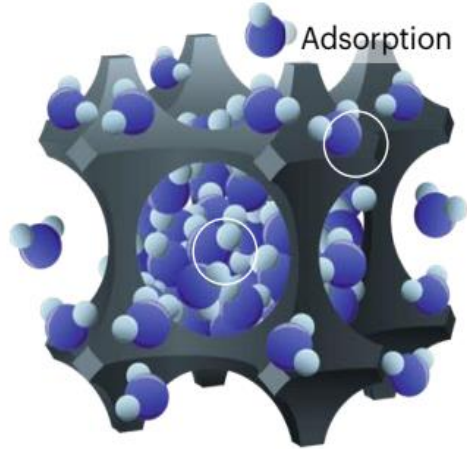
Thermodynamic cycle





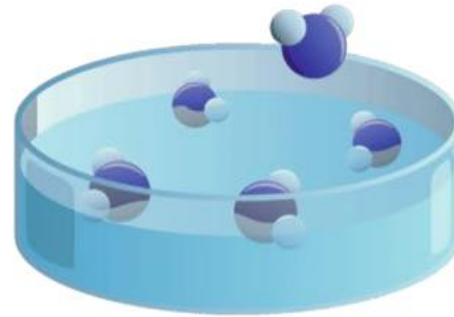
AWH sorbents

Porous solid



Pore filling and capillary condensation

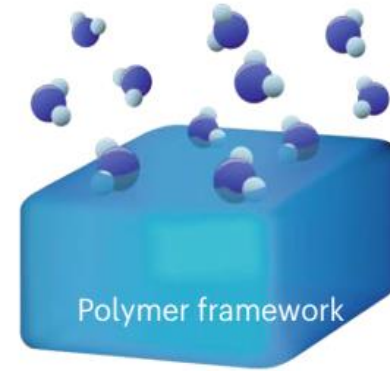
Liquid



Absorption

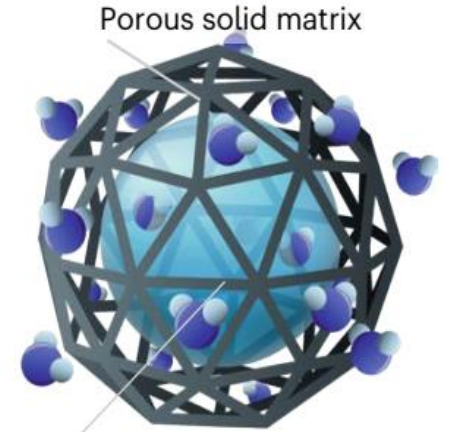
Water vapour

Hydrogel



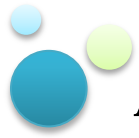
Absorption

Hybrid solid@liquid

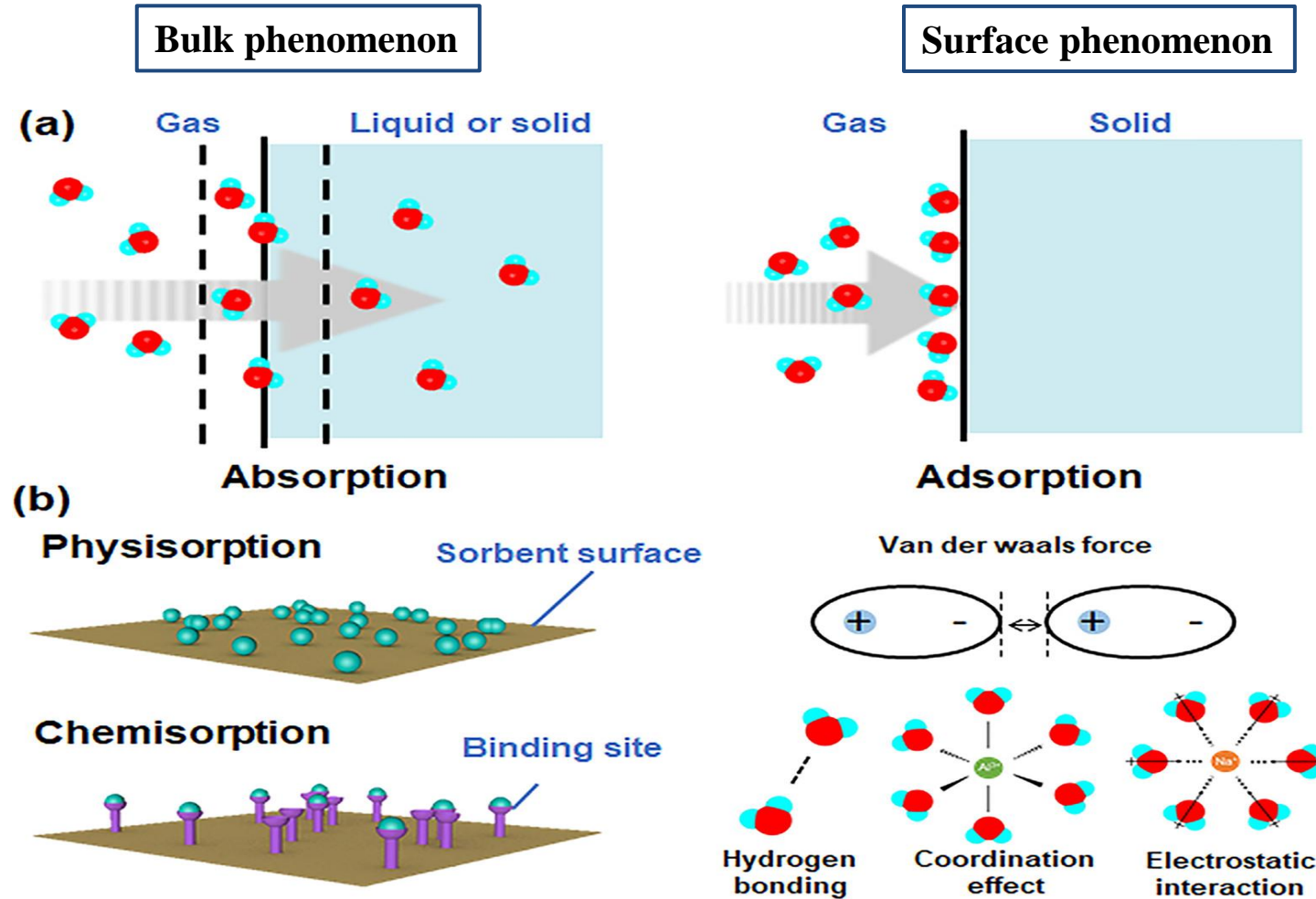


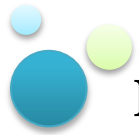
Hygroscopic core: absorption

	Porous solide sorbent	Liquid sorbent	Hydrogel-based sorbent	Hybrid solid@liquid sorbent
Examples	COFs, MOFs, silica gels, and some zeolites	CaCl ₂ , LiCl, LiBr, and ionic liquid	PAETA-Ac, PAM-CaCl ₂ , and SMAGs	LiCl@HCS and LiCl@MOF
Water vapor sorption mechanisms	Adsorption, pore filling and capillary condensation	Absorption	Absorption	Adsorption-absorption









Adsorption VS Absorption





Liquid sorbent : Calcium Chloride (CaCl₂)

Different hosts

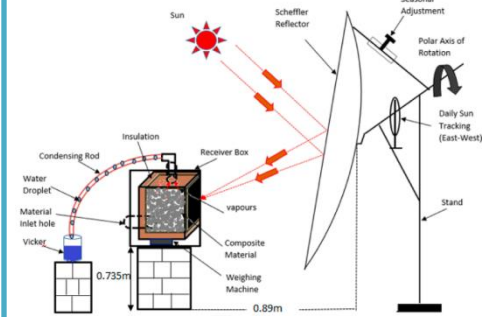
 Cotton black cloth	 Sand	 Coal ash/brick powder /river sand
 Jute	 Saw wood	 Wool



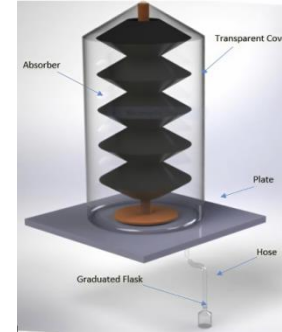
0.09 L/m²/day - 1 L/m²/day

Property	Specification
Appearance	White hygroscopic crystalline powder
Molecular formula	CaCl ₂ .xH ₂ O
Solubility	147 g/l (20°C) in water – completely soluble
pH	5-8
Molecular weight	147.02 g/mol
Density	1.85 g/cm ³
Melting Point	176 °C

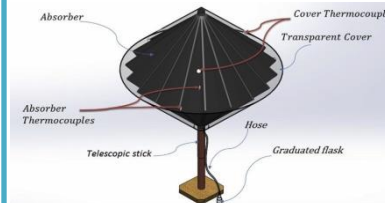
Various designs



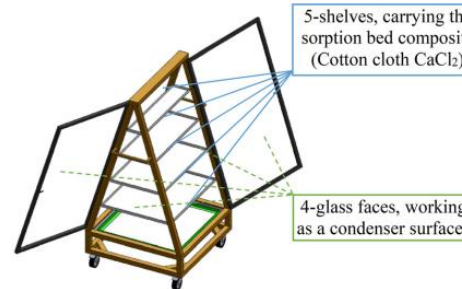
92 mL/kg/day



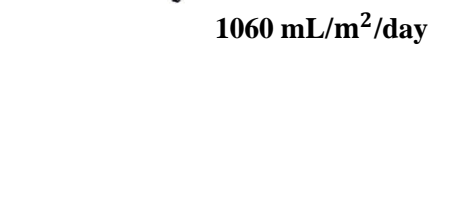
750 mL/day



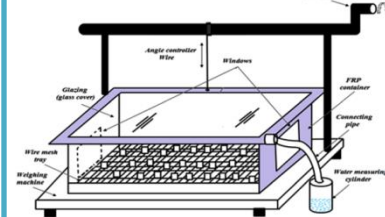
631 mL/m²/day



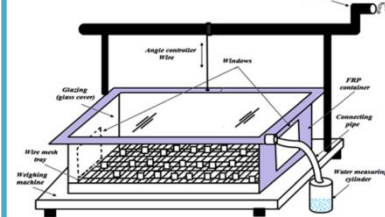
5-shelves, carrying the sorption bed composite (Cotton cloth CaCl₂)



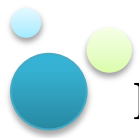
4-glass faces, working as a condenser surfaces



1060 mL/m²/day

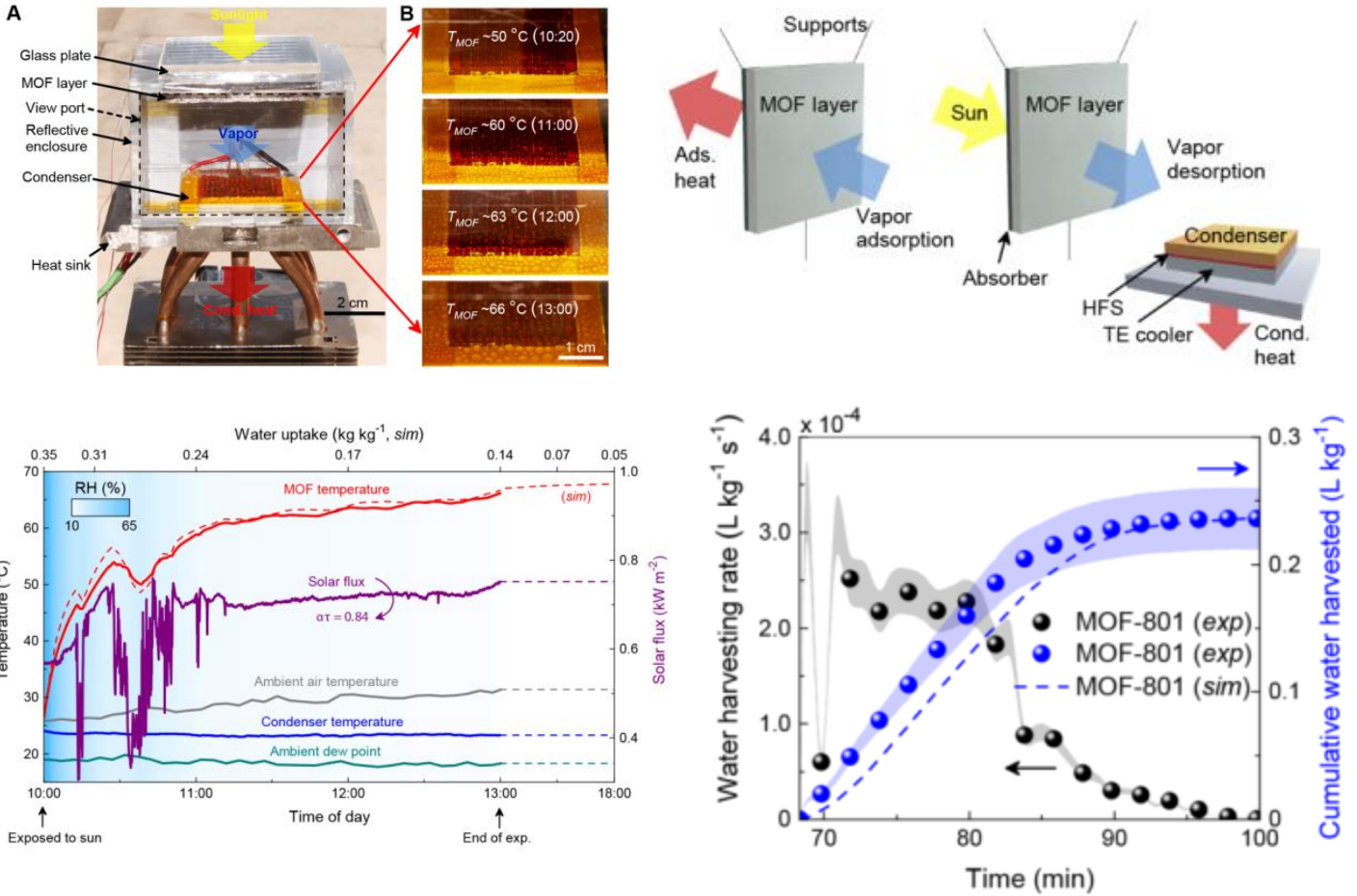


195 mL/kg/day

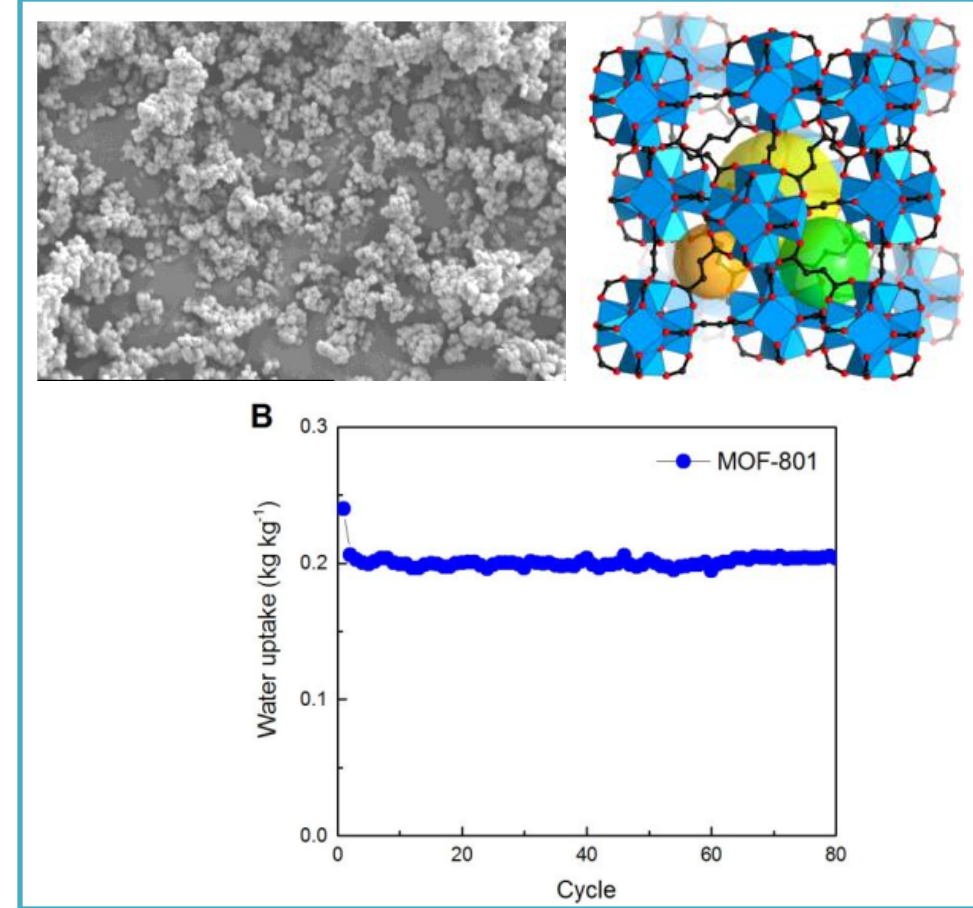


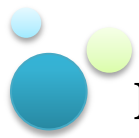
Porous solid : Metal-Organic Framework (MOF-801)

SAWH device performance



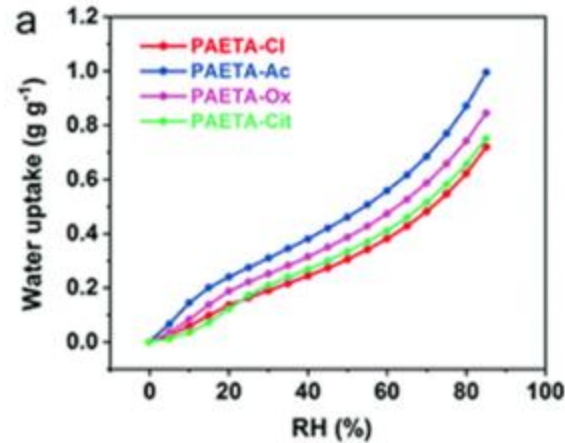
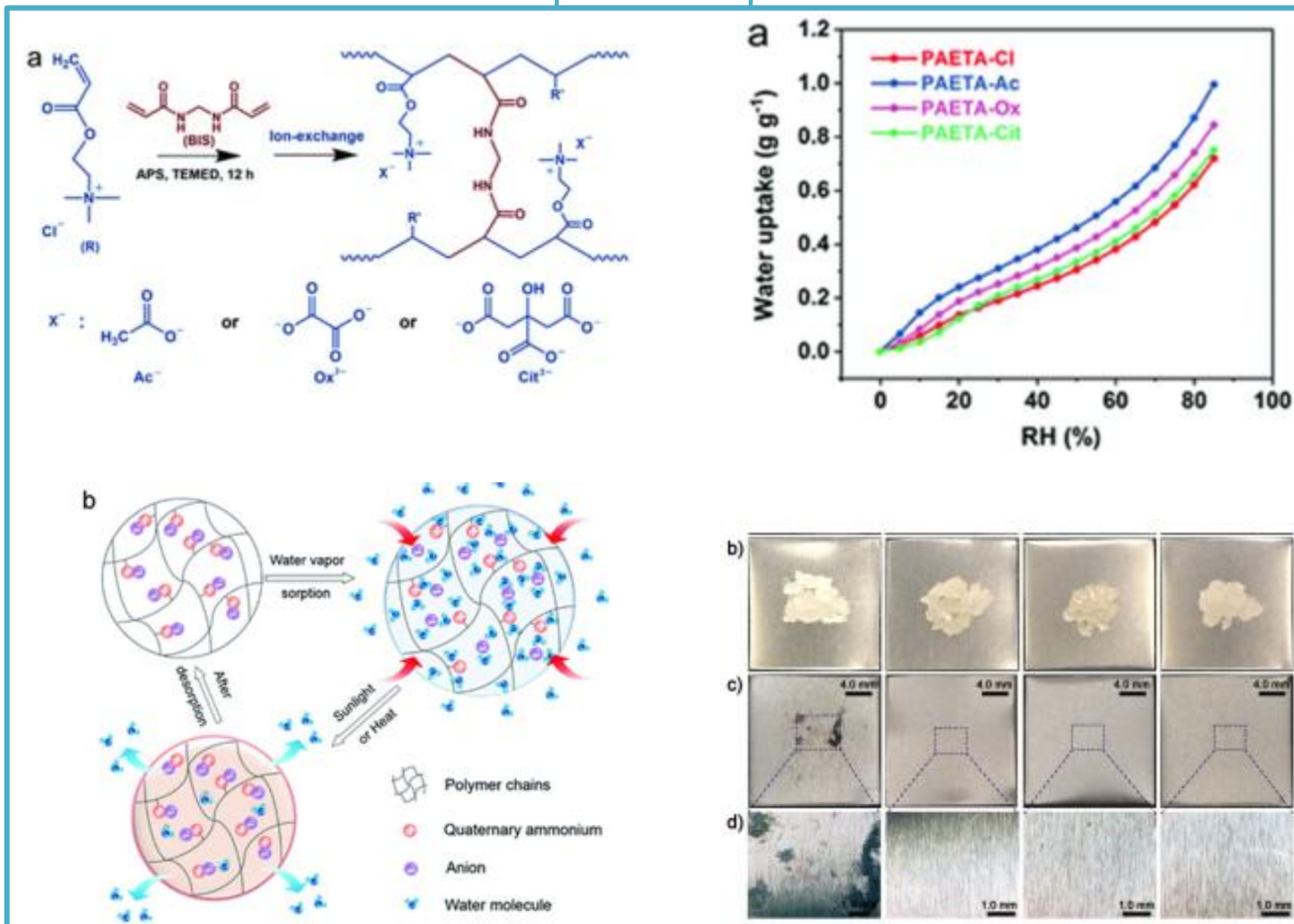
MOF-801 characterization



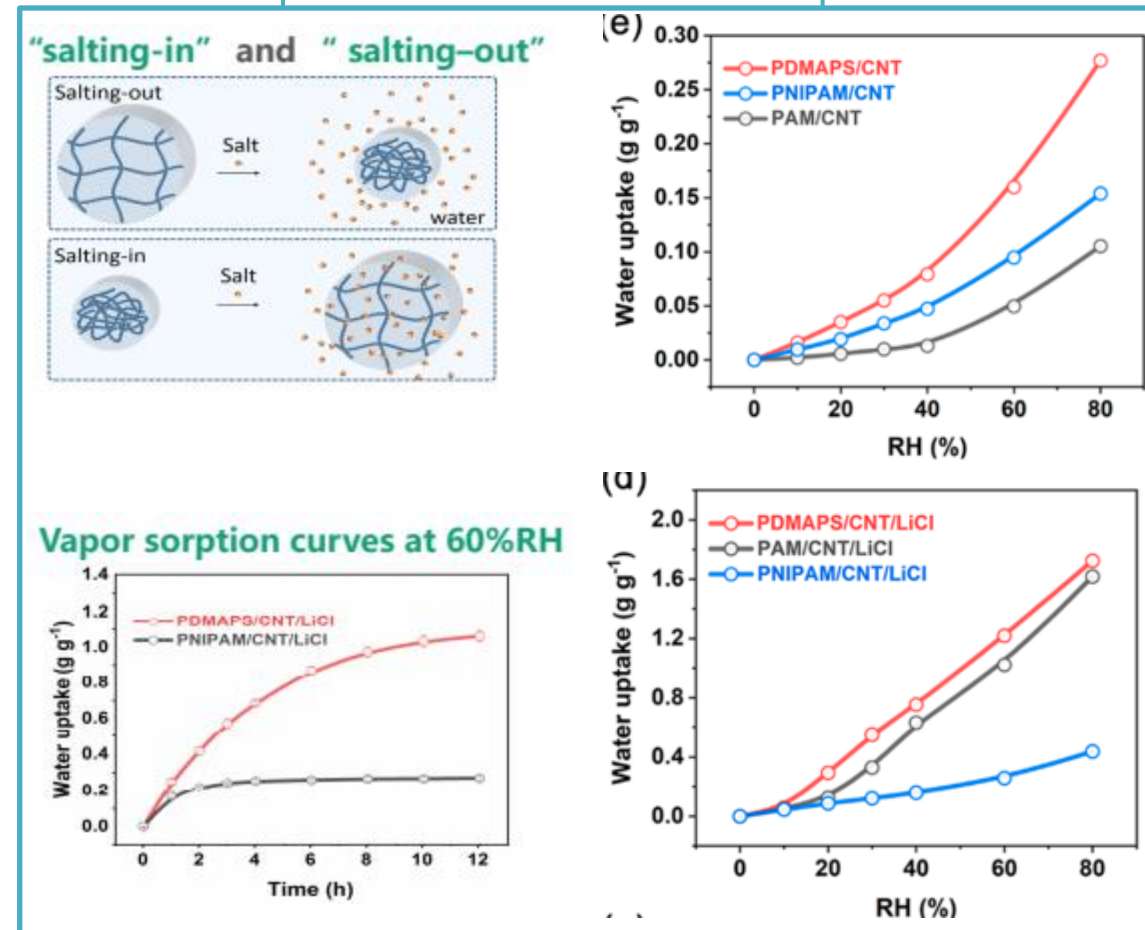


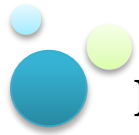
Hydrogel-based sorbent : PAETA and salting-in

PAETA



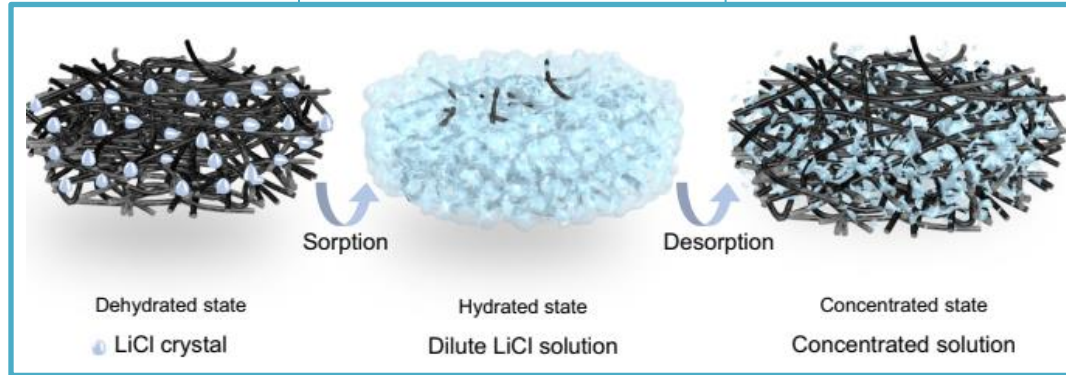
Saltin-in and salting-out



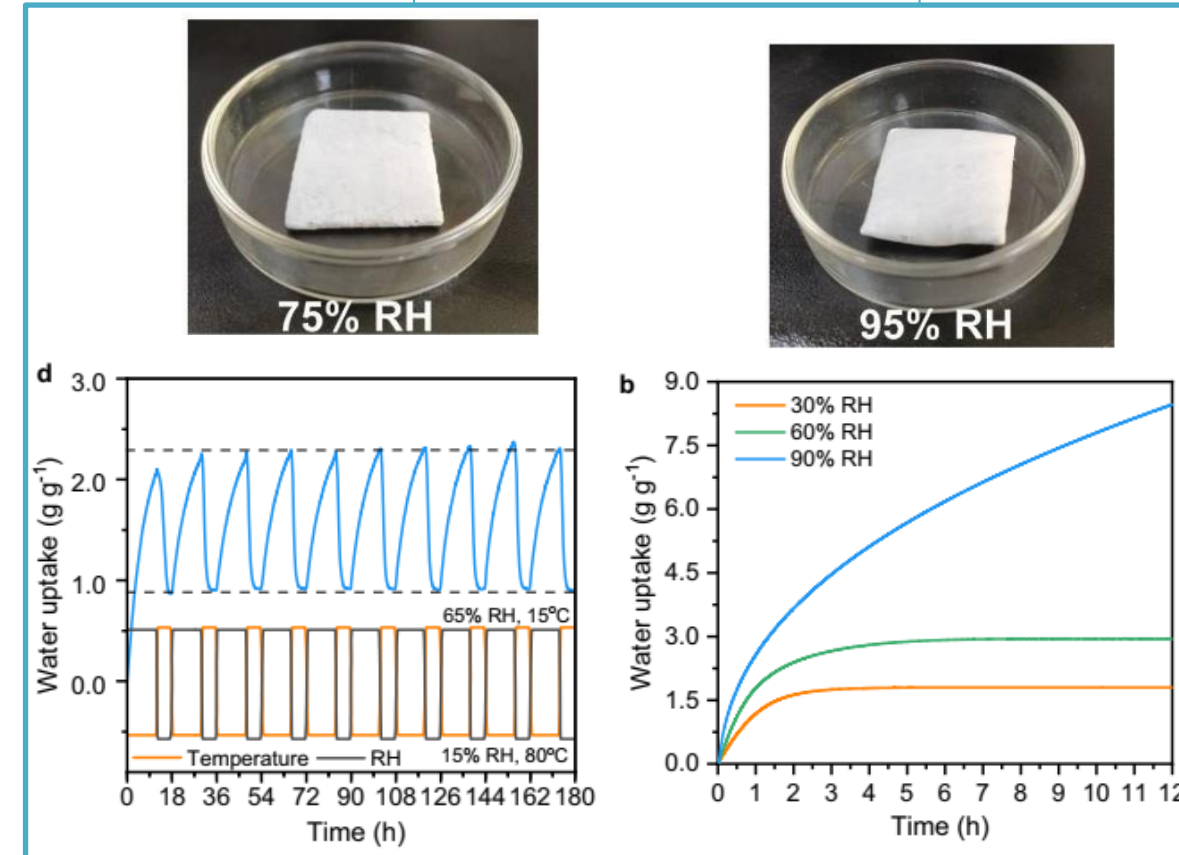


Hybrid liquid@solid sorbent : LiCl@SHC

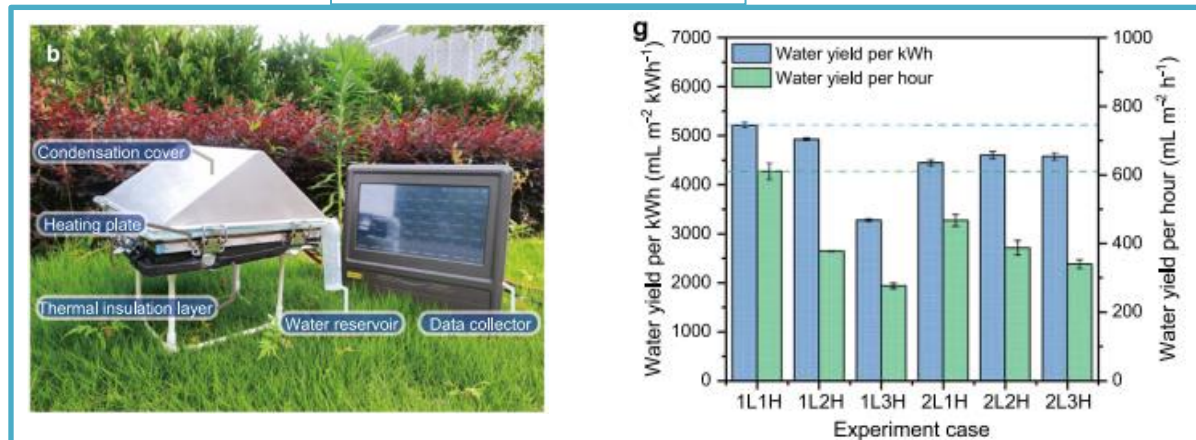
Sorption-desorption process

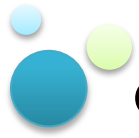


Stability evaluation of the sorbent



SAWH device performance





Overview of the presentation



Background of Atmospheric Water Harvesting



Sorbents for Sorption-Based AWH

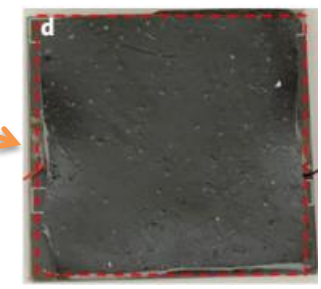
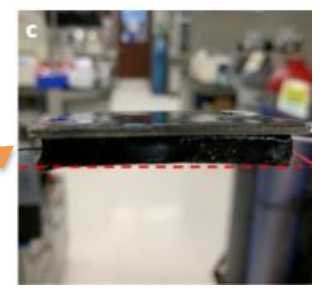
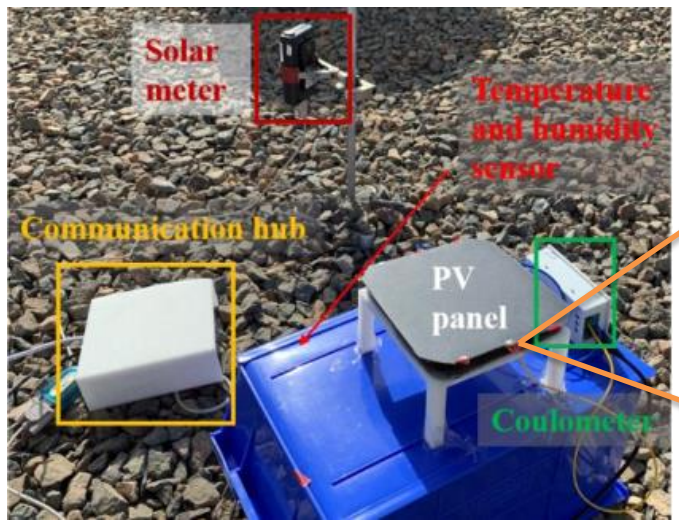
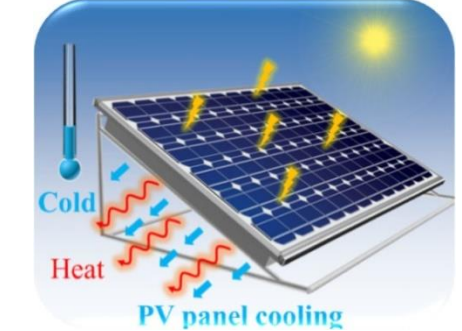
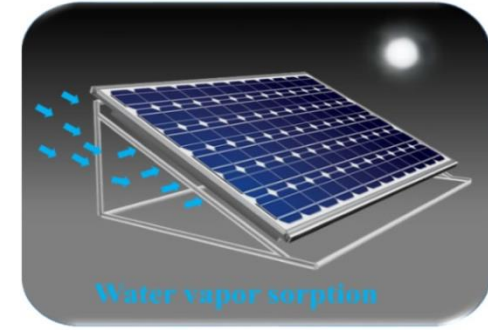
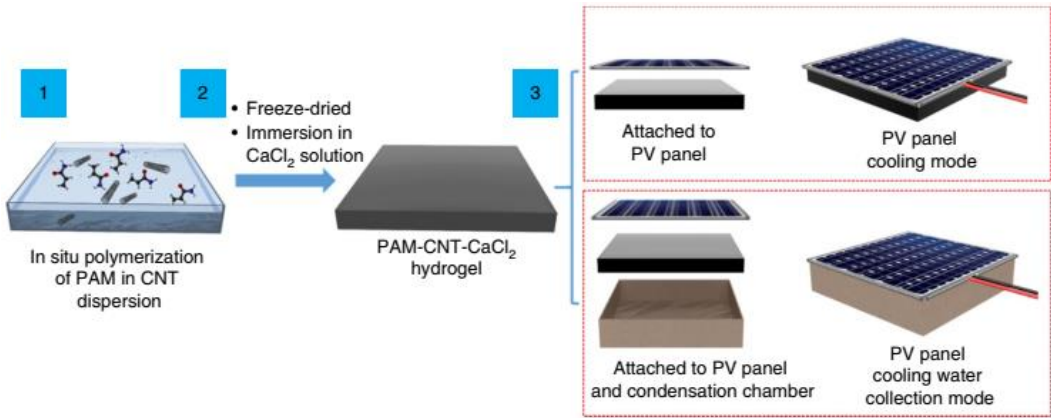


Applications and Future Perspectives

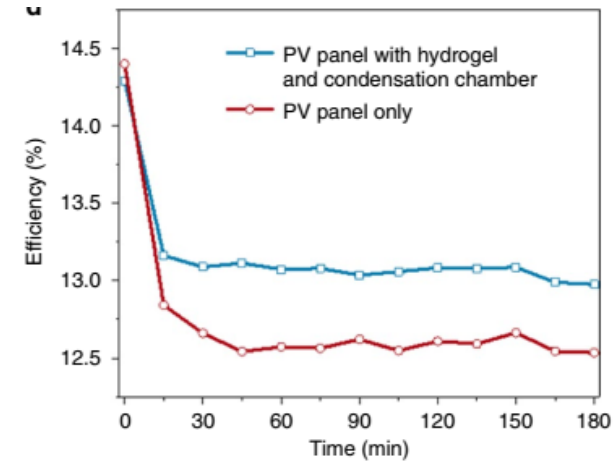
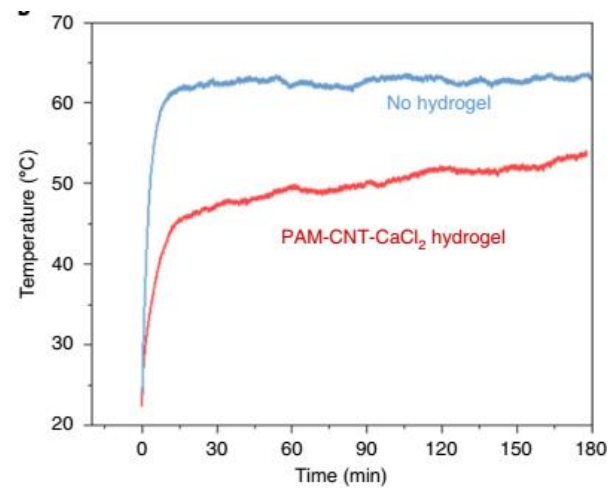




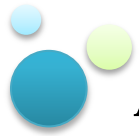
New application of AWH : PV cooling



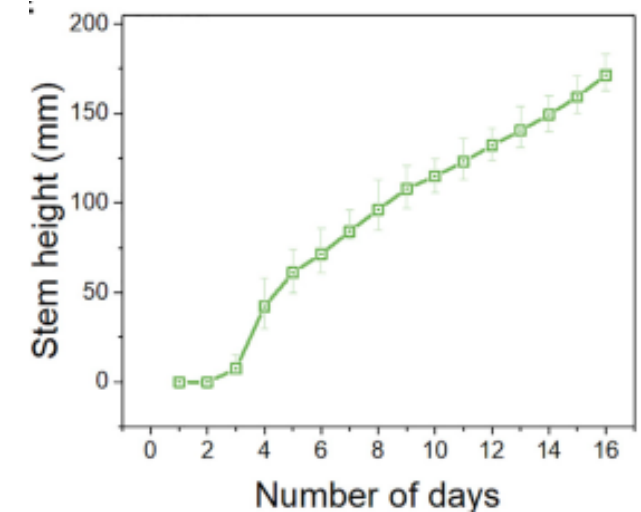
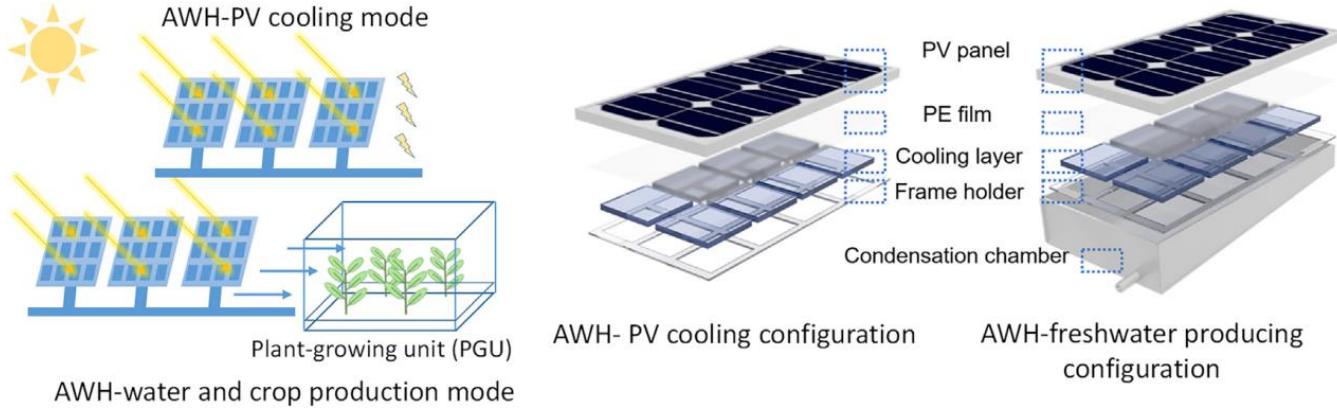
Digital photos of PAM-CNT-CaCl₂ hydrogel



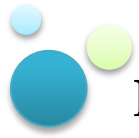
Electricity generation was increased by 19%



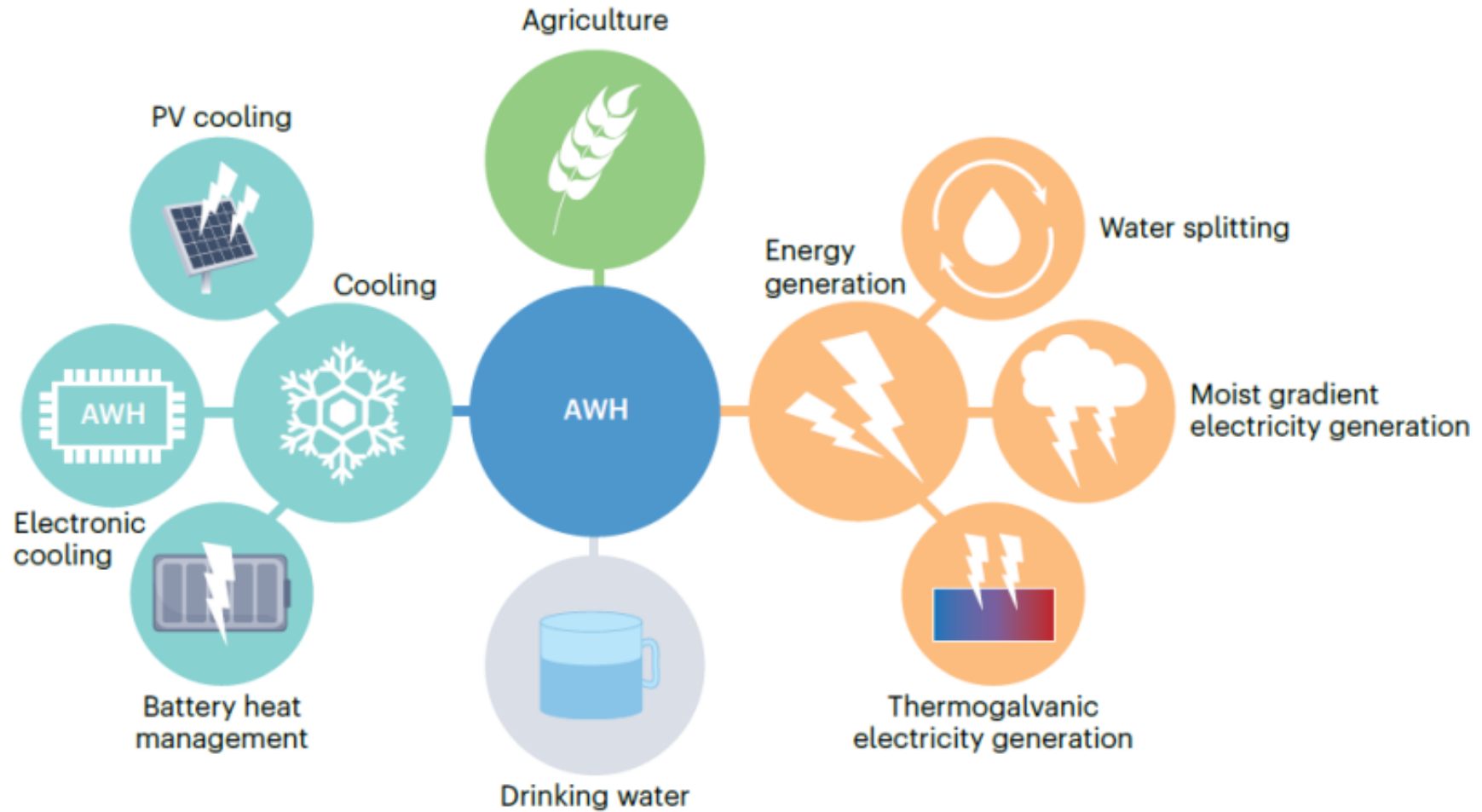
AWH for agriculture in (semi) arid regions



Ranked 100th in 'Mentions' and 99% in 'Social Media' among all papers published by CRPS in the past 3 years.



Perspective applications of AWH beyond drinking water production



Under the High Patronage of His Majesty King Mohammed VI



XIX WORLD WATER CONGRESS
International Water Resources Association (IWRA)
Marrakech, Morocco | 1-5 December 2025

Thank you!

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www.worldwatercongress.com